Brinker, Piermattei, and Flo's

Handbook of Small Animal Orthopedics and Fracture Repair

FOURTH EDITION



Donald Piermattei
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BRINKER, PIERMATTEI, AND FLO'S HANDBOOK OF SMALL ANIMAL ORTHOPEDICS AND FRACTURE REPAIR, Fourth Edition

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PREFACE

The publication of the fourth edition of *Brinker, Piermattei, and Flo's Handbook of Small Animal Orthopedics and Fracture Repair* comes soon after the ninety-third birthday of Wade O. Brinker. Wade will receive the "Founder's Award" from the American College of Veterinary Surgeons this year in celebration of a lifetime of contributions to our profession. This book is but one small contribution of the many he has made. Recently, Wade explained very clearly and firmly that his motivation in founding this book was to establish a solid reference for veterinary students and practicing veterinary surgeons. Through the years we have tried to maintain a balance of information in a straightforward, well-illustrated, and understandable manner that will not only challenge the avid veterinary student, but also provide a reasonable, though not exhaustive, reference for the practicing clinical surgeon.

Twenty-three years have passed since publication of the first edition. With each edition, we note the introduction of many new concepts and fixation strategies (e.g., biologic osteosynthesis). These new developments validate the very same principles that Wade has stressed from the first pioneering days of veterinary surgery. Surgical values of respect for tissue, surgical efficiency, aseptic technique, and appropriate planning will always be relevant to the optimal healing of our patients. Although Wade's active participation ended with the second edition, his influence continues to permeate every page of this text.

With the fourth edition, sections have been expanded to reflect common and accepted improvements with external fixators, interlocking nails, and plate fixations. An introductory chapter on canine arthroscopy has been added to introduce the student to the value of minimally invasive joint surgery. Sections on hip dysplasia, cruciate ligament rupture, and patella luxation reflect continuous progress in treatments of these common conditions.

We continue to be blessed with the artwork of F. Dennis Giddings. Our publisher has changed from W.B. Saunders to Elsevier. This conversion has been seamless, and we thank the new publishing staff for their patient efforts.

Readers will also note the addition of a new author, Charlie DeCamp, who has worked diligently to balance the wealth of information from the first 20 years to that which will be most relevant to students and surgeons in the next 10 years. Two of us (GF and DP) are making our final contribution to this work, which we started with Wade in 1981. We sincerely strive to move this textbook forward in time, and Wade will be with us, every step of the way.

DONALD L. PIERMATTEI
GRETCHEN L. FLO
CHARLES E. DECAMP

To Wade O. Brinker and all the surgeons before us,
and to the families behind us.

1

Orthopedic Examination and Diagnostic Tools

GENERAL EXAMINATION

An orthopedic examination must begin with an adequate history and general physical examination. A systemic approach to the examination ensures that multiple problems are discovered. The animal's general health should be ascertained before focusing on the orthopedic complaint. The entire examination varies with case complexity, a history of recent trauma, the intended use of the animal (e.g., breeding, showing, racing, hunting), and economics dictated by owners. Severely traumatized animals with hemorrhaging wounds and unstable fractures that could become open fractures obviously need different immediate steps; these animals are not discussed in this chapter. This chapter focuses on the examination for orthopedic problems (Table 1-1) and presents some of the diagnostic tools available.

History

Specific historical information is useful for categorizing orthopedic problems to rule out. This information includes breed, age, gender, occurrence of trauma, owner identification of limb(s) involved, chronological progression of the problem, efficacy of treatments tried, and variability with weather, exercise, and arising from recumbency. Other features, such as fever, inappetance, lethargy, and weight loss, may indicate some systemic problem, such as inflammatory joint conditions, or a ruptured bladder after trauma.

Certain historical facts and deviation from the "normal" presentation of certain orthopedic conditions alert the clinician to investigate further by asking appropriate questions or performing additional tests or procedures. For example, a 10-year-old dog that falls down two stairs and sustains a fractured radius and ulna should be carefully scrutinized for pathological fracture. Normally, chronic luxating patellas usually do not suddenly cause a carrying-leg lameness, and cruciate ligament rupture may have become the more recent problem. Chronic osteoarthritic conditions usually do not cause severe pain. In older animals with severe progressive pain, neoplasia must always be considered. With pelvic fractures, trauma to the chest, abdomen, or spine often occurs. Answers to specific questions help assess concurrent problems. For example, knowing whether the recumbent animal has been eating, voiding large pools of urine, or moving the legs spontaneously is helpful.

TABLE 1-1. CAUSES OF LAMENESS IN THE DOG (EXCLUDING FRACTURES AND MINOR SOFT TISSUE INJURIES)

Pelvic Limb	Forelimb
GROWING DOG	
1. Hip dysplasia	1. OCD—shoulder
2. Avascular necrosis (Legg-Calvé-Perthes)	2. Luxation/subluxation shoulder—congenital
3. Avulsion of long digital extensor	3. Avulsion supraglenoid tubercle
4. OCD—stifle	4. OCD—elbow
5. OCD—hock	5. UAP
6. Luxating patella complex	6. FCP
7. Genu valgum	7. UME
8. Panosteitis	8. Elbow incongruity
Medium to large breeds = 1, 3-8	a. Congenital
Toy to small breeds = 2, 6	b. Physeal injury
Chondrodystrophied breeds = 1, 2, 6, 8	9. Radius curvus
	10. Retained cartilaginous cores (ulna)
	11. Panosteitis
	12. HOD
	13. Congenital shoulder luxation
	Medium to large breeds = 1, 4-7, 8b, 9-12
	Toy to small breeds = 2, 8, 9, 13
	Chondrodystrophied breeds = 2?, 5, 8a, 8b, 9, 11, 13
ADULT DOG	
A. Arthritis (or continuum): 1-7	A. Arthritis (or continuum): 1-6, 8, 9
B. Luxating patella complex	B. UME
C. Panosteitis	C. Panosteitis
D. Cruciate/meniscal syndrome	D. Bicipital tenosynovitis/biceps rupture
E. Inflammatory joint disease	E. Calcification of supraspinatus tendon
F. Neoplasia	F. Contracture of infraspinatus or supraspinatus
Medium to large breeds = A1, A 3-7, B, F	G. Bone/soft tissue neoplasia
Toy to small breeds = A2, B, D-F	H. Luxation/subluxation—shoulder
Chondrodystrophied breeds = A1, A2, B, D-F	I. Inflammatory joint disease
	J. HO
	K. SCM
	Medium to giant breeds = A, 7, 11, I, J, K
	Toy to small breeds = 2, G, H, I, J, K
	Chondrodystrophied breeds =2(?), A-5, A-8, A-9, C, H, I, J, K

OCD, Osteochondritis dissecans; *UAP,* ununited anconeal process; *FCP,* fragmented coronoid process; *UME,* ununited medial epicondyle; *HOD,* hypertrophic osteodystrophy; *HO,* hypertrophic osteopathy; *SCM,* synovial chondrometaplasia.

A good appetite probably does not occur with significant internal injuries. "Urinating" or dribbling small amounts of urine does *not* mean the bladder is intact, and voluntary leg movement usually means serious thoracolumbar spinal injury has not occurred.

Distant Observation

The animal should be observed for general thriftiness and relative weight status. Patient disposition and potential lack of animal or owner cooperation should be noted. Sedation should not be used if possible, or at least until the area of involvement is known, because tranquilizers may mask detection of painful regions. The animal should be observed for body conformation, decreased weight bearing, trembling, asymmetrical joint or soft tissue swellings, muscle atrophy, and digit

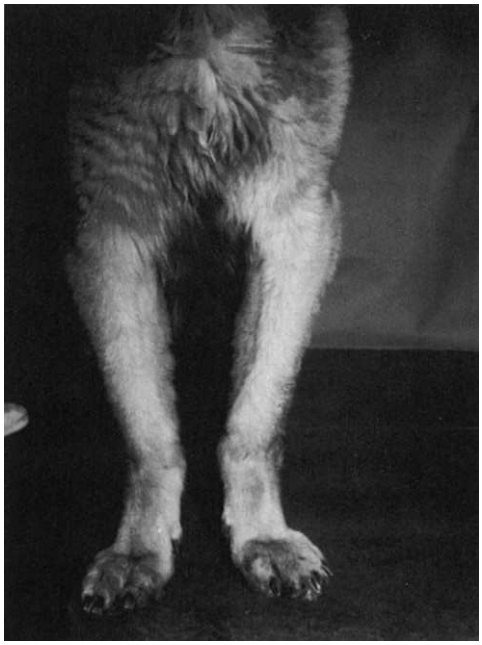


FIGURE 1-1. Typical forelimb curvature in a German shepherd affected with ununited anconeal process. Note varus angulation of the elbows and valgus of the carpi.

and joint alignment. Dogs with tarsocrural *osteochondritis dissecans* (OCD) tend to be very straight legged in the pelvic limb, whereas dogs with elbow problems tend to have curvature of the forelimbs (Figure 1-1).

Gait

Observing the lameness is helpful before examining the limb. It helps confirm or contradict owner complaints. Often in an examination room environment, however, chronic lameness disappears. The gait is observed at a walk and if necessary a trot. Covert lameness may become apparent with tight circles or stair climbing. Abnormalities include a shortened stride, dragging of the toenails, "toeing-in" or "toeing-out," limb circumduction, hypermetria, stumbling, generalized weakness, ataxia, crisscrossing of the legs, abnormal sounds (e.g., clicks, snaps), and a head "bob," which is a bobbing motion of the head that occurs with foreleg lameness. The head elevates as the painful leg strikes the ground.

Standing Palpation

With the animal standing as symmetrically as possible, both hands examine the contralateral aspects of the limbs simultaneously, observing for asymmetry produced by trauma, inflammation, neoplasia, degenerative joint changes, and congenital defects. Signs to palpate are swelling, heat, malaligned bony landmarks, crepitus, and muscle atrophy. Muscle atrophy may be palpated directly if the examiner can grasp around a muscle (e.g., gastrocnemius) or indirectly by discerning a more prominent adjacent bone (e.g., acromion, trochanter major). With bilateral conditions, experience or radiography is used to distinguish abnormality.

Foreleg

Specific landmarks to observe in the foreleg are the acromion, spine and vertebral border of the scapula, greater tubercle of the humerus, humeral epicondyles, olecranon, and accessory carpal bone, which is located at the level of the radiocarpal joint.

Scapulohumeral Region

Trauma and neoplasia affect the scapula. The scapulohumeral region is affected with congenital OCD, developmental calcification of the supraspinatus muscle, bicipital tendinitis (or rupture), and joint luxation. The lateral aspect is palpated. The relative position and size of the greater tubercle of the humerus are noted, which are altered with shoulder luxation or tumors of the proximal humerus. Muscle atrophy from any chronic (over 3-4 weeks) foreleg lameness is often detected as a more prominent acromion. Bicipital muscle pain may be elicited by internally rolling or pressing the belly of the biceps.

Elbow and Forearm

Traumatic and congenital elbow incongruities, congenitally unstable fragments, fracture, and luxation occur in the elbow. Elbow joint effusion is especially noted laterally between the lateral epicondyle of the humerus and the olecranon. Normally, only a thin anconeus muscle lies under the skin. With increased joint fluid, a bulge occurs between these two bony landmarks in the weight-bearing limb that often disappears with non-weight bearing. Osteophytes are noted as an extra ridge lying between the epicondyle and the olecranon. The width of the condyles is compared to the opposite side and is increased with condylar fracture, elbow dislocation, or osteoarthrosis. The radius and ulnar regions are palpated for swelling and malalignment.

Carpus and Paw

The carpal and paw regions are affected with fracture, malalignment, joint swelling, and proliferative bony changes. Valgus and external rotation of the carpus are frequently seen with congenital elbow conditions (see Figure 1-1) and with growth plate injuries. The dorsal carpal and metacarpal regions are palpated for swelling. Further examination takes place in the recumbent animal.

Neurological Examination

Conscious proprioception of the foreleg is carried out at this point. With the animal standing with the forelegs parallel, the chest is supported while the paw is knuckled over on its dorsal aspect. This is repeated several times. The paw should quickly right itself. A normal animal will usually not even allow the dorsum of the forepaw to be placed on the floor, unlike the rear limb (Figure 1-2). The neck is flexed and

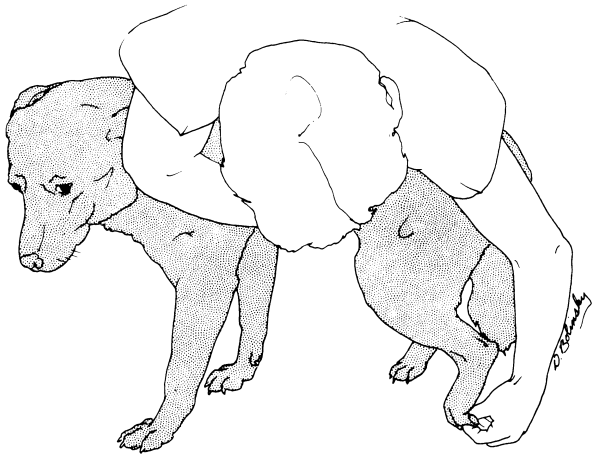


FIGURE 1-2. Conscious proprioceptive response is elicited while the dog is standing with the limbs in a normal position. The dog is supported while the toes are turned over and released. A delay or absence of the dog's quickly returning the toes to a normal position may mean neurological rather than orthopedic problems.

extended to elicit a painful response or stimulation of cervical muscle spasms. The dorsal spines of the thoracolumbar regions are pressed downward to elicit pain. In dogs with lumbosacral disease, the pressure in this area may cause a sudden sitting position.

The thoracic and abdominal areas are palpated before proceeding to the pelvic limb.

Pelvic Limb

Pelvis

Landmarks to note on the pelvic limb are the iliac crests of the ilium, trochanters major, tubers ischii, extensor mechanism (quadriceps, patella, patellar ligament, and tibial tubercle), femoral condyles, distal tibia, fibular tarsal bone, and Achilles tendon.

Asymmetry of the bones of the pelvis could mean pelvic fracture, hip dislocation, femoral head fracture, or chronic coxofemoral arthritis. If imaginary lines are drawn from the wings of the ilium, trochanters major, and tubers ischii, a triangle is formed (Figure 1-3). With craniodorsal coxofemoral dislocation, the triangle becomes more acute (Figure 1-4), the trochanter major more prominent, and when the rear quarters are elevated, the toes on the dislocated side appear "shorter." With unilateral ilial fracture and overriding segments, the trochanter major may be closer to the wing of the ilium than the opposite side. In addition, the lateral musculature is swollen. The muscles of the cranial and caudal thigh and the gastrocnemius muscle are palpated.

Stifle

The stifle joint is frequently affected with degenerative, congenital, and traumatic conditions that include cruciate ligament rupture, patellar luxation, OCD, and physeal fracture. Stifle palpation begins with locating the tibial tubercle and following the patellar ligament proximally. Abnormal deviation of the tubercle from the midline plane should be noted and occurs with patellar luxation. Normal patellar ligaments should be taut and approximately pencil thick. The cranial two thirds of the pencil-like ligament can be grasped. With stifle injury, swelling from the joint pushes forward around the caudal and lateral aspects of the patellar ligament, making the ligament less distinct and more bandlike than pencil-like. The patella is found 1 to 4 cm proximal to the tubercle, but it may be examined better in the recumbent animal when joint manipulation is possible. With chronic stifle

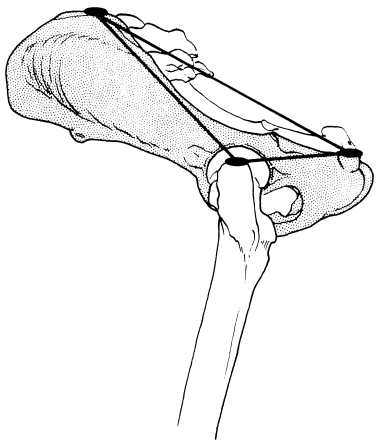


FIGURE 1-3. If imaginary lines are drawn between the wing of the ilium, tuber ischii, and trochanter major, a triangle is formed.

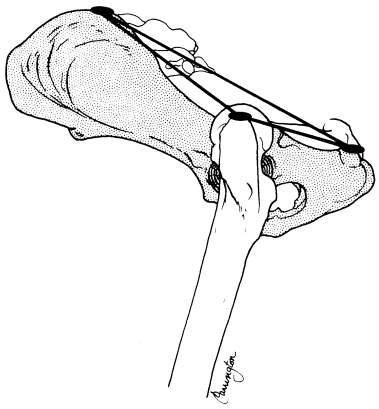


FIGURE 1-4. With hip dislocation, the triangular shape becomes altered when compared with the other normal hip of the dog (compare with Figure 1-3).

swelling and osteophyte formation, the diameter of the femoral condylar ridges is enlarged; this is assessed 1 to 2 cm behind the patella. In addition, there may be joint swelling medially between the femur and tibia.

Hock

The tarsocrural joint is affected with traumatic and congenital conditions. Swelling of the hock joint is detected on the standing animal by palpating between the distal tibia and the fibular tarsal bone. Normally, only skin, subcutaneous tissue, and bone are present. Joint swelling from increased fluid accumulation or fibrosis is detected as a firm, soft tissue mass between those two landmarks. Additionally, swelling may be detected cranially or medially. The Achilles tendon is examined above the calcaneus for swelling and continuity.

Recumbent Examination

The animal is placed in lateral recumbency to examine previously noted abnormalities thoroughly. This allows patient restraint and limb manipulations but precludes simultaneous palpation of the opposite side. Most maneuvers discussed do not produce pain in normal animals. Pain production gives the diagnostician clues as to the location of the problem. It may be best to examine the normal side first to relax the animal and to learn individual responses to certain maneuvers. The veterinarian looks for instability, crepitus, painful regions, and altered ranges of motion. Animals usually do not resist gentle manipulation of abnormal areas. Unfortunately, many animals do not indicate when a painful area is manipulated, which creates a diagnostic challenge at times. In general, it is recommended to examine from the toes proximally. Known abnormal areas or maneuvers that may produce pain should be examined last to ensure patient cooperation. Maneuvers producing painful responses should be carefully and gently repeated while immobilizing surrounding tissues to reduce the possibility of misinterpreting the origin of the pain.

Crepitus (a sound or palpable friction sensation) occurs when bone rubs bone, cartilage rubs bone, or subcutaneous tissues move over air pockets or foreign materials such as wires, pins, or suture material. The sensations palpated are characterized as clicks, snaps, clunks, crackling, grinding, or grating. Normal laxity of the carpal, tarsal, or shoulder regions produces innocent clicks that are mistaken as crepitus. In some thin dogs, elbow flexion produces clicks when the ulnar nerve moves over a prominent humeral epicondyle.

Forelimb

Paw and Elbow

The digits are flexed, extended, and examined for swelling, crepitus, and pain. The interdigital webbing and foot pads are examined for discoloration, abrasions, and other conditions. The proximal sesamoid bones are palpated for swelling on the palmar aspect of the paw at the metacarpophalangeal junction. The carpus is flexed and extended, and a valgus/varus stress is applied. Swelling detected on the standing examination is better identified when the exact location of the joint space can be identified. This helps to rule out joint problems from distal radial swelling seen with neoplasia or hypertrophic osteodystrophy. The radiocarpal joint space lies at the same level as the base of the accessory carpal bone.

The elbow is similarly placed through a range of motion. Hyperextension of the elbow may produce pain in dogs with ununited anconeal process, whereas internal and external rotation with digital pressure applied at the medial joint line may produce pain that accompanies conditions such as OCD or fragmented coronoid process.

Shoulder

Swelling of the shoulder joint unfortunately cannot be appreciated because of its depth under musculature. The shoulder is examined for pain by flexing and extending the joint while grasping the forearm with one hand while the other hand stabilizes the front of the shoulder. OCD usually produces pain with this maneuver. Bicipital tendinitis or rupture is painful when the tendon is stretched. To produce diagnostic discomfort, the elbow is extended, and the entire limb is pulled caudally along the thoracic wall while digital pressure is applied to the proximal medial humeral region over the tendon (Figure 1-5). With the advent of arthroscopy, tearing of the medial ligaments of the scapulohumeral joint has been documented and may be quite common. Under sedation, increased abduction of shoulder can be compared to the normal side. With the dog in contralateral recumbency, the acromial process is pushed downward while the extended limb is abducted maximally. The limb is maintained approximately perpendicular to the spine during the test. Comparing the abduction angle to the other limb helps establish its significance.

Fractures of the acromion can cause discomfort and possibly crepitus when the acromion is manipulated. Shoulder instability may be appreciated, usually in the

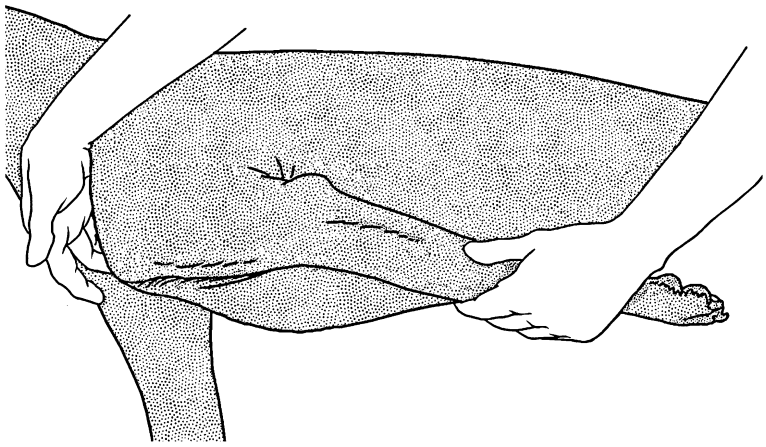


FIGURE 1-5. To detect bicipital tendon pain, the tendon is stretched by extending the elbow and bringing the entire limb parallel to the thorax. Digital pressure is applied to the tendon in the proximal medial humeral region.

sedated or anesthetized patient, by applying a mediolateral or craniocaudal sliding motion at the joint level.

Long-Bone Palpation

All areas of the limb are gently squeezed. Long-bone palpation is reserved for the last part of the examination because pain from bone tumor or panosteitis is exquisite at times. To avoid production of pain from pressing normal muscle, the examiner should find muscle planes where the fingers can reach bone. These locations include the distal radius, the proximal ulna, and the distal and proximal humerus. Once the fingers touch the bone, a gentle pressure is applied.

Neurofibromas or neurofibrosarcomas must be considered in older dogs with severe progressive foreleg lameness. In these special cases, deep digital pressure in the axilla may detect a mass and produce exquisite pain. In addition, ocular signs of Horner's syndrome (unilateral miosis, ptosis, and enophthalmos) may be present. The "mass" may be compared to the other side in the standing animal.

Rear Limb

Paw and Hock

The digits and paw are examined similar to the foreleg. The tarsal region is maximally flexed, extended, and stressed in varus and valgus angles. Instability, pain, and crepitus may be produced with fracture, tendon and ligament breakdown (seen especially in collies and shelties), and OCD of the talus. Achilles tendon continuity is palpated during flexion and extension of the tarsocrural joint.

Stifle

The stifle joint is often affected with luxating patellas and cruciate ligament disease, as well as physeal fractures of the distal femur. With fracture, the stifle is quite swollen with a history of young animals sustaining trauma. Swelling also occurs with inflammatory joint conditions and OCD. Localized swelling occurs with avulsion of the origin of the long digital extensor tendon.

Patellar Luxation. With some animals, there is normal mediolateral movement within the trochlea of the femur. Luxation out of the trochlea is abnormal and can cause lameness. *Subluxation* (patella rides on the trochlear ridge, and "catches" during flexion) occasionally causes lameness. Luxation may be medial, or less often lateral, and occasionally in both directions. Luxation of a patella is normally not a painful maneuver. The examiner should stand caudal to the animal. To begin the examination, the tibial tubercle is located and its position noted. Noting the medial location of the tibial tubercle helps avoid misinterpreting a medial luxation (ectopic) that is replaced into the trochlea (i.e., reduced) from a reduced patella that can be luxated laterally. Cat tubercles are not as prominent as dog tubercles. The patella may be found 1 to 4 cm proximally. In small dogs or cats with ectopic patellas, the patella is palpated as a small, pealike bump on the medial (or lateral) femoral condyle. It may or may not move with flexion, extension, and digital pressure. It may or may not be reducible. To luxate a reduced patella medially, the stifle is extended, the toes are internally rotated, and digital pressure is applied to the patella in a medial direction (Figure 1-6). Conversely, to luxate a patella laterally, the stifle is flexed slightly, toes are externally rotated, and pressure is applied in a lateral direction (Figure 1-7). Sometimes an unstable patella may be luxated simply by internally or externally rotating the paw. A patella that has been luxated on examination should be reduced. The stifle should *always* be examined for cruciate ligament instability and with the patella reduced.

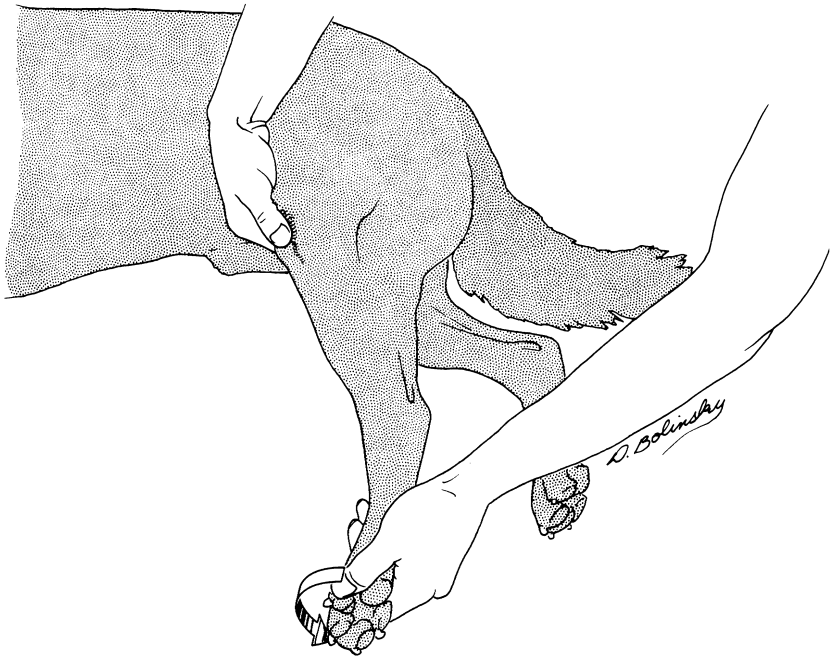


FIGURE 1-6. To luxate the patella medially, the stifle is extended and the toes rotated medially while the patella is pushed medially.

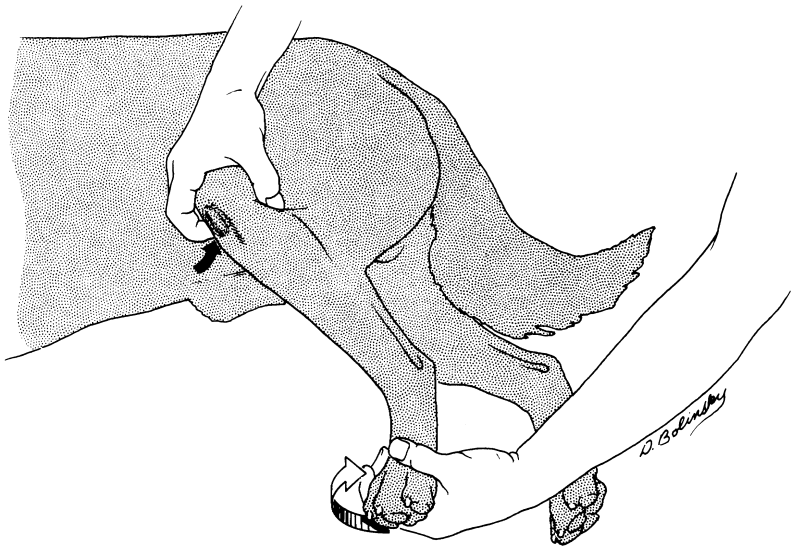


FIGURE 1-7. To luxate the patella laterally, the stifle is partially flexed and the toes are rotated laterally while the patella is pulled laterally.

Cruciate Ligament Instability. Palpation for cruciate ligament instability can produce pain and should be performed gently in the relaxed patient. Sedation may be needed if no abnormality can be detected in the tense animal. *Drawer movement* is the sliding of the bony tibia in relation to the femur. Normally, there is no cranial or caudal drawer movement in the adult animal. Some large puppies have "puppy" drawer, which lasts up to 10 to 12 months of age because of normal joint laxity.

Some rotary motion of the tibia is normal and is occasionally mistaken as drawer movement. In a fresh, fully torn cruciate ligament in a relaxed medium-sized animal, the tibia may slide 5 to 10 mm (grade 4). In relative terms, larger dogs have less drawer movement than small dogs. Other factors that diminish full drawer movement are chronicity, animal tenseness, partial ligament tear, and presence of a meniscal injury. Increased drawer movement occurs with multiple ligament tears in the traumatized animal or in cushingoid dogs. If there is patellar luxation, the patella should be reduced if possible before examining for cruciate instability.

The *tibial compression test,* or cranial tibial thrust[1] (*indirect* drawer movement), compresses the femur and tibia together, and when there is cranial cruciate ligament incompetence, the tibia slides forward in relation to the femur. This occurs during weight bearing as well, and its surgical elimination is the basis of the tibial plateau–leveling procedure for cruciate repair.[1] It can be elicited by holding the stifle in a slightly flexed position while the paw is alternately dorsiflexed as far as possible and then relaxed. The index finger of the opposite hand lies cranial to the femur, patellar ligament, and tibial tubercle and detects the tubercle sliding forward (Figure 1-8). It is repeated several times quickly but gently.[2] Interpretation of this maneuver is more subjective than direct drawer movement but has the advantage of producing minimal pain in animals with ruptured cranial cruciate ligaments.

Direct drawer movement is examined by placing the fingers as close as possible to bone and not soft tissue (Figure 1-9). The index finger of one hand is placed on the cranial proximal patellar region while the thumb is placed caudally on the lateral fabella. The index finger of the opposite hand is placed on the cranial aspect of the tibial crest while the thumb is positioned caudally on the fibular head. With the wrists held straight and not bent, the femur is held stable while the tibia is pushed forward (and not rotated), then pulled backward. This is repeated quickly and gently several times. At first the stifle is held firmly in slight extension, and then the movement repeated with the stifle held in extension, then in flexion. In large dogs it is helpful to have an assistant or the examiner's foot (if performed on the floor) support the dog's foot.

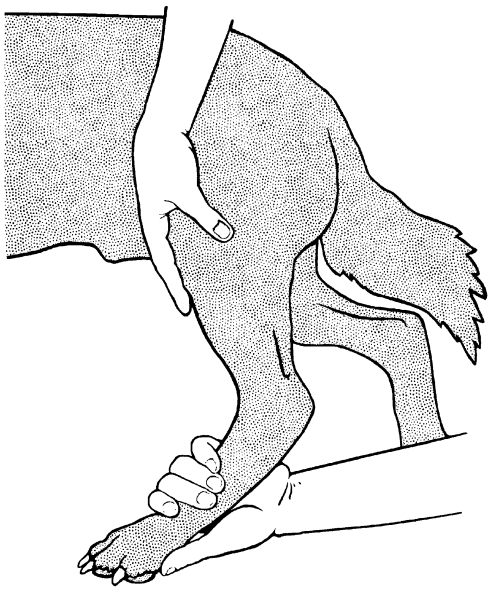


FIGURE 1-8. The tibial compression test produces indirect drawer movement. With the stifle angle held in slight flexion, the metatarsal region is dorsiflexed as far as possible. The index finger of the opposite hand detects the forward movement of the tibial tuberosity if drawer movement is present. It is repeated several times.

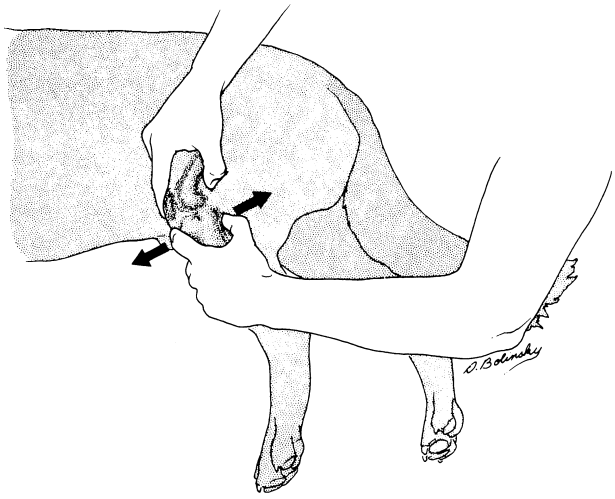


FIGURE 1-9. To palpate direct drawer movement, the index finger of one hand is placed on the proximal patellar region while the thumb is placed caudal to the lateral fabella. The index finger of the opposite hand is placed on the cranial aspect of the tibial crest, and the thumb is placed on the caudal aspect of the fibular head. With the femur stabilized, the tibia is pushed forward and then pulled backward. This is repeated several times and is performed gently but quickly to detect 1 to 10 mm of movement of the tibia in relation to the femur.

Interpretation of Instability. With cranial cruciate ligament rupture, the cranial end point is "soft," with no sudden stoppage, because the secondary restraints of the stifle become taut. When the tibia is pulled caudally, a sudden "thud" is palpated as the normal caudal cruciate ligament becomes taut. Conversely, with rare caudal cruciate rupture (usually grade 2 or less of motion), when cranial force is applied, there is a sudden "thud" that is not present when caudal force is applied. "Puppy" drawer (grade 2 or less of motion) has a sudden end point cranially and caudally. It usually disappears by 6 to 9 months of age unless chronic painful conditions of the hip, stifle, or hock exist.

Inexperienced palpaters of the stifle can make the following five common mistakes:

1. If the wrists are bent, proper force cannot be applied.
2. If just the fingertips alone touch bone, proper force cannot be applied.
3. If the fingers are placed laterally/medially instead of cranially/caudally, the skin moves and is misinterpreted as drawer movement.
4. If drawer movement is performed slowly, detection of 1 to 2 mm of motion is impossible.
5. Tibial rotary movements, which may be normal or excessive, are misinterpreted as drawer movement.

Collateral Ligament Instability. When the collateral ligaments *and* joint capsule are torn, the stifle will have medial, lateral, or combined instability. Cutting either of these ligaments alone without cutting the joint capsule does not produce much instability in research animals. The cruciate ligament(s) is (are) invariably torn in clinical cases of collateral instability. To detect this instability, the stifle should be held in "neutral" drawer while a valgus (stifle inward) or varus (stifle outward) force is applied. The thumb is placed on the fibular head while the index finger is placed along the medial joint line to perceive the joint opening abnormally with its respective instability.

Meniscal Injury. Meniscal injury is suspected when the owner hears a click when the animal walks or when the animal has a severe three-legged lameness several weeks after acute onset of stifle lameness. In addition, a worsening of

an improving lameness several weeks to months after cruciate rupture with or without surgical repair sometimes indicates meniscal involvement. Meniscal injury is suspected when flexion, extension (with and without rotation about the stifle), and direct and indirect drawer manipulations produce a click, snap, clunk, or grating. Definitive diagnosis is made on visualizing the unstable caudal horn or a part of it malpositioned after arthrotomy (see Chapter 18).

Hip Joint and Pelvis

The hip joint and pelvis are often affected by trauma, congenital conditions such as Legg-Calvé-Perthes disease, and hip dysplasia. Manipulations may cause pain, crepitus, and instability. The femur is grasped at the stifle, and the hip is flexed and extended several times. If pain or crepitus is not produced, external hip rotation is added to the flexion and extension maneuvers. This maneuver frequently elicits pain in the animal with Legg-Calvé-Perthes disease. Fine crepitus may be heard when the examiner's ear or stethoscope is placed on the trochanter major during these manipulations. Pressing the femur into the acetabulum accentuates the crepitus (Figure 1-10). This crepitus must be distinguished from hair coat noises. Suspected fracture and dislocation are further evaluated by radiography.

The sacroiliac joint is examined for instability by gentle manipulation of the wing of the ilium. The tuber ischii is pressed to detect instability and crepitus. A rectal examination may detect pubic and ischial fractures.

Hip laxity seen with hip dysplasia may be detected by three methods. First, *Ortolani' sign* is a noise or palpable "thud" produced when an unstable hip is replaced into the acetabulum.[3] To produce this sound while the dog is in lateral recumbency, the hip is subluxated proximally by grasping the adducted stifle and pushing proximally while the other hand stabilizes the pelvis. Second, when the stifle is abducted, downward pressure is applied across the trochanteric region. A noise is produced as the femoral head glides over the rim into the acetabulum (Figure 1-11). This can also be done bilaterally with the dog in dorsal recumbency. The stifles are adducted, pushed proximally, and then abducted to produce the "thud" (see Figure 16-10, C, *D*, and *E*). A third way to detect this instability is to

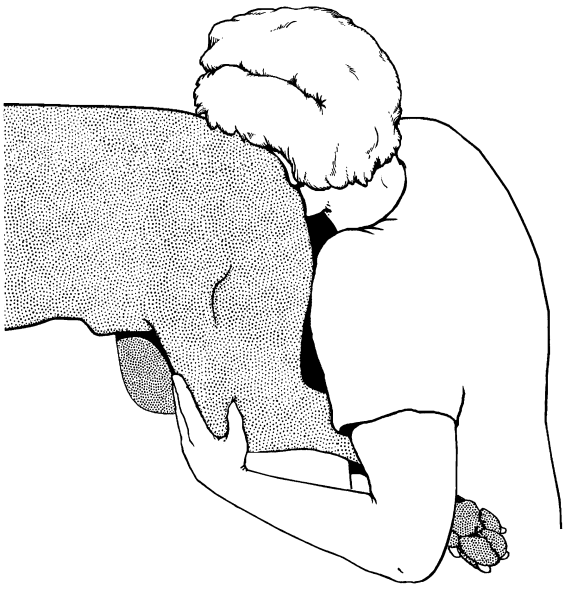
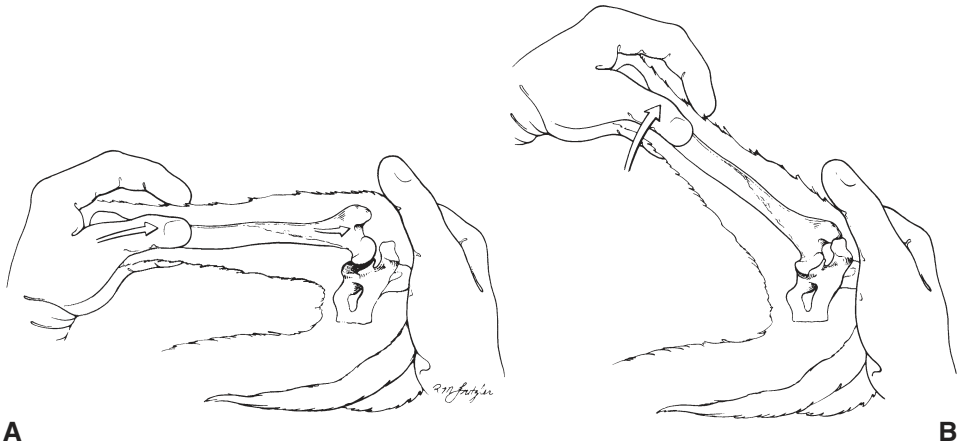


FIGURE 1-10. To hear finer crepitus from coxofemoral arthritis, the examiner's ear is placed on the trochanter major during flexion, extension, abduction, and adduction of the hip joint. Proximal pressure during these movements accentuates the sounds.



A B

FIGURE 1-11. Ortolani's sign is the sound produced when the subluxated hip is suddenly reduced into the acetabulum. **A,** To subluxate the hip joint, the stifle joint is adducted while proximal pressure is applied. **B,** Reduction of the subluxation occurs when the stifle is abducted, which reduces the hip, creating a "thud."

place the dog in lateral recumbency. One palm stabilizes the pelvis with two fingers on the trochanteric region while the other hand grasps the distal femur and positions it parallel to the table or floor. The femoral head is alternately levered laterally and relaxed while the fingers on the trochanter major are alternately relaxed and then pressed downward. The amount of subluxation in millimeters may be detected. However, this maneuver is often painful even in normal animals because of the force applied on the thigh muscles. Muscle tension often masks hip laxity occurring with hip dysplasia.

DIAGNOSTIC TOOLS

Beyond the physical examination, several tools are available for diagnosing and evaluating orthopedic diseases and treatments. These include radiography, fluoroscopy, arthrography, myelography, diagnostic ultrasonography (DUS), computed tomography (CT), magnetic resonance imaging (MRI), nuclear imaging, arthroscopy, force plate analysis, kinematic gait analysis, exploratory surgery, biopsy, clinical pathological tests, arthrocentesis with joint fluid analysis, serology, and hormonal assay. A brief description of each of these modalities follows, along with their uses.

Radiography

The most common diagnostic tool used to investigate orthopedic disease is radiography. The history and physical examination should suggest the area of the body involved. Radiography is also used to rule out other concurrent common diseases, such as a large dog with cruciate ligament rupture with concurrent hip dysplasia. It is extremely useful in detecting and evaluating fractures, joint dislocations, osteoarthrosis, neoplasia, joint incongruities, and congenital joint conditions (e.g., OCD, hip dysplasia). It is also useful in evaluating fracture fixation and healing as well as in following progress of joint treatments. In general, two

orthogonal (90 degrees to each other) views of an area are taken. (Special views are discussed in other chapters for each disease.) Many times, animals even with fractures may be positioned for radiography without sedation if enough personnel are available. If personnel are unavailable or state laws prohibit their exposure to radiation, sedation or anesthesia may be required using appropriate positioning and restraining devices.

Fluoroscopy

Another modality using radiation is fluoroscopy, with or without image intensification. It is occasionally used to detect instability (e.g., shoulder luxation), retrieve metallic foreign materials (pins, wires, bullets), observe contrast material used in arthrography, confirm needle placement for myelography and angiography, and aid placement of surgical implants. Fluoroscopy is a "movie" of radiographic images, and image intensification enhances the signal to reduce the amount of radiation necessary to see the images. Spot hard-copy films can be made from selected images.

Arthrography

An arthrogram is a radiograph of a joint after a contrast substance such as an iodine solution, air, or both have been injected. Injection techniques are discussed later in the arthrocentesis section. The most frequent joint undergoing arthrography is the shoulder joint. Interruption of contrast material flow occurs with bicipital tendonitis or rupture. Arthrography is useful in identifying obscure cartilaginous flaps in OCD. The contrast solution we prefer is a half-and-half mixture of sterile water and 60% Hypaque (diatrizoate meglumine and diatrizoate sodium, used for intravenous pyelograms). The shoulder of a 30-kg dog should have 2 to 3 ml of this mixture injected, and radiographs are taken within 5 to 10 minutes, after which the ionic solution is resorbed or diluted with synovial effusion and loses its contrast quality. In a recent study, nonionic contrast agents were found to have superior radiographic imaging qualities because of their decreased absorption rate and joint fluid influx. However, they are also more costly.[4]

Myelography

Myelography is the process of injecting the spinal intrathecal space with a water-soluble nonionic sterile iodine solution to detect abnormal obstruction or deviation of contrast material flow caused by spinal neoplasia, degenerative disk disease, or vertebral trauma and instability. Contrast agents, such as iohexol and iopamidol, are used for myelography.

Computed Tomography

CT is specialized radiography in which cross-sectional images of a body structure are reconstructed by a computer. A CT unit is an apparatus in which the x-ray source moves in one direction while the x-ray detector moves in synchrony in the opposite direction (Figure 1-12). This allows detailed vision without obscuration from superimposed structures. With computer configuration, serial "slices" as small as 1.5 mm in width may be made through a body part. These machines cost between $350,000 and $1.1 million, and some veterinary teaching hospitals have these machines or have access to them at human hospitals. CT's primary use

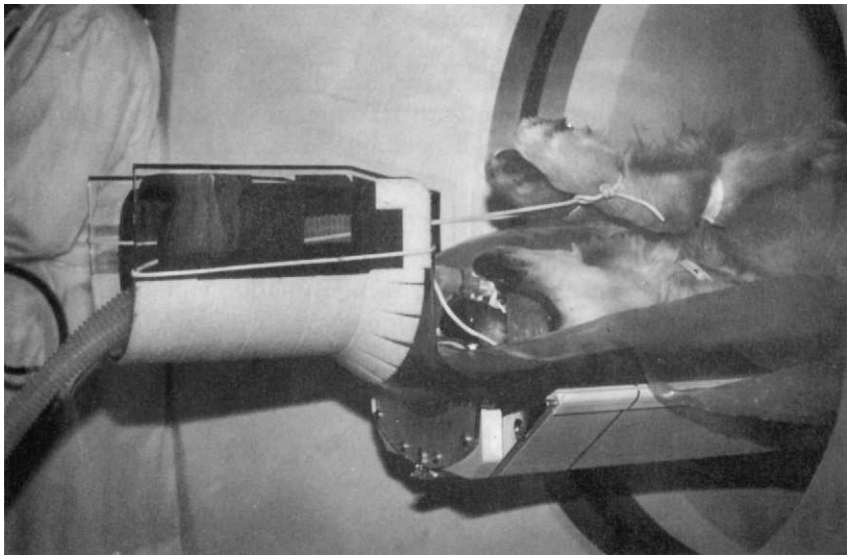


FIGURE 1-12. Anesthetized dog is placed into the gantry of a CT machine. The black circular region contains the ionizing radiation source.

in small animals is examination of the spine, skull, and brain. CT can also be used in conjunction with contrast agents. It is very helpful in diagnosing fragmented coronoid process disease in dogs (see Chapter 12). It is useful in guiding a surgeon trying to locate a radiodense foreign body or discovering subtle joint fractures. Two disadvantages of this diagnostic modality are that anesthesia must be used and that CT is not particularly useful for soft tissue conditions.

Magnetic Resonance Imaging

MRI uses imaging equipment that is even more expensive than for CT ($750,000 to $2 million) and requires a special dedicated room for its use. MRI produces computer images of internal body tissues from magnetic resonance of atoms within the body induced by the application of radio waves. Again, animals must be anesthetized, and the study is usually performed at human hospitals or modular units. The main advantage of MRI in human orthopedics is that soft tissue and articular cartilage can be studied. It is *the* best noninvasive technique for diagnosing meniscal and cruciate injuries in humans.

Nuclear Imaging

Nuclear imaging uses radioactive pharmaceuticals injected intravenously that accumulate in certain organs based on their chemical structure and the carrier to which they are bound. These radioactive materials accumulate in vascularized tissues, which can be compared with contralateral limbs to detect increased vascularity seen with inflammation, trauma, or neoplasia. Radioactive decay emits gamma radiation that is detected by a scintillation crystal (gamma camera; Figure 1-13) and transmitted to a dedicated computer for image production. In animals, technetium-99m methylene diphosphonate (^{99m}Tc MDP) is used for bone scans and is distributed in soft tissues for imaging within 4 to 8 minutes. Bone uptake may be imaged 2 to 8 hours after intravenous injection. Both phases are



FIGURE 1-13. Sedated dog is positioned over the radiation detector or gamma camera (white object) for nuclear imaging.

scanned with the animal under sedation. The animal must be housed in special holding facilities while radiation decay occurs. Gamma cameras cost more than $2000, but the computer that creates the image and hard copy can cost more than $300,000. In humans, nuclear imaging can be used to detect stress fractures. In the horse, it is helpful in identifying the anatomical origin of occult lameness. In small animals, use of nuclear imaging is becoming more popular to detect early neoplastic, inflammatory, and traumatic lesions. Unfortunately, in the United States, most state radiation laws require special dedicated rooms to house animals that have been given radioactive materials. Nuclear imaging is helpful at times to locate the region of occult lameness. Dogs younger than 3 years of age, however, have normally reactive physeal plates, which may obscure the detection of real joint problems.

Diagnostic Ultrasonography

DUS is infrequently used for musculoskeletal problems in small animal medicine. It has been used somewhat successfully in diagnosing bicipital tendonitis in dogs, although it was less reliable than arthrography.[5] It may be useful for other problems, such as the evaluation of soft tissue masses and OCD. The application of DUS in skeletal evaluation is poor because of absorption of sound waves by bone.

Arthroscopy

Arthroscopy involves puncturing a joint with a specialized endoscope after distention with a liquid or gas for the purpose of exploration and surgical repair if indicated (see Chapter 8). This modality is extremely useful in human medicine because there is less surgical trauma, resulting in less pain, shorter hospitalization, less time off work or physical activity, quicker healing time, and less

adhesion formation. When appropriate arthroscopic equipment became available to perform therapeutic manipulations, it became more than a diagnostic tool. Many surgeons became trained in its use, and it is cost-effective. Arthroscopy is also extremely useful in horses with loose bone or cartilage bodies in joints, especially when open surgery and the long rehabilitation would cause an economic loss in the performance individual.

Pet owners frequently ask if small animal veterinarians have the capability to perform arthroscopy, and the answer at this point is that it is impractical, although a few referral centers have used it.[6,7] Other surgical manipulations, such as ligament reconstruction, internal fixation of bony fragments, and meniscal repair, require more sophisticated equipment and surgical training. Dogs usually do not develop the joint stiffness that people do from open surgery, probably because of their high pain tolerance. Dogs that could benefit from the commonly available equipment are those with loose OCD or coronoid fragments. However, these dogs use their legs immediately after conventional open surgery, thereby minimizing the apparent advantages of arthroscopy. Additionally, there are no savings in anesthesia or patient preparation time.

Force Plate Analysis and Kinematic Gait Analysis

Two relatively new research tools used in veterinary medicine to evaluate gait performance are force plate analysis[8] and kinematic or motion analysis.[9] They are included in this chapter because they are a more objective means than clinical impression to evaluate function after certain orthopedic treatments. Some recent reports compare different treatments for specific conditions (e.g., different cruciate ligament repairs, total hip replacement vs. excisional arthroplasty) using these modalities. These tools detect altered gait that may not be apparent on visual observation.

Briefly, *force plate analysis* is a system in which the magnitude of weight-bearing (ground-reactive) force can be measured as the animal steps onto a sensor plate during gait (Figure 1-14). Multiple passes are completed across the force plate to acquire representative data. Assessment of lameness grade may now be quantitated. However, it only measures the force on that single step as the animal strikes the plate. This tool does not measure problems that owners see, such as stiffness on arising or lameness after running 3 to 4 miles.

Motion analysis has the advantage of allowing multiple measurements of successive motions during locomotion. Multiple markers are placed on the skin at different joint levels. During locomotion, these markers move and are detected by video cameras, and the signals are sent to a computer (Figure 1-15). Limb movements may be calculated at 60 to 100 measurements per second, which allows precise definition of normal versus lame gait. Different joint angles and the duration of stance and swing phases of the gait cycle vary with the joint affected. Thus the gait of a dog with hip dysplasia may be characterized.[10] During most of the stance phase, hip extension is quicker but has increased extension compared with normal hip movement. Coxofemoral flexion is more rapid in the early swing phase but slower in the middle of swing phase. There are also distal alterations in the stifle and tarsus. Medical or surgical treatments may then be compared to the individual's baseline data. In the future, kinetic gait analysis may be helpful in distinguishing which area is the cause of lameness when multiple abnormalities are found in the same limb (e.g., elbow arthrosis, calcification of supraspinatus muscle, possible bicipital tendonitis).

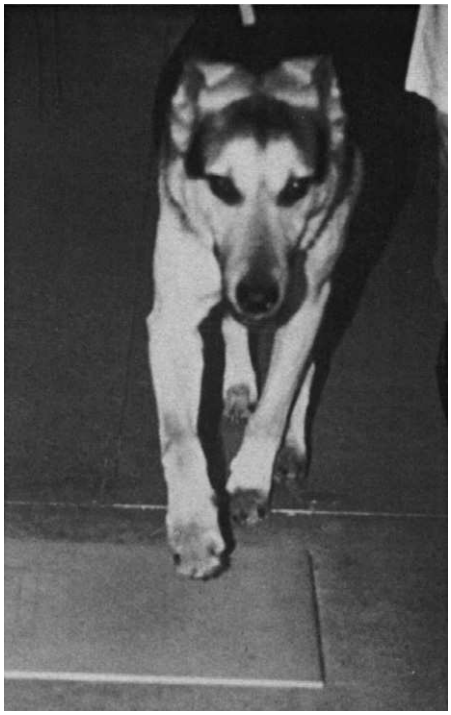


FIGURE 1-14. This dog is stepping with one foot on the rectangular force plate.

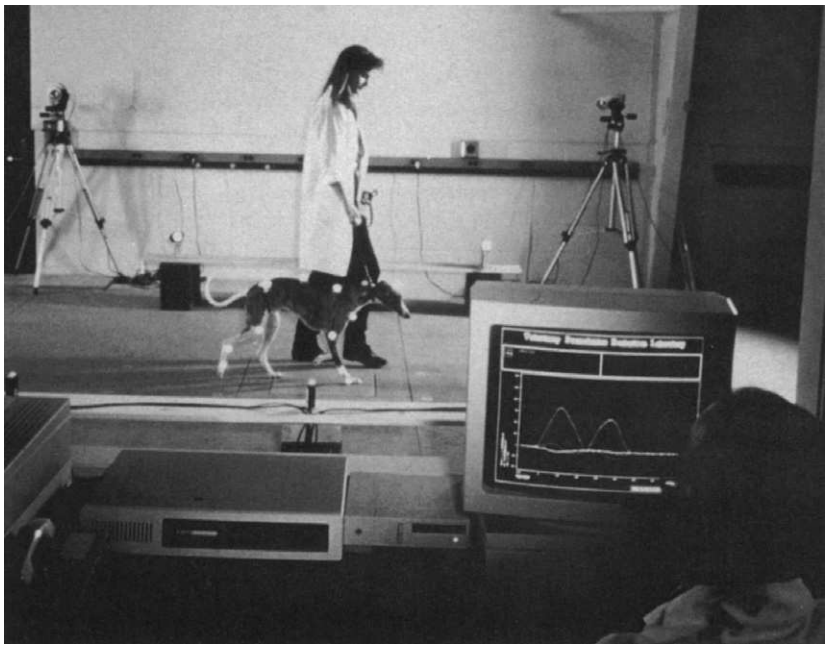


FIGURE 1-15. Kinematic gait (motion) analysis. Multiple markers are attached to the animal and then gaited between video cameras that send marker location signals to a computer. As many as 100 measurements per second can be made. Joint angles and duration of gait phase may be analyzed. (Courtesy Dr. Charles DeCamp.)

Exploratory Surgery

Exploratory surgery is often used to assess a condition totally or to discover the origin of joint, muscle, or bone problems. For example, a mature dog with a swollen stifle without drawer movement or patellar instability may have a partial cruciate tear, a previous OCD lesion, inflammatory joint disease, synovial tumor, or synovial chondromatosis. Exploratory surgery allows gross inspection of the joint as well as the opportunity to obtain biopsy specimens. Tissues removed should be of sufficient volume to be representative and to allow for histopathology, microbiology, or both.

Arthrocentesis

Arthrocentesis involves puncture and aspiration of joint fluid. Fluid may be grossly inspected, cultured, or analyzed for cell types and numbers (see Table 6-3), protein, viscosity, and glucose content. In addition, arthrocentesis allows instillation of medications, dye, or air for arthrography. As with all joint injections, the hair is clipped and surgical scrub applied. Spinal needles (18-22 gauge) are used. Care must be taken to avoid scratching the articular surfaces and make a "clean" puncture to avoid blood contamination. The appearance of joint fluid confirms proper needle placement. If no fluid appears, the needle is reintroduced in the same region, moved slightly, or approached from the other side of the joint if possible. Often, with swollen inflamed joints (rheumatoid arthritis), minimal extracellular fluid is present.

The injection techniques for various arthrocentesis sites are as follows:

Coxofemoral joint. The needle is introduced just cranioproximal to the trochanter major, aimed slightly ventrally and caudally (Figure 1-16).

Stifle. With the stifle flexed, the needle is introduced medial or lateral to the patellar ligament midway between the femur and tibia. Lack of fluid could mean the needle is in the fat pad or cruciate ligaments (Figure 1-17). Alternatively, the needle may be aimed carefully toward the femoral condyle just below the patella. There is less fat pad interference, but the needle may scratch the femoral surface.

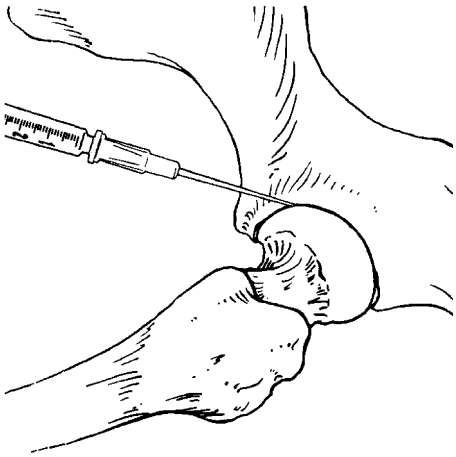


FIGURE 1-16. Arthrocentesis of the coxofemoral joint. The needle is introduced proximal and cranial to the trochanter major and is directed somewhat ventrally.

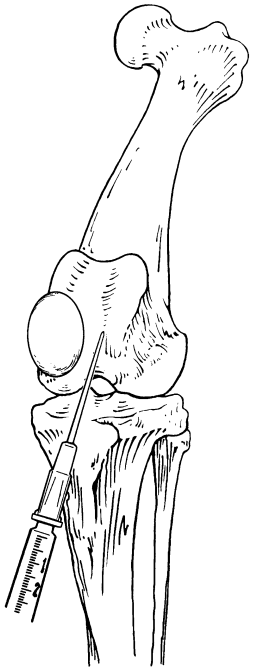


FIGURE 1-17. Arthrocentesis of the stifle joint. With the knee flexed, the needle is introduced just medial or lateral to the mid-portion of the straight patellar ligament.

Tarsocrural joint. With the tarsocrural joint hyperextended (that distends the joint caudally), the needle is inserted lateral or medial to the fibular tarsal bone and aimed cranially toward the middle of the joint (Figure 1-18). If swelling appears to be more cranially, a cranial approach can be used.

Shoulder joint. The needle is inserted about 1 cm distal to the acromion process and just slightly caudal to it (Figure 1-19). If fluid is not found, the needle should be "walked" in different directions from the same skin puncture site. If the forearm is pulled distally (separating the humerus from the scapula),

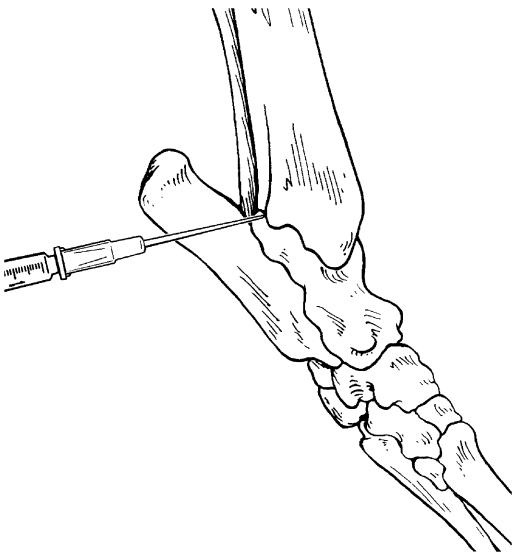


FIGURE 1-18. Arthrocentesis of the tarsocrural joint. With the hock held in extension, the needle is introduced lateral to the fibular tarsal bone and aimed toward the middle of the joint.

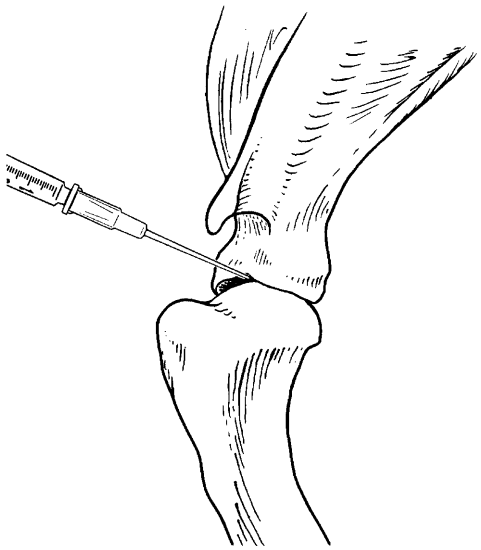


FIGURE 1-19. Arthrocentesis of the scapulohumeral joint. The needle is introduced about 1 cm distal to the acromion process of the scapula. If no fluid is obtained, an assistant may gently pull the forearm distally to "open" the joint space.

sometimes the needle is introduced in the center of the joint rather than under the capsule lateral to the humeral head.

Elbow joint. The elbow is hyperextended to allow the joint to distend caudally. The needle is introduced lateral to and alongside the olecranon and inserted cranially toward the middle of the joint until contact is made with the humeral condyle (Figure 1-20).

Carpal joint. The carpal joint is located with thumbnail pressure during joint motion. This joint is located on the same level as the *base* of the accessory carpal bone. The needle is introduced from the dorsal cranial aspect of the joint (Figure 1-21).

Other tests that may help diagnose systemic musculoskeletal disorders include testing for infections affecting muscle and joints (e.g., toxoplasmosis, Lyme disease),



FIGURE 1-20. Arthrocentesis of the elbow joint. With the elbow in extension, the needle is introduced just lateral to the olecranon.

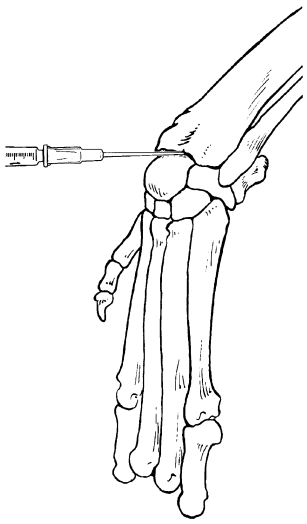


FIGURE 1-21. Arthrocentesis of the carpal joint. The joint lies on the same level as the base of the accessory carpal bone. With the joint flexed, the needle is introduced at the midline of the joint.

endocrine myopathies (hyperadrenocorticism, hypothyroidism), immune-mediated myopathies, and immune-mediated joint disease (rheumatoid arthritis, systemic lupus erythematosus). These tests include hematology, serology, histochemical staining of muscle, serum enzymes, electromyography, and cytology of swollen tissues.

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2

Fractures: Classification, Diagnosis, and Treatment

A *fracture* is a complete or incomplete break in the continuity of bone or cartilage. A fracture is accompanied by various degrees of injury to the surrounding soft tissues, including blood supply, and by compromised function of the locomotor system. The examiner handling the fracture must take into consideration the patient's local and overall conditions.

CLASSIFICATION OF FRACTURES

Fractures may be classified on many bases, and all are useful in describing the fracture.[1-3] These bases include causal factors; presence of a communicating external wound; location, morphology, and severity of the fracture; and stability of the fracture after axial reduction of the fragments.

Causal Factors

Direct Violence Applied to Bone. Statistics indicate that at least 75% to 80% of all fractures are caused by car accidents or motorized vehicles.

Indirect Violence. The force is transmitted through bone or muscle to a distant point where the fracture occurs (e.g., fracture of femoral neck, avulsion of tibial tubercle, fracture of condyles of the humerus or femur).

Diseases of Bone. Some bone diseases cause bone destruction or weakening to such a degree that trivial trauma may produce a fracture (e.g., bone neoplasms, nutritional disturbances affecting bone).

Repeated Stress. Fatigue fractures in small animals are most frequently encountered in bones of the front or rear foot (e.g., metacarpal or metatarsal bones in the racing greyhound).

Presence of Communicating External Wound

Closed Fracture. The fracture does not communicate to the outside.

Open Fracture. The fracture site communicates to the outside. These fractures are contaminated or infected, and healing at best may be complicated and delayed (see Figure 2-3, *A*).

Location, Fracture Morphology, and Severity

The system used for location, morphology, and severity of long-bone fractures is based on the classification system adopted by AO Vet, which was developed to allow fractures to be alphanumerically coded for easy data retrieval by computer.[3] It is based on the system used by the Arbeitsgemeinschaft fur Osteosynthese and Association for the Study of Internal Fixation (AO/ASIF) group for documentation of human fractures.[4] It permits grading of the complexity of fracture configuration and relative stability after reduction, thus providing information regarding appropriate treatment and prognosis (Table 2-1).

Localization of the fracture is provided by numbering each long bone (*1*, humerus; *2*, radius/ulna; *3*, femur; *4*, tibia/fibula) and dividing each bone into *1*, proximal; *2*, shaft; and *3*, distal zones. As a measure of severity, each fracture is typed as *A*, simple; *B*, wedge; or *C*, complex (Figure 2-1). Each grade is further grouped into three degrees of complexity (e.g., *A1*, *A2*, *A3*) depending on the type and extent of bone fragmentation. Thus the simplest shaft fracture of the humerus would be characterized as "1 2 A1." Proximal and distal zones may require individual descriptions to accommodate the specific bone morphology (Figure 2-2).

Additional specific *nomenclature* can be applied to each of these descriptions to convey more information. The orientation of the fracture line relative to the bone's

TABLE 2-1. THE AO VET ALPHANUMERIC MORPHOLOGICAL FRACTURE CLASSIFICATION SYSTEM

Localization			Fracture Morphology	
Bone 1 2 3 4	Segment 1 2 3	–	Type A B C Group A1, A2, •••C3	Subdivision 1 2 3

Redrawn from Unger M, Montavon PM, Heim UFA: *Vet Comp Orthop Trauma* 3:41-50, 1990.

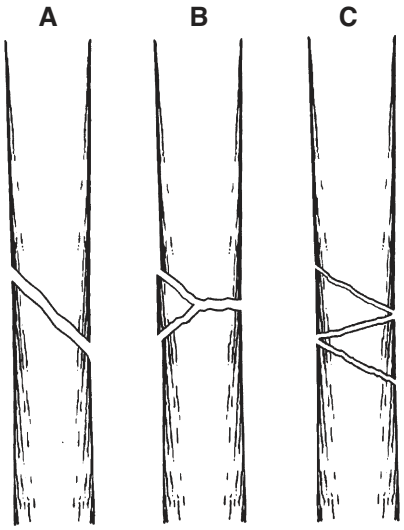


FIGURE 2-1. Diaphyseal fracture types. **A,** Simple fracture. **B,** Wedge fracture. **C,** Complex fracture. (Redrawn from Unger M, Montavon PM, Heim UFA: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

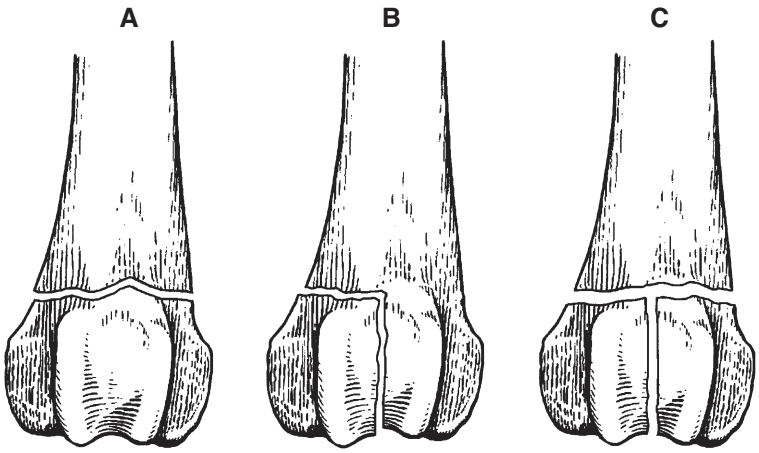


FIGURE 2-2. Proximal and distal long-bone fracture types. **A,** Extraarticular fracture. **B,** Partial articular fracture. **C,** Complete articular fracture. There are some special cases in the proximal humerus, radius/ulna, and femur because of their specific anatomy.

long axis allows the following descriptions:

Transverse Fracture. The fracture crosses the bone at an angle of not more than 30 degrees to the long axis of the bone (Figure 2-3, *D*).

Oblique Fracture. The fracture describes an angle of greater than 30 degrees to the long axis of the bone (Figure 2-3, *E*).

Spiral Fracture. This is a special case of oblique fracture in which the fracture line curves around the diaphysis (Figure 2-3, *F*).

The extent of damage can be described as follows:

Incomplete Fracture. Most often used to describe a fracture that only disrupts one cortex, an incomplete fracture is called a *greenstick* fracture in young animals because of the bending of the nonfractured cortex (Figure 2-3, *B*). *Fissure* fractures exhibit fine cracks that penetrate the cortex in a linear or spiral direction. In skeletally immature animals the periosteum is usually left intact (Figure 2-3, *C*).

Complete Fracture. A complete fracture describes a single circumferential disruption of the bone. Any fragmentation that results in a defect at the fracture site must be smaller than one third of the bone diameter after fracture reduction (see Figure 2-3, *D*).

Multifragmental Fractures. Also known as *comminuted* fractures, multifragmental fractures have one or more completely separated fragments of intermediate size. These fractures can be further described as follows:

Wedge fracture. A multifragmental fracture with some contact between the main fragments after reduction (see Figures 2-1, *B*, and 2-3, *G*).

Reducible wedges. Fragments with a length and width larger than one third the bone diameter (Figure 2-3, *G*). After reduction and fixation of the wedge(s) to a main fragment, the result is a simple fracture.

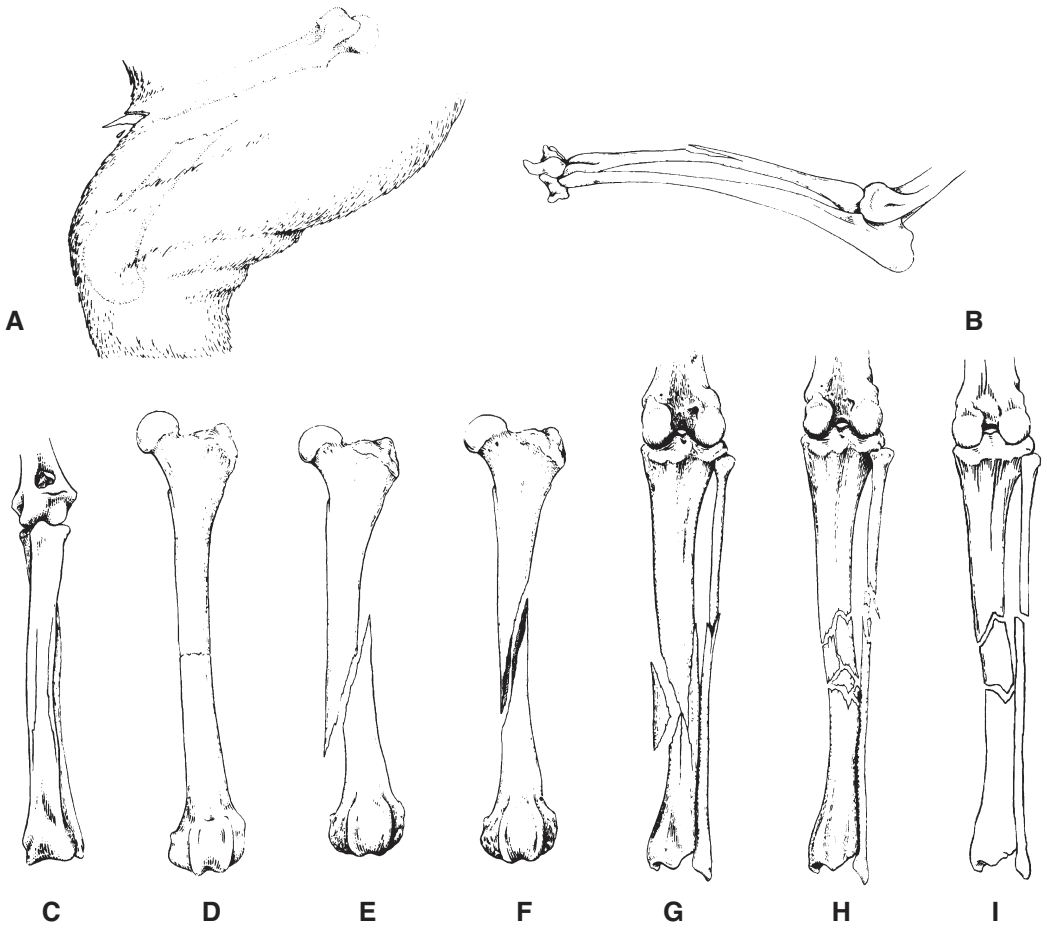


FIGURE 2-3. Descriptive nomenclature of diaphyseal fractures. **A,** Open. **B,** Greenstick. **C,** Fissure. **D,** Transverse. **E,** Oblique. **F,** Spiral. **G,** Reducible wedge. **H,** Nonreducible wedges. **I,** Multiple or segmental.

Nonreducible wedges. Fragments with a length and width less than one third the bone diameter and that result in a defect between the main fragments after reduction of more than one third the diameter (Figure 2-3, *H*).

Multiple or segmental fracture. The bone is broken into three or more segments; the fracture lines do not meet at a common point (Figure 2-3, *I*). This is a special case of a *reducible* wedge fracture.

Proximal and distal metaphyseal zones require specific nomenclature to describe the wide variety of extraarticular and intraarticular fractures seen in these locations, as follows:

Extraarticular Fractures. The articular surface is not fractured but is separated from the diaphysis (see Figure 2-2, *A*). These are typically called *metaphyseal* fractures. In a *physeal* fracture the fracture-separation occurs at the physeal line or growth plate. This type occurs only in the young, growing animal (Figure 2-4, *C*).

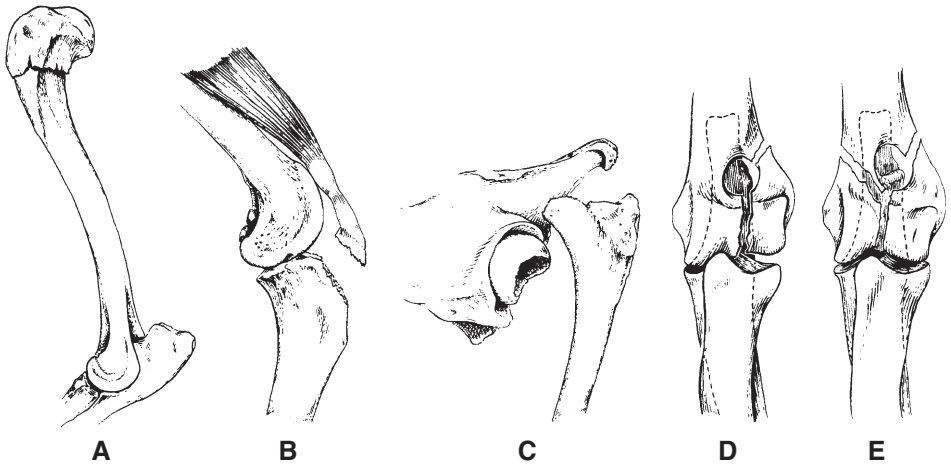


FIGURE 2-4. Descriptive nomenclature for proximal and distal zone fractures. **A,** Metaphyseal, impacted. **B,** Metaphyseal avulsion. **C,** Physeal. **D,** Partial articular or unicondylar. **E,** Complete articular or bicondylar.

Partial Articular Fractures. Only part of the joint surface is involved, with the remaining portion still attached to the diaphysis (see Figure 2-2, *B*). *Unicondylar* fractures are the most common example (Figure 2-4, *D*).

Complete Articular Fractures. The joint surface is fractured and completely detached from the diaphysis (see Figure 2-2, *C*). Humeral T or Y fractures are representative of this type (Figure 2-4, *E*).

The following additional descriptive terms are applied to certain fractures:

Impacted Fracture. The bone fragments are driven firmly together (Figure 2-4, *A*).

Avulsion Fracture. A fragment of bone, which is the site of insertion of a muscle, tendon, or ligament, is detached as a result of a forceful pull (Figure 2-4, *B*).

Stability after Replacement in Normal Anatomical Position

Stable Fracture. Fragments interlock and resist shortening forces (e.g., transverse, greenstick, impacted). The primary objective of fixation is to prevent angular and rotational deformity.

Unstable Fracture. The fragments do not interlock and thus slide by each other and out of position (e.g., oblique, nonreducible wedges). Fixation is indicated to maintain length and alignment and to prevent rotation.

BLOOD SUPPLY AND HEALING OF BONE

Until about 1940, almost all fractures were reduced, closed, and stabilized by external means, such as coaptation splints, plaster of Paris casts, and Thomas splints. The various methods of internal fixation were introduced and developed

during the same period as aseptic technique in veterinary surgery, open approaches to the various bones and joints, and open reduction of fractures. To handle tissues properly and implement reduction and fixation to best advantage, an understanding of blood supply and bone healing is essential.

Normal Vascularization of Bone

An adequate blood supply is necessary for bone to carry out its normal physiological function. Clinically, most vascular problems arise in the long bones. Blood supply to these bones is derived from three basic sources: (1) the afferent vascular system, (2) the intermediate vascular system of compact bone, and (3) the efferent vascular system.[5,6] The afferent system carries arterial blood and consists of the principal nutrient artery, the metaphyseal arteries, and the periosteal arterioles at muscle attachments (Figure 2-5). The periosteal arterioles are minor components of the afferent system and supply the outer layers of the cortex in the vicinity of firm fascial or muscle attachments.

The vessels in compact bones are intermediate between the afferent and efferent systems and function as the vascular lattice where critical exchange between the blood and surrounding living tissue occurs. This system consists of the cortical canals of Havers and Volkmann and the minute canaliculi, which convey nutrients to the osteocytes.

Venous drainage (the efferent system) of cortical bone takes place at the periosteal surface. Blood flow through the cortex is essentially centrifugal, from medulla to the periosteum. Although other venous drainage from the marrow



FIGURE 2-5. Normal blood supply to bone. **A,** Schema of afferent blood supply to immature bone. After the growth plate closes (adult bone), the metaphyseal and epiphyseal vessels anastomose. **B,** Section of diaphysis showing schema of normal afferent blood supply to compact bone. (From Rhinelander F, Phillips RS, Steel WM, et al: *J Bone Joint Surg* 50A:643, 1968.)

cavity is present, this is connected with the hematopoietic activity of the marrow cavity.

Response of Vascularization after Fracture

Disruption of the normal blood supply to bone varies with the complexity of the fracture. The afferent vascular components are stimulated and respond by hypertrophy, increasing in both diameter and number. In addition, a new blood supply is developed, termed the *extraosseous blood supply of healing bone,*[5,6] from the immediately surrounding soft tissues. This is separate from the normal periosteal arterioles. It furnishes blood to detached bone fragments, devitalized cortex, and the developing periosteal callus. When stability at the fracture site and continuity of the medullary circulation are established, the extraosseous blood supply regresses. Fortunately, the regenerative powers of the medullary arterial supply are rapid and enormous under favorable circumstances, since this must be reestablished for healing of cortical bone.

Some of the factors that may deter vascular response and thus bone healing are (1) trauma in connection with the original accident, (2) careless or improper surgical handling of the soft tissues, (3) inadequate reduction, and (4) inadequate stabilization of bone fragments. Intramedullary nails may temporarily damage the medullary afferent system, whereas plates may block the venous outflow. Either blood supply to the bone may be partially compromised, but both must be present to an adequate degree for bone healing.

Bone Healing

The pattern of bone healing varies according to the mechanical conditions present within the fracture line after reduction and stabilization of the fracture. The following four basic mechanical situations can be observed, and all may be present in one fracture[7]:

1. Bone immediately adjacent to a compression plate or lag screw may experience very high static (stabilizing) load, with very little dynamic (destabilizing) component.
2. A site farther from a compression plate, or a fracture stabilized with a very stiff external fixator, will experience moderately high compressive static loading with a small dynamic component. This situation could also be present in certain intramedullary pin/cerclage wire fixations.
3. A site slightly farther from a compression plate or screw, fixation with a buttress or bridging plate, or a fracture stabilized with a moderately stable external fixator will experience more even distribution between static and dynamic components. This would also be typical of many intramedullary pin fixations.
4. At the cortex opposite a plate or a unilateral external fixator, in some buttress or bridging plate situations and in some intramedullary pin fixations, a gap is continuously present because of varying dynamic loads (tension, bending, shear) that continuously exceed the stabilizing compressive loads.

In areas of intermittent bone contact, there will be resorption of the fracture surfaces to enlarge the gap, followed by *indirect bone union* (Figure 2-6). The sequence of events in this case may be briefly stated as (1) hemorrhage in the area, (2) clot formation, and (3) inflammation and edema, followed by (4) proliferation of pluripotential mesenchymal cells, (5) cartilage and bone formation, and (6) remodeling of callus back to

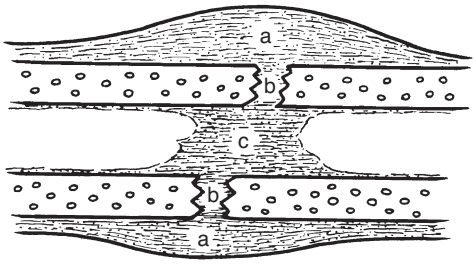


FIGURE 2-6. Callus formation in bone healing: *a,* periosteal bridging callus; *b,* intercortical bridging callus; *c,* medullary bridging callus.

normal bone. The sequence of events results in a progressive replacement of the tissue in the fracture gap with stiffer and stronger tissue, going from granulation tissue to connective tissue to fibrous tissue to cartilage to mineralized cartilage to lamellar bone to cortical bone. This entire process is under the direction and control of a host of cellularly produced active mediators, such as chemoattractants, as well as angiogenetic and growth factors.[8]

Callus formation may be subdivided on the basis of location into (1) medullary bridging callus, (2) periosteal bridging callus, or (3) intercortical bridging callus (see Figure 2-6). The pattern of callus formation will vary greatly in response to circumstances and stimuli present. In general, however, stabilization of fractures by external splintage, the external fixator, buttress (bridging) plates, and intramedullary pins is characterized by the formation of callus in all three areas. Stability of the fracture fragments is not absolute, and micromotion is present. The developing callus is responsible for early stabilization of the fracture and results in relatively early clinical union, that is, the point at which the bone is able to assume normal weight-bearing forces without dependence on the fixation device. In contrast, excessive dynamic loading is responsible for *delayed union,* where the transformation of callus from cartilage to bone is delayed because of the poor blood supply within the areas of excessive motion. Other than in the young growing animal, the amount of callus is in inverse relation to the degree of stability at the fracture site.

Healing in areas of contact and high compression forces, as well as in very small, stable gaps (<0.1 mm), is described as *direct bone union* (Figure 2-7). This type of union bypasses most of the steps previously described and goes directly to cortical remodeling. Union of the cortices is achieved by internal remodeling of the haversian system without resorption of the fracture surfaces. This intense remodeling at the fracture surface may be radiographically confused with resorption because it results in slight loss of density in the fracture zone. Thus, stabilization of fractures by use of compression plates and screws is characterized by no visible intercortical callus and small amounts of medullary bridging callus. Healing in areas of mixed compressive and dynamic loads can exhibit all three types of healing patterns.

Successful healing in areas of direct contact of the bone fragments or in areas of very small fracture gaps depends on absolute stability, because *strain* on individual cells filling the fracture gap is magnified by any motion at the site and can easily cause rupture of these cells.[9] As can be seen from Table 2-2, there is a dramatic difference in the tolerance to strain by the three major cell types found in the healing fracture gap. Figure 2-8 illustrates the effect of micromotion in a small fracture gap.[10] Thus it becomes obvious that if closed reduction and interfragmentary compression are chosen, it becomes imperative to provide absolutely stable fixation. If this cannot be guaranteed, it is better not to reduce the fragments too closely in order to ensure survival of the tissues in the fracture gap in the presence of the micromotion inevitable in such a mechanical situation. This is the basis of the concept of "bridging osteosynthesis," as discussed in the following section.

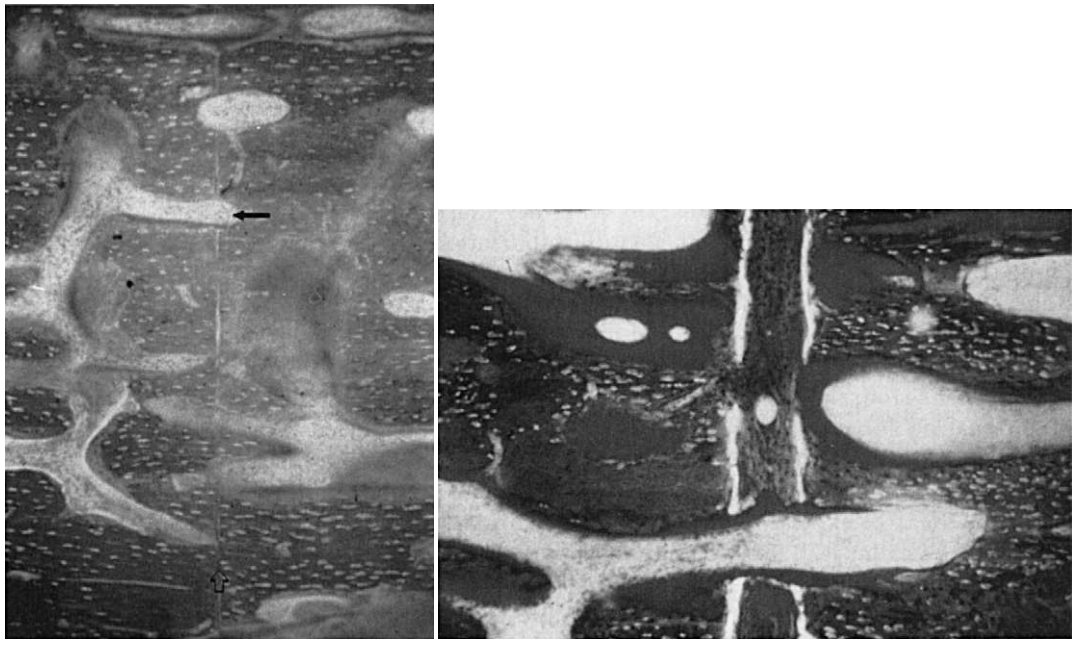


FIGURE 2-7. Direct (primary) bone union. **A,** Contact healing at 4 weeks of osteotomy stabilized by compression plate. A thin zone of necrotic bone can be seen in the center of the section. There is extensive haversian remodeling of the bone ends, with osteons growing across both living and dead cortex and bridging the osteotomy. **B,** On the side opposite the plate there is a small fracture gap. This space is invaded by capillaries and accompanied by osteoblasts that deposit osteoid. Bone lamellae form initially parallel to the fracture line and then are replaced by axially oriented osteons to complete the remodeling. This type of direct bone healing without the intermediate steps of fibrous tissue and cartilage formation is possible under conditions of good stability and a gap up to 0.3 mm wide. (Courtesy Dr. Robert Schenk.)

TABLE 2-2. TOLERANCE TO INTERFRAGMENTARY STRAIN

Cell Type	Tolerance to Elongation	Tolerance to Bending
Granulation tissue	100%	40 degrees
Cartilage	15%	5 degrees
Bone	2%	0.5 degree

Data from Perren SM, Cordey J: The concept of interfragmentary strain. In Uthoff HK, editor: *Current concepts of internal fixation,* Berlin, 1980, Springer-Verlag.

In summary, bone healing depends on and is influenced by blood supply at the fracture line, reduction of the fracture fragments, and the degree of stabilization of the fracture fragments.

DIAGNOSIS OF FRACTURES AND PRINCIPLES OF TREATMENT

The history and clinical signs usually indicate the presence of a fracture; however, radiographs are essential for precise determination of its nature.

The first consideration is preserving the patient's life; repair of tissues and restoration of function are secondary. Treatment for shock, hemorrhage, and

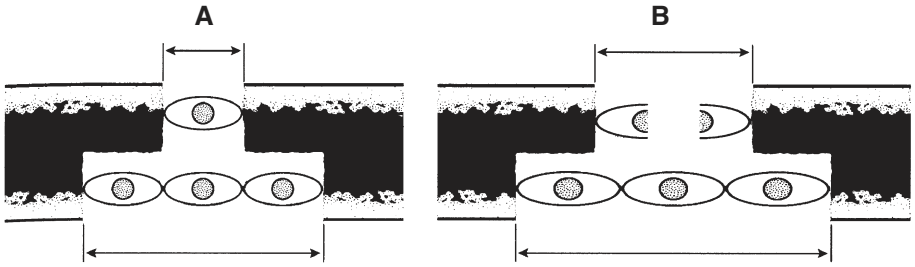


FIGURE 2-8. Concept of interfragmentary strain in a small fracture gap. **A,** One granulation tissue cell is seen within the 10-μm fracture gap and three cells within the 30-μm gap. **B,** Increasing the gap by 10 μm (not perceptible to the eye) causes a 100% strain and rupture of the cell in the small gap, but only a 33% strain on the cells in the larger gap. Thus the resorption of fragment ends seen in areas less than totally stable is an attempt to protect the soft tissues by widening the gap. (Redrawn from Rahn BA: Bone healing: histologic and physiologic concepts. In Sumner-Smith G, editor: *Bone in clinical orthopaedics,* Philadelphia, 1982, Saunders, pp 335-386.)

wounds of the soft tissues, if present, should be instituted immediately, and the patient should be made as comfortable as possible.

Examination of an animal with a fracture or suspected fracture should include the following:

1. Assessment of the animal's general health.
2. Determination of whether tissues or organs adjacent to the fracture or other parts of the body have been damaged and, if so, to what extent.
3. Examination to ascertain whether fractures, ligamentous instability, or dislocations are present in other parts of the body.
4. Precise evaluation of the fracture or fractures. (See Chapter 1 for a more complete discussion on physical examination of the locomotor system.)

Clinical Signs

Even though they are not always readily detectable, visible signs at the fracture area include one or more of the following:

1. Pain or localized tenderness
2. Deformity or change in angulation
3. Abnormal mobility
4. Local swelling (This may appear almost immediately or not until several hours or a day after the accident. It usually persists for 7 to 10 days because of the disturbed flow of blood and lymph.)
5. Loss of function
6. Crepitus

Radiographic Examination

Radiographs of at least two views at right angles to each other are essential for accurate diagnosis and selection of the best procedures for reduction and immobilization.

Reduction and Immobilization

Because movement of fracture fragments results in pain to the animal, these radiographs usually require sedation or short-acting general anesthesia. If this presents a problem because of respiratory compromise from traumatized lungs, it may be necessary to delay performing radiography. In this situation it is often helpful to obtain only the one view that can be taken without anesthesia to confirm the location and severity of the fracture. This then allows the formation of a basic treatment plan. Bear in mind that the second view should be taken before attempting reduction and stabilization.

In the immature or deformed animal, interpretation of the radiograph may present special problems because of the presence and stages of development of various osseous growth centers. Radiographs of the opposite limb are usually helpful.

Treatment

The goal of fracture treatment is early ambulation and complete return of function.

Return to Function

The principles of fracture treatment have been articulated best by the AO/ASIF group,[11-13] as follows:

1. *Anatomical reduction* of fracture fragments, especially in articular fractures.
2. *Stable fixation,* suitable to the biomechanical and clinical situation.
3. *Preservation of the blood supply* to the bone fragments and surrounding soft tissues through atraumatic reduction and surgical technique.
4. *Early active pain-free mobilization* of muscles and joints adjacent to the fracture to prevent development of fracture disease.

The interpretation and emphasis of these principles have undergone a gradual change in recent years as AO/ASIF has promoted the concept of *biological fixation*. The primary consideration in this concept is the protection of the soft tissues and the blood supply of the fracture fragments. This means that anatomical reduction, in the sense of total reconstruction of all fracture lines, is deemed necessary only for articular fractures or shaft fractures treated by interfragmentary compression using lag screws or cerclage wires, which are then protected by a neutralization plate. Direct bone union without callus is to be expected under this protocol. Other shaft fractures are treated by leaving the fragments undisturbed to protect their blood supply. The fracture zone either is spanned by a bridging plate attached to each end of the bone or is stabilized by an external skeletal fixator or interlocking medullary nail. Healing in this case is by the indirect route, with early callus formation responsible for much of the stabilization. Hulse and Aron[14] have proposed the term "bridging osteosynthesis," which is useful and descriptive and thus is used throughout this text. Anatomical reduction in this circumstance means restoring axial alignment in both the frontal and the sagittal plane, eliminating torsional deformity, and maintaining bone length to the extent possible, although the latter is not as consequential in quadripeds as in bipeds.

The concept of *stable internal fixation* must also be reevaluated in consideration of the aims of bridging osteosynthesis. All fixation must maintain axial alignment and length and provide rotational stability. Stabilization by interfragmentary compression demands absolute stability of the small remaining fracture gap in order for direct haversian bridging to occur (see previous section on bone healing). When the objective is bridging osteosynthesis, the fixation must be only as strong as needed to

allow callus formation. *Small* amounts of interfragmentary motion are not only probable but also even *desirable* for callus formation, which actively enters into the role of stabilizer of the fracture, thus protecting the internal fixation from mechanical overload and failure. How much fixation is needed in a given situation is difficult to define succinctly but is addressed in detail later in this chapter (see also specific fractures in later chapters).

The concept of *atraumatic technique* has received increased emphasis in the employment of bridging osteosynthesis strategies, especially as applied to preservation of blood supply to bone fragments. Providing sufficiently strong internal fixation to allow early pain-free mobilization of the limb has always been and continues to be of primary importance to the veterinary orthopedic surgeon. Not only is bone healing aided, but the soft tissue integrity of the limb is better maintained, and nursing care of the animal is greatly simplified.

Reduction and Fixation

Reduction and fixation of the fracture should be undertaken as soon as the patient's condition permits.[15,16] Delay makes reduction more difficult because of spastic contraction of the muscles and inflammatory thickening of the soft tissue. In some cases, fixation can be accomplished when the patient is presented; in others, it may be advisable to delay for a day or longer until the patient becomes an acceptable anesthetic risk. It is inadvisable to wait until the swelling has subsided before going ahead with reduction and fixation. By this time, organization of the hematoma and callus formation are well underway. Callus formation also obscures fracture lines, nerves, and blood vessels. In addition, surgical hemorrhage is greatly increased as a result of increased circulatory response in the area. This circulatory response is usually evident about the fourth day after trauma. Surgery before this time is accompanied by less hemorrhage.

RATE OF BONE UNION AND CLINICAL UNION

The moment a fracture occurs, changes in the tissue in the immediate area set the stage for its repair, and many factors may influence the rapidity of the repair process. The surgeon can do little to alter such factors as age, character of the fracture, state of the soft tissues in the surrounding area, and certain systemic or local bone diseases. Unfavorable factors, however, such as poor reduction, inadequate immobilization, excessive operative trauma, and lack of aseptic surgical procedures, are within the surgeon's control. These factors, along with owner compliance or animal disposition, may slow or even interrupt the healing process. When all other factors are equal and the fracture is optimally treated, *age of the patient* is the most influential factor affecting the rate of healing.

Clinical union refers to the period in the recovery process of a fracture when healing has progressed to the point in strength that the fixation can be removed. Table 2-3 lists average periods of anticipated healing for the typical, uncomplicated fracture treated optimally. These healing times vary somewhat, depending on the type of fixation used. Fractures immobilized with external fixation, skeletal fixation, and intramedullary pins heal with the development of an external and internal bridging callus. The bridging callus does give added early strength to the fracture site. Fractures immobilized with rigid fixation (bone plate) heal primarily by direct union and some internal callus, and animals with fractures treated by this method should have the fixation in place for a longer period.

TABLE 2-3. RATE OF UNION IN TERMS OF CLINICAL UNION

Age of Animal	External Skeletal and Intramedullary Pin Fixations	Fixation with Bone Plates
Under 3 months	2-3 weeks	4 weeks
3-6 months	4-6 weeks	2-3 months
6-12 months	5-8 weeks	3-5 months
Over 1 year	7-12 weeks	5 months-1 year

Table 2-3 is not to be interpreted as an indication that one method of fixation is superior to another. Each method has its place, indications, and contraindications, as described later.

Radiographic evaluation of fracture healing (Figure 2-9) should be routinely performed at the time of expected union, as indicated in Table 2-3. The mnemonic "AAAA" has proved useful for evaluation of such radiographs (Egger E, Schwarz P: Personal communication, 1994), as follows:

1. *Alignment*. This is basically an assessment of the restoration of the bone as a whole. Alignment is evaluated in relation to angular and torsional displacement relative to normal. Return to normal alignment is necessary for normal long-term function.
2. *Apposition*. Looking more directly at the fracture site, the examiner here is evaluating the degree of realignment of the fracture fragments. A certain degree of apposition is required for routine bone healing, but this degree is highly dependent on the type of fixation employed; thus, no single definition can be used in all situations.
3. *Apparatus*. Is the fixation device functioning as intended to maintain stability of the fracture until healed? Were applicable protocols for the device followed? Is there evidence of loosening of implants? Is there evidence of impending failure of the implant, such as bending or screw loosening?
4. *Activity*. This is the biological activity of the bone in response to the fixation used. To evaluate activity, it is necessary to know the age of the animal, the length of time since the fracture was stabilized, and the degree of functional use of the limb. It is also useful to consider such factors as preexisting infection and open wounds or other devascularizing injuries. This is the area where the type and amount of callus formation are evaluated. The examiner must search for signs of infection (e.g., bone lysis) and periosteal, new bone formation. Bone resorption is evaluated to decide if this represents normal revascularization of bone fragment edges or indicates infection or loosening of an implant. Table 2-4 details typical radiographic signs of healing.

REDUCTION OF FRACTURES

Reduction of a fracture refers to the process of replacing the fractured segments in their original anatomical position. Fractures can be reduced by either *closed reduction* with traction and manipulation of the fragments or *open reduction* and direct visual reconstruction of the bone. Bones with their muscles attached may be likened to a system of levers with springs attached. Muscles are constantly contracting *(normal tonus)*. Flexors oppose extensors, counterbalancing the part at the joint. When a bone is fractured, all opposing muscles contract maximally, and overriding

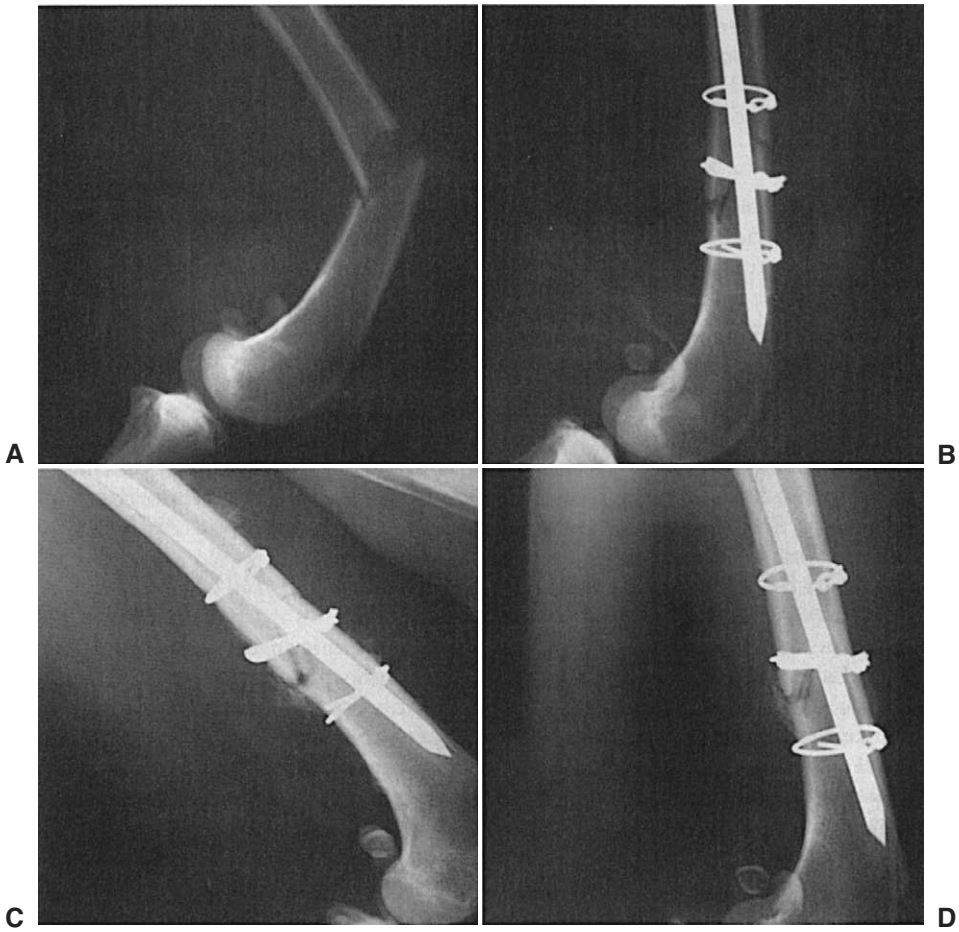


FIGURE 2-9. Fracture healing in various forms. Table 2-4 summarizes this process. *Indirect healing* is illustrated in parts *A* through *J*. **A** and **B,** Type A2, simple diaphyseal fracture of the femur stabilized with a Steinmann pin, two cerclage wires to prevent propagation of fissure fractures, and an interfragmentary skewer-pin and wire. The fracture lines are clearly visible postoperatively. **C,** At 4 weeks the fracture line is less visible, and there is patchy mineralization of unstructured bridging callus. **D,** The fracture line is faintly visible at 7 weeks, and callus is smoothing and becoming uniform in density. The Steinmann pin was removed.

and shortening of the bone occur. Spastic contraction of the muscle is intensified by injury to soft tissues of the region. The pull caused by the muscle spasm is constant and continuous, even under general anesthesia. Initially, the contraction and overriding are primarily muscular and are responsive to general anesthesia, countertraction, and some of the muscle-relaxing drugs. After several days, inflammatory reaction in the area with its accompanying proliferating changes leads to contraction of a more permanent nature; thus, more difficulty is encountered when attempting reduction.[2]

Gas anesthesia (halothane, methoxyflurane, or isoflurane) is superior to the barbiturates in bringing about relaxation of muscle spasm. The addition of muscle relaxants is helpful in overcoming spastic contraction when used in addition to general anesthesia and within the first 3 days after a fracture occurs. Succinylcholine (0.44 mg/kg) or pancuronium (0.05 to 0.1 mg/kg) has been used in small animals;

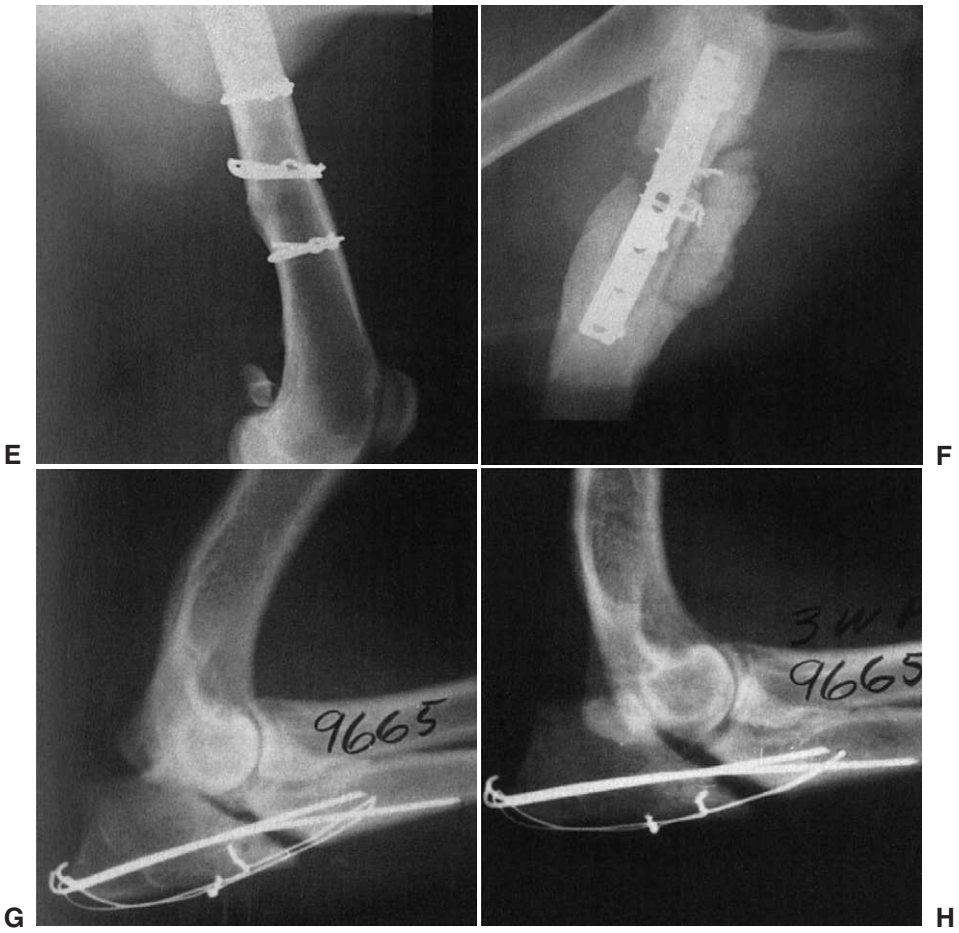


FIGURE 2-9. *Continued* **E,** By 14 weeks, only a faint hint of the fracture line remains, and the dense callus is being remodeled on the periosteal and endosteal surfaces. **F,** Florid periosteal callus in a skeletally immature dog 4 weeks postoperatively. This extreme callus is not caused by instability but rather by intraoperative trauma to the active periosteum. Note the absence of callus cranially at the fracture site, which was the area most devitalized by intraoperative handling. This area later bridged with callus. **G** and **H,** To illustrate the widening of the fracture gap caused by vascularization of the fracture edges, compare the postoperative gap seen in *G* with the situation 3 weeks later in *H*. This is a more dramatic than normal response because the fracture was 3 weeks old at surgery and the fracture fragment edges were more devascularized than in a fresh fracture.

Continued

succinylcholine is preferred. At the doses listed, these drugs also produce respiratory paralysis, and assisted respiration is necessary. The duration of action is about 20 to 30 minutes.

To a large extent, healing is influenced by the handling of the soft tissues, blood supply to the fracture segments, accuracy of reduction, and efficiency of immobilization. All these factors may be influenced or altered by the surgeon.

The ideal situation is anatomical replacement of the fracture segments, because this gives the possibility of maximum stability when fixation is applied.

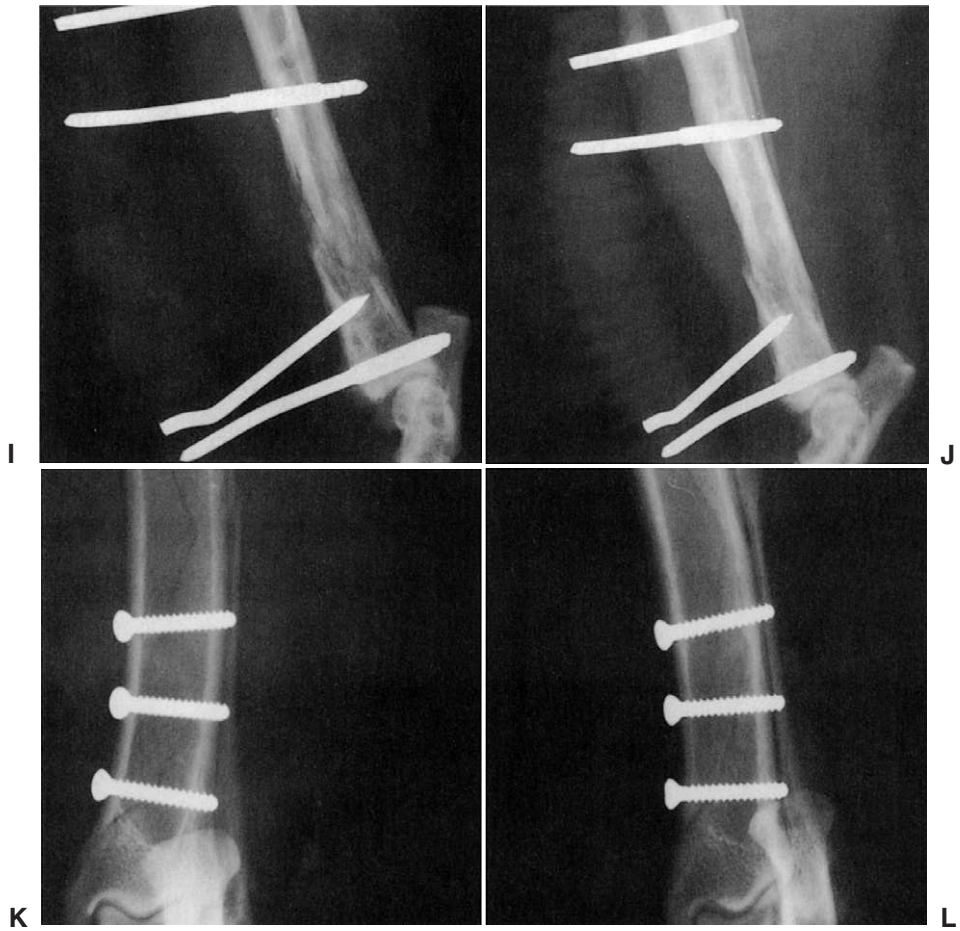
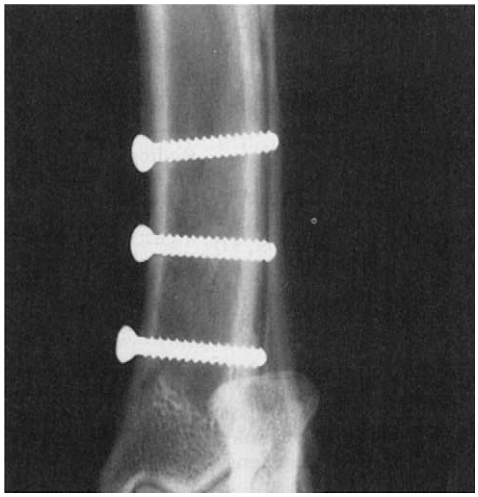


FIGURE 2-9. *Continued* **I,** This type A3, complex distal extraarticular tibial fracture was stabilized by external fixator and closed reduction (biological osteosynthesis) 20 weeks previously. Fracture lines are faintly visible, with remodeling of callus and cortical bone evident. The fixator was destabilized at this time by removing some of the proximal fixation pins. **J,** At 32 weeks, cortical remodeling is almost complete, and the fixator was removed. *Direct healing* is illustrated in parts *K* through *M*, a type A1, simple extraarticular tibial fracture stabilized with lag screws and external coaptation. **K,** Postoperatively the double-spiral fracture line is obvious despite the perfect reduction. **L,** Fracture lines are becoming hazy and fading proximally at $6^1/_2$ weeks. No callus is present except at the fibular fracture.

Anatomical apposition is always preferred but not always necessary, particularly in fractures of the diaphysis. Rotational alignment must be restored between the joints proximal and distal to the fracture to ensure good function. Axial bending in the cranial-caudal direction (sagittal plane) is well tolerated unless the limb becomes excessively shortened. Moderate medial angulation in the frontal plane *(varus)* of the distal segment is quite well tolerated, but lateral angulation *(valgus)* usually produces significant functional problems.

When a joint surface is involved in a fracture, the articular fragments must always be reduced anatomically to restore joint congruency and thus to eliminate or at least minimize abnormal wear and secondary osteoarthrosis. The secret of reduction is the application of continual, steady pressure over time. This fatigues the muscles, bringing about relaxation and lengthening.



M

FIGURE 2-9. *Continued* **M,** At 10 weeks the fracture lines have disappeared in most areas and are obviously well bridged in those areas where they can be identified. (Radiographs courtesy Dr. Richard Park.)

TABLE 2-4. RADIOGRAPHIC SIGNS OF FRACTURE HEALING*

Radiographic Sign	Postoperative Time
Sharp fracture margins (Figure 2-9, *A* and *B*)	1 week
Indistinct fracture margins and widening of fracture gap (Figure 2-9, *G* and *H*)	2 weeks
Unstructured and patchy mineralization of bridging callus; fracture line still visible (Figure 2-9, *C* and *F*)	4-6 weeks
Bridging callus of even density and smooth borders; fracture line faintly visible (can remove some of fixation; e.g., pins from external fixators) (Figure 2-9, *D*)	6-9 weeks
Dense callus of reduced size; fracture line barely visible, early corticomedullary remodeling (stage of early clinical union) (Figure 2-9, *E*)	8-12 weeks
Further condensation of callus; distinct corticomedullary separation caused by remodeling; fracture line not visible (Figure 2-9, *I* and *J*)	10 weeks>>>

*Assuming normal adult fracture situation with stable fixation and good vascularity to the fracture fragments.

Closed Reduction

Closed reduction is usually accomplished by manipulation along with the application of traction and countertraction. This is ideal, provided that it can be accomplished and maintained with minimal tissue trauma, and many fractures are so treated in human patients. This should not influence veterinary surgeons unduly, since the problems they face in regard to patient cooperation and aftercare cannot be compared with those in humans. Closed reduction is the norm when external fixation devices such as casts and splints are employed. This method is most useful *below the elbow and stifle,* where soft tissues are not a hindrance in palpating the bone to aid in determining reduction. This is also the region where casts and splints are most applicable in animals.

Closed reduction has greater success in small and relatively long-legged breeds than in large, chondrodystrophied, or heavily muscled breeds. This approach should be attempted as soon as the patient's condition permits general anesthesia, because any delay increases muscle spasm and contracture as well as the difficulty

in obtaining reduction. Do not wait for the swelling to go down; it will not regress until reduction restores normal circulation. Initially, the contracture and overriding are primarily muscular in nature and respond to traction, general anesthesia, and muscle relaxants. After 2 to 3 days, inflammatory reaction and its proliferative changes cause a much more permanent and difficult-to-overcome contracture.

Methods of Closed Reduction

The guiding principle in any method of closed reduction is to apply slow, continuous traction to the fragment that can be controlled, aligning it with the less manageable fragment. It is important to perform all manipulations while being alert to the possibility of laceration, perforation, or compression of a major vessel or nerves. Apply traction *slowly* to relax muscles and not cause irritation.

Traction can be obtained by manual force (Figures 2-10 and 2-11) or by gravity (Figure 2-12). *Manual traction* is facilitated if a gauze or soft rope loop is placed around the axillary or groin region and anchored to the edge of the table near the animal's back. Another gauze or rope loop is placed around the carpal or tarsal area, and traction is applied against the first rope. The *Gordon extender* is a mechanical device that allows comparable traction to be exerted without the surgeon exerting as much force (Figure 2-13). Relaxation of muscle is best accomplished by a slow, progressive increase of traction tension over 10 to 30 minutes.

To use *gravity* to obtain traction, position the animal on its back, and place gauze, tape, or soft rope around the paw of the affected limb, then attach this to an infusion stand or to a ceiling-mounted eyebolt (see Figure 2-12). The length of the attaching material is adjusted to raise the animal slightly off the table so that a portion of the body weight is being supported and thus producing traction on the limb. Traction for 10 to 30 minutes adequately fatigues the muscles and aid in reduction.

In *skeletal traction,* sterile pins or ice tong–like devices are attached to the distal fragment and traction is exerted on the device. This method is not widely used in veterinary surgery but has merit, since it allows for a straight pull on the bone

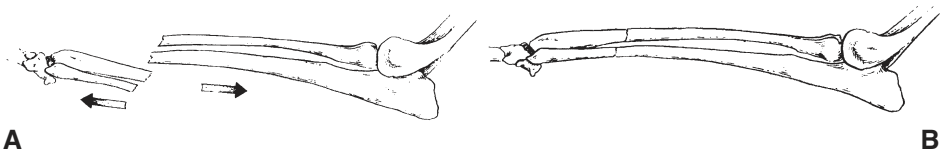


FIGURE 2-10. Application of traction, countertraction, and manipulation.

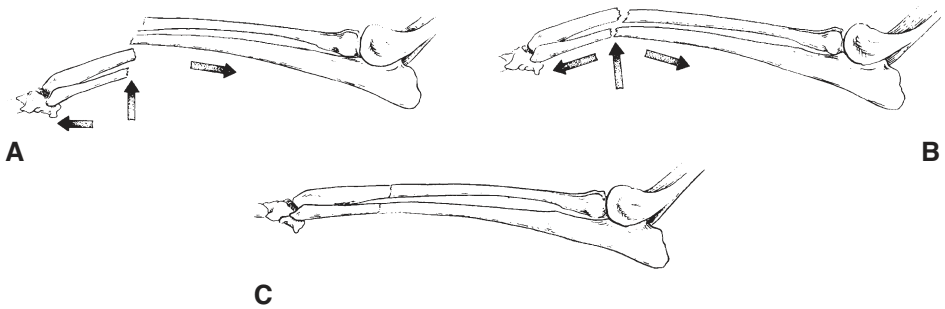


FIGURE 2-11. Application of traction, countertraction, and toggeling or bending.

fragments, whereas the other methods all cause some distraction of bone ends because of muscle pull. The Gordon extender is a useful method of producing traction.

After adequate traction, directly reducing the fragments may be possible by direct manipulation of the more movable fragment (see Figure 2-10). More likely is the necessity of resorting to *toggeling,* or angulation of the bone ends (see Figure 2-11).

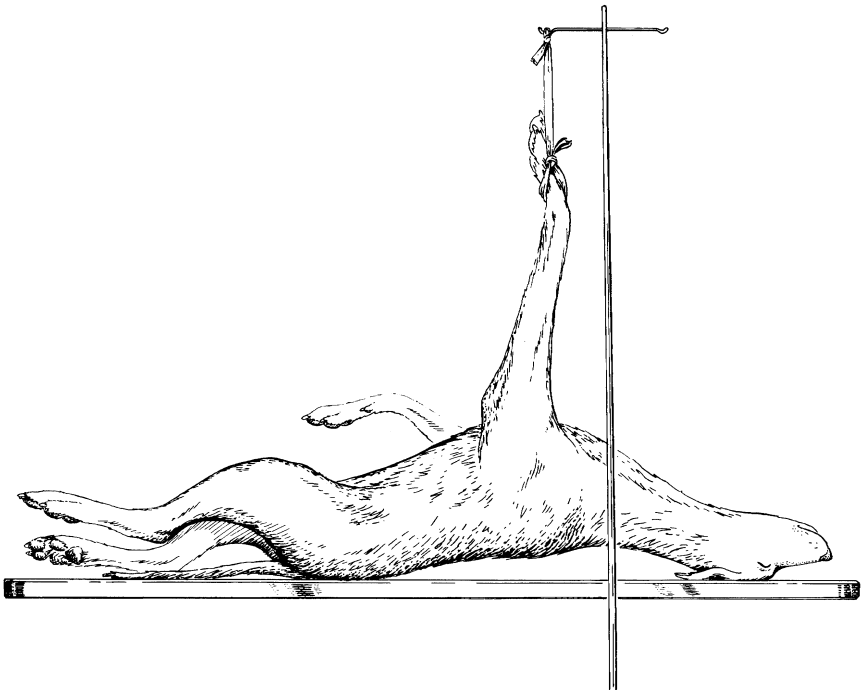


FIGURE 2-12. Use of animal's weight to apply traction and countertraction in fatiguing spastically contracted muscles.

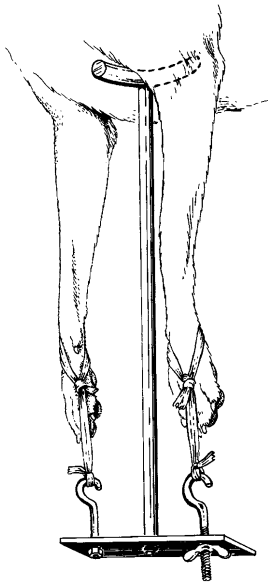


FIGURE 2-13. Use of the Gordon extender. Gradual turning down of the wing nut increases traction on the affected limb. The wing nut is tightened at about 5-minute intervals to increase traction.

In toggeling the bone fragments are angulated to form a V so that the ends can be brought into contact; the ends are then maintained in reduction while the angle formed by the bones is forcefully reduced by pressure at each end of the bone. Maintenance of this pressure fatigues the muscle to allow restoration of length.

Open Reduction

Open reduction is the method of choice in many fracture cases. The fragments are reduced under direct vision, and usually some type of internal fixation is applied to ensure that the position is maintained. (Internal fixation is discussed in the section on immobilization and in the chapters covering treatment of specific fractures.)

Open reduction technique is used particularly in a high percentage of (1) fracture cases that are unstable and more complicated, (2) those of more than several days' duration, (3) those involving an articular surface, and (4) those for which internal fixation is indicated. Many of the more common open approaches are described in association with the treatment of fractures involving the various bones; *An Atlas of Surgical Approaches to the Bones and Joints in the Dog and Cat* is the standard reference for these approaches.[17] The surgeon should strive continually to improve techniques for handling soft tissue. Key guidelines in this area include the following:

1. Be gentle and efficient. All soft tissues are handled carefully and retracted with respect. Avoid excessive handling of any tissue to preserve viability and healing potential of soft tissue and bone.
2. Attain strict hemostasis. Active bleeding must be controlled if the operative field is to be clearly visualized. Control of hemorrhage may also be critical in preserving the life of the animal, and it reduces some of the possible complications in postoperative healing. Electrocoagulation is invaluable because it is efficient in sealing small bleeding points and shortens operating time.
3. Follow normal separations between muscles and fascial planes.
4. If a muscle needs to be severed for exposure, do this near its origin or insertion to minimize trauma and hemorrhage, facilitate closure, and minimize loss of muscular function.
5. Know the location of major blood vessels and nerves. Locate these structures and work around them.
6. Avoid putting excess traction on nerves because this may lead to temporary or permanent injury.
7. Preserve soft tissue attachments (and therefore blood supply) to bone fragments in the process of exposure, reduction, and application of fixation.
8. Use suction, rather than blotting, to minimize soft tissue trauma.
9. When necessary, blot with moist gauze sponges (Ringer's solution) to help clear the area. Avoid wiping.
10. Irrigate copiously to remove blood clots and debris.

Each fracture is unique and may require a different maneuver or combination of maneuvers to bring about reduction. Again, the preferred technique in most cases is the application of gradual, progressive pressure over time to fatigue the muscles and bring about sufficient relaxation to allow the reduction of bone fragments.

Disposition of Bone Fragments at Fracture Site

The surgeon frequently encounters various bone fragments in the fracture area. As a general rule, all fragments are kept whether or not they have soft tissue attachment.

The exact disposition of these fragments depends on what scheme of internal fixation will be employed. As discussed in the section on immobilization, the surgeon either can try to achieve anatomical reconstruction of the fragments or can leave the fragments untouched to preserve their blood supply. If anatomical reconstruction is chosen, all fragments with soft tissue attachments are carefully handled to maintain this attachment. The pieces that are too small for internal fixation with bone screws, wires, or Kirschner wires are maneuvered back into position as best as possible with minimal disruption of soft tissue attachments. In most cases the surrounding soft tissue maintains or even improves the position of these pieces as the process of healing begins. Large fragments, with or without soft tissue attachment, are usually fixed in place with lag screws, wires, or Kirschner wires.

As a general rule, these fragments aid in restoring the original bone substance and function as an autogenous bone graft. They only form sequestra when contamination or infection is present, and even under these circumstances, they may enter into callus formation.

Removal of fragments often results in delayed union, nonunion, or a decrease in diameter of the bone in that area. Generally, if removed, fragments should be replaced by a bone graft. That is particularly true if rigid fixation (plate) is applied or if any conditions are present (e.g., older animal, devitalized surrounding tissue, architectural deficits after reduction) that result in slow healing (see Chapter 3).

Methods of Open Reduction

The following methods are suggested approaches to open reduction:

1. Application of levering by use of some instrument, such as an osteotome, bone skid, periosteal elevator, or scalpel handle (Figure 2-14).
2. Application of direct force (using bone-holding forceps) on one or more of the bone fragments (Figure 2-15).
3. Direct application of force on both the bone fragments (Figure 2-16, *A* and *B*). After the fragments are reduced by the application of traction, countertraction, and corrective rotation, self-holding bone forceps may be used to maintain reduction temporarily while fixation is applied (Figure 2-16, *E*).
4. Application of distraction force through the bone-holding forceps (Figure 2-16, *C* and *D*). If the overriding muscle forces are strong enough, it may be difficult to achieve the last small amount of distraction to allow complete reduction by simple traction, as illustrated in Figure 2-16, *A* and *B*. If the bone-holding forceps is applied with finger pressure across the bone at an angle, it can then be rotated to force each bone fragment into the reduced position. This maneuver depends on the friction between the bone and forceps being greater than that between the bone fragments. Apply this method cautiously in young

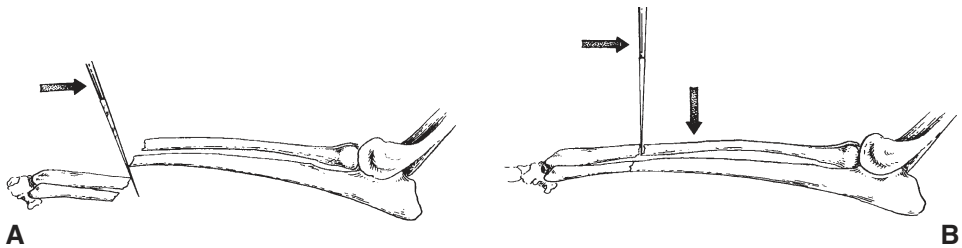


FIGURE 2-14. Application of levering by use of an osteotome.



FIGURE 2-15. Application of direct force (using bone-holding forceps) on one or more bone fragments.

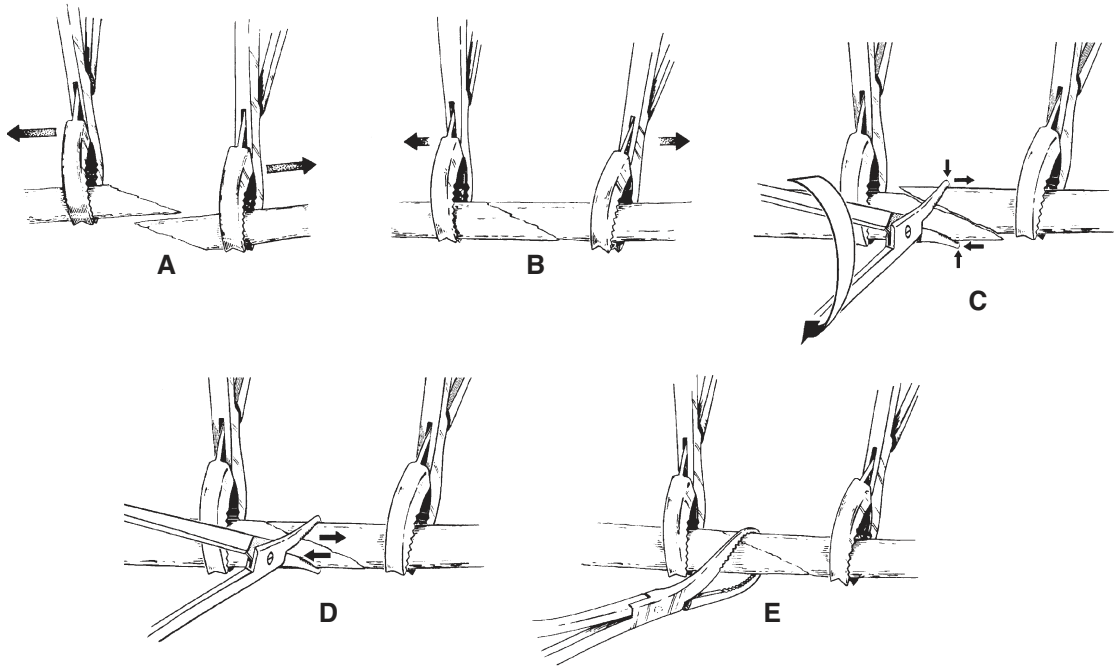


FIGURE 2-16. Open reduction of fractures. **A** and **B,** Direct application of force to the bone fragments. **C,** Oblique fracture overriding can be reduced by grasping the fragments with a bone-holding forceps that is angulated so that each jaw is toward the end of the bone fragment. The forceps is not locked but held by finger pressure only. **D,** By rotating the forceps in the direction shown in *C* while applying enough pressure to cause the forceps to grasp the cortex, the fragments will slide into reduction. **E,** After reduction, a locking bone-holding forceps is used to maintain temporary reduction of the fragments while fixation is applied.

animals, because the bone may be crushed before adequate friction is created between the bone and forceps.

5. Direct application of force on both the bone fragments combined with the use of levering (Figure 2-17).
6. Use of the *fracture distractor* (Synthes, Ltd., Paoli, Pa; Jorgensen Laboratories, Loveland, Colo) (Figure 2-18). In multifragmentary fractures, it is often difficult to restore length through direct distraction forces, and the distractor is invaluable in these cases. Fixation pins are applied through both cortices, then attached to the distractor with finger nuts. Wing nuts on a threaded rod

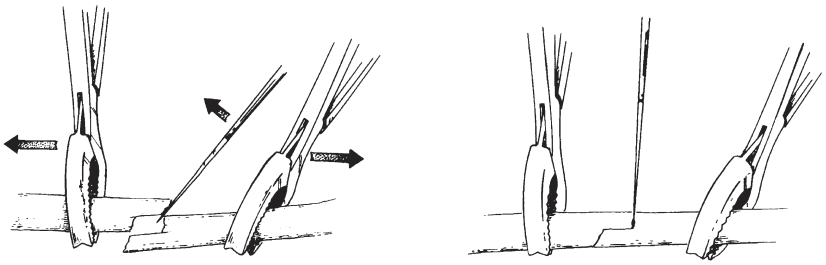


FIGURE 2-17. Direct application of force on both bone fragments combined with the use of levering.

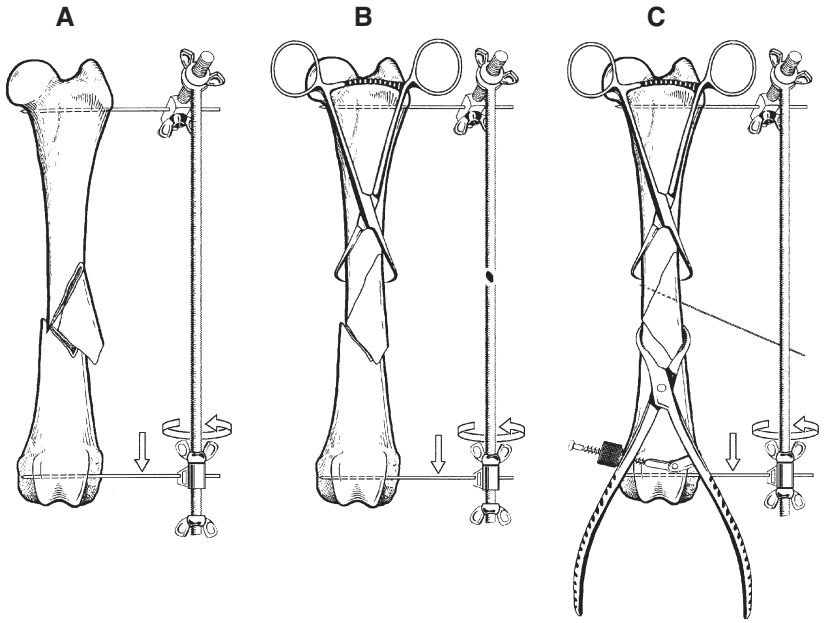


FIGURE 2-18. Use of the fracture distractor to aid in reduction is particularly helpful in femoral fractures in large-breed dogs. **A,** Fixation pins are placed through both cortices of the proximal and distal fragments in locations that will cause minimal interference when fixation is applied. In most cases these pins are placed through the skin outside using the open approach. Clockwise rotation of the wing nut will cause distraction of the fracture. **B,** As length is regained, individual fragments can be reduced and held with bone-holding forceps. **C,** When length is totally restored, it is possible to reduce the fracture completely and stabilize it with a bone-holding forceps. Kirschner wires are also useful for temporary fixation. If bone plate fixation is used, the plate can be molded and clamped to the bone before the distractor is removed.

allow the fracture to be slowly distracted until the fragments can be secured with bone-holding forceps, Kirschner wires, or cerclage wires. Definitive fixation, usually a bone plate or external fixator, can be applied at this time. Some angular deformity develops as distraction progresses, and this will need to be reduced during application of the definitive fixation.

7. Use of the *Steinmann pin* as a fracture distractor (Figure 2-19). This is a simple alternative to the fracture distractor applicable to fractures of the humerus and femur. A Steinmann pin with a diameter of 50% of the

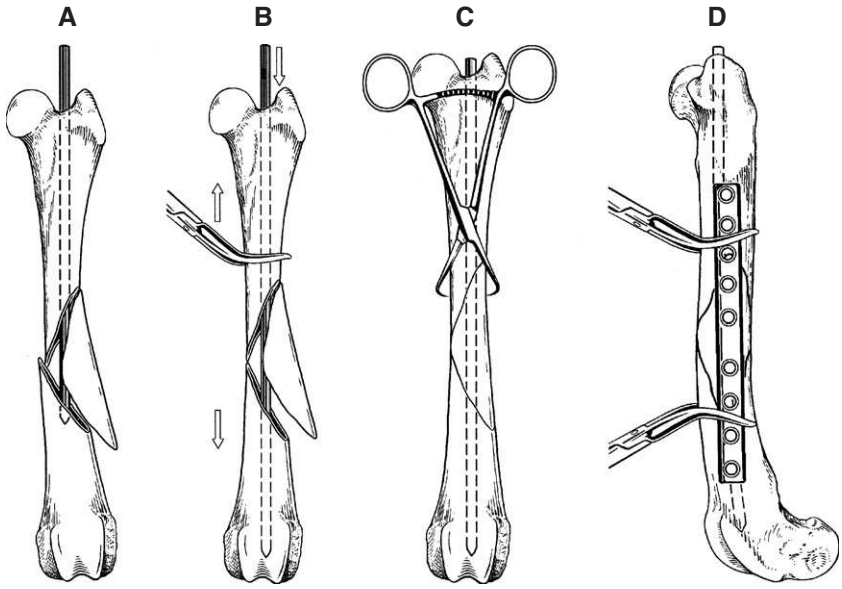


FIGURE 2-19. Fracture distraction with an intramedullary (IM) pin. **A,** Steinmann pin is placed in the normograde manner and driven distally across the fracture site, and the pin is maneuvered into the medullary canal of the distal fragment. If the IM pin will not be used for final fixation, the pin diameter can be smaller than usual. **B,** The distal fragment is brought into axial alignment by bone-holding forceps and traction through the proximal tibia while the stifle is flexed 90 degrees. The pin is driven distally by pressure without rotation until it seats in the distal metaphysis. As pressure is applied to the pin with counterpressure on the proximal fragment using a bone-holding forceps, the distal fragment is gradually reduced. **C,** Bone-holding forceps are used to hold reduced fragments. **D,** If bone plate fixation is used, the plate is molded and clamped to the bone before the IM pin is removed.

medullary canal is introduced into the bone in either a normograde or a retrograde manner. It is then driven across the fracture line(s) into the distal fragment. This is facilitated if the distal fragment is angulated to restore axial alignment by means of a bone-holding forceps. While the proximal fragment is secured with a bone-holding forceps to allow force to be applied in a proximal direction, the pin is driven against the distal metaphyseal area without any rotational drilling action, thus producing distraction. Once adequate length is attained, the fragments are secured with bone-holding forceps, Kirschner wires, cerclage wires, or a bone plate, and the pin is withdrawn.

Note: Bone fragments must be handled with care because too much force may result in additional fragmentation. In skeletally immature animals the bone is easily crushed by bone-holding forceps.

IMMOBILIZATION (FIXATION)

Immobilization involves fixing the bone fragments so that they are motionless with respect to each other during the healing process. The objectives are to stabilize the fragments and to prevent displacement, angulation, and rotation. Ideally, the

fixation method used should (1) accomplish uninterrupted stabilization at the time of the original surgery, (2) permit early ambulation, and (3) permit the use of as many joints as possible during the healing period.

The peculiarities of each fracture will dictate or suggest the method of immobilization to be employed. Some fractures lend themselves to a variety of methods, whereas in other fractures the methods may be very limited for a successful outcome.

Methods of Fixation

The methods of fixation may be classified as follows:

1. Limb splintage (coaptation splints, casts, modified Thomas splint)
2. Bone splintage (intramedullary pin, external skeletal fixator, bone plate)
3. Compression (lag screw, cerclage/interfragmentary wire, tension band wire, tension band/compression plate)

Fixation by *splinting* stabilizes the bone either *indirectly* as with casts and splints or *directly* as with pins, fixators, or bone plates that are attached to the bone. There is a certain amount of motion at the fracture site because of the inherent flexibility of these types of devices. The surgeon must ensure that the amount of motion at the fracture site is still within the limits consistent with callus formation. Fixation by *compression* utilizes interfragmentary friction produced by relatively small implants to produce stability of the bone surfaces. The compression may be *static* in nature, as with a lag screw or cerclage wire, in which case the compression is not expected to change with time. *Dynamic* compression, on the other hand, does change cyclically with loading of the limb as limb function periodically loads and unloads the bone surfaces. Functionally induced tension of the bone fragments is transformed into compression forces by the tension band wire or plate.

Temporary Splintage

If for some reason there is a delay in reduction and fixation, temporary splintage (e.g., Robert-Jones dressing, coaptation splint, Thomas splint) of the limb may be indicated to reduce additional trauma. This is true particularly for fractures distal to the elbow and stifle. In most other fractures, the animal is more comfortable simply with cage rest and mild sedation/analgesia. The objective in most fracture cases is early reduction and fixation.

Coaptation Splints and Casts

Knowledge of internal fixation of fractures is highly advanced, with diverse fracture fixation systems available to all veterinary surgeons; however, a definitive therapeutic role remains for coaptation devices. We must not neglect the "art" of constructing a proper splint. Rigid materials such as fiberglass, plaster, and splint rod provide the mechanical strength and stiffness required in external coaptation, but these may also endanger the splinted limb if used improperly. In choosing between the various types of bandages, splints, and casts, it is important to consider the somewhat conflicting basic principles of orthopedic bandaging versus external coaptation. The challenge is to balance a patient's needs for soft bandaging with the strict requirements for bone splinting.

External casts, splints, and bandages are often called "coaptation fixation devices," the word "coapt" meaning to approximate. This is accomplished by

simply immobilizing muscles, as with a bandage, or by transmitting compression forces to the bony structures by means of the interposed soft tissues, as with casts and splints. Such pressure must be uniformly distributed throughout the cast or splint to avoid circulatory stasis and swelling.

Casts are generally considered to be molded tubular structures that, if removed, would form a mold from which a casting of the limb could be made. A *splint* is something less than a full cast and typically is molded only to one aspect of the limb. A wire frame structure such as the Schroeder-Thomas splint is a special case, using soft bandage materials to suspend the limb within the wire frame.

As a general rule, molded casts and splints are more efficient stabilizers of the bones and joints than premade ones or the Schroeder-Thomas splint, although good use can be made of both latter methods. The advantage of molded devices is that they custom-fit the animal perfectly and therefore cause fewer soft tissue problems and are better tolerated by the patient. For many years, plaster of Paris was the only moldable material available, but many such materials have become available. Of these, two types have proved especially useful, the thermomoldable and the fiberglass/resin materials. *X-Lite* (AOA Kirschner Medical Corporation, Marlow, Okla) and *Vet-Lite* (Jorgensen Laboratories, Loveland, Colo) are *thermomoldable* plastic materials, impregnated onto an open-mesh fabric. When heated to 160° to 170° F, the material becomes very soft and self-adherent and then hardens within a few minutes as it cools to room temperature. It is available as precut splints or rolls in 3-, 4-, and 6-inch widths. These materials are most useful in small animal patients for making splints. *Veterinary Thermoplastic* (VTP) (IMEX Veterinary Inc., Longview, Texas) is similar in application but is a solid, homogenous material rather than an open mesh; it is also available in rolls of varying widths. Because these materials are self-adherent, they can be made as stiff as necessary by adding layers to effect.

Fiberglass materials have a resin-binding material impregnated into the roll of knitted fiberglass tape. They are popular because of ease of application and relatively few complications. The resin is activated by a 10- to 15-second immersion in water of room temperature, after which the material cures and hardens within a few minutes at room temperature. Fiberglass has proved very useful for full-cylinder casts, although it can also be used for splints. Cast-cutting saws are essential for removing cylinder casts. All these products are lightweight, strong, and waterproof. Because wider width material generally makes stronger casts, use the widest roll consistent with the animal's size.[18] To obtain maximal usefulness, use them with polypropylene or other synthetic stockinet and cast padding, both of which shed water. Because these materials all "breathe" and do not retain water, there are few soft tissue problems such as maceration of skin. Pressure sores are still possible when casts are incorrectly applied, but even this problem occurs less frequently than when cotton padding materials are used. Synthetic orthopedic felt used over bony prominences will do much to reduce pressure sores. In general, the middle and distal phalanges of the middle toes should be left exposed to monitor swelling. Often the cast, once hardened, is cut longitudinally in two places (bivalved) to create two half-shells and to facilitate future cast changes. The two halves are secured to each other with non-elastic adhesive tape.

Owners should be instructed to observe the protruding toes twice daily, looking for signs that the toenails are spreading apart. Such a sign indicates swelling and requires that the cast be removed immediately to prevent pressure necrosis. Reapplication of the cast with less pressure can follow immediately, or the limb can be placed in a Robert-Jones bandage for a few days to allow swelling to be resorbed. The animal should be kept indoors to minimize damage to the external fixation device.

If taken outside for elimination in wet or damp conditions, a plastic bag or similar impervious material should be temporarily placed over the foot to keep the cast/splint or bandage material clean and dry. An electric hair dryer can be applied to hasten drying in case the cast becomes wet. The owner should be instructed to have the device checked regularly at 7- to 10-day intervals or at any sign of foul odor, drainage, loosening, chafing, instability, or obsessive licking or chewing on the appliance. Such signs are indications for removal of the device and evaluation of the soft tissues, with appropriate treatment. Reapplication of the cast/splint may require some revision to prevent recurrence of the problem. The thermomoldable materials are reheated and reapplied as originally. Do not remove a cast or splint simply because a certain amount of time has elapsed and you are curious to see the soft tissues; if the animal is tolerating the device well and it is still functional, it should be left undisturbed until the appropriate time for removal.

Because of the pain created by manipulating broken bones and the muscular relaxation needed for most reductions, general anesthesia is almost always indicated when applying these devices.

Indications for Coaptation

Consider the forces acting on the bone and how well the proposed immobilization will neutralize them: angulation or bending, rotation (shear), shortening or overriding (shear), and distraction. The following indications generally fall within the range of casts and splints:

1. Closed fracture below elbow or stifle. In Figure 2-20, *a′, b′, c′,* and *d′* indicate the length of cast/splint needed for fractures in zones *a, b, c,* and *d.*
2. Fractures amenable to closed reduction, as previously discussed.
3. Fractures in which the bone will be stable after reduction relative to shortening or distraction; classified above as type A or B fractures (see Table 2-1).
4. Fractures in which the bone can be expected to heal quickly enough that the cast/splint will not cause severe joint stiffness and muscle atrophy (fracture disease).
5. Specific indications follow:
   - Greenstick fractures.
   - Long-bone fractures in young animals in whom the periosteal sleeve is mostly intact.
   - Impaction fractures.

Long-Leg Cylinder Cast

A long-leg cast is one that extends from the toes to the axilla or groin (Figure 2-21). Plaster of Paris or fiberglass/resin tape are the most commonly used materials. A variety of casting tapes made of knitted fiberglass substrate and impregnated with various resins are now available and utilized in much the same manner as plaster of Paris. These products are strong, lightweight, waterproof, and porous but cannot be molded as perfectly as plaster. These casts must be removed with a cast-cutting oscillating saw whether they are made of plaster of Paris or fiberglass.

The cast can be bivalved after it has hardened for ease of inspection and redressing. To prevent the padding from sticking to the resin, it is covered with a sheet of thin polyethylene film (as used for food storage) while the cast material is applied. After hardening of the resin, the cast-cutter saw is used to split the cast into halves along either the sagittal or the frontal plane. The plastic film is removed after separating the two halves, which are then reapplied and held together with nonelastic white tape. Future cast changes are accomplished by cutting the tape, removing the

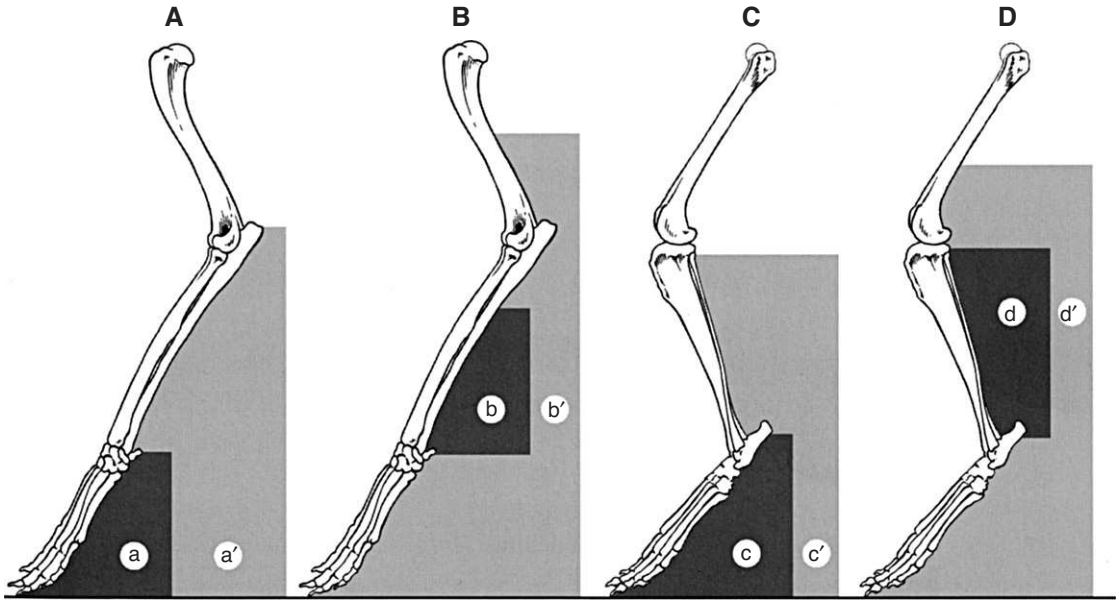


FIGURE 2-20. Optimal splint or cast length for fractures in the dark-shaded areas are shown by the length of the light-shaded areas.

half shells, repadding the limb, and reapplying the half shells. Care must be taken to apply the same amount and type of padding as was used originally to prevent either undue pressure or looseness when the cast is reapplied.

Indications. Immobilization of the elbow and stifle, the radius and ulna, and the tibia and fibula.

Short-Leg Cylinder Cast

A short-leg cast extends only to the proximal tibia or radius (Figure 2-22). The elbow and stifle joints are free to move normally. The casts must be distal enough (1-2 inches below the humeral epicondyle or tibial tubercle) so that there is no binding during flexion/extension. Limb swelling under a cast may lead to disastrous sequelae.

Indications. Immobilization of the carpus and metacarpus and the tarsus and metatarsus. As a general rule, short-leg casts are used primarily in large, active animals to provide more stabilization than short-leg splints.

Spica Splint—Foreleg

Although this splint can be constructed with wood, rigid plastics, or aluminum, the molded splint is better tolerated and gives better immobilization (Figure 2-23). The spica splint is named for the method of attaching it to the body by a "spica" (figure-of-8) bandage. In the dog the bandage is modified to be only half a figure-of-8. It can be applied to the hip, but bandaging in this region is very difficult, especially in the male dog, and ambulation is awkward.

Indications. Immobilization of the shoulder, humerus, and elbow.

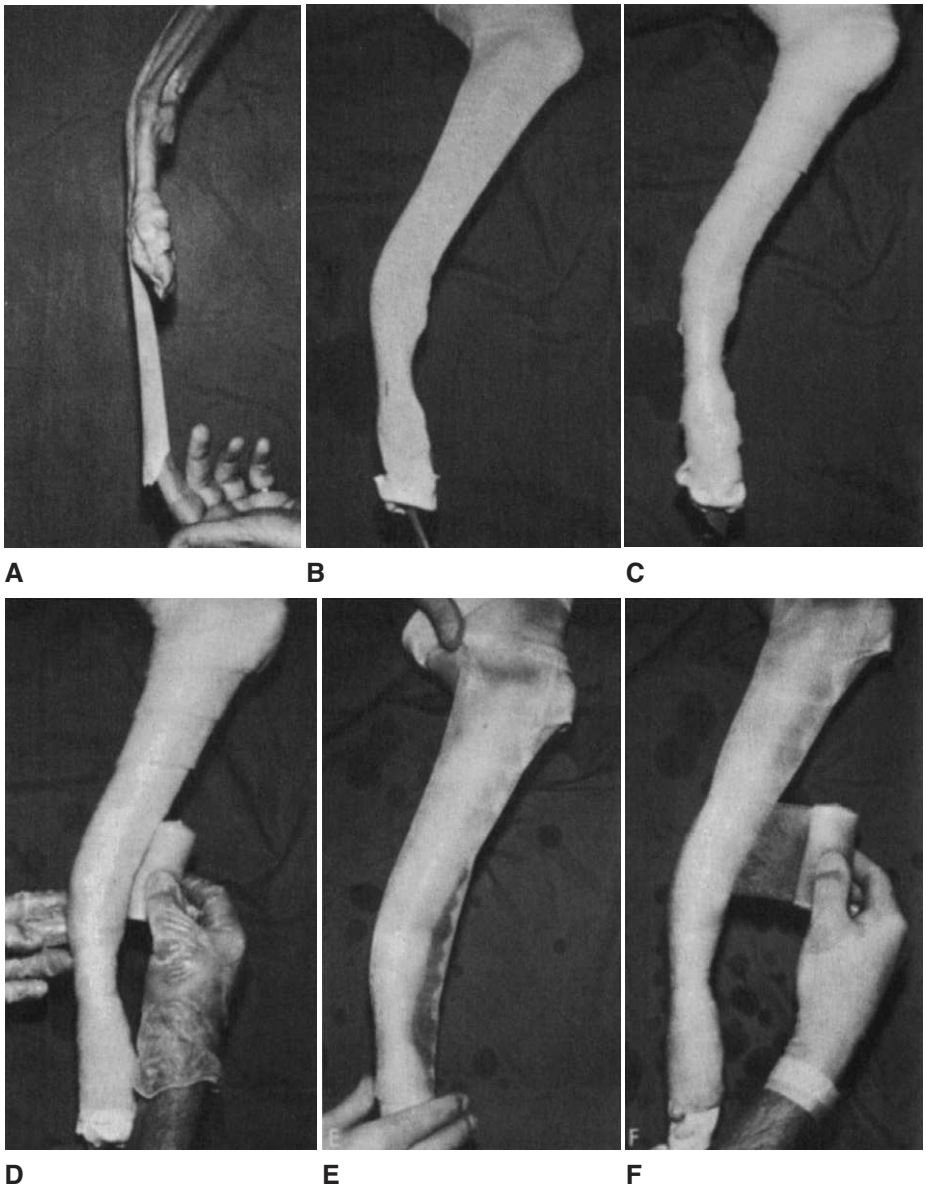


FIGURE 2-21. Long-leg cylinder cast extends from the toes to the axilla or groin. Application here is to the forelimb with fiberglass material. **A,** Adhesive tape stirrups are applied to the lower limb and extend several inches beyond the toes. **B,** Polypropylene stockinet is applied to the limb. The material should be long enough to extend distally beyond the toes and well into the axilla proximally. **C,** Two or three layers of polypropylene cast padding are applied to the limb starting at the toes and proceeding proximally. **D,** After the fiberglass tape is immersed in water at room temperature for 12 to 15 seconds and gently squeezed of excess water, the roll of fiberglass is spiraled onto the limb; rubber or vinyl (as recommended by the manufacturer) gloves are used to protect the hands. This material should be rolled on smoothly using even pressure, which is facilitated by rolling continuously around the limb in a spiral fashion and not raising the roll away from the skin. Two layers of cast material are produced by overlapping the spirals by half the width of the roll. The distal end of the cast should be at the level of the base of the distal phalanx of the middle toes. **E,** A longitudinal splint is applied to both the medial and lateral sides. This material is cut from the roll and applied over the spiraled material. Mechanical testing has revealed that these splints add more strength to fiberglass casts when applied cranially and caudally.[18] **F,** A second spiral layer is applied over the splints, resulting in four spiraled layers plus the medial and lateral splints. Very large breeds may require six layers.

Continued

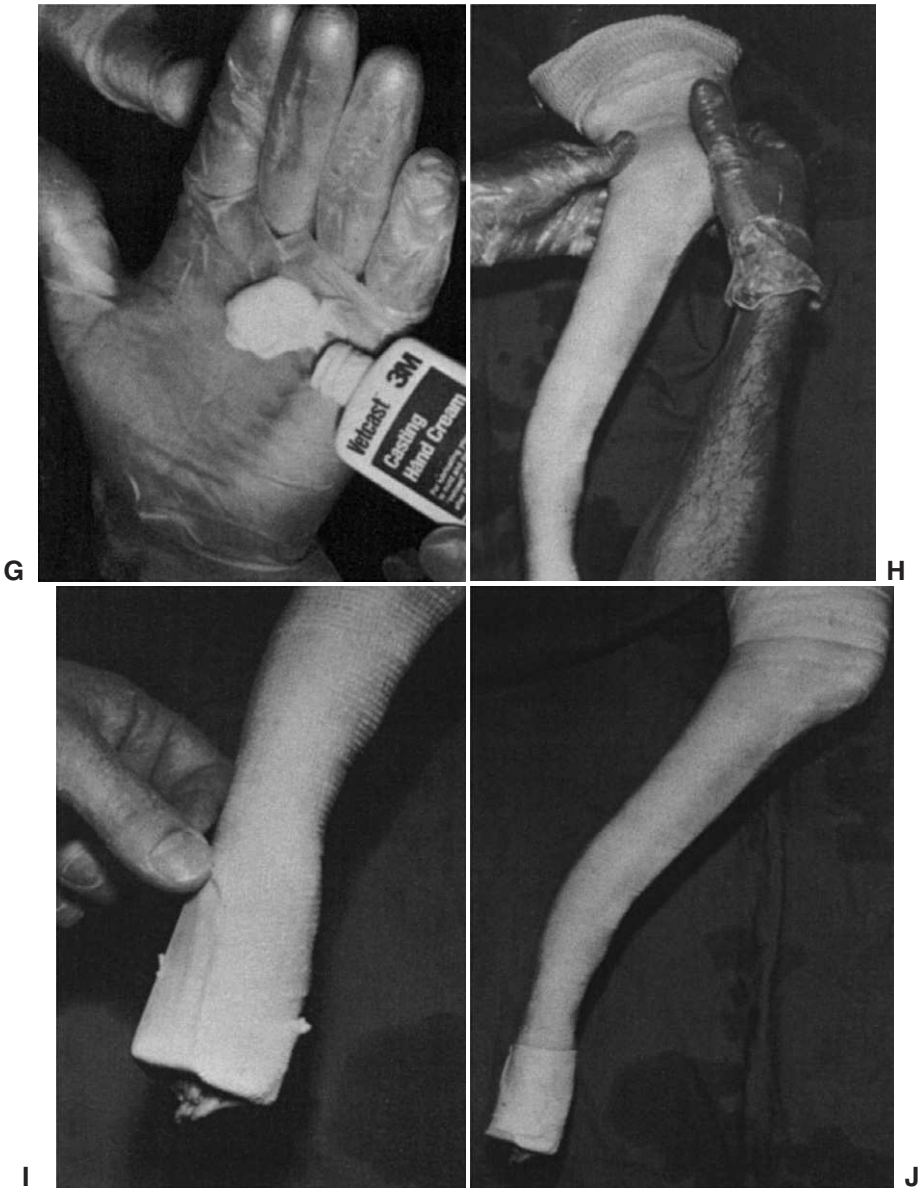
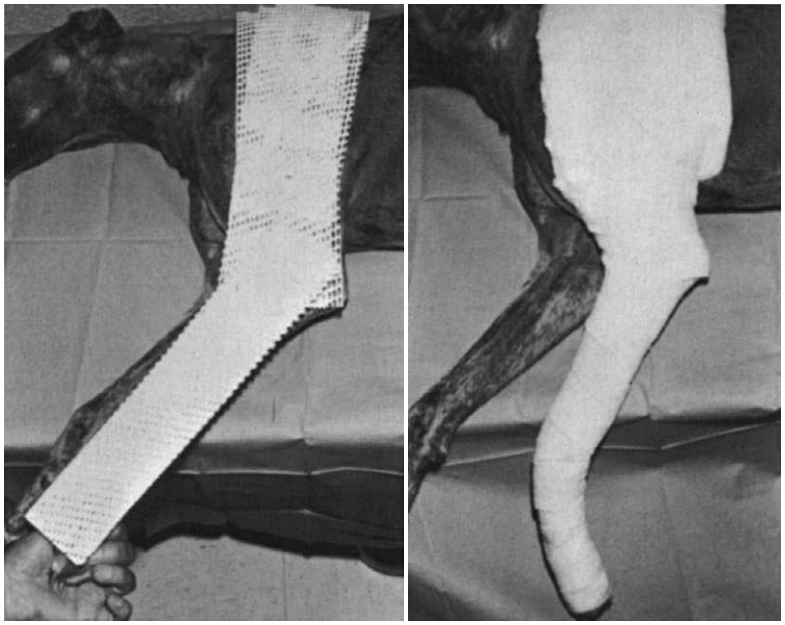


FIGURE 2-21. *Continued* **G,** Hand lotion or lubricating jelly is used to treat the gloves to prevent them from sticking to the fiberglass resin. Some products do not require the use of lotion. **H,** After use of the lotion or jelly on the gloves, it is possible to smooth the fiberglass and conform it to the limb. The material begins to harden in 4 to 5 minutes under average temperature conditions. **I,** After hardening of the fiberglass, the ends of the cast are dressed by folding the stockinet over the end of the fiberglass. At the distal end, the tape initially applied to the skin is folded over the end of the cast. This tape and the stockinet are secured with circular wraps of tape. The proximal end of the cast is similarly taped. **J,** The completed cast. Note that both the elbow and the carpus have been maintained in moderate flexion.



FIGURE 2-22. Short-leg cylinder cast is made in the same manner as the long-leg cast but does not cover the elbow or the stifle. In this case the cast has been applied to the forelimb and ends just distal to the elbow joint, leaving the two middle toenails exposed for daily monitoring. To ease redressing, after hardening, the cast may be cut mediolaterally or craniocaudally (bivalving) and retaped.



A **B**

FIGURE 2-23. Spica splint for the foreleg. **A,** Precut X-Lite splints are laid over the limb, and the area of overlap is noted. Veterinary Thermoplastic can be applied in one piece, since it comes in long rolls. Three to six thicknesses are used, depending on the size of the animal and the degree of rigidity required. **B,** The limb has been padded with two or three layers of polypropylene cast padding to the axilla, and sheet cotton is placed over the proximal humerus, shoulder joint, and scapula. This padding should extend dorsally to the midline.

Continued

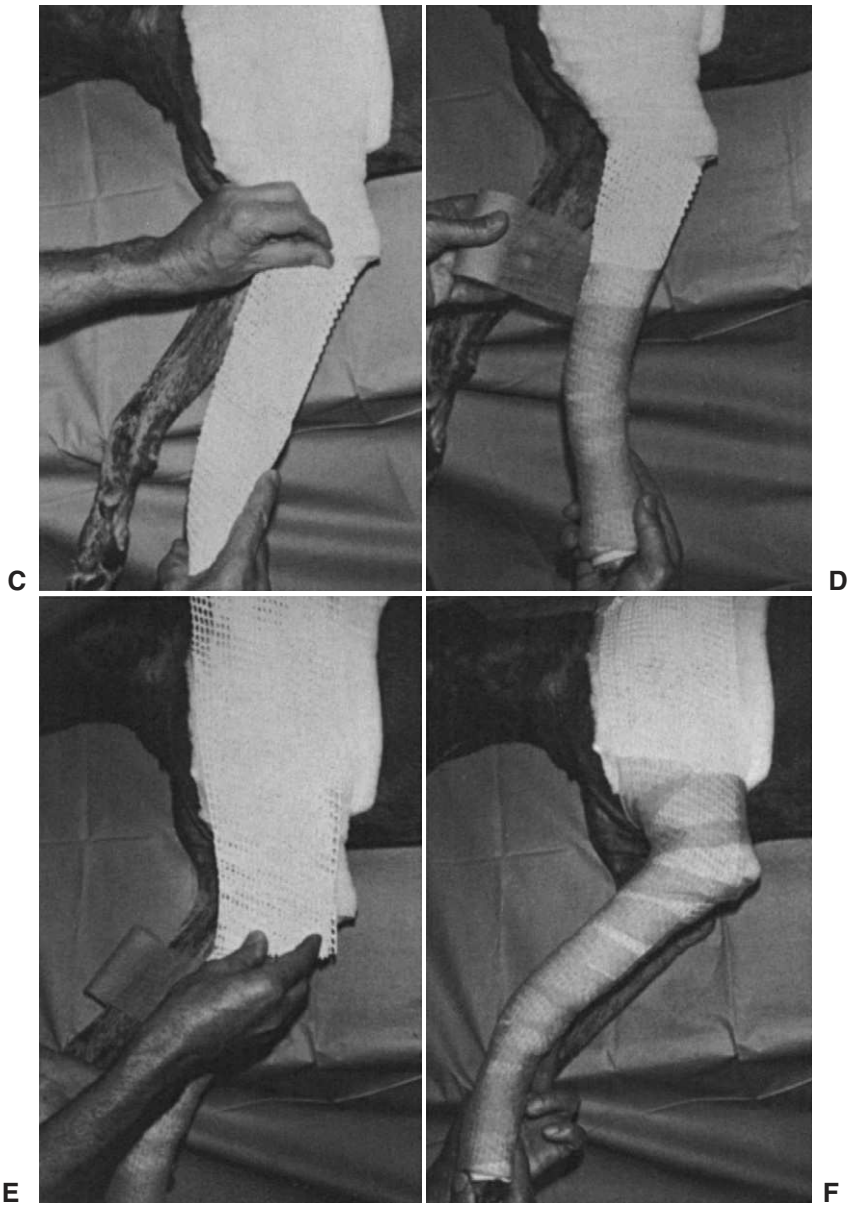


FIGURE 2-23. *Continued* **C,** The distal splints have been heated by immersion in water at 170° F and are being placed over the lower limb, then molded by hand. **D,** Conforming gauze is used to hold the softened splint material against the limb while it hardens. The proximal end of the splint is left exposed for attachment to the upper splints. **E,** The upper splints have been heated and are placed over the shoulder and onto the more distal splints. The material will adhere to itself and form a continuous splint. These splints are then molded by hand to conform to the limb. **F,** Conforming gauze has been rolled proximally to the axilla to complete molding of the proximal splints. The upper end of these proximal splints can be molded over the shoulder by hand pressure until sufficiently cooled to harden.

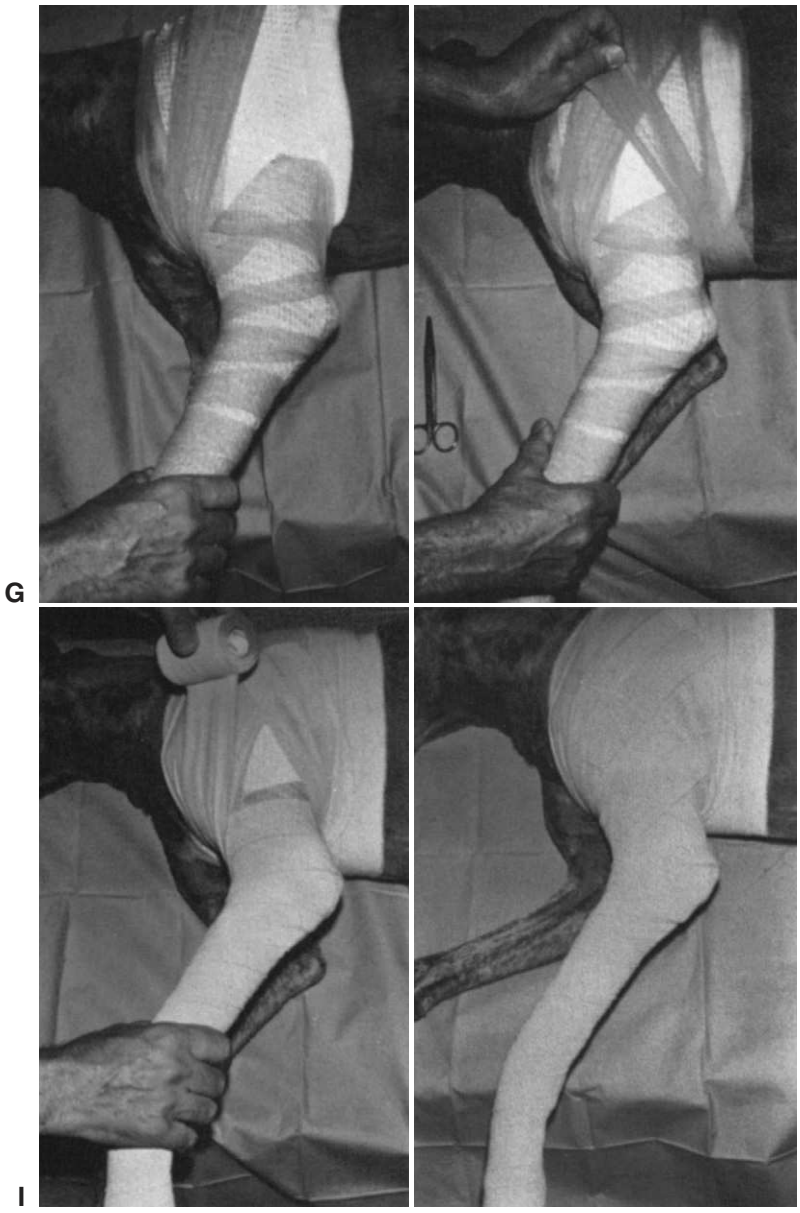


FIGURE 2-23. *Continued* **G,** Conforming gauze is used to attach the splint to the chest wall. This gauze creates a half figure-of-8 around the splinted limb but is carried behind the opposite axilla. **H,** Bandaging has been completed. **I,** The bandage is covered with wide elastic tape, applied in a pattern similar to that of the gauze. If short-term immobilization is contemplated, white tape can be substituted. **J,** Bandaging has been completed.

Long Lateral Splint

This splint is shorter than a spica splint, but otherwise the long lateral splint is constructed and attached similarly from the axilla or groin distally (Figure 2-24).

Indications. Immobilization of the elbow and stifle joints.

Schroeder-Thomas Splint

This versatile splint has been widely used for immobilization of fractures (Figure 2-25). Considerable artistry is required to construct a functional, well-tolerated, and effective Schroeder-Thomas splint. Widely used in the past,[19] it has been largely superseded by molded splints and casts. Nevertheless, it remains useful for those versed in its application.

Indications. Immobilization of the elbow, stifle, carpus, and tarsus; the radius and ulna; and the tibia and fibula. The Schroeder-Thomas splint may be the most effective device for immobilization of the stifle joint at a functional angle. Care must be taken to keep the splint as short as possible to allow active weight bearing; this is accomplished by placing all joints at functional (standing) angles.

Short Lateral Splint—Hindleg

Although this type of molded splint (Figure 2-26) can be applied to any surface of the lower hindlimb, the lateral surface has resulted in fewer soft tissue injuries.

Indications. Immobilization of the tarsus and metatarsus.

Short Caudal Splint—Foreleg

This splint (Figure 2-27) replaces the preformed rigid plastic and metal "spoon" splints in wide use. Such splints are not suitable for long-term use because of the incidence of soft tissue problems and poor immobilization. The only way a curved limb can be put in a straight premolded splint is with copious padding, and this destroys rigid immobilization. A properly made molded splint can often be left on for 6 weeks with no soft tissue problems.

Indications. Immobilization of the carpus and metacarpus.

Phalangeal Splint

This bivalved splint (Figure 2-28) is designed to protect the toes while leaving the antebrachiocarpal or tarsocrural joints free to move normally.

Velpeau Sling

This bandage is generally well tolerated by most animals (Figure 2-29). In addition to its main use for shoulder and scapular injuries, the Velpeau sling can serve as a substitute for hard casts or splints when the objective is simply to prevent weight bearing of the foreleg, although the carpal flexion bandage is much easier to apply.

Carpal Flexion Bandage

The flexion bandage is intended solely to discourage weight bearing while maintaining passive motion of the shoulder and elbow joints. It is useful after lateral shoulder luxation, supraspinatus, and biceps brachii surgery. The carpus is less than fully flexed while two or three layers of wide white tape are applied from the distal third of the radius/ulna to the metacarpal region. Narrower tape is used in the middle to keep

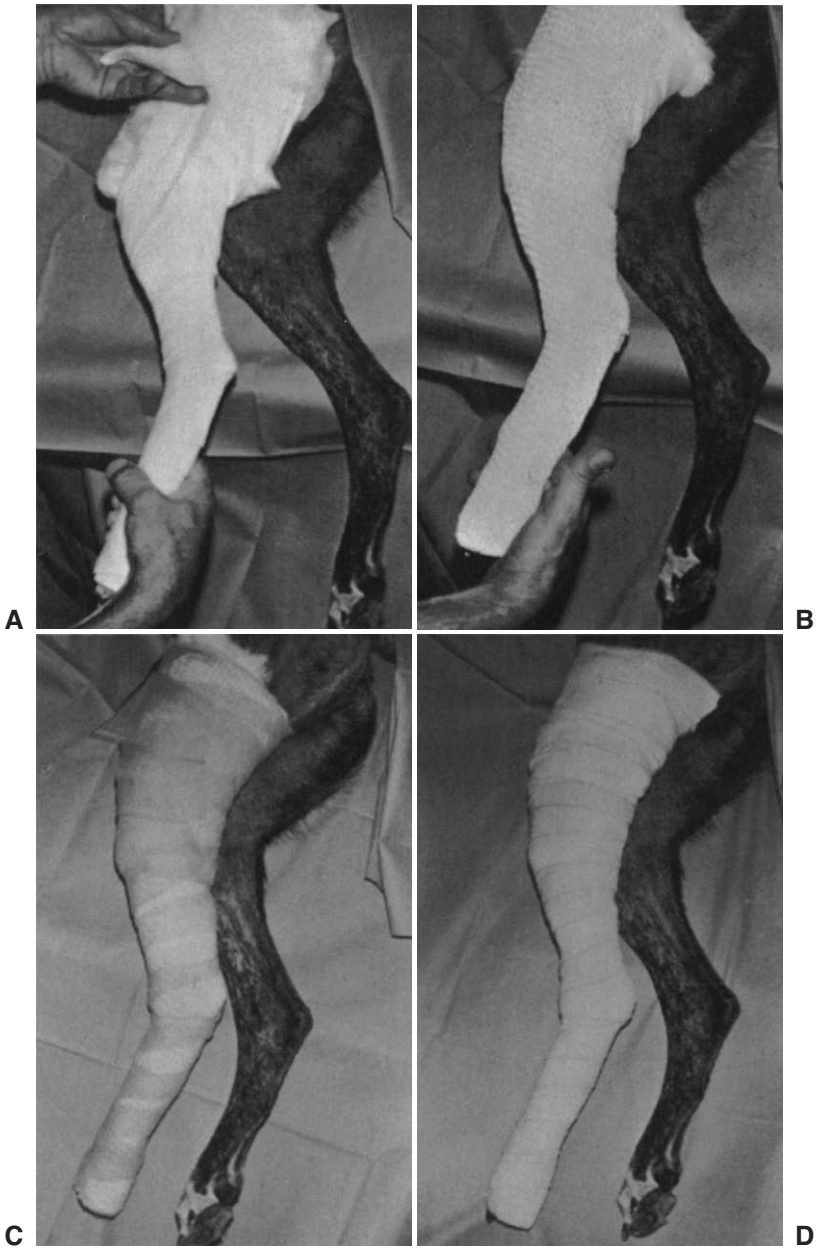


FIGURE 2-24. Long lateral splint applied to the hindlimb. **A,** The lower limb is padded with two or three layers of polypropylene cast padding to the level of the stifle, and sheet cotton is applied from the stifle to the level of the hip joint. The cast padding overlaps the lower end of the sheet cotton to help fix it in place. **B,** Overlapping precut X-Lite splints or full-length Veterinary Thermoplastic splints are applied proximally and distally, with three to six thicknesses, depending on the size of the animal and the rigidity required. The splints will stick together where they overlap, and the splints are initially molded by hand to conform to the limb. **C,** The softened splints are covered with conforming gauze bandage to hold the splints conformed to the limb while they harden. **D,** After hardening, the splint material is covered with wide elastic tape to complete the splint.

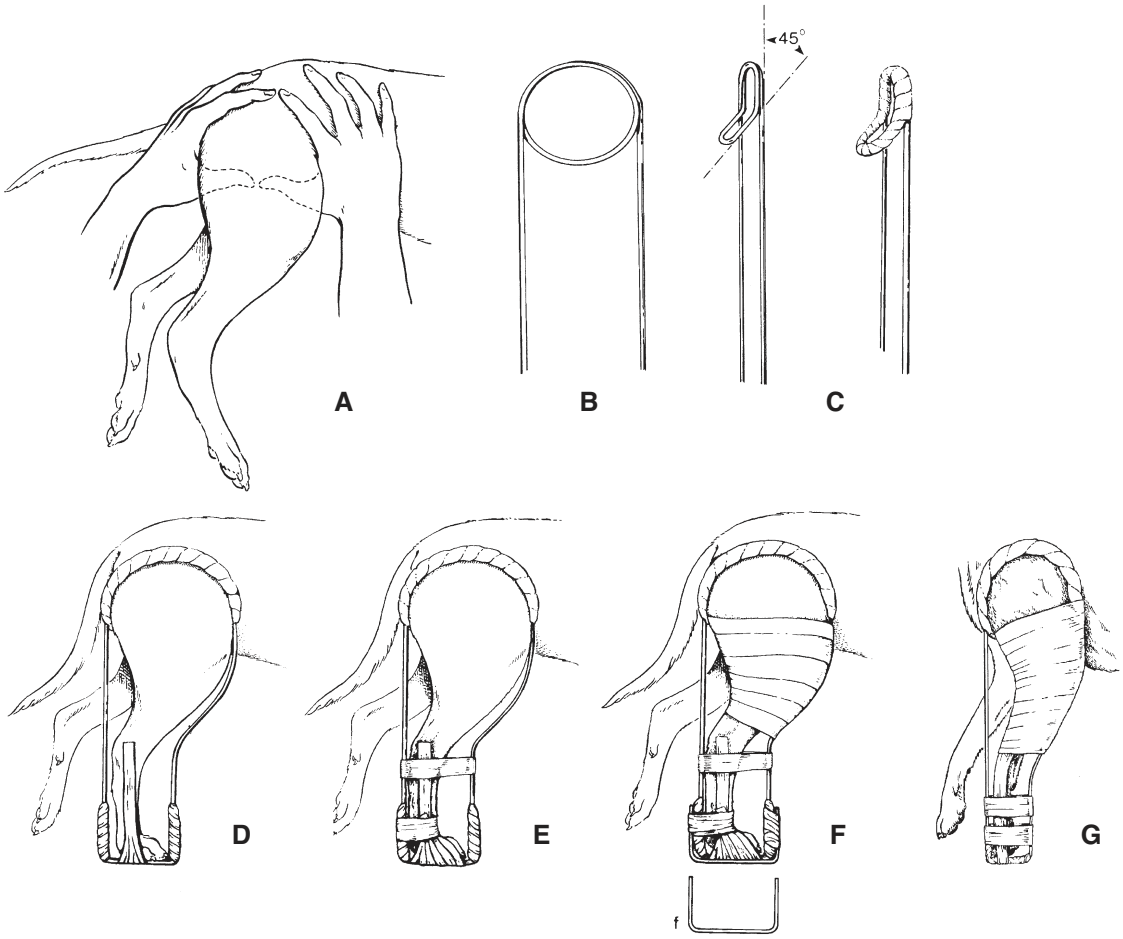


FIGURE 2-25. Fabrication of modified Thomas splint. **A,** After the diameter of the thigh is approximated, **B,** the aluminum alloy rod is bent, forming 1½ circles. **C,** The lower half of the ring is bent at a 45-degree angle to accommodate the thickness of the thigh and to avoid femoral vessel pressure; foam, cotton, or cast padding is added, followed by gauze and tape. **D,** With the splint pushed firmly up in the inguinal region, the caudal bar is first bent to approximate the length of the leg with the limb in normal standing angulation and the toes flexed to simulate standing. Next, the cranial rod is bent to approximate normal angulation of the limb, with the toes flexed to simulate standing. The distal ends of the bars are then taped securely together. **E,** Splint is again pushed firmly up in the inguinal region; foot is anchored with adhesive tape. **F,** If a dog weighs more than 25 pounds, a walking bar *(f)* is applied. A layer of cotton is placed around the upper leg, then both are anchored as one to the cranial bar with a layer of gauze and tape. Anchoring the tape to the bar in the inguinal area holds the padding for the thigh in place; otherwise, it slips distally and serves no useful purpose. **G,** The forelimb splint is reversed from the hindlimb to accommodate the normal joint angles.

the bandage from slipping off the leg. Although usually well tolerated when applied as illustrated in Figure 2-30, some animals will develop skin irritation on the cranial surface of the antebrachium and must have cast padding applied between the skin and tape.

Ehmer Sling

Primarily used to partially immobilize and stabilize the hip joint (Figure 2-31), this bandage can also be used to prevent weight bearing of any joint of the hindlimb.

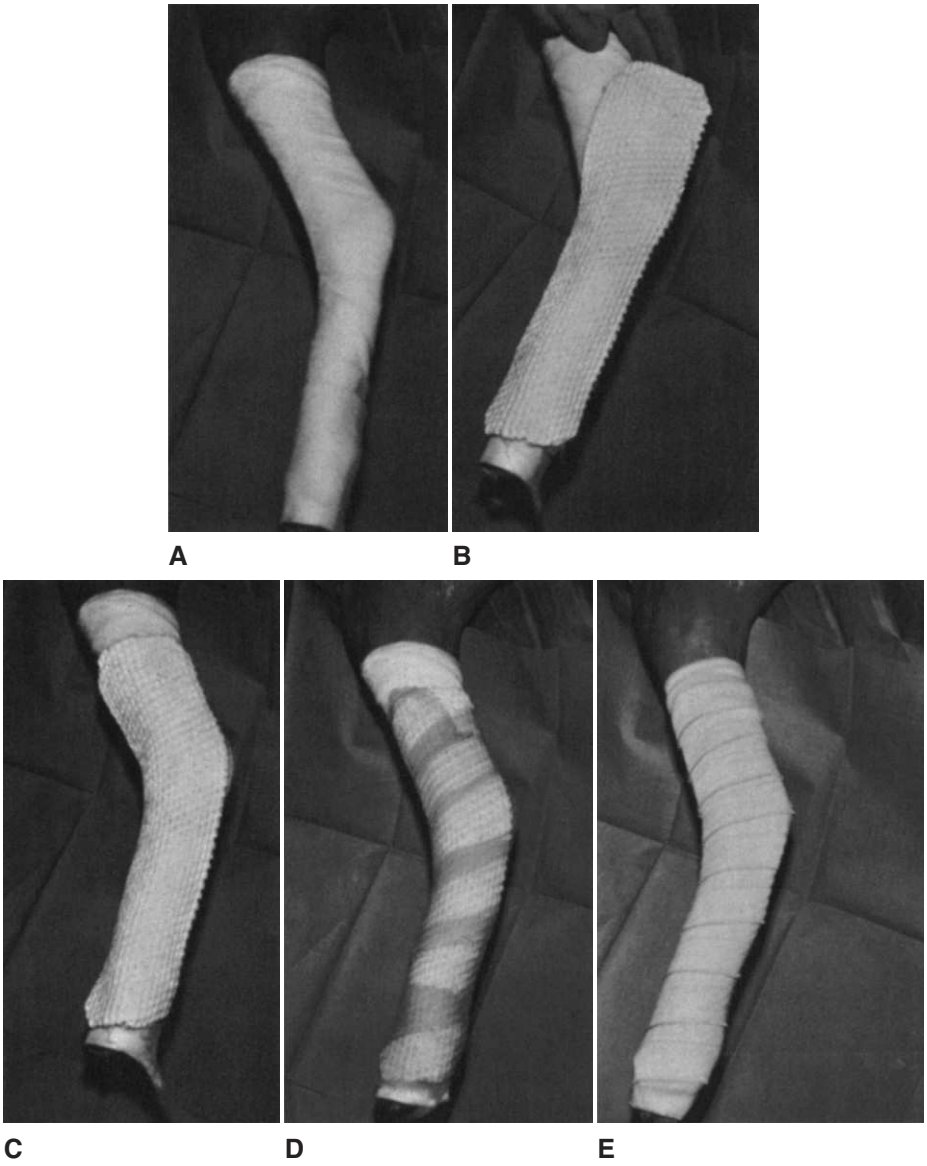


FIGURE 2-26. Short lateral splint for the hindleg. **A,** The limb is padded with two or three layers of polypropylene cast padding to the level of the tibial tubercle. A small piece of orthopedic felt is placed on the tuber calcis and is secured by the cast padding. Additional thicknesses of cast padding can be substituted. **B,** Four to six thicknesses of precut X-Lite splints or full-length Veterinary Thermoplastic splints are placed on the lateral side of the limb. The distal end of the splint extends to the level of the base of the distal phalanx of the middle toes. **C,** The splint is molded to the standing angle of the hock while the material is placed laterally to slightly dorsolaterally on the hock region. If the splint material extends more than 180 degrees around the limb, it should be trimmed. **D,** The splint is held in position by a conforming gauze bandage while the material hardens. **E,** The splint is completed by covering it with elastic tape.

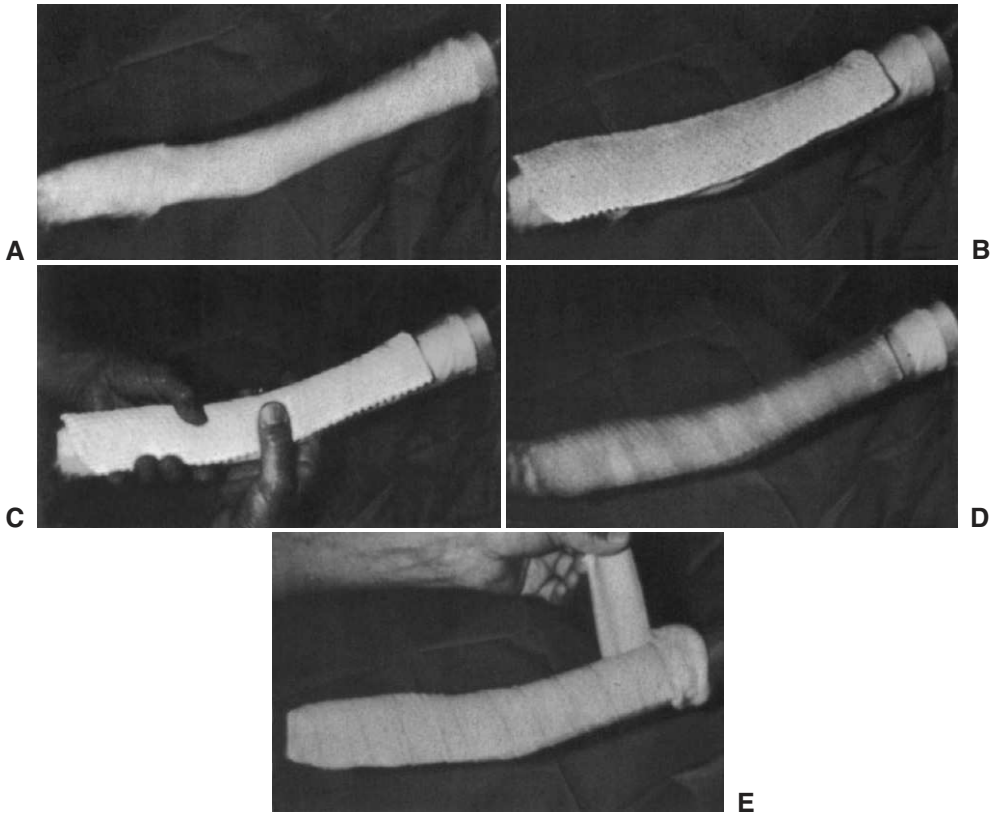


FIGURE 2-27. Short caudal splint for the foreleg. **A,** The dog is positioned in dorsal recumbency to expose the caudal surface of the lower limb, which is padded with two or three layers of polypropylene cast padding. **B,** Three to six precut X-Lite splints or full-length Veterinary Thermoplastic splints are heated and applied to the caudal surface of the limb. If the splint material extends more than 180 degrees around the limb, it should be trimmed. **C,** The splints are conformed to the limb with the desired degree of carpal flexion. The distal end of the splint should extend to the level of the base of the distal phalanx of the middle toes. **D,** The softened splints are held in position by a conforming gauze bandage. This bandage material must not be rolled too tightly, for it will create soft-tissue pressure sores along the edge of the splint. **E,** After the splint hardens, it is completed by covering with conforming tape.

The ASPCA sling is probably better tolerated than the Ehmer sling when prevention of weight bearing is the primary objective.

ASPCA Sling

This sling is very effective in preventing weight bearing on the hindlimb while still allowing passive motion of the hip and stifle joints (Figure 2-32). The ASPCA sling is better tolerated and has fewer complications than the Ehmer sling.[20]

Robert-Jones Bandage

This highly padded bandage is very versatile, being useful not only in immobilization distal to the elbow or stifle but also in decreasing or preventing edema (Figure 2-33). It is well tolerated, but because of the large volume of cotton, it can

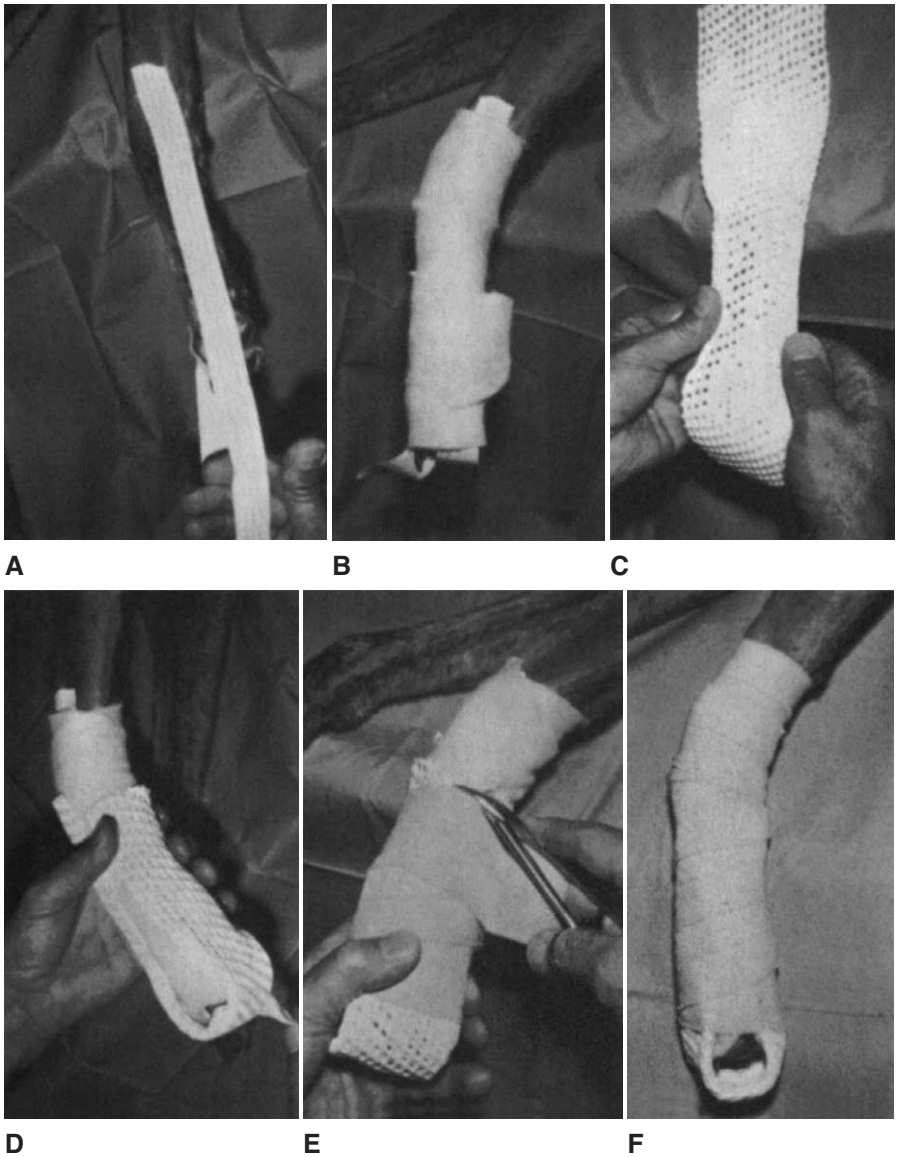


FIGURE 2-28. Phalangeal splint applied to the front foot. On the hindfoot, the splint extends proximally to the level of the distal tarsal bones. **A,** Adhesive tape is attached to the medial and lateral surfaces of the paw. **B,** The paw and lower limb are covered with three or four layers of polypropylene cast padding to a point just proximal to the carpus. **C,** Two or three thicknesses of precut X-Lite splints or full-length Veterinary Thermoplastic splints are heated to soften them. The middle portion is then crimped on each edge to make the splints slightly narrower at this point and to create extra thickness at the end of the splint. **D,** The soft splint material is applied on the dorsal and palmar sides of the foot with the splint material folded over the toes. There should be room to insert a finger between the toes and the end of the splint. The splint is conformed by hand pressure while the material cools and hardens. **E,** The splint is covered with elastic tape. A portion of the proximal end of the palmar portion of the splint is trimmed when necessary to avoid pressure caused by flexion of the carpus. Wire-cutting scissors can be used for this trimming. **F,** Elastic tape is applied over the splint and proximally to the end of the padding.

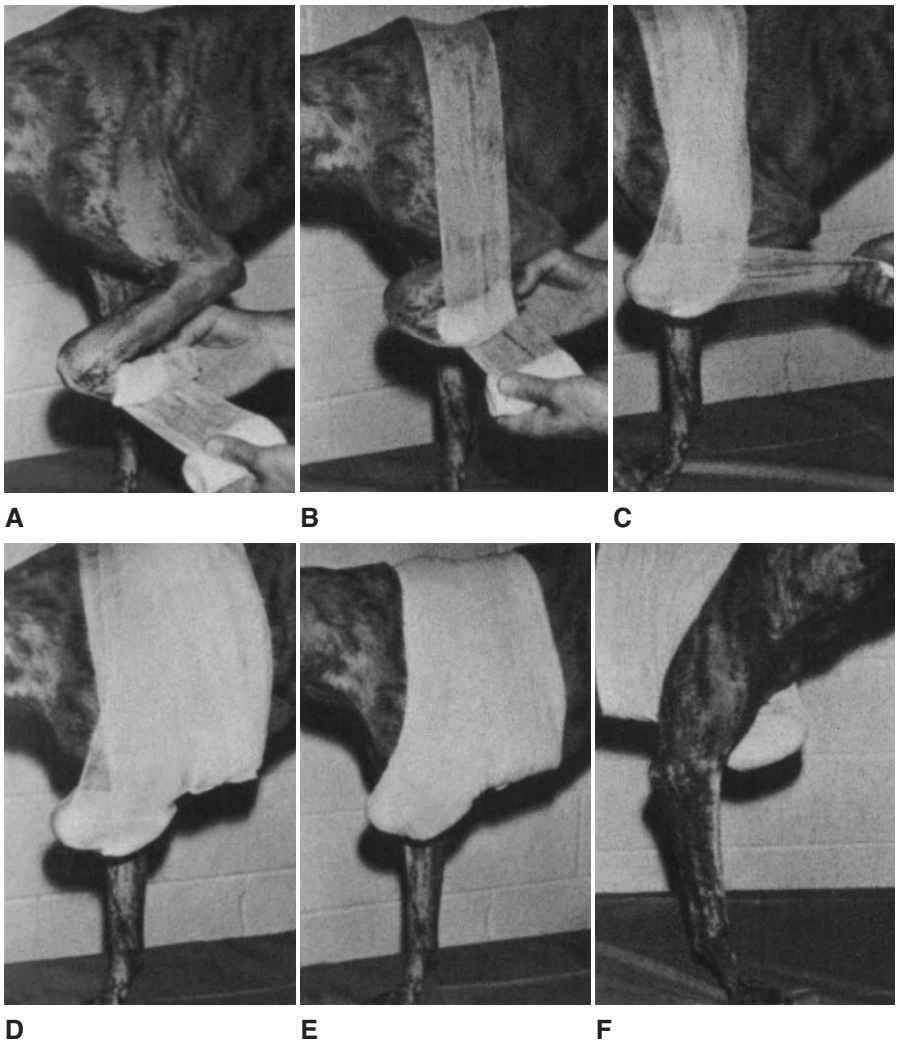


FIGURE 2-29. Velpeau sling bandage used to immobilize the shoulder region. **A,** Conforming gauze bandage material is wrapped loosely around the paw in a lateral-to-medial direction. **B,** With the carpus, elbow, and shoulder all flexed, the gauze is brought from the paw over the lateral aspect of the limb and shoulder, over the chest, and behind the opposite axilla. It then continues under the chest, back to the starting point. **C,** Several more layers of gauze are applied in a similar manner, and a few layers are brought around the flexed carpus to prevent extension of the elbow. Such extension could force the lower limb out of the bandage. **D,** Gauze bandaging is completed. **E,** Wide elastic tape is used to cover the gauze in a pattern similar to the gauze application. **F,** On the opposite side of the animal, both gauze and adhesive tape are brought behind the opposite axilla.

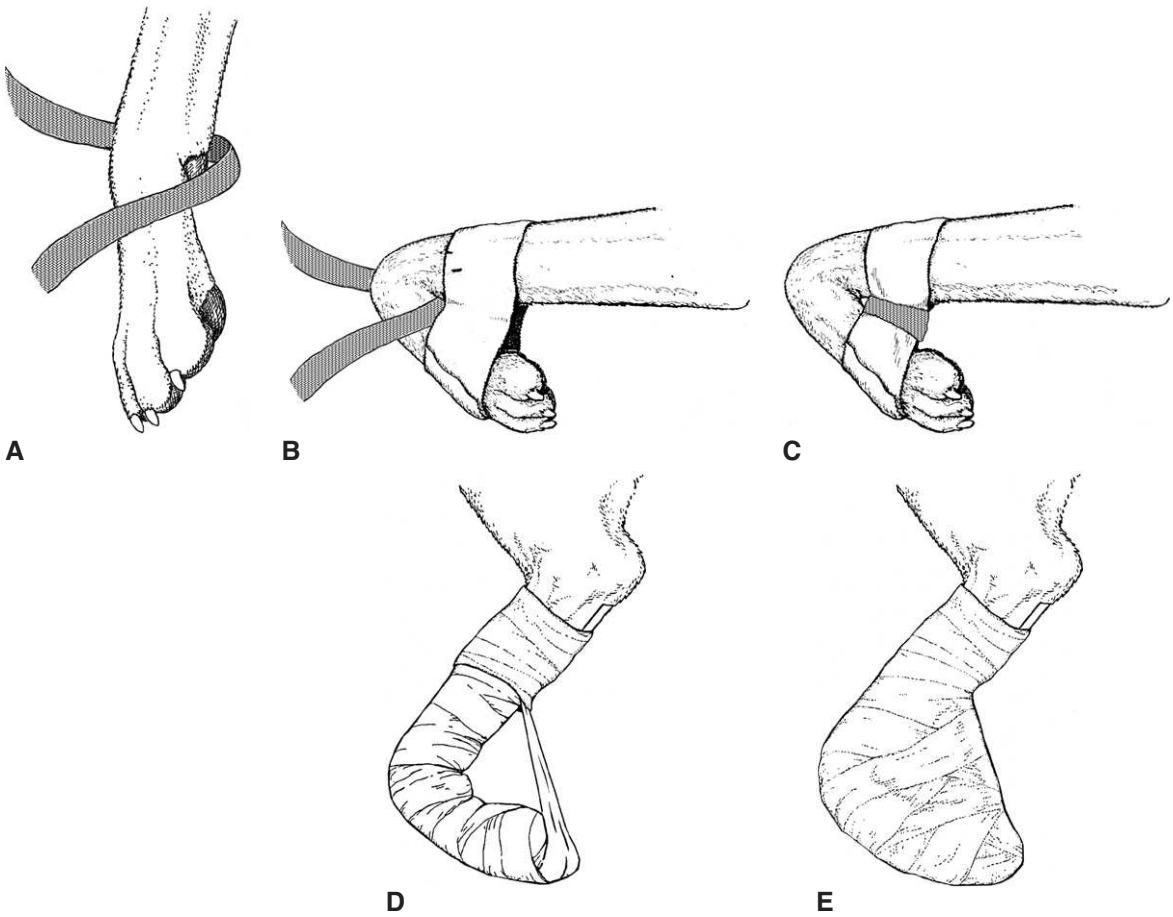


FIGURE 2-30. Carpal flexion bandage. **A,** A strip of 1-inch white tape is preplaced along the palmar surface of the carpus to facilitate wrapping around the encircling tape later. **B,** The carpus is flexed while 2-inch white tape encircles the distal radius and ulna and the metacarpal region. **C,** The preplaced narrow tape is wrapped around the middle area of both sides of the encircling tape to prevent the tape from slipping over the carpus. **D,** Another method involves covering the lower limb with padding and tape, then flexing the carpus with several thicknesses of tape from the dorsal surface of the toes to the proximal antebrachium. **E,** The entire bandage is covered with tape.

absorb considerable quantities of water and cause maceration of skin or contamination of surgical incisions. The Robert-Jones bandage is generally used only for short-term immobilization. Additional rigidity can be obtained by adding a wire frame or molded splints to the bandage. Coat hangers (for very small animals) or aluminum rods can be bent to conform to joint angles and can be applied cranially, caudally, or laterally depending on the support desired.

Padded Bandage

Often after joint surgery and fracture repair, a padded bandage is applied for additional support. It is applied similar to a Robert-Jones dressing, except that less padding and less compression can be applied to the outer wraps.

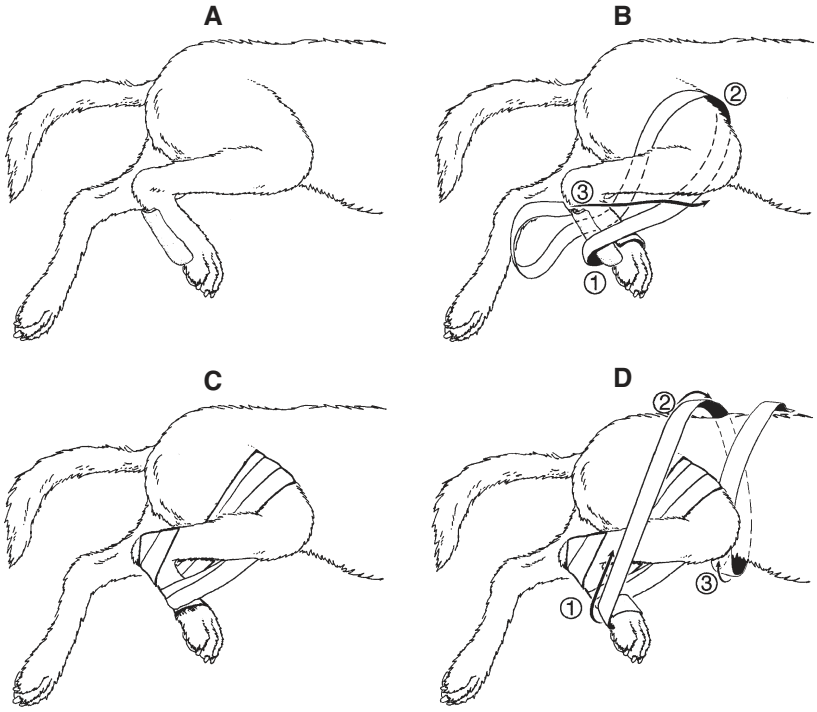


FIGURE 2-31. Ehmer (figure-of-8) sling. **A,** Application of the sling begins with placing some padding on the plantar surface of the metatarsus. **B,** Conforming roller gauze bandage is wrapped around the metatarsus *(1)* from lateral to medial, being sure to include most of the metatarsal pad. After several wraps to secure it, the gauze is carried medial to the flexed stifle *(2)* and over the cranial surface of the thigh. This internally rotates the limb at the hip joint. Finally *(3)* the gauze is brought medial to the tibia and tarsus and over the plantar surface of the tarsus. Several more circuits are made in the same manner. **C,** The gauze is continued in a figure-of-8 fashion around the flexed hock and paw to secure it. The entire bandage is then covered with elastic adhesive tape that overhangs the gauze to anchor the sling to the hair. Although some construct the bandage without any gauze by starting with adhesive tape applied to the skin, this invariably leads to considerable skin irritation on the cranial thigh region as well as the difficulty of removing the large amount of tape. **D,** It is difficult to keep the sling from slipping down over the stifle on short-legged breeds. One solution is to attach wide adhesive tape to the paw area of the completed sling *(1)*, then carry the tape upward over the back *(2)* and around the belly *(3)*. This is simple in the bitch or cat, but care must be taken to avoid the sheath in the male dog.

General Considerations

When a coaptation splint or cast is used, the following factors should be considered:

Padding. If closed reduction is used, the hair is usually not clipped. A light padding (cast padding, stockinet, cotton, sheet wadding, felt) should be applied to protect the soft tissues, with particular emphasis given to bony prominence (e.g., accessory carpal pad, tuber calcis, olecranon process, dewclaw). This is best accomplished by increased padding in the depressed areas over the fracture site

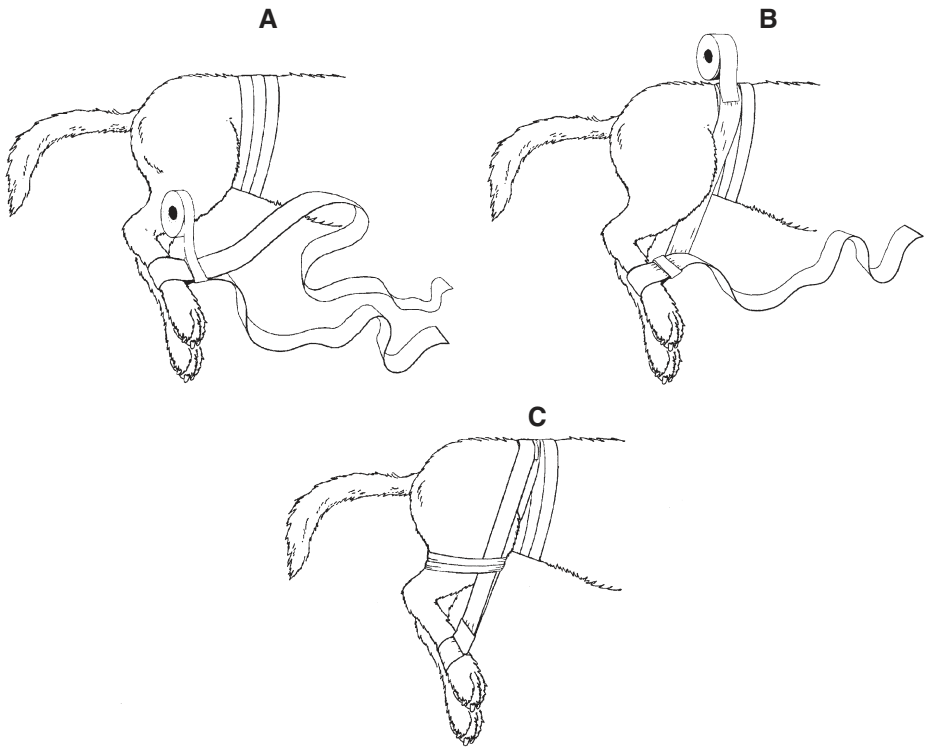


FIGURE 2-32. ASPCA (Robinson) off-weight-bearing sling.[20] **A,** Six to 8 feet of 2-inch white tape is folded at the center and the adhesive sides pressed together. This double-thickness tape is secured to the tarsus by wrapping with 1-inch tape. A belly wrap of adhesive tape is applied. **B,** The inner section of double-thickness tape is passed medial to the stifle and is secured to the belly wrap with additional adhesive tape. The length of this section is adjusted to shorten the limb just enough to prevent weight bearing. **C,** The outer section of double-thickness tape is passed lateral to the stifle and secured to the belly band. The double-thickness tape is stabilized by a wrap of tape approximately halfway between the hock and stifle joints.

and less padding over the prominences. Avoid overpadding because it may allow movement of bone fragments inside the coaptation splint or cast.

Fixation. Anchor the cast/splint in place to avoid shifting on the limb. This is particularly applicable if the leg is swollen when the cast is applied. This may be accomplished with use of adhesive tape and by molding the cast to the contour of the limb.

Radiographs. Check reduction radiographically before and after application and again in several days.

Extent. Distally, the toes may be covered, or preferably the center two digital pads may be exposed.

Patient Tolerance. Usually, coaptation splints are reasonably well tolerated by the animal, if they are accomplishing their purpose, if the cast is kept dry,

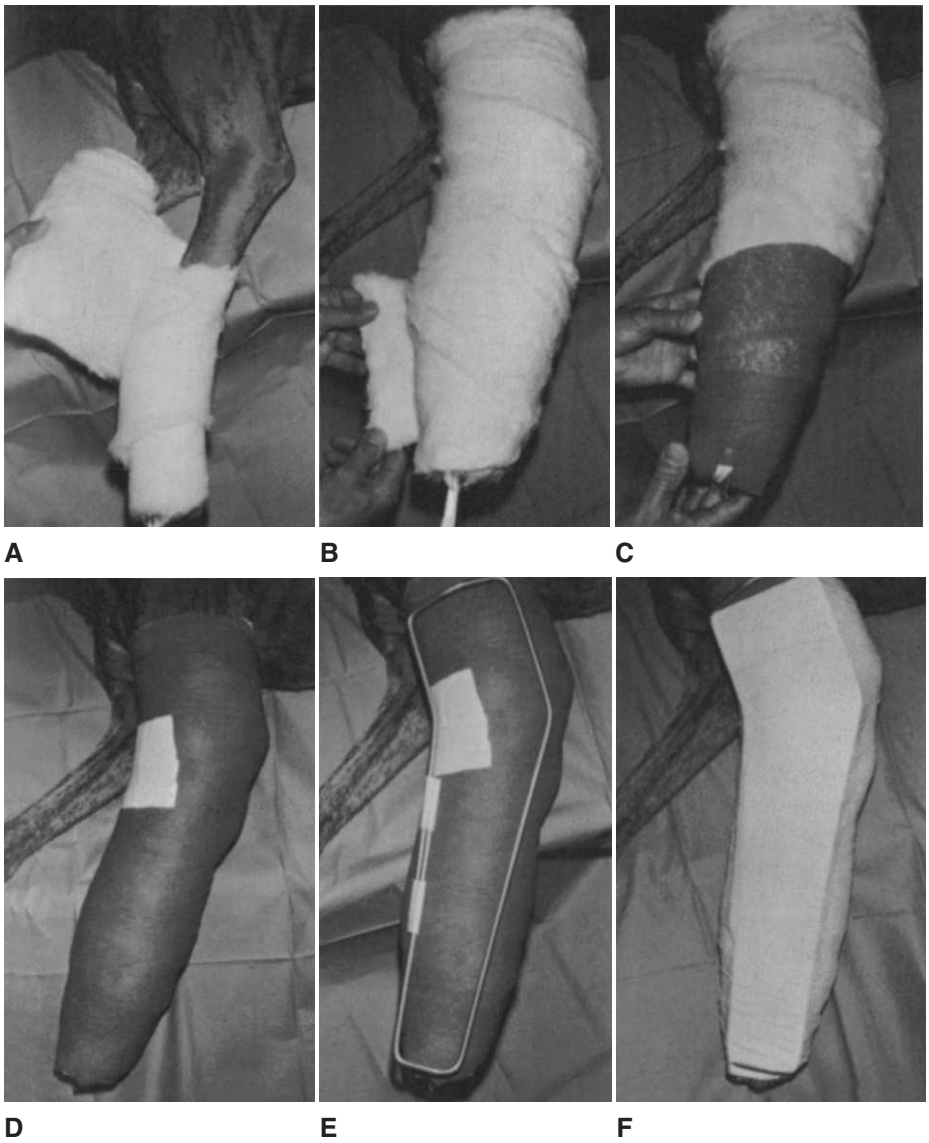


FIGURE 2-33. Robert-Jones bandage. Application of the cotton for this heavily padded bandage is simplified by splitting a 1-pound roll of cotton into two narrower 1/2-pound rolls. **A,** Adhesive tape stirrups have been applied to the lower limb and are used for traction while cotton is spiraled proximally. The tape is carried as high as possible into the axilla or groin. **B,** Half to 2 pounds of cotton are necessary to complete the padding, depending on the size of the animal. **C,** Vetrap (3M Animal Care Products, St. Paul, Minn) is used to compress the cotton. The tape applied to the limb is folded back and incorporated into the 4-inch-wide Vetrap. The first layer of Vetrap is used to conform and compress the cotton, and the second layer is used to further compress and firm the cotton padding. **D,** Adhesive tape is used to secure the end of the Vetrap. **E,** Additional stability can be obtained by bending an aluminum splint rod to conform to the Robert-Jones bandage. **F,** The splint rod is attached to the Robert-Jones bandage with nonelastic tape. X-Lite or Veterinary Thermoplastic splints can also be used to stiffen the bandage by molding one or more layers over the lateral side in place of the aluminum rod.

and if activity is limited. Indications of a complication include pain, elevation of temperature, swelling, edema, numbness, foul odor, cyanosis of digits, loss of appetite, systemic depression, irritated areas, and chewing on the cast.

EXTERNAL SKELETAL FIXATION*

Use of the external fixator for immobilization of long-bone fractures requires transcutaneous insertion of two to four pins in each of the proximal and distal bone fragments, which are then connected by one or more external bars or rods (see Figures 2-36, 2-42, 2-43, and 2-44).[2,21-24] The entire apparatus is referred to as a *splint* or a *frame,* whereas the bone and attached frame are called a *construct* or *montage.* Fixators can be used on all the long bones, on the mandible, and for bridging joints but are not adaptable to most intraarticular fractures.

Indications or Uses[2,21-36]

The external fixator is adaptable to the following:

1. Stable and unstable fractures
2. Open fractures
3. Gunshot fractures
4. Osteotomies
5. Delayed unions and nonunions
6. Arthrodesis of certain joints
7. Stabilization of certain joints after ligament or tendon reconstruction

The advantages of the external fixator include (1) ease of application; (2) its usefulness in treating fractures reduced by either open or closed methods; (3) if applied in connection with an open approach, minimization of the approach; (4) fixation pins that can usually be inserted some distance from an open wound; (5) an open wound is readily accessible for dressing; (6) its compatibility for use in conjunction with other internal fixation devices; (7) tolerance by both dogs and cats; (8) in most cases, removal without placing the animal under general anesthesia; and (9) reasonable cost.

Components of External Fixator

An amazing variety of fixators are available throughout the world, most developed for human use. Because of their size and cost, most are not practical for veterinary use, although some are adaptable, especially those designed for hand or forearm use in humans. In North America the traditional devices commercially available (IMEX Veterinary, Longview, Texas; Osteo-Technology International Inc., Hunt Valley, Md; Gauthier Medical, Rochester, Minn; Securos, Charlton, Mass) are based on the Kirschner-Ehmer adaption of the Roger Anderson splint.[22] The earlier Stader apparatus did not achieve lasting popularity.[21] Similar devices are available from various manufacturers in Europe. The clamps used in these fixators are rather simple in design, and although they have some inherent deficiencies relative to stability, they still function adequately if properly applied, and they provide a relatively

*The authors gratefully acknowledge the contributions of a colleague, Dr. Erick Egger, to this section.

economical method of stabilizing a wide variety of fractures. Unless otherwise noted, all frames depicted in this text are of the Kirschner-Ehmer variety.

Fixation Pins

Most fixator frames are fastened to the bone by stainless steel fixation pins that must penetrate both first and second cortices. If the fixation pin penetrates only one skin surface and two bone cortices, it is called a *half pin*, and it is the only pin used in type I frames (Figure 2-34, *A* and *B*). Those pins that penetrate two skin surfaces and two bone cortices are called *full pins* and are the basis of type II frames. A minimum of two pins is required in each major bone fragment to ensure stability, but more often, three or more pins are indicated (see section on biomechanical considerations). These pins may be smooth, partially threaded, or fully threaded in design; the latter are not widely used because of their lack of stiffness. Smooth pins are typically Steinmann pins of the appropriate diameter cut to length after insertion into the bone. Partially threaded pins are either end-threaded or center-threaded pins. Threads can be cut from the stock of the pin (negative-thread-profile pins) or can be built up (raised-thread, enhanced-thread, or positive-thread-profile pins) to a larger diameter than the pin shaft (Figure 2-34, *C*). Negative-thread-profile pins usually have a fine thread, that is, a relatively high number of threads per unit of length, and are designed for cortical bone insertion. Positive-thread-profile pins are available in both the cortical thread and a coarser, flatter pitch thread intended for insertion into cancellous bone, such as found in the metaphyses of long bones. Typically, a mixture of threaded and smooth pins is used in most frames. Kirschner-Ehmer clamps allow the use of pin diameters up to 5/64 inch (2.0 mm) in small clamps, to 1/8 inch (3.2 mm) in medium clamps, and to 3/16 inch (4.8 mm) in large clamps. An important consideration in the fabrication of frames using positive-profile-threaded pins is that the threads of these pins will not slide through Kirschner-Ehmer clamps, so they must always be inserted into the clamps from the unthreaded end unless oversized clamps are used. Two relatively new systems (Secur-U, Securos, Charlton, Mass; IMEX-SK, IMEX Veterinary, Longview, Texas) use clamps that accept positive-profile-threaded pins and allow attachment to the connecting bar between previously installed pins.

Miniature positive-profile end-threaded pins are available with a roughed central area of the pin shank to allow greater purchase of acrylic connecting bars (Figure 2-34, *D*). These pins have a cortical thread (IMEX Veterinary, Longview, Texas) and have shank sizes ranging from 0.35 inch (0.9 mm) to 3/32 inch (2.4 mm). Miniature positive-profile-threaded pins are very useful for tiny mandible and long-bone fractures.

Connecting Bars

The connecting bar, or *rod,* functions to connect the fixation pin clusters attached to the bone fragments. The resulting bone-frame construct provides enough stability to allow the bone to heal while maintaining functional use of the limb. The bars used for Kirschner-Ehmer clamps are typically solid stainless steel rods with a diameter between 1/8 and 1/4 inch (3.2 and 6.5 mm) (Figure 2-34, *E*). Traditionally, the connecting rod has been used only as a straight rod, but as illustrated later, in many cases it is useful to contour the rod. Although hollow rods are more rigid, they cannot be contoured, and their cost makes them impractical for veterinary use.

Mechanical stiffness of the connecting bar affects axial loads at the fracture site and shear loads on the fixation pins (see Biomechanical Considerations). One fixation system (IMEX-SK) uses larger connecting rods of increased stiffness (Figure 2-34, *G*). The SK system is available in three sizes.[37] The small SK connecting rod is 1/4 inch

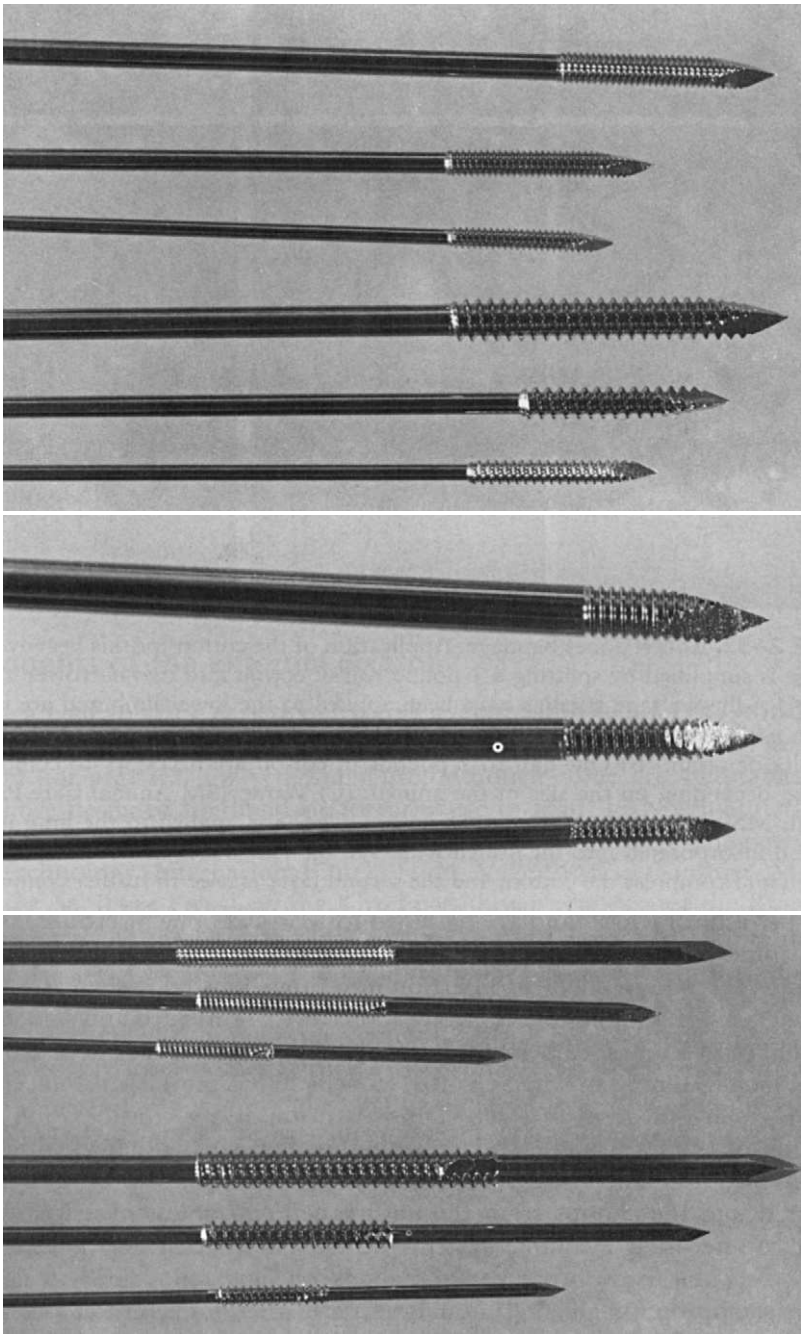


FIGURE 2-34. External fixator components (IMEX Veterinary, Longview, Texas). **A,** Fixation half pins with positive thread profile in large (3/16 inch; 4.8 mm), medium (1/8 inch; 3.2 mm), and small (5/64 inch; 2.0 mm) diameters. The upper three pins have cortical threads and the lower three pins have cancellous threads. **B,** Ellis pins are partially threaded pins with negative cortical thread profile. The threads penetrate the second cortex, and the smooth part of the pin rests in the first cortex. **C,** Fixation full pins with positive thread profile in large (3/16 inch; 4.8 mm), medium (1/8 inch; 3.2 mm), and small (5/64 inch; 2.0 mm) diameters. The upper three pins have cortical threads, and the lower three pins have cancellous threads.

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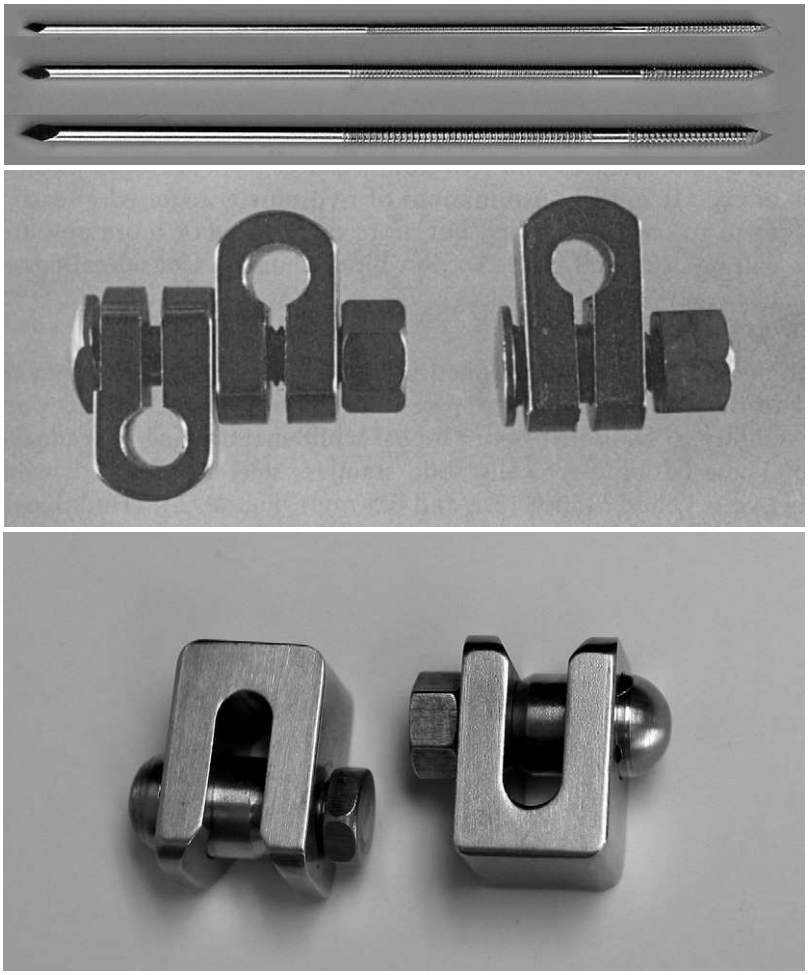


FIGURE 2-34. *Continued* **D,** Miniature positive-profile end-threaded pins with a roughed central area of the pin shank to allow greater purchase of acrylic connecting bars. These pins have a cortical thread and have shank sizes ranging from 0.35 inch (0.9 mm) to 3/32 inch (2.4 mm). **E,** Kirschner-Ehmer double and single clamps. **F,** The Secur-U external fixation clamp (Securos, Charlton, Mass) may be applied to connecting bars between two previously installed clamps and allows installation of enhanced-thread pins at any location.

(6.3 mm) in diameter and available in carbon fiber or titanium. The larger SK connecting rod is 3/8 inch (9.5 mm) in diameter and available in carbon fiber or aluminum. The mini-SK system is designed for use with the small stainless steel connecting rods (3.2 mm) of the Kirschner-Ehmer system. The use of carbon fiber, titanium, and aluminum allows for increased diameter and stiffness without significantly increasing weight. The carbon fiber rods are also radiolucent.

Acrylic materials can often be used to mold a connecting bar between the fixation pin clusters. This method is particularly applicable to bones such as the mandible and maxilla, as well as in transarticular applications, where it can be difficult to drive all the fixation pins in the same plane.[24]

Clamps

Traditional external fixator clamps are designed as part of the Kirschner-Ehmer system. *Single clamps* grip the fixation pin and connecting bar and are rotatable in

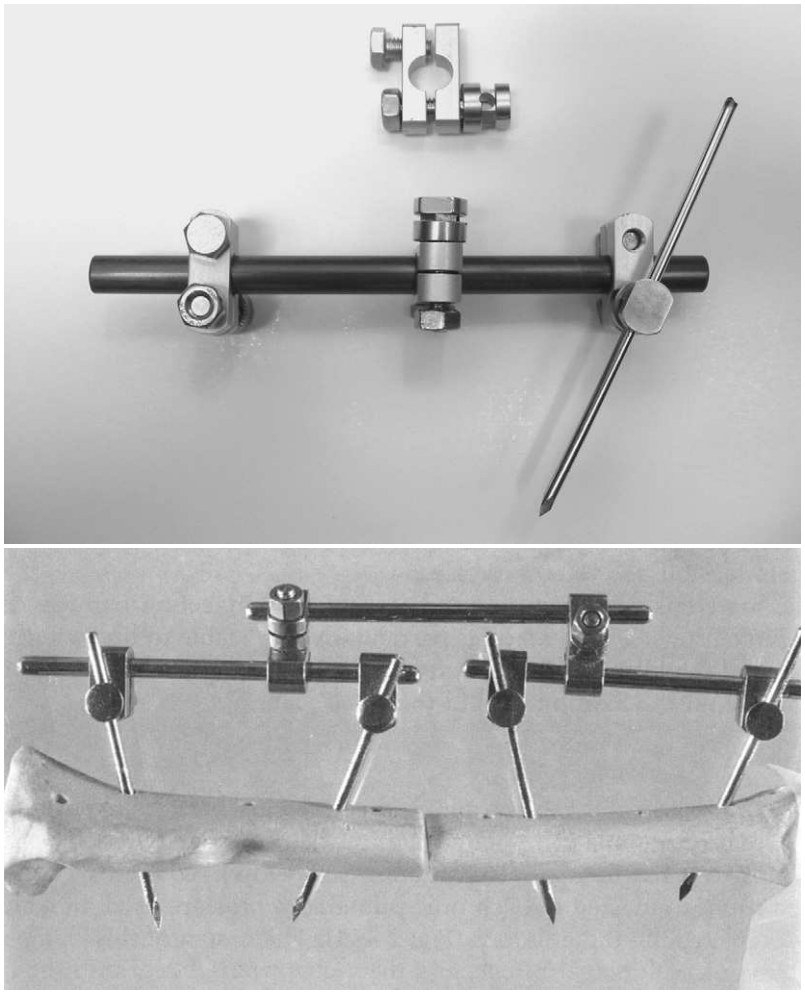


FIGURE 2-34. *Continued* **G,** The SK clamp (IMEX Veterinary) is a split clamp, which allows the addition of clamps between two previously installed clamps. The SK clamp accommodates a wide range of fixation pin diameters and allows the passage of enhanced-thread pins directly through the clamp bolt. The SK system uses larger connecting rods of increased stiffness made of titanium, aluminum, or carbon fiber. Carbon fiber is illustrated here. **H,** The original Kirschner-Ehmer splint utilizing both double and single clamps.

two axes: that of the fixation pin and that of the bolt. Single clamps are the only clamps required for one-plane frames (see following discussion). Where two connecting bars need to be connected to each other, *double clamps* are used, in which two clamps rotate around the bolt axis (Figure 2-34, *H*). The design of the double clamp allows construction of multiplane frames, and these clamps are integral to the type IA double-clamp frame, the basic design used by Ehmer.[22] Because they are not inherently as "stiff" (resistant to deformation when subjected to loading) as single clamps, double clamps have been relegated to an ancillary role in fracture fixation. However, they are still useful in fixation of corrective osteotomies in young dogs, in which bone healing is vigorous and the need for long-lasting stability is only moderate. The use of two connecting bars between the pin clusters significantly stiffens type IA double-clamp frames.

Two clamp designs have become available that offer distinct improvements over the Kirschner-Ehmer clamp. The Secur-U external fixation clamp (Securos) has several design advantages (see Figure 2-34, *F*). This clamp may be applied to connecting bars between two previously installed clamps and allows installation of enhanced-thread pins at any location. Secur-U clamps are available in small and medium sizes and are attached to traditional stainless steel connecting rods, 1/8 inch (3.2 mm) and 3/16 inch (4.8 mm), respectively. The small Secur-U clamp can accommodate fixation pins with a shaft diameter of 1/6 inch (1.6 mm) or 3/32 inch (2.3 mm). The large Secur-U clamp can accommodate fixation pins with a shaft diameter of 3/32 inch (2.3 mm) or 1/8 inch (3.2 mm). Secur-U clamps have been shown to be more resistant to pin-clamp slippage compared with the traditional Kirschner-Ehmer clamp, and type II frames constructed with Secur-U clamps are 1.64 times more rigid in axial compression than the standard Kirschner-Ehmer system.[38,39]

The IMEX-SK system (IMEX Veterinary, Longview, Texas) is also a relatively new system of both connecting bars and pin-gripping clamps. The SK clamp (see Figure 2-34, *G*) is a split clamp, which allows the addition of clamps between two previously installed clamps in an existing fixator frame. The SK clamp can accommodate a wider range of fixation pin diameters and allows the passage of enhanced-thread pins (except cancellous center threaded) directly through the clamp bolt. Therefore, placement of enhanced-thread pins at multiple sites is much easier than the traditional Kirschner-Ehmer system. The SK system is available in three sizes: small, large, and mini. The small SK system is designed to be used in cases in which a small or medium Kirschner-Ehmer fixator would have been used. The large SK system should be used in cases in which a medium or large Kirschner-Ehmer fixator would have been appropriate. The mini SK system is designed for the smallest patients. The clamps of the SK system cannot be used in conjunction with the standard stainless steel connecting bars because of size variation, except for the mini SK system. The small SK clamp can accommodate fixation pins ranging from 3/32 inch (2.3 mm) to 5/32 inch (4.0 mm) in diameter. The large SK clamp can accommodate fixation pins ranging from 1/8 inch (3.2 mm) to 3/16 inch (4.8 mm) in diameter. The mini SK clamp accommodates fixation pins from 0.035 inch (0.9 mm) to 3/32 inch (2.5 mm) in diameter.

Classification of Frame Configurations

For many years the various types of frames were described and named in a variety of ways. Gradually, however, some uniformity of nomenclature has been emerging, which is necessary for easy communication. It is probably naive to believe that everyone will agree on a single system, so here we use the two most common nomenclatures, as described by Roe.[40] As used in this discussion, the terms "unilateral" and "bilateral" refer to the insertion of fixation pins through either one or two skin surfaces, and the term "plane" refers to the projected plane formed by the fixation pin clusters.

Type I/Unilateral (Figure 2-35, *A* and *B*)

Although type I splints can be used in either one or two planes, perhaps the most widely used frame is the type I/unilateral half-pin splint, which is applicable to all long bones. Such a splint can be further described using either the alphanumeric descriptor "IA" or the adjectival form "one plane." Further description requires the use of the adjectives "double" or "single" to specify the type of clamps or number of connecting bars.

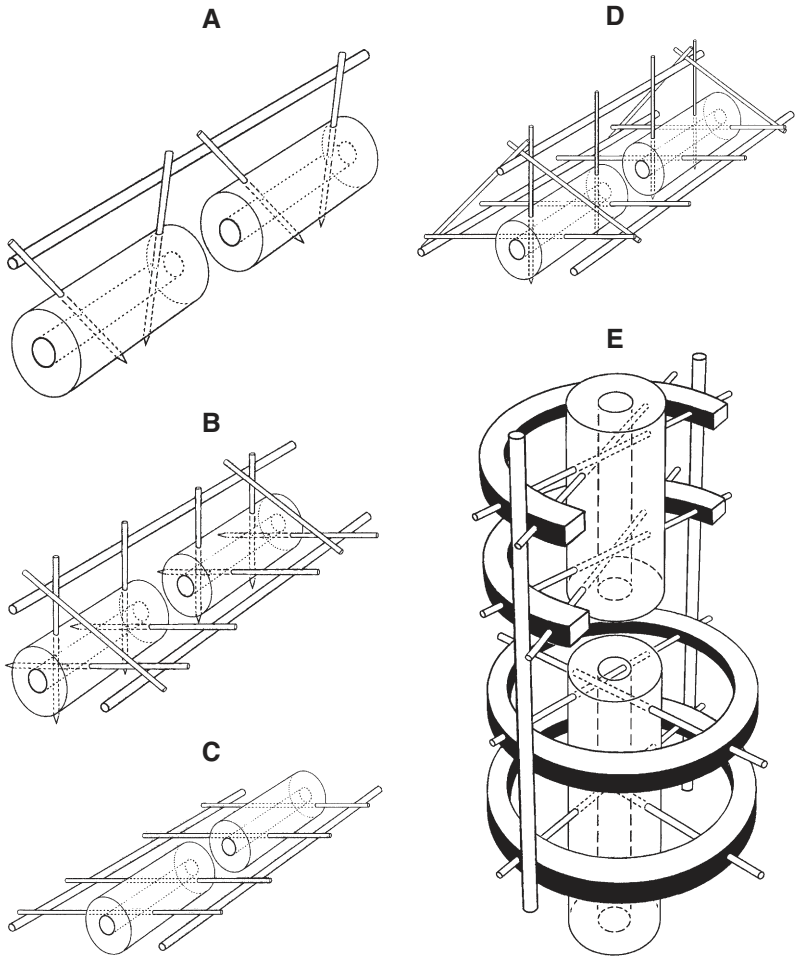


FIGURE 2-35. Classification of external fixator frame configurations. **A,** Type IA/one plane unilateral. **B,** Type IB/two plane unilateral. **C,** Type II/bilateral one plane. **D,** Type III bilateral two planes. **E,** Ring fixator, showing complete and partial rings.

IA/One Plane

Three subtypes of frames are included within this group, as follows:

Double Clamp (see Figure 2-47). This was the original veterinary device, commonly referred to simply as the "Kirschner-Ehmer pin splint."

Single Bar (see Figure 2-42, *A*). It is assumed that only single clamps are used for attaching the fixation pins to the connecting bar in the single-bar frame. This form is widely applicable and is responsible for the renewed interest in the external fixator stimulated by Brinker and others in the 1970s.[23]

Double Bar (see Figure 2-43, *E*). As with the single-bar frame, the use of only single clamps is assumed in the double-bar frame design.

IB/Two Plane (see Figures 2-35, *B*, and 2-45, *B*)

This frame is simply two type IA single-clamp frames applied at an angle of 60 to 90 degrees to each other. Interconnecting the connecting bars increases torsional

rigidity and decreases pin loosening. The number and geometry of interconnecting bars affect gap strain (rigidity) at the fracture site, as discussed in the section on biomechanical considerations.

Type II/Bilateral One Plane (Figure 2-35, *C*)

Because they utilize full pins, these frames are applicable only to the lower limbs, distal to the elbow or stifle. They are particularly suitable for closed reduction and stabilization of radial and tibial fractures. Various combinations of full and half pins are used in these frames.

IIA/Full Pins (see Figure 2-44, *F*)

Widely applied to tibial fractures in human patients, there are some technical problems in driving all the pins in the same plane to allow attachment to the connecting rods, as described in the later section on fundamentals of application. These frames are very versatile and useful not only in fractures of the lower limbs but also in transarticular fixation of lower limb joints.

IIB/Full and Half Pins (see Figure 2-44, *B*)

The problem of driving more than two full pins in the same plane is eliminated in this design, at the price of a slight loss in stiffness compared with the full-pin frame.

Type III/Bilateral Two Plane (see Figures 2-35, *D*, and 2-46)

With the strongest as well as the most complicated and costly design, this frame is used only in situations of extreme instability of the fracture and when slow healing is anticipated. Tibial fractures are the primary application, but it can also be adapted to the radius.

Ring (Figure 2-35, *E*)

Unlike other frames that depend on stiff fixation pins for stability at the bone-pin interface, the ring fixator pioneered by Ilizarov[38,41] utilizes small-diameter, flexible Kirschner wires as fixation pins. Stiffness of these pins is created by placing them under tension as they are attached to the rings. By use of threaded connecting rods, the rings can be adjusted to align the bone fragments and to provide either compression or tension on the fragments. Their primary veterinary application is in corrective osteotomy for angular deformity or limb lengthening (see Chapter 23), although ring fixators have also been described for fracture repair and arthrodesis.[42,43]

Biomechanical Considerations (see Figures 2-42, 2-43, and 2-44)

An approximation of the strength, or stiffness, of fixator frames is suggested by the numbers of the classification system, with "I" being the weakest and "III" being the strongest. Matching the required fixator strength to the clinical situation is partly art and partly science. The art portion is only acquired by experience, but the science can be explained and studied. In general, fractures that are expected to heal readily, with abundant callus formation, will heal consistently with type I frames. In contrast, fractures in which delayed union is the norm are best fixed with type II or III frames. A specific plan for choosing the appropriate form of fracture fixation for a given situation is discussed later in the section on selection of fixation method (see p. 145).

Mechanical studies have elucidated much knowledge regarding the mechanical characteristics of external fixators and the fixator-bone construct, from which we can gain insight to the clinical situation.[30-35,44] Based on these studies, certain generalizations can be made, as discussed next.

Overall Frame Stiffness

As stated earlier, stiffness in compression and torsion increases from type IA to IB to type II to type III. Bilateral splints are two or more times as stiff as unilateral splints. All frames are stiffest in the plane of their application; therefore, bilateral type II frames are stiff in medial-lateral bending, whereas unilateral type IA splints lose stiffness when the bending is toward the side of the splint. However, type IB splints are stiffer in bending than type II splints. Medium Kirschner-Ehmer frames are a mean 85% stiffer than small frames.[45]

Fixation Pin Number, Spacing, and Angle of Insertion

The pin-bone interface is subjected to very high-stress loads, which can lead to bone resorption around the pins and subsequent pin loosening. Increasing the number of fixation pins from the minimum of two pins per major fragment increases the area of the pin-bone interface, thus decreasing the incidence of bone resorption and subsequent pin loosening, *which is the major postoperative complication seen.* This is the most important factor to understand in clinical application of external fixators. Increasing the number of fixation pins also stiffens the frame, which further decreases the incidence of pin loosening, but the effect is probably not important once a total of four pins per major fragment is reached.

Widening the spacing between pins to place them as close as practical (half the bone diameter) to the ends of the bone and to the fracture line (see Figure 2-42, *C* and *F*) stiffens the construct in the bending plane perpendicular to the pins. Angling smooth pins 70 degrees relative to the long axis of the bone stiffens the frame and helps prevent accidental dislodgement of the pins by the patient. Angling of fixation pins is not important when positive-profile-threaded pins are used, which simplifies application.

Fixation Pin Design, Size, and Type

Threaded pins have better holding power than smooth pins (about tenfold acutely and even more chronically), and most frames should be constructed either with all fixation pins threaded or with a combination of smooth and threaded pins. Negative-thread-profile pins are weakest at the junction of the threaded and unthreaded portions; this area acts as a stress concentrator and is susceptible to fatigue failure from repetitive bending. The Ellis pin depicted in Figure 2-34, *B*, has a short negative-profile-threaded tip to allow the threaded end to penetrate the second cortex while the junction of threaded and unthreaded portion is protected within the medullary cavity. Positive-thread-profile pins offer the most holding power, and end-threaded half pins do not undergo loss of stiffness at the junction of threaded and unthreaded areas. In type I unilateral frames, it is optimal to place these pins at each end of a pin cluster. Centrally threaded, positive-thread-profile pins are advisable for at least the most proximal and most distal full pins in type II and III frames.

Drilling a pilot hole for insertion of positive-thread-profile pins can improve tightness (end-insertional torque) and pull-out strength of the pin acutely by 25% and 14%, respectively, compared with no predrill.[46,47] Less mechanical damage to the cortex develops at the pin-bone interface when a pilot hole is used, and less bone resorption may occur over time.

Larger pins are stiffer than smaller pins by a direct relationship to the fourth power of the radius; thus a small increase in diameter produces a large increase in stiffness. However, pin diameters larger than 20% to 25% of the bone diameter weaken the bone and should be avoided.

Type II bilateral frames offer some technical difficulties in full-pin placement. Insertion of the most proximal and distal pins and attaching them to the connecting bars is not difficult, but placing additional full pins is hindered by the need to place these pins in the same plane as the first pins. Half pins can be substituted for full pins in this situation (see Figure 2-44, *A*, *B*, and *D*), but at the cost of some loss of stiffness. One method for placing the intermediate pins follows:

1. With the end pins placed, the medial and lateral connecting bars, with the appropriate number of empty clamps placed on each, are positioned in the end clamps.
2. The fracture is reduced and held by any means in the reduced position while the four end clamps are tightened.
3. A third connecting bar with the same number of empty clamps is attached to the end pins on the most convenient side.
4. The intermediate fixation pins are placed through the clamps attached to the double connecting bars and drilled through the bone to emerge on the opposite side. The fracture must be reduced satisfactorily before these pins are drilled.
5. Because all three connecting bars are in the same plane, the fixation pins will line up with the clamps on the opposite side, where the pins are secured by tightening the clamps.
6. When all the fixation pins are placed and secured in their clamps, the temporary connecting bar and clamps are removed.

Connecting Bars and Clamp Configuration

Stiffness of the connecting bar is of greatest concern in type I unilateral splints, where it is the limiting factor in frame stiffness. Increasing the stiffness of the connecting bar decreases axial loads at the fracture site and reduces shear loads on some of the pins.[48] Several strategies have been developed to increase bar stiffness. Adding a second bar to unilateral splints (see Figure 2-43, *D*, *E*, and *F*) almost doubles frame stiffness. Conforming the connecting bar to keep it as close to the bone as possible (see Figure 2-48, *C*) is helpful in increasing frame stiffness because it decreases the working length of the fixation pin. Stiffness of the pin is inversely proportional to the third power of the length, so keeping the length as short as possible is desirable. For similar reasons, clamps should be positioned on the connecting bar with the bolt inside the connecting bar (see Figure 2-41, *B*) because this also shortens the working distance of the fixation pin. Clamp design may also affect frame stiffness. The Secur-U design has a more secure fixator pin/connecting bar junction than the Kirschner-Ehmer clamps.[38,39] Connecting bars of larger diameter and stiffness are available in carbon fiber, titanium, or aluminum materials in the IMEX-SK fixator system. The large SK system has been shown to be more than two times as stiff in axial compression compared with a six-pin type 1A fixator using the medium Kirschner-Ehmer system. Frame stiffness may be affected by number and geometry of interconnecting bars between the axial planes in more complex fixator designs. Four horizontal or single or double diagonal interconnecting bars have reduced fracture gap strain in type 1B fixators compared with other geometries (see Figure 2-45, *C*).[49]

Acrylic connecting bars offer good mechanical characteristics, such as easy conformation of the bar to the skin surface, thereby maximizing fixation pin

stiffness. In mechanical testing a 3/4-inch (19-mm) column of molded methyl methacrylate displayed more strength and stiffness than the 3/16-inch (4.6-mm) stainless steel rod typically used in the medium Kirschner-Ehmer frame.[50] Curving the acrylic connecting bars up to 25 degrees between pins does not affect frame stiffness, compared with a medium Kirschner-Ehmer frame.[51] Additionally, acrylic connecting bars offer more freedom of fixation pin placement to accommodate the fracture and the anatomy and allow the use of positive-thread-profile fixation pins anywhere in the frame.

Fundamentals of Application

The first consideration in applying an external fixator is the decision about which basic approach will be taken toward reduction of the fracture. Because of its versatility, the external fixator lends itself to either (1) an open approach, with anatomical bone reconstruction and rigid fixation, or (2) a closed approach or minimal open approach, with reduction aimed at aligning the diaphysis relative to angular and rotational deformity, and little or no reduction of bone fragments by direct manipulation. The first method represents the traditional rigid fixation approach to internal fixation, whereas the latter represents the *biological fixation* or *bridging osteosynthesis* approach discussed earlier. Consideration should always be given to finding a way to reduce the major fragments sufficiently to allow load sharing between the bone and fixator, even if it requires some shortening of the bone. This will allow the use of a simpler frame and will reduce the possibility of premature pin loosening and loss of fixation caused by high stress loads at the pin-bone interface.

The following guidelines are suggested[2,3,23,24,52-54]:

1. *Use aseptic technique.* This includes preparation of the patient, the operating room, the equipment, the surgeon, and postoperative care.
2. *Use proper bone surface location for insertion of pins.* Complications can be minimized if the splint is located on the bone surface that allows insertion of the fixation pins through the skin and directly into the bone. This minimizes the length of pin between the fixation clamp and bone, thus maintaining maximum pin stiffness. It also minimizes soft tissue irritation; pins penetrating through muscle and skin are more irritating than those penetrating skin alone. The proper surface for the unilateral splint on the tibia is medial; for the radius, craniomedial or medial; for the humerus, craniolateral; and for the femur, lateral (Figure 2-36). To insert the pins in the humerus and femur, it is necessary to penetrate both skin and underlying muscle; however, the surfaces just mentioned keep muscle thickness to a minimum.
3. *Use the most suitable configuration of the splint.*[22,23,28-30,34,35] Guidelines relative to this decision in specific clinical situations are discussed later (see Selection of Fixation Method). General guidelines are that type I unilateral configurations can be used on all the long bones and the mandible, and that biplanar and bilateral configurations are limited to fractures of the tibia, radius and ulna, and mandible to avoid interfering with the body wall. Although static strength and stiffness evaluation of the various frame configurations (starting from the lowest) places them approximately in the order of (1) type IA unilateral one plane, (2) type IB unilateral two plane, (3) type II bilateral one plane, and (4) type III bilateral two plane, it must be remembered that clinical performance depends on many variables, as mentioned earlier, such as the diameter and contouring of the connecting bars, diameter and number of

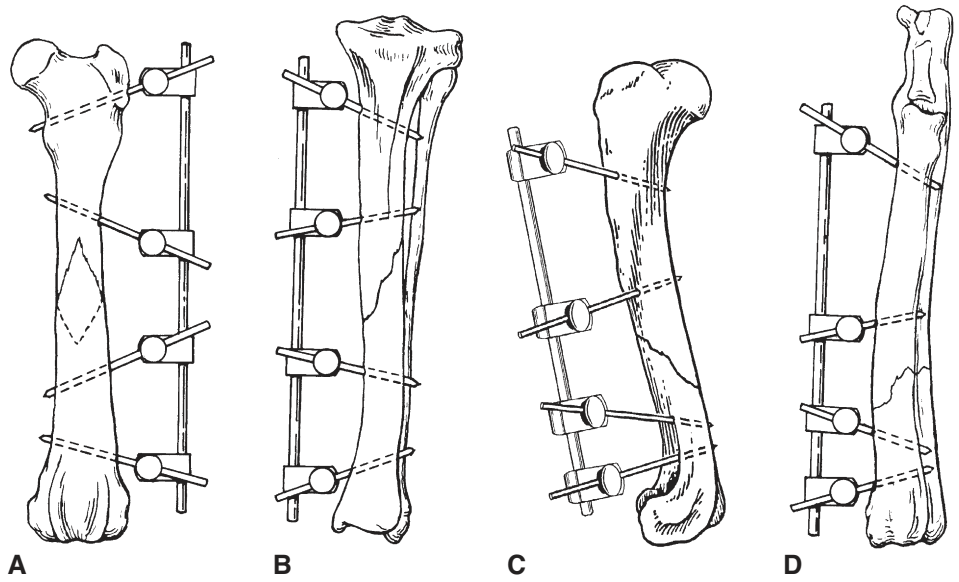


FIGURE 2-36. Preferred location of the unilateral external fixator in relation to the bone surface and associated soft tissue. **A,** Lateral surface of femur. **B,** Medial surface of tibia. **C,** Craniolateral surface of humerus. **D,** Craniomedial or medial surface of radius.

fixation pins, angle and location of pins in the cortical bone, length of the pins from the fixation clamps to the bone, and inherent stability at the fracture site. The importance of the latter is difficult to overemphasize; if *load sharing* can be achieved between the bone and frame, as in type A simple or type B wedge fractures, the frame can be less stiff than in the situation where there is no load sharing, as in type C complex fractures, and the fixator must function as a *buttress*. Clinical experience supports that the stiffness produced by the type IA unilateral configuration—one connecting bar with two to four pins per bone fragment—is adequate in type A simple and most type B wedge fractures where load sharing can be achieved and when supplemented with appropriate auxiliary fixation as indicated. Because fractures vary widely in type, stability, condition of soft tissue, animal activity, and size of the patient, no single configuration is best suited for all fractures; however, the simple configurations serve very well on most fractures.

4. *Auxiliary fixation should be used when indicated.* If the goal of fracture treatment is rigid, uninterrupted stabilization of the main fracture fragments, auxiliary fixation (which may include use of lag screws, intramedullary pins, Kirschner wires, and cerclage or interfragmentary wire configurations) may be helpful in maintaining reduction during insertion of the fixation pins and in aiding rigid stabilization (Figure 2-37). However, rigid devices such as lag screws and cerclage wire should be used cautiously in combination with the less stiff, type IA unilateral frames, since they can act as stress concentrators and cause secondary fractures or loosening of the implant because of bone resorption. An additional consideration is the disruption of fracture biology caused by their placement. These frames are safest in situations in which good stability can be achieved and rapid bone healing is anticipated.

   An intramedullary (IM) pin used as auxiliary fixation to an external fixator can be especially helpful in achieving the concept of biological fixation in more

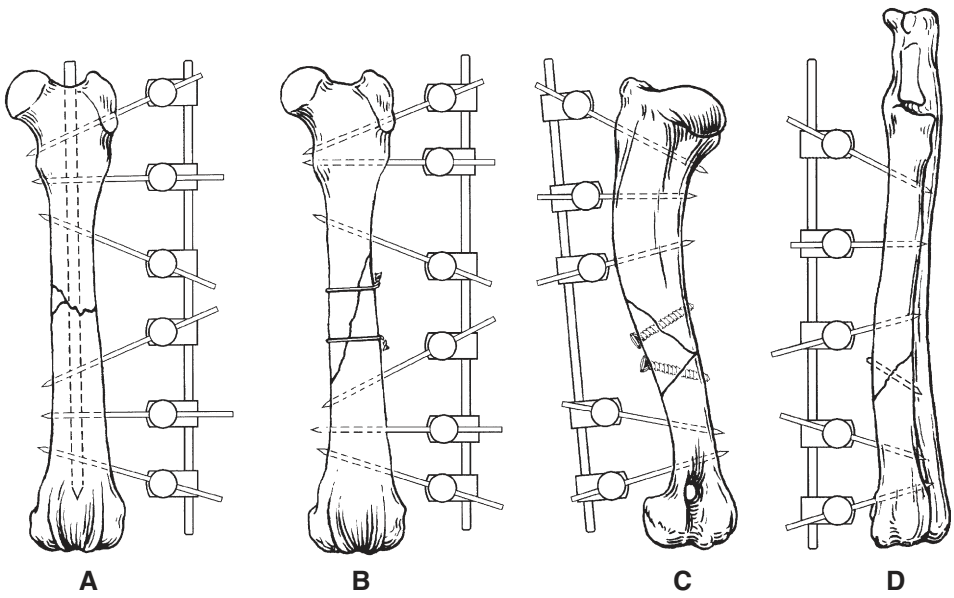


FIGURE 2-37. Auxiliary fixation commonly used with the external fixator. **A,** Intramedullary pin. **B,** Cerclage wire. **C,** Lag screws. **D,** Diagonally inserted Kirschner wire.

complex long-bone fractures. A minimal open approach is used to expose the fracture site, with no disruption of fracture hematoma or manipulation of cortical fragments. An IM pin is placed to approximate axial alignment and minimize fracture manipulation during placement of fixator pins. Modified type IB frames are useful for complex femoral or humeral fractures with IM pins.[55] Modified type IB, II, and III frames may be used with IM pins for difficult tibial fractures. The IM pin can be connected to the fixator connecting bar with an additional "tie-in" connector. IM pin tie-in improves fixator construct strength and stiffness.[56]

5. *The fracture should be reduced and maintained in reduction during application of the splint.* With the fracture reduced, the soft tissues are restored to their normal anatomical position, and the pins can be inserted without distorting the soft tissues. This helps to minimize tissue irritation and discomfort to the animal. If reduction is lost during pin insertion, it should be regained before proceeding. Fractures of the radius/ulna and the tibia can often be reduced closed by applying the splint while the limb is suspended overhead (see Figure 2-12). Suitable draping technique includes a sterile cover for the suspending tape or rope that extends far enough upward to preclude accidental contamination of the surgeons.
6. *Insert pins through soft tissue in a manner that does not distort the tissue.* A short (1/4-inch or 2- to 3-mm) stab incision is made in the skin. If the pin is inserted through muscle, tunnel bluntly through the muscle with a hemostat and then spread the hemostat jaws to allow the pin to be placed through the tunnel into contact with the bone. Placing the pins between muscle bellies and tendons to the extent possible helps to reduce postoperative problems (see later discussion). With open reduction the pins should not be placed through the incision, and it is important to remove all retractors from the incision before pins are placed to prevent soft tissue distortion. At the conclusion of the

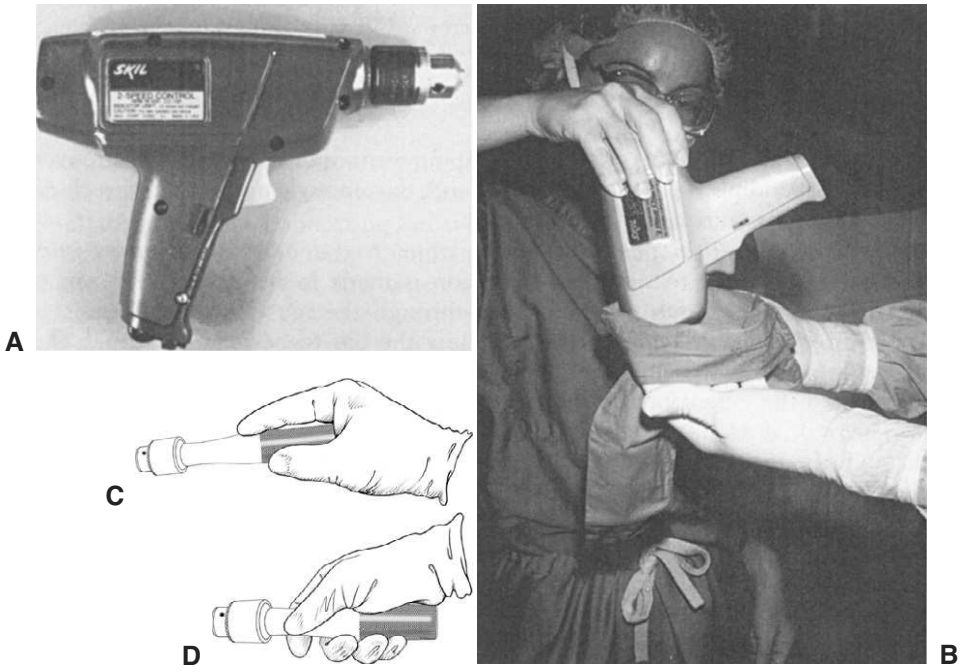


FIGURE 2-38. **A,** Fixation pins are inserted with a standard low-speed (150 rpm) orthopedic or battery-powered drill. **B,** Nonsterile battery-powered electric drill being dropped into a sterile shroud held open by the surgeon. The shroud is secured by hook and eyelet material to keep it closed over the drill. A sterile Jacobs chuck and extension tube is then screwed into the drill through a small opening in the shroud. Care must be taken to prevent the shroud from becoming wetted and allowing bacterial "strike-through." Alternatively, the drill can be sterilized in ethylene oxide gas. **C,** The correct method of holding the pin chuck to minimize wobbling is with the wrist straight and the elbow flexed so that the forearm, pin chuck, and pin are rotated as a unit around a constant axis. The chuck handle is pushed by the palm. **D,** This handgrip on the chuck is a common error and cannot apply proper force and control while driving pins.

procedure, extend the original pin incisions as necessary to relieve any skin wrinkling. If there is no alternative to inserting pins through the incision, it must be done in a manner that allows penetration of the muscles without distortion of the muscle, and relief incisions must be made in the skin to allow it to return to its normal position.

7. *Pin-drilling technique is critical.*[2,3,30,31,52] Use a slow-speed power drill (150 rpm or less) for pin insertion; a higher-speed power drill creates an undue amount of heat, which can cause bone necrosis and pin loosening. Rechargeable battery-powered drills operate at these low speeds and have sufficient torque to make them an economical substitute for true surgical drills (Figure 2-38, *A*). The technical problem in the use of these drills is the issue of sterilizing them, since they cannot be steam-sterilized. Ethylene oxide sterilization is a simple and satisfactory solution, if available, and the drill can be handled as any other sterile instrument during surgery. If ethylene oxide sterilization is not an option, sterile fabric shrouds (Figure 2-38, *B*) to cover the drill and an extended shaft and detachable and sterilizable chuck are needed (Extend-a-Chuck drill extension and shroud, Animal Clinic Products, Montgomery, Ala). Use of the hand chuck is acceptable if extreme care is taken

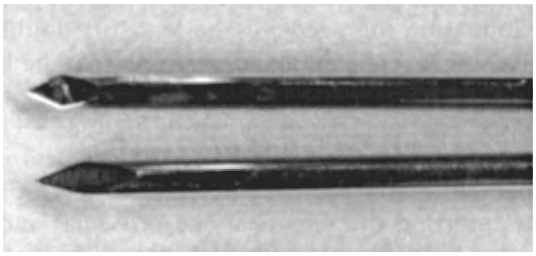


FIGURE 2-39. Trocar-pointed Steinmann pins. The relatively long point is preferred over the short point; it penetrates faster and easier.

to prevent wobble of the pin during insertion, and this works quite well in immature bone (Figure 2-38, *C, D*). Hand-held rotary bone drills are not satisfactory because they generate excessive heat at the pin, and it is impossible to control wobble of the pin during insertion. Pins should be inserted through the center of the bone to maximize the distance between the first and second cortex and better stabilize the pin within the bone. After insertion, each pin should be checked to make sure it is solidly anchored in the bone. Trocar-pointed pins are favored, and those with a relatively long point are preferred because they penetrate the bone faster and are easier to insert (Figure 2-39). Positive-thread-profile pins should not be inserted directly into bone because they produce microfractures of the cortex at the entry and exit points, particularly with cancellous threaded pins. This damage can be reduced by predrilling a pilot hole in the bone that is 10% smaller than the pin diameter. Such drilling requires the use of a drill sleeve to protect the soft tissues if a twist drill is used; alternatively, the pilot hole can be drilled using a smooth pin or Kirschner wire. After drilling pilot holes, it is safest then to insert positive-thread-profile pins using a hand chuck, since this will minimize bone damage, such as accidental stripping of the threads.

8. *Insert pins through both cortices of the bone.* Invariably, any pin that is not fully inserted through both cortices loosens and thus does not accomplish its purpose. With few exceptions, the pinpoint can be palpated on penetration of the far cortex. When using a power drill, a definite change in the pitch of the drill's motor sound will be detected as the pin penetrates through the second cortex. When inserting pins by hand, an increased amount of torque is needed as the point of the pin penetrates the second cortex, followed by a sudden decrease in resistance as the tip of the pin clears the cortex. The pin should penetrate about the length of the trocar point. If pins should penetrate too far on insertion, they should be left in position if possible; withdrawing the pin weakens the pin-bone interface and diminishes pull-out strength.[52] Even overly long, protruding pins rarely cause any clinical problem.
9. *Insert smooth and negative-thread-profile pins at an angle of 70 degrees to the long axis of the bone*[23,24,45] (Figure 2-40). Pins inserted at this angle give maximum stiffness to the fixator along with maximum pull-out resistance from the bone. This angularity is not important with positive-thread-profile pins, thereby simplifying insertion of an adequate number of pins per fragment.
10. *Insert all related fixation pin clusters in the same plane.* This has two advantages: (1) all pins can be attached to a common connecting bar, thus eliminating the need for the less stiff double clamps; and (2) if postoperative swelling occurs, the fixation clamps can be loosened and readily adjusted without affecting reduction at the fracture site. The procedure for application using one connecting bar is shown in Figure 2-41.

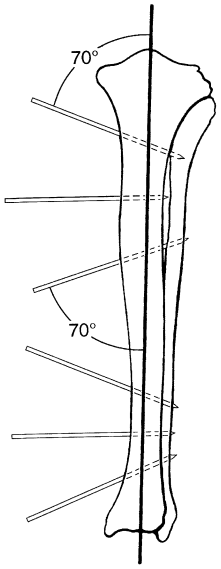


FIGURE 2-40. For maximum stiffness, the end fixation pins in each group should be inserted at a 70-degree angle to the long axis of the bone.

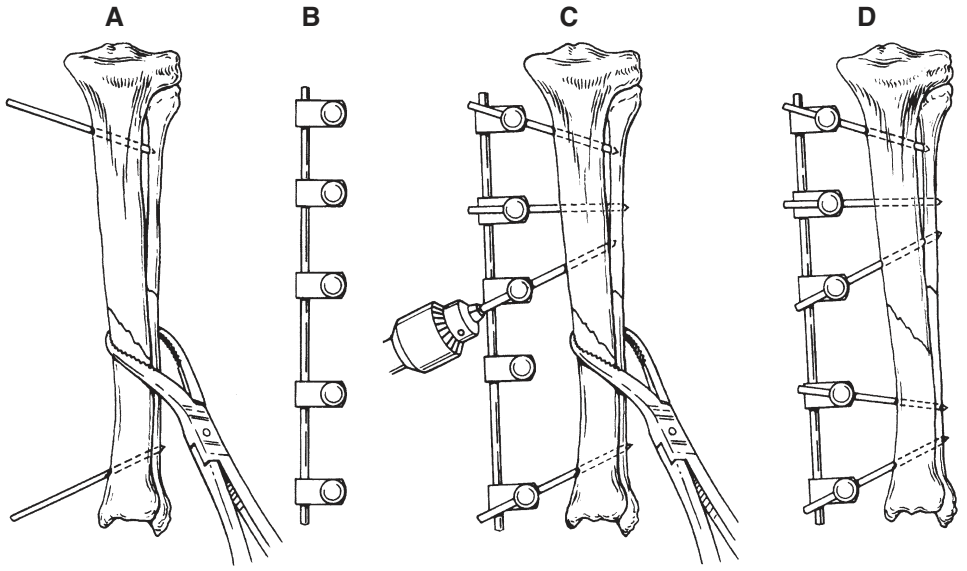


FIGURE 2-41. Unilateral (type IA) external fixator, one connecting bar, 3/2 pins. **A,** The fracture is first reduced, and reduction is maintained during the application procedure. The proximal and distal pins are inserted. **B,** The fixation clamps are assembled on the connecting bar. **C,** The fixation clamps are attached to the proximal and distal pins. The remaining three pins are inserted through the clamps and bone. **D,** All clamps are tightened, and the incision is closed.

11. *Insert pins in the proper location of the bone fragment.* Experimental studies[34,44] and clinical studies indicate that maximum stability is accomplished by inserting the pins near the proximal and distal ends of the bone fragment rather than by inserting both pins near the ends or near the fracture site (Figure 2-42). The pins should be kept half the bone diameter distant from the fracture line, and fissures in the cortex must be avoided. Because the cortex is normally quite thin in the proximal metaphyseal region

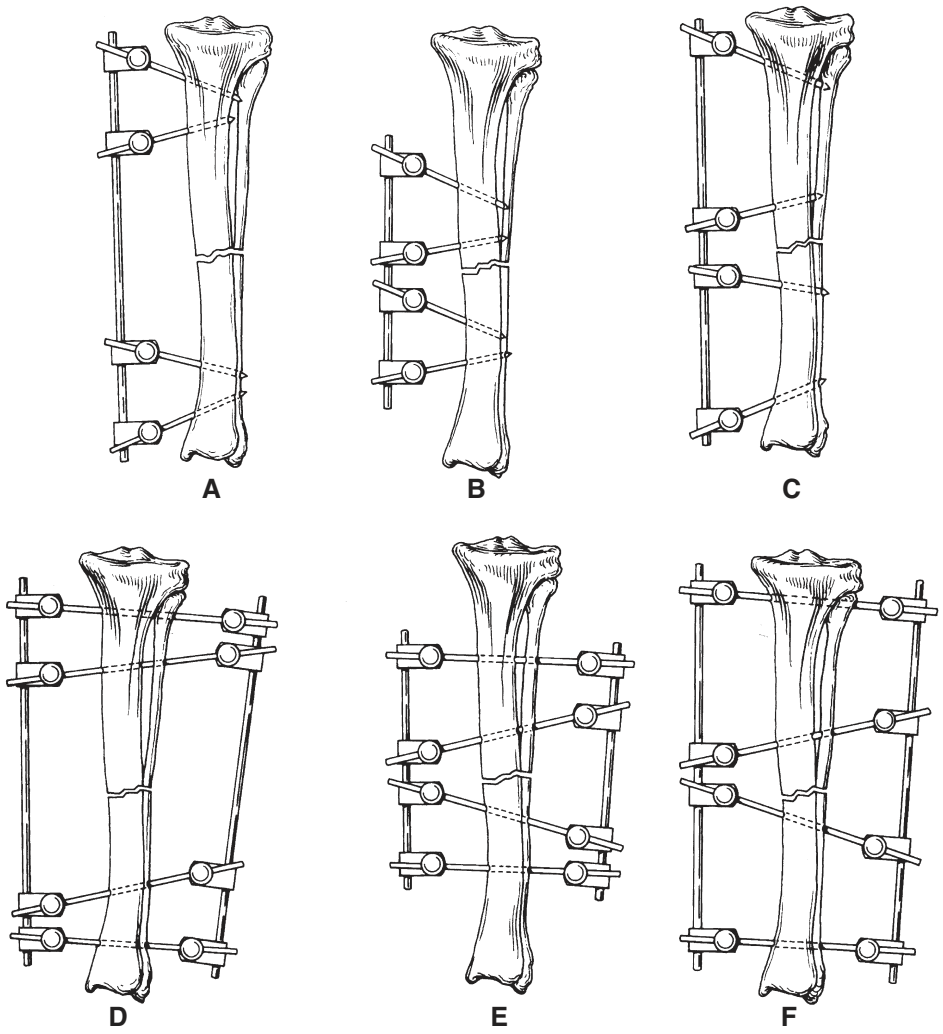


FIGURE 2-42. **A, B,** and **C,** Unilateral (type IA) configurations. **D, E,** and **F,** bilateral (type IIA) configurations. Maximum stability is accomplished by inserting the pins near the proximal and distal ends of the bone fragment (**C** and **F**) in preference to both pins near the proximal end (**A** and **D**) or the fracture site (**B** and **E**).

of the humerus and tibia and the distal metaphysis of the femur, it is advantageous to avoid placing smooth or negative-thread-profile pins in these areas, because cancellous bone has very little holding power on the pins. Cancellous positive-thread-profile pins should be used in these areas, after drilling a pilot hole.[54]

12. *Insert two to four pins in each major bone fragment.* Until the early 1970s, two pins per bone fragment were used in most cases. Studies since that time definitely indicate that three or four pins per fragment increase the stiffness of the construct* (Figures 2-43 and 2-44). The degree of stiffness needed to heal a specific fracture is unknown, but general guidelines are presented in the later section on selection of fixation method. Biomechanically, it appears that

*References 24, 30, 34, 35, 44, 45.

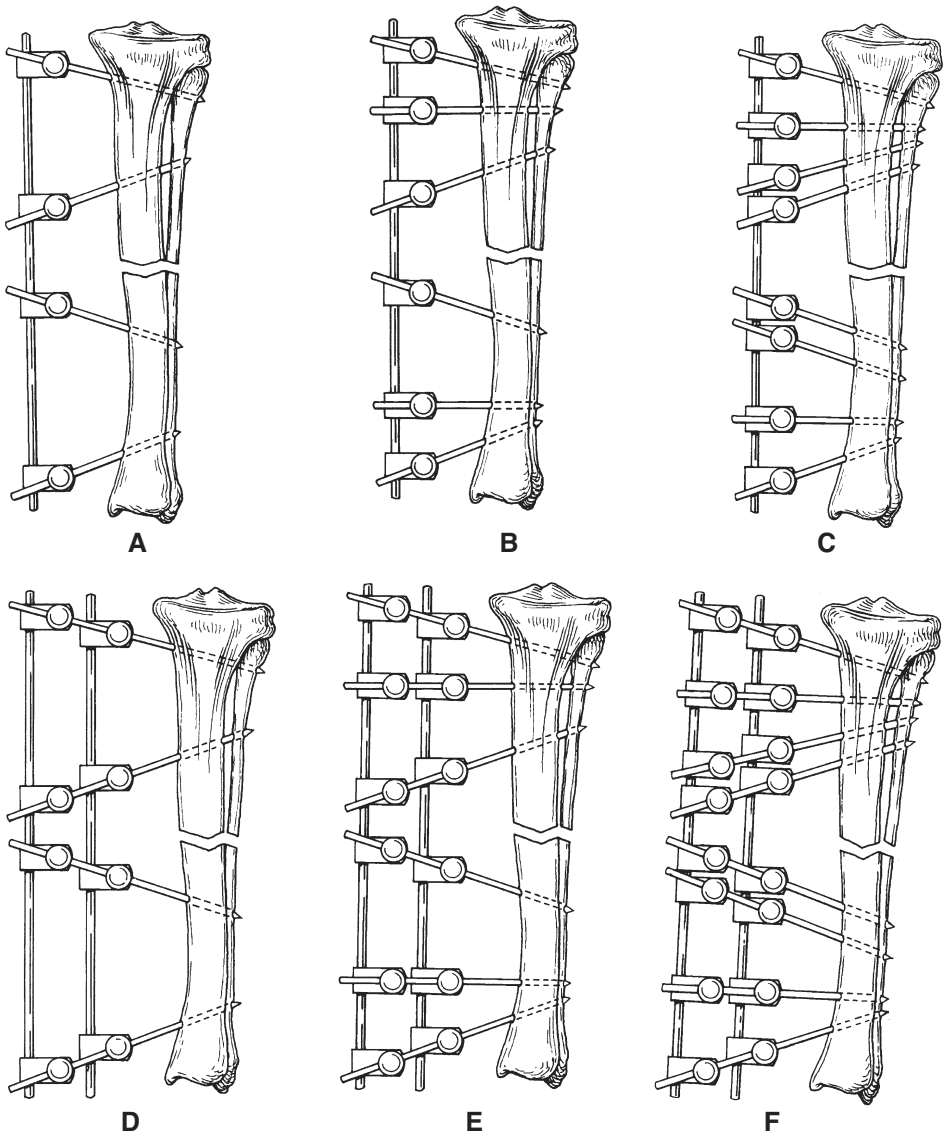


FIGURE 2-43. Unilateral (type IA) configurations. One connecting bar: **A,** 2/2 pins/fragment; **B,** 3/3 pins/fragment; **C,** 4/4 pins/fragment. Two connecting bars: **D,** 2/2 pins/fragment; **E,** 3/3 pins/fragment; **F,** 4/4 pins/fragment. Using two connecting bars approximately doubles the stiffness of the splint; however, this is usually indicated only in the very large dog. *Note*: The "fracture gap" is for artistic clarity.

one of the major advantages of using more than two pins per fragment is a decrease in pin-bone stress forces to which the pins are subjected during healing. This appears to hold true in clinical use because bent pins and loosening are much less frequently encountered when three or four pins per fragment are used. All fractures require a minimum of two pins on each major bone segment. If healing is anticipated to be slow as a result of fragmentation, contamination, or old age, more pins per segment are useful.

13. *Choose optimal size fixation pins and connecting bars.* The appropriate size of both varies with the size of the bone involved. In the United States the Kirschner-Ehmer splint is the apparatus used almost exclusively in small

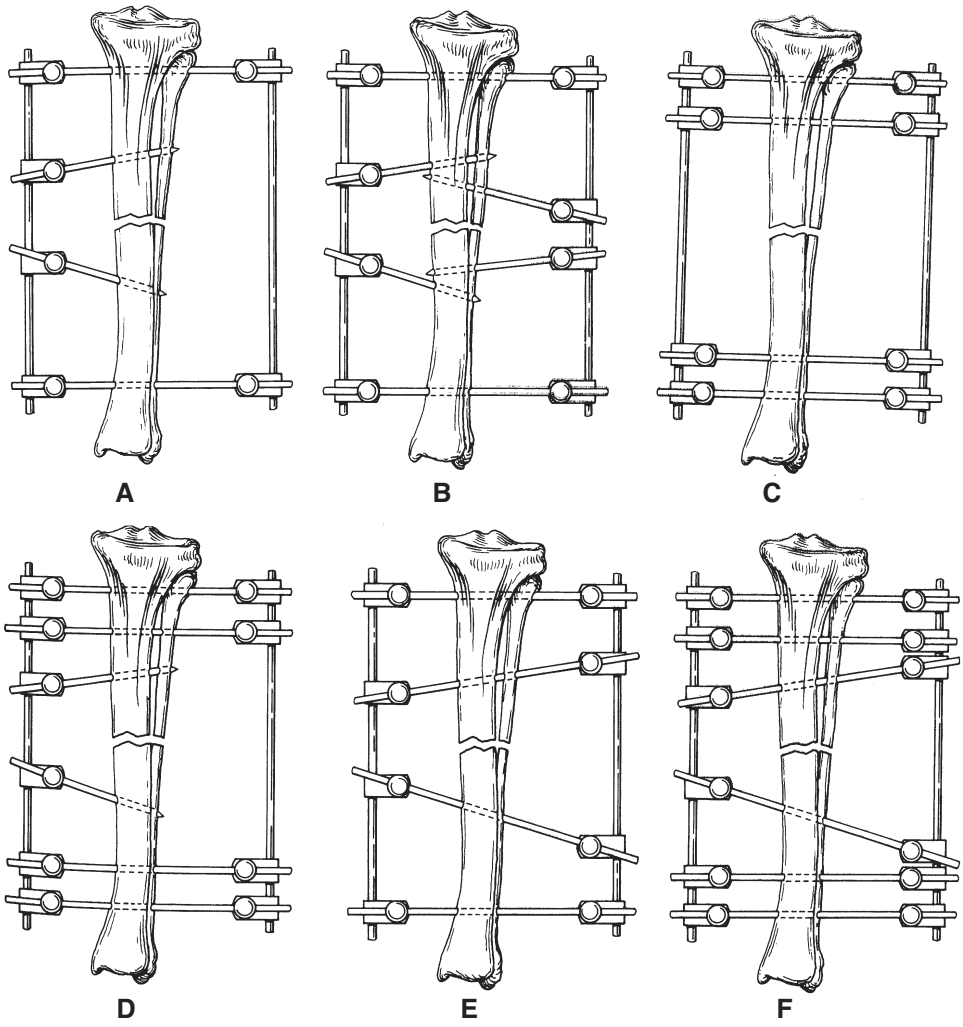


FIGURE 2-44. Various bilateral (type II) configurations. On the basis of stiffness response, starting from the least and progressing upward, the ranking is **A** through **F**. Stiffness is improved by through-and-through pins instead of half pins, using angled pins, or increasing the number of pins. *Note*: The "fracture gap" is for artistic clarity.

animals (Figures 2-45, 2-46, and 2-47). The medium-size fixation clamps accommodate a 3/16-inch (4.6-mm) connecting bar. The use of two connecting bars (see Figure 2-43) approximately doubles the stiffness of the splint and may be indicated for use in some large-breed or giant-breed dogs. The medium-size fixation clamps accommodate 3/32-inch and 1/8-inch (2.4- to 3.2-mm) fixation pins. The 1/8-inch pins are used most frequently; however, the 3/32-inch pins may be used on animals in the 18- to 25-pound (8- to 11-kg) range. The small Kirschner-Ehmer clamps accommodate an 1/8-inch connecting bar, and fixation pins can range up to 5/64-inch (2.0-mm) diameter. In clinical settings the largest practical pin size is used because this gives stiffness to the apparatus, bends less at the pin-bone interface on cyclical loading, and is less apt to loosen during the healing period. However, in general, the fixation pin should not exceed one fourth of the diameter of the

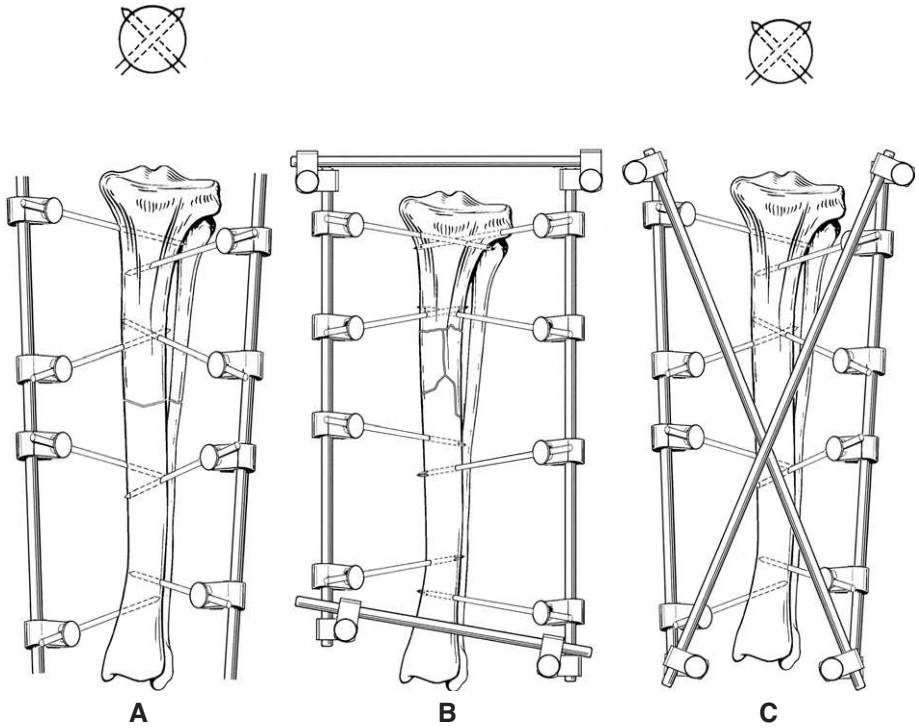


FIGURE 2-45. **A,** Biplanar type I configuration. One unilateral external fixator is placed on the medial surface of the tibia or radius, and another is placed on the cranial surface. Their connecting bars or the end pins (see *B*) may be bridged by two or more connecting bars. **B,** Modifications of this configuration work well on very proximal or distal fractures. *Note*: The "fracture gap" is for artistic clarity. **C,** Frame stiffness may be affected by number and geometry of interconnecting bars between the axial planes. Single or double diagonal interconnecting bars reduce fracture gap strain in type IB fixators.

bone because weakening and fracture can occur. Pins should be cut as close to the clamp as possible, with a pin (bolt) cutter or saw, to minimize the overall dimensions of the splint.

14. *Place the connecting rods an optimal distance between the fixation clamps and the skin.* This distance at the time of application varies depending on the size of the animal and the anticipated postsurgical swelling. The distance is usually $^3/_8$ to $^1/_2$ inch (10-13 mm) (Figure 2-48). The thickness of the small finger is a good approximation in most people. Contour the rod to fit the skin/muscle surface where necessary to minimize the clamp-bone distance (Figure 2-48, *C*). Postsurgical swelling, which usually occurs within the first 10 days, may necessitate readjustment and moving the fixation clamps outward on the pins because contact pressure will result in necrosis of the soft tissue. Regions of tissue movement (e.g., near joints) swell more than do regions of little motion.
15. *Use a bone graft for significant cortical deficits.* Because rigidity of fixation using the external fixator is usually less than when using plates, the body is stimulated to produce more bridging callus. If definite architectural deficits are present, however, they should be filled with a bone graft. This is particularly true in mature and older animals, in those with osteotomies of diaphyseal bone, and in nonunions.

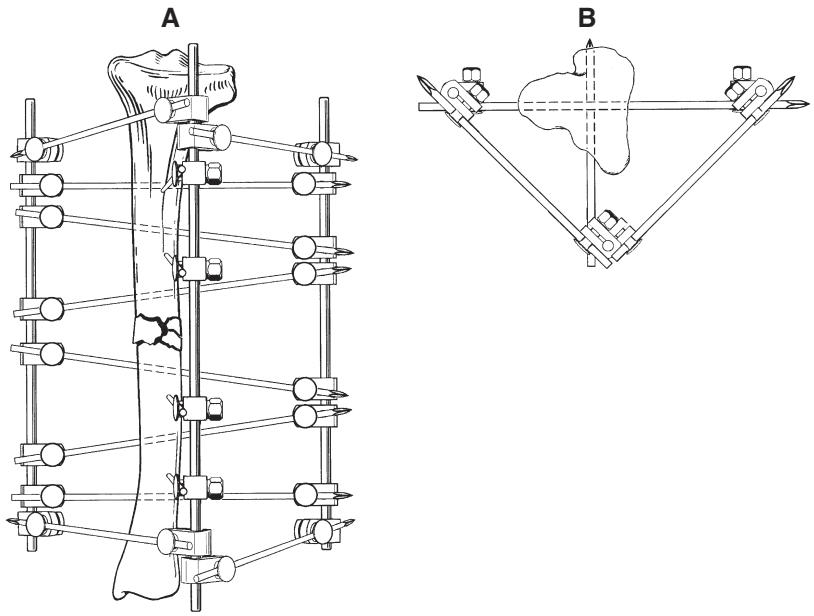


FIGURE 2-46. Type III bilateral two-plane splint. **A,** This splint is most applicable to the tibia, although it can also be adapted to the radius. **B,** The tentlike configuration can be seen in this proximodistal view.

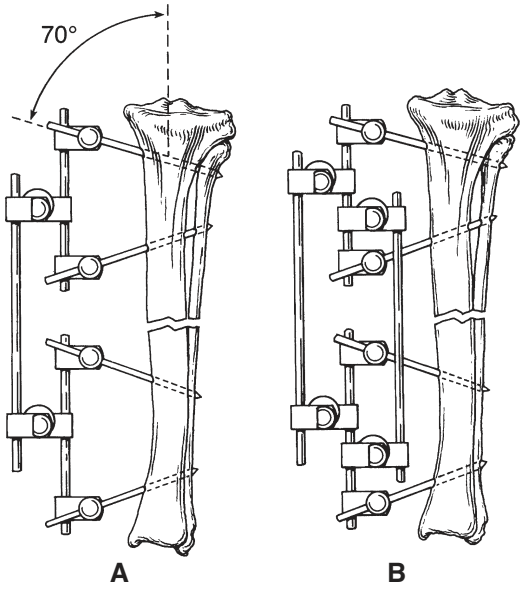


FIGURE 2-47. Original Kirschner type IA configurations using one (**A**) or two (**B**) connecting bars. With clinical patients, two connecting bars are used in most cases because this greatly increases splint stiffness and stability. *Note*: The "fracture gap" is for artistic clarity.

Aftercare

Following surgery, a compressive (Robert-Jones) bandage is applied to protect the incision and minimize swelling in fractures of the radius/ulna and tibia (Figure 2-49). Any open wounds and all incisions are covered with a sterile nonadherent dressing, and roll cotton or cast padding is packed around the pins and under the connecting bars. Additional cotton or padding is rolled on the leg from the toes

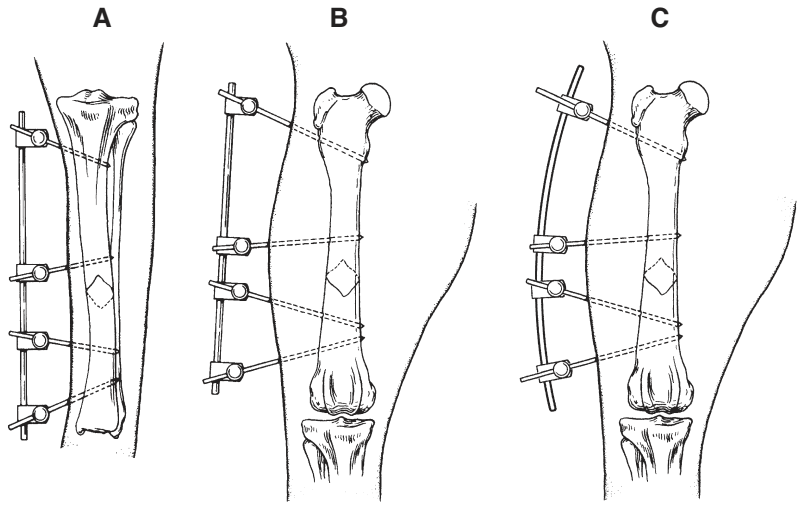


FIGURE 2-48. The distance between the fixation clamps and the skin is usually 3/8 to 1/2 inch. **A** and **B,** This distance varies with the size of the animal and anticipated postsurgical swelling. If swelling causes the skin to press against the fixation clamps, readjustment and movement of the clamps outward on the pins are indicated because contact pressure will result in necrosis of the soft tissue. **C,** In some situations it is useful to gently contour the connecting rod to follow the skin/muscle surface.

to the frame. The padding is then compressed with an elastic conforming bandage (Vetrap, 3M Animal Care Products, St. Paul, Minn; Flexus, Kimberly-Clark Corporation). It is important that the padding and wrapping start at the toes and then proceed proximally to cover the frame. Covering only the frame with this type dressing will cause severe swelling of the limb distal to the frame. In most cases this bandage is removed after 2 to 5 days. This step is not possible with humeral and femoral fractures. With open fractures or with severe soft tissue injury, the wound is often debrided, lavaged, and rebandaged every 2 to 3 days until it is covered with granulation tissue. Because of the stability the fixator provides, such frequent bandage changes can be performed without traumatizing early vascular granulation tissue and callus formation.

The compressive bandage is replaced with a gauze and Vetrap cover, which encloses only the connecting clamps and bars and the protruding ends of the fixation pins of the fixator (Figure 2-50). This cover protects the animal and the owner from the sharp ends of the fixation pins and decreases the chance of catching the apparatus on fixed objects. Flexible plastic caps can also be fitted on the ends of the fixation pins, which are usually quite sharp as a result of being cut with a pin (bolt) cutter. The cover should be applied so that it does not contact the skin but does allow air circulation around the skin-pin interface. Do not use adhesive tape for this cover because it is very difficult to remove from the metal frame components. Gauze can be used as a first layer, which is then covered by adhesive tape, but the tape is not brought into contact with the frame components. This type of cover for the frame is done immediately postoperatively in the case of humeral and femoral fractures.

The use of a broad-spectrum antibiotic is indicated for contaminated open or infected fractures until a culture and sensitivity can direct more specific therapy. Because of the soft tissue trauma attending even most closed fractures, we tend to

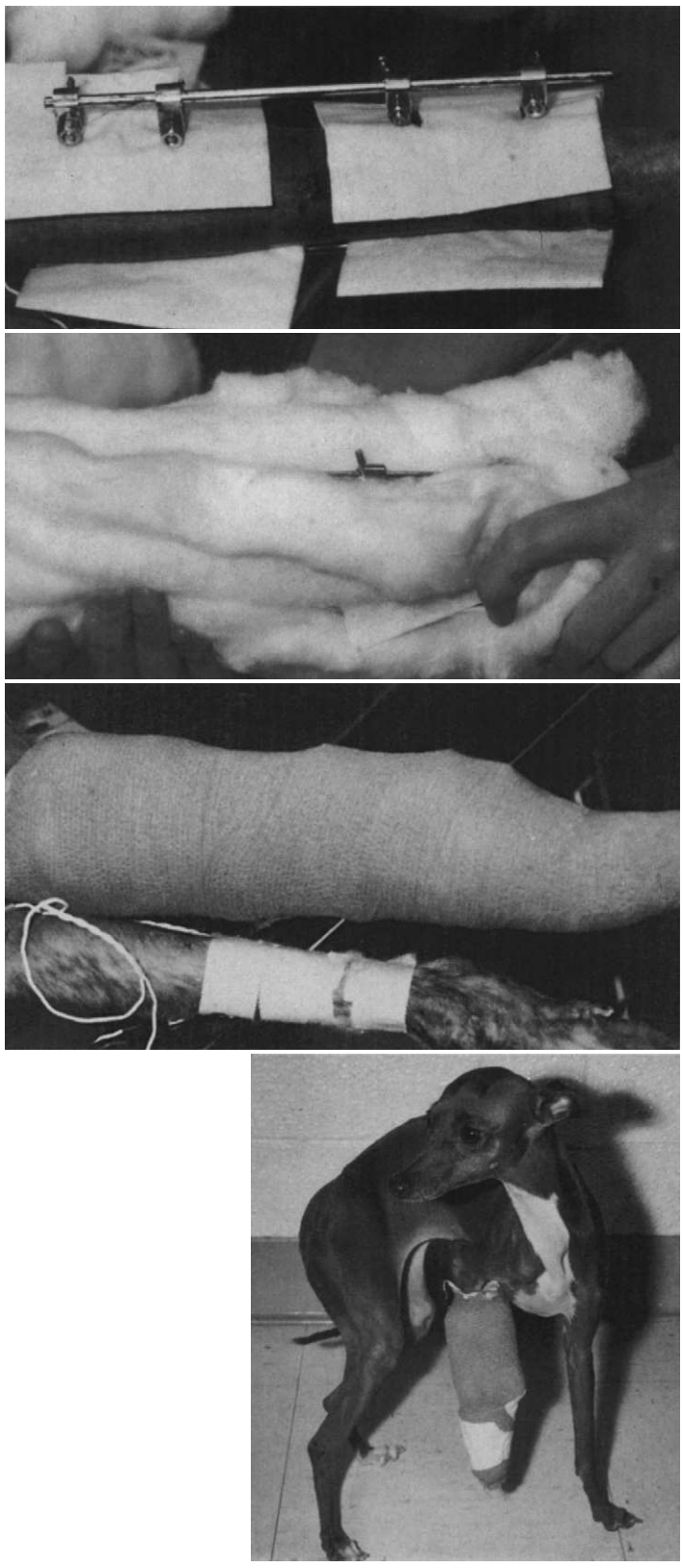


FIGURE 2-49. (See p. 92 for legend.)

FIGURE 2-49. Postoperative dressing of an external fixator. **A,** Nonadherent dressings are partially cut to allow them to be positioned over the pin-skin sites. **B,** Roll cotton, cotton fluffs, or other bulky dressing material is positioned on the skin along the fixator and distally to the toes. **C,** Starting at the toes, elastic bandage material (Vetrap here) is applied with moderate compression to cover all the cotton padding. **D,** The dressing and the patient 24 hours postoperatively. This dressing is usually left in place 3 to 4 days.

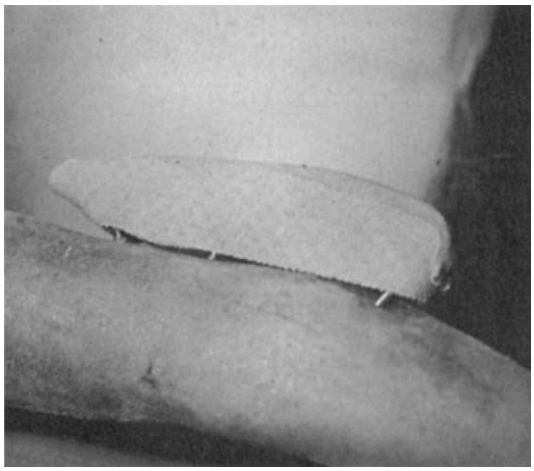


FIGURE 2-50. Protective cover for the fixator is applied after the postoperative dressing is removed. The objective of the cover is to help prevent the fixator from becoming "snagged" on fences, bushes, etc. The cover shown here is fashioned from gauze and elastic tape but can also be covered with Vetrap. Do not allow the gauze padding to contact the skin at the pin sites, and do not adhere adhesive tape directly to the splint.

use a broad-spectrum antibiotic such as cephalexin for 4 to 7 days after surgery, until the body defenses are mobilized.

The animal is released with instructions to limit exercise to leash walking for elimination only and to take particular care to avoid fencing or similar structures that might catch the apparatus. Protection of the apparatus with a cover should be maintained until the device is removed. The owners are instructed to inspect the apparatus daily and advised to expect a small amount of dry crust to develop at the skin-pin interface. In the absence of complications (see next section), we advise no or minimal cleaning or treatment of the pin sites. Others advise a rigorous regimen of postoperative care that includes daily cleaning of crusts and exudate around the pins, treatment of the pin sites with a topical antibacterial medicine, and a dressing to cover the splint and to compress and immobilize soft tissues under the splint with gauze padding placed between the skin and splint. This dressing is changed every few days, depending on the amount of exudate present around the pin tracks.[53,54]

Complications

The most common cause of morbidity after external skeletal fixation is drainage from the fixation pin tracks (Figure 2-51, *A*). This problem is associated with excessive skin and deeper soft tissue movement, causing pressure against the pins, or with loose pins. This tends to be a somewhat closed-loop series of events, since one of the causes of loosening of fixation is muscle motion against the pin. Constant motion of soft tissues around the pin, or motion of the pin relative to soft tissues, prolongs the debridement phase of wound healing and results in continual exudation of the pin track.[53] There is inevitably a degree of bacterial contamination from the skin and environment, and these bacteria propagate within the pin track, adding to the exudation. Careful placement of the pins through nondisplaced soft tissue and

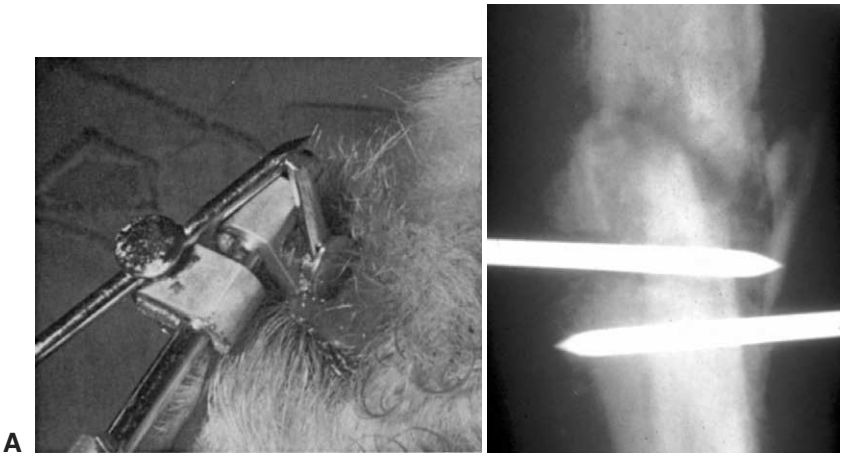


FIGURE 2-51. Complications from fixator pins. **A,** Drainage from pin track caused by motion of the soft tissues relative to the fixation pin. Swelling of soft tissue has caused the clamp to become very close to the skin, adding further to the skin exudation. **B,** This fixator pin has been placed too close to the fracture site and may have contributed to delayed union. Note the osteoporosis of the fragment.

avoiding large muscle masses will minimize this problem in most cases. The use of the bulky splint dressing with pressure on the soft tissues advocated by Aron and Dewey[53] is aimed at both immobilizing soft tissue and minimizing bacterial contamination. In some locations, such as the distal femur, soft tissue movement against the pins is unavoidable, and some drainage is to be expected. In this situation, activity restriction and periodically cleansing the pin site with 2% hydrogen peroxide or organic iodine solution is recommended first. If this is not effective in controlling drainage, the padded bandage of Aron and Dewey is used.

Moderate drainage from pin sites is not associated with significant loss of function as long as the skin around the track is healthy and the pin remains stable. If function of the limb is impaired in the absence of a loose pin, and if the drainage does not respond to the simple measures just outlined, true infection of the pin track, although rare, should be suspected. The surrounding skin will appear tense and erythematous and may be tender to touch. Steps should be taken to ensure drainage around the pin by incising skin for 1 cm on each side of the pin. Topical antibacterials and mechanical cleansing by lavage should be done at least daily. Administration of systemic antibiotics for several days is useful in controlling the infection. Bacterial culture and antibiotic sensitivity testing are not usually helpful because many skin organisms are present in the sample. It is safe to assume *Staphylococcus* species as the cause of the drainage and to choose the antibiotic on this basis. Only rarely does such infection affect the bone, although radiographic signs of bone reaction are often seen.[57]

Loosening of fixation pins is most often caused by soft tissue interference, as detailed earlier, or by instability of the fracture and resultant motion because of an overly flexible fixator frame or insufficient fixation pins. Such motion of the bone results in high stress loads at the pin-bone interface, leading to bone resorption and pin loosening. Correct choice of frame type and number of fixation pins for the clinical situation is the only help for preventing this problem. Loosening of the fixation pin at the pin-bone interface typically results in drainage and may lead to infection of the pin tract. Once a pin becomes loose, the only effective treatment is removal. The drainage usually resolves rapidly. Besides the nuisance of drainage,

loosening of pins may cause a decrease in limb function. If too many pins loosen too quickly, stability may be lost, and delayed union or nonunion can follow, although this is a rare problem.[57] If the fracture is not yet healed and the loss of a loose pin appears to significantly weaken the fixator, additional fixation pins must be inserted to maintain adequate stability. Although this requires general anesthesia and aseptic technique, it can be done by closed insertion of a new pin at a new site. Selection of an appropriate frame type, use of three or four pins per fragment, and use of positive-thread-profile pins will prevent most pin loosening and subsequent drainage or infection.

Pin tract drainage can be of particular concern if the affected pin has been placed marginally close to a fracture site. Ongoing contamination of the fracture with bacteria associated with pin tract drainage may contribute to delayed fracture healing (Figure 2-51, *B*). Pins that are suspected of contributing to fracture site contamination should be removed, whether or not radiographic signs of pin loosening are evident.

Another uncommon source of drainage and loosening of pins is the ring sequestrum that forms around a pin after insertion with a high-speed drill or with undue pressure that caused excessive heat generation (Figure 2-52). Bone death occurs in a circular pattern around the pin, with secondary infection, drainage, and pin loosening. The radius is the most common site of this problem, since placing pins in the frontal plane of the bone requires drilling through primarily cortical bone because of the elliptical cross section and small medullary cavity of this bone. Treatment is removal of the pin and sequestrum, curettage of the tract, and replacement of the pin, if needed for continuing stability.

A relatively rarely encountered problem is iatrogenic fracture of the bone through the fixation pinholes. This usually occurs when oversized fixation pins (>33% of bone diameter) are used, when fixation pins are placed too close together, or when fixation pins are placed in fissure fractures. The latter problem is usually avoided if pins are not placed closer than half the bone diameter from the fracture line. Unrestricted postoperative activity can also result in fractures through pinholes, particularly if the holes are enlarged by loose pins. Such problems are managed by replacement of pins in intact bone.

Removal of Frames

When radiographic and clinical signs of bone union are confirmed, the fixator can be removed. In many cases this can be done with little or no sedation; if the animal is apprehensive or excitable, a narcotic-tranquilizer combination by injection is usually adequate. Often the pins are somewhat loose by the time of clinical union because of the increasing activity of the animal; this is especially true with smooth fixation pins.

Clamps are loosened and connecting bars removed. Loose half pins often can be removed with the fingers without any signs of pain. If resistance is encountered, or if threaded pins are present, a Jacobs chuck with handle is attached to the pin and it is unscrewed from the bone. This may cause slight pain because periosteum can be stimulated. Full pins are cut close to the bone on one side, and the short protruding end is disinfected, after which the pin is removed by pulling the short end through the bone.

Some bleeding accompanies pin removal; this is cleaned, and the pin sites are covered with sterile gauze dressings and a light bandage, which is maintained for 48 to 72 hours. Even pin sites that have enlarged to 2 cm in diameter because of skin motion heal very quickly without visible scarring. Do not suture pinholes, since this can result in entrapment of exudate and lead to abscessation.

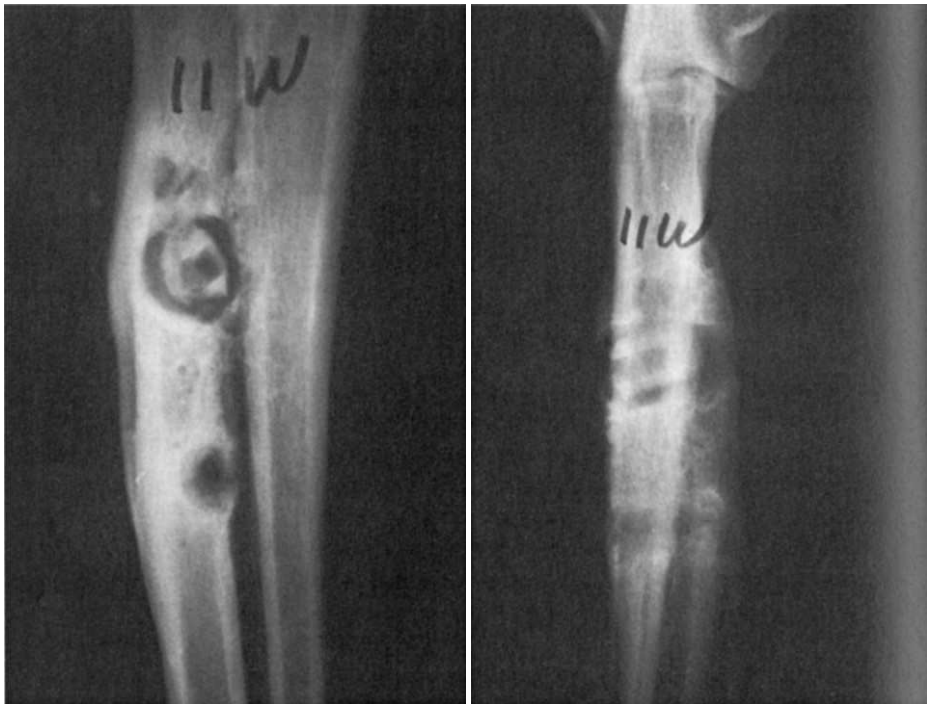


FIGURE 2-52. Ring sequestrum caused by thermal necrosis during insertion of fixation pin. **A,** In this mediolateral view of the proximal radius, the sequestrum appears doughnut shaped because of the lucency of the pinhole and the area of detachment from surrounding bone. **B,** Three lucent zones are seen in the craniocaudal view.

Acrylic Frames[24,36,50,58,59]

Replacement of the conventional clamp and connecting bar system with a plastic material may offer significant advantages in the clinical application of external skeletal fixation. The ability to conform the connecting bar to any shape allows placement of pins in multiple planes to make best use of whatever bone is available for their placement and to allow orientation of the pins to avoid soft tissue entrapment. Although applicable to any external skeletal fixation application, this method is especially advantageous in the areas of the mandible, in the long bones of toy and miniature breeds, and in transarticular applications in the carpus and tarsus. Eliminating the need for fixation clamps also reduces the cost of the apparatus, always a consideration in veterinary applications.

The material most often used for the plastic connecting rod is methyl methacrylate, an acrylic resin used for many years in the production of tray molds for the fabrication of dental prostheses and in veterinary applications for hoof wall repair (Orthodontic resin, L.B. Caulk Co., Division of Dentsply International Inc., Milford, Del; Technovit hoof acrylic, Jorgensen Laboratories, Loveland, Colo). In a sterile and much more costly form, methyl methacrylate is also used for anchoring various types of metal and plastic prostheses to bone in both humans and animals. There is no difference in strength between the sterile and nonsterile forms, and therefore, for economic reasons, the nonsterile form is most frequently used, although careful planning is needed to allow most fixator applications to be performed without the need for sterile cement.

Solid methyl methacrylate is created by mixing a volatile liquid monomer solvent with methyl methacrylate powder, which initially creates a liquid stage not unlike a flour/water batter. This liquid stage lasts 2 to 3 minutes and is followed by a doughy, moldable phase (4-5 minutes) that hardens into a very strong mass 7 to 10 minutes after initial mixing. There are slight variations in these times because of ambient temperatures, with higher temperatures lowering and cool temperatures lengthening the cure time. Considerable exothermic heat is liberated by the polymerization reaction of the last 2 to 3 minutes of the cure cycle. Peak temperatures of fixator pins may reach greater than 55° C at 5 mm from a standard acrylic column, which could affect tissue viability.[60] Provided the acrylic columns are maintained 10 mm from tissue, higher temperatures are not achieved in the fixator pin, and there seems to be no real danger.[60,61] A 3/4-inch (19-mm) column of solid methyl methacrylate has been shown to have superior mechanical characteristics to the 3/16-inch (4.6-mm) rod typically used with the medium Kirschner-Ehmer splint.[41] Material testing has been performed on available acrylics. Although differences in flexural and torsional stiffness exist between acrylic products, the effect of these differences on overall frame stiffness and bone healing is, as yet, undefined.[62]

Fundamentals of Application

The exact sequence followed for applying acrylic frames depends on the choice of using the liquid or the moldable stage of methyl methacrylate. Liquid methyl methacrylate can be injected with a catheter-tipped, 60-ml-dose syringe into flexible plastic tubing that has been impaled over the fixation pins, whereas the doughy stage requires hand molding of a column that is pressed onto the pin clusters. A useful method applicable to nonsterile acrylic fixator frames is the *biphase technique*. If nonsterile acrylic is to be used during an open reduction, the fracture must be reduced and the soft tissues closed before the connecting acrylic column can be attached to the fixation pins. This may make it difficult to maintain fracture reduction during attachment of the connecting columns. Even during a closed reduction, it can be difficult to maintain reduction during attachment of the columns. The biphase technique utilizes a temporary frame using normal clamps and connecting bars to maintain reduction while the acrylic column is attached.

Phase 1 involves reduction of the fracture by either open or closed methods and insertion of fixation pins as previously described. The fixation pins are not cut short; they are left long enough to attach clamps and a connecting bar 1 1/2 to 2 inches (3.8-5 cm) from the skin surface. It is seldom necessary to attach all fixation pins to this temporary connecting bar. This phase can be done aseptically; thus the bone can be reduced and stabilized under open reduction. After closure of the open reduction, radiographic confirmation of the reduction can be obtained if desired.

Phase 2 is the joining of all pin clusters by an acrylic column, as described further next. If nonsterile methyl methacrylate is used, the incision must be closed at this point. After the acrylic has hardened, the fixation pins are cut close to the column, and the temporary clamps and bar are discarded. It may be useful to dress the protruding cut pins with a file or rotary burr to reduce the sharpness of the end produced by the pin cutter and to reduce the chances of the protruding pin hanging up on clothing and other objects.

Liquid-Stage Application

Methyl methacrylate powder and liquid monomer are mixed with a tongue depressor in a disposable paper (*not* polystyrene) cup in the approximate ratio of three parts powder for dental acrylic, or two parts powder for hoof acrylic, to one

part liquid. Mix smoothly, without "whipping," to avoid trapping air bubbles in the mixture, and as soon as the powder is well mixed with the liquid, pour the mixture into the barrel of a catheter-tipped dose syringe, then replace the plunger.

Thin-walled flexible tubing of appropriate inner diameter (3/4 inch for medium fixation pins, 1/2 inch for small fixation pins) is used as a mold for the liquid. Disposable plastic adult anesthesia breathing-circuit tubing works well for the larger columns, and polyvinyl or rubber medical tubing or pediatric breathing-circuit tubing is useful for the smaller sizes. The tubing is impaled over the fixation pins, taking care to avoid tearing large holes in the tubing. Short incisions are necessary in polyvinyl and some rubber tubing. If the biphase technique will be used, the clamps and connecting bar are attached at this time to the fixation pins "outboard" of the tubing. Note that the tubing would need to be sterilized if this part of the procedure were being done in conjunction with an open approach. An open procedure could continue nonaseptically from this point once the incision was closed. The lower end of the tube is plugged with cotton wadding or a sponge to prevent leaking, and the liquid acrylic is injected in the opposite end to fill the tubing. After hardening of the acrylic, the pins are cut close to the column and dressed as previously described.

A commercially available kit contains all the components needed to apply type II biphase fixators of the small or medium size (APEF System, Innovative Animal Products, Rochester, Minn) (Figure 2-53). An advantage of this kit is that the materials are all sterile, thus allowing the entire fixation under direct vision during an open approach.

Moldable-Stage Application

This method eliminates the need for tubing molds and simplifies the use of the biphase technique with nonsterile methyl methacrylate powder. Mixing of the liquid and powder proceeds as described earlier, but mixing is continued until the mixture becomes doughy and no longer sticks to the surgical glove. The dough is removed from the cup to a flat surface, where it can be rolled to a rod of appropriate diameter with the palm of the hand. This soft rod is then impaled on the fixation pins and molded firmly around the pins by digital pressure. After hardening of the acrylic, the pins are cut and dressed as already discussed. It is also possible to inject liquid-stage acrylic into soft tubing (e.g., Penrose drain), allow it to reach the doughy stage, and then impale it on the pins.

Further refinements of either the liquid-stage or the moldable-stage method are useful to allow a more firm adhesion of the acrylic to the fixation pins. Notches can be produced in the ends of the pins with a pin cutter to provide a roughened surface. Stainless steel wire can be attached between fixation pins to provide a foundation for the bridging acrylic column. An extension of this concept involves bending the ends of fixation pins to bridge the gap between pins (see Figure 21-11). Both these latter two techniques can complicate removal or adjustment of the frame, as discussed next.

Removal or Revision

Removal of an acrylic frame can be done either by cutting fixation pins to free the acrylic column or by cutting the column between each pin to allow removal of the pin and attached column as a unit. Cutting the pins between the skin and the acrylic is the simplest method in theory but may be difficult to execute because of insufficient clearance between the skin and the column to allow use of a pin cutter. A hand-held hacksaw can be used for cutting the pins in this situation. Cutting of

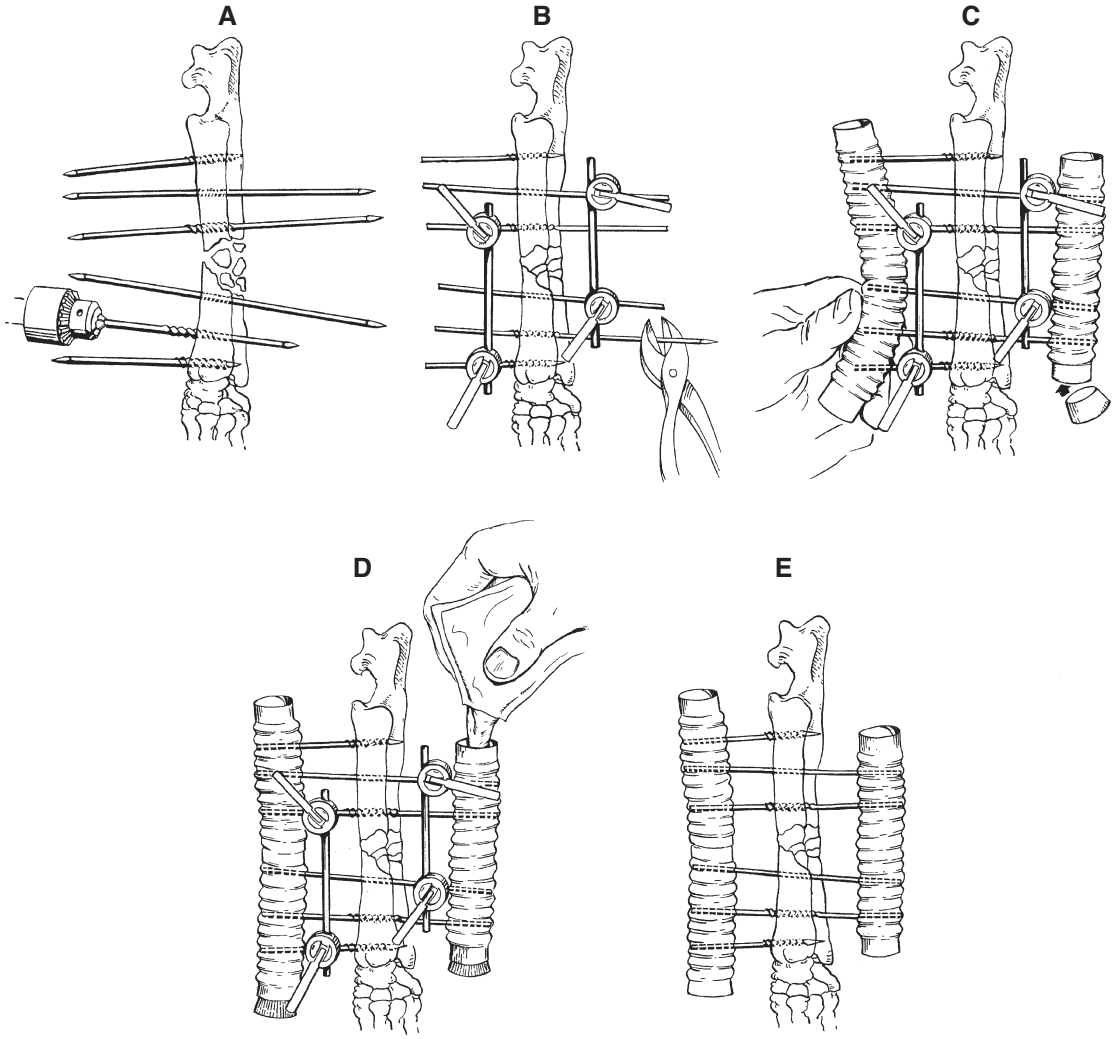


FIGURE 2-53. APEF biphase method. **A,** Pin placement and size can be optimized for fracture stability and minimal soft tissue interference. Any combination of positive-thread-profile pins or smooth pins can be used. Predrilling pinholes for threaded pins is simplified because no drilling or pin placement is done through fixation clamps. **B,** The fracture is reduced, and temporary stabilization is achieved by use of two connecting bars and APEF alignment frame clamps, which are placed at skin level. If an open reduction was done, the soft tissues are closed, or a closed reduction can be radiographically verified. Fixation pins are cut $1^1/_2$ to 2 inches (4-5 cm) from the skin. **C,** The corrugated plastic tubing that will mold the connecting bars is pushed over the fixation pins and pushed toward the clamps. Fixation pins too long to allow the tubing to rest against the clamps without penetrating the outer wall of the tubing must be recut to shorten them. The dependent ends of the tubing are plugged. **D,** Prepackaged acrylic is mixed within its plastic bag, the corner of the bag cut, and the liquid phase acrylic poured into the open ends of the tubes. Leakage of acrylic at pin sites is controlled with cotton balls or sponges. Biplanar configurations are interconnected by pins placed through the connecting bar tubing while the acrylic is still in liquid phase. **E,** After hardening of the acrylic, 10 to 12 minutes from the start of mixing, the frame alignment clamps are loosened and removed with the temporary connecting bars. Excess length of the connecting bars can be removed by saw. (Courtesy Innovative Animal Products, Rochester, Minn.)

the acrylic column is most easily done with an oscillating cast saw if there is no wire or fixation pin to be cut. In the latter case, or in the absence of an oscillating saw, the hacksaw works well to cut the acrylic.

At times it may be necessary to alter the reduction after the column has hardened or to replace a loose pin. Revision of the frame begins either by removing a segment of the acrylic column bridging the area to be realigned or by cutting on each side of the pin to be removed. After cutting away several centimeters of the column, several small holes approximately 1 cm deep are drilled into the opposing cut ends and around the circumference of the end of the column. The purpose of these holes is to key the patch to the existing column to increase the adhesion of the patch. Methyl methacrylate is mixed to the doughy stage and hand-packed and molded into the existing gap in the column while the desired reduction is maintained or after the pin has been replaced. Using similar methods, acrylic frames can be revised to different-type frames, adding or removing portions of the frame as circumstances dictate.

Ring Fixators

Although ring fixators were originally employed for fracture fixation, they are more costly and complex than conventional fixators and seem to have very little application in fracture repair. The technique for their use is discussed in Chapter 23.

Bone Healing with External Skeletal Fixation

In biological fracture fixation or bridging osteosynthesis, as discussed earlier, some degree of interfragmentary motion or loading is accepted if the fracture can be stabilized in a manner that minimally disrupts soft tissues and bone vascular supply. Reliance is placed on early bridging callus to stabilize the fracture and allow continued healing. Placement of external skeletal fixation with closed reduction or with minimal open exposure is ideally suited to such a strategy.

Fracture healing can be manipulated in the presence of an external skeletal fixator in a unique strategy called "dynamization."[63] This concept involves modification of an initially rigid frame to allow axial compressive loading of the fracture with physiological weight bearing after early healing has occurred. This should enhance callus hypertrophy and remodeling of the fracture while providing protection from excessive stress, which might cause refracture. This concept would be most useful in unstable fractures that initially require a relatively rigid frame to maintain reduction. An undesirable situation can arise when very stiff fixators are left in place too long, in which bone healing proceeds by direct haversian remodeling, as often seen with bone plate fixation. Although there is no question that the bone will heal, clinical union is much slower than when healing is by the indirect route and external callus is present. This means that the fixator must be maintained for a longer period, with its attendant cost and morbidity. Thus, it is optimal to have callus form when using external skeletal fixation. Experimental studies have indicated that about 6 weeks after surgery is the optimal time for dynamization of fractures in dogs. This can be achieved by removing the connecting bars and pins from one side of a type II or two sides of a type III splint to create a type I splint, which allows increased compressive loading while still protecting from bending loads. Removing alternate fixation pins of a type I splint accomplishes the same effect, although these splints are rarely stiff enough to require such manipulation.

INTRAMEDULLARY PINS*

Intramedullary (IM) pin (or nail) fixation for fracture treatment in small animals started in the 1940s.[2,64-67] It slowly gained popularity largely through the advent of safe general anesthesia, aseptic technique, antibiotics, and awareness by veterinarians and clients alike that successful repair could be accomplished in the majority of cases. Despite its limitations, IM pinning remains as the most common form of internal fixation worldwide in veterinary orthopedic surgery. In recent years, largely because of a better understanding of the biomechanical considerations necessary for successful bone healing, and in combination with cerclage and tension band wire techniques and external fixators, IM pinning has entered a new phase.

The key element for successful application of both pinning and wiring techniques is an *acute awareness of their shortcomings* in stabilizing fractures. Once these deficiencies are recognized and counteracted, pins and wires can be successfully used in a high percentage of routine fractures, with minimal complications.

General Considerations

Advantages of Intramedullary Fixation

There are many potential advantages of pin and wire fixation over bone plates for the veterinary surgeon. Pin and wire fixation is much less expensive than bone plate fixation when the cost of implants, the large inventory of equipment needed, maintenance, and repair costs for bone plating equipment are compared to pinning costs. The issue of cost is less important when comparing IM fixation to external skeletal fixation, but it is true that less inventory is needed for pin fixation. However, as discussed later, pin fixation cannot be applied to its maximum advantage without the availability of external skeletal fixation. Most equipment needed for pins and wires is readily available from many manufacturers and is basically the same as that used for external skeletal fixators. For a small investment, newer wire tighteners and pin cutters will update existing equipment. Most pin and wire equipment will last a lifetime of heavy use, whereas plating requires periodic replacement of taps and drill bits. Most pin and wire fixations require less surgical exposure than for bone plates, resulting in less tissue trauma and vascular damage and enhanced healing. In general, pins and wires can be applied in less time than needed for plates; this factor saves money and decreases anesthesia time.

Pins are usually much easier to remove than plates, often being removed under simple sedation and local analgesia. Plate removal, on the other hand, necessitates a second major invasive procedure with its attendant costs. Pins and wires have minimal effect on medullary blood supply and thus on bone healing. Except in cases in which active reaming for seating of large IM nails (not widely practiced in animals) has taken place, total destruction of the medullary supply does not occur. Use of a Steinmann pin will decrease this medullary blood supply initially but will not destroy it. Hypertrophy of medullary vessels will take place around the pin unless the pin completely fills the cavity or when the inner cortex has been reamed (as with Küntscher-type nails in human patients). Serious interference with medullary blood supply is most likely when a large pin fills the medullary cavity of a straight femur, as found in toy/miniature breeds and cats. When plates (or any implant) are applied, there is some interference with cortical blood supply under the plate, which can lead

*The authors gratefully acknowledge the contribution of a colleague, Dr. S.J. Withrow, to this section.

to weakening of the bone. The problems created are postplate removal fracture or eventual cycling fatigue and fracture of the plate if the fracture is delayed in healing. Pins and wires only rarely result in this vascular interference.

Disadvantages of Intramedullary Fixation

Pins and wires definitely have disadvantages compared with plates, with most relating to the biomechanical factors discussed next. If bone fragments are too small to be reduced and stabilized, pin and wire fixation may not be as stable as a plate. Pin and wire fixation is not designed to maintain bone length (act as a buttress), since there is no load sharing between the round pin and the bone. Plates, on the other hand, can and do have the capability to prevent compressive forces from causing collapse (shortening) of a multifragment fracture that cannot be anatomically reconstructed. This is referred to as the *buttress effect*. Without plates, the best method of achieving a buttress effect is with external skeletal fixators.

It has been stated that IM pinning of open fractures may disseminate infection up or down the medullary cavity. This is surely theoretically possible, but it is a rare occurrence. If any internal fixation is used in treatment of open fractures, it must produce very stable fixation, because bone will heal in the presence of infection if it is stabilized.

Biomechanical Factors

An understanding of how pins resist the various stresses or forces of bending, compression, and rotation acting on a long-bone fracture is necessary. The stainless steel material used for IM pins is manufactured to be very stiff when subjected to bending forces, unlike the steel material used for bone plates or wire.[68] Therefore, bending stress from any direction is counteracted when a round pin of adequate diameter is anchored both proximally and distally in the bone. Bone can still bend around an undersized pin, however, and the diameter of the medullary canal may be too small (e.g., the radius) to allow a suitable pin to be introduced. Rotational and compressive forces are counteracted only by frictional force between the bone and the pin, which is too small to be effective in the clinical situation. Although transverse fractures have minimal tendency to override or shorten, spiral and multifragment fractures need ancillary support (as listed later) to stop axial collapse. Likewise, a pin has virtually no ability to resist rotational forces. Occasionally, if the fracture interdigitates and the muscles pull the bone ends together, rotation may be stopped. In general, however, some means of antirotation must be utilized with the pin. The interlocking nail, widely used in human orthopedics,[69] can resist both compression and rotational forces and is being used more often in veterinary orthopedics.[70] Distraction forces are not present in shaft fractures but are present in areas of musculotendinous attachment, such as the tuber olecranon and calcaneus. In such bones a pin alone rarely will adequately stop distraction. These fractures typically require the use of a pin and tension band wire or a lag screw.

The most common forms of *ancillary fixation* employed with IM pins to counteract rotational and compressive forces are the following:

- Cerclage or interfragmentary wire (see Figure 2-56, *A, B*, *G*, and *H*).
- External skeletal fixation (see Figure 2-56, *C* and *D*).
- Stack pins (see Figure 2-56, *F*). Multiple Steinmann pins are not very effective.
- Lag screw fixation (see Figure 2-56, *E*). Although lag screw fixation is very effective, the bone size required to place both a screw and a pin within the medullary canal limits the application of this technique.

These fixation methods are discussed in detail in the following sections. Proximal pin migration postoperatively is a definite indication of motion caused by insufficient stability at the fracture site, since motion of the pin relative to the bone causes bone resorption and subsequent loosening of the pin. With very few exceptions, distal pin migration into the joint means that the pin penetrated distal articular cartilage at the time of insertion. This can usually be corrected at surgery by retracting the point of the pin back into the medullary cavity, then angling the distal fragment in a slightly different direction before advancing the pin. Do not simply retract the pin and leave it in its original pin track.

External coaptation is sometimes combined with intramedullary fixation but should be necessary only in intramedullary fixation of metacarpal and metatarsal bones. External coaptation is never used in long-bone fractures because it defeats the main goal of internal fixation (i.e., early return to functional use of the limb). Immobilizing the elbow or stifle joint in the presence of a long-bone fracture has an unacceptably high risk of loss of joint motion because of periarticular and intraarticular fibrosis. Fixation of the joints distal to the fracture has the effect of increasing the disruptive lever arm forces acting at the fracture site.

In discussing the "pros and cons" of pinning, it is assumed that the surgeon adheres to the fundamental principles of the technique. Any technique will fail if not properly performed. In retrospect, very few nonunions or delayed unions are free of error at the surgery table.

Pin Types

Steinmann Pins and Kirschner Wires

Both Steinmann pins and Kirschner wires (K-wires; pins that look like Steinmann pins but are smaller in diameter: 0.035, 0.045, and 0.062 inch, or 0.9 to 1.5 mm) are circular in cross section and either smooth or with partial or fully negative-thread-profile shanks (Figure 2-54, *A*). Steinmann pin diameters vary from 1/16 inch (1.5 mm) to 1/4 inch (6.5 mm). The threads probably offer little stability and are actually weaker than the standard smooth pins. This weakness is especially pronounced in the partially threaded pin where the thread meets the shank. This is an area of stress concentration, and if this junction falls at or near the fracture site and is subjected to repetitive bending forces, these pins will often break. If a partially threaded pin binds against the bone during placement, the threads may cause the shank to be twisted completely off, just as a screw that is overtorqued will shear off at a thread.

The major reason that the threads do not achieve any extra stability initially is that the point of the pin is as wide as the outside thread diameter, and in placing the pin, no threads are cut in bone; that is, the point produces a glide hole rather than a tap or thread hole. The threaded or partially threaded pin cannot be equated to a bone screw (see section on bone screw fixation). Mechanical testing of the force required to pull out smooth pins and partially threaded pins from bone showed insignificant differences between the two.[71] On removing a threaded pin after fracture healing, it is sometimes necessary to "unscrew" the pin because bone has grown into the threads, not because the pin has been threaded into the bone.

The tip of a Steinmann pin is designed to cut bone as it is inserted with a drilling motion. The most common tip is the three-sided *trocar* (or trochar) point, with a very sharp end that allows the pin to be started into bone at some angle to the bone (Figure 2-54, *B*). The four-sided *diamond* or *chisel* point is more effective in cutting through very dense bone but is not as easy to start without slipping on the bone

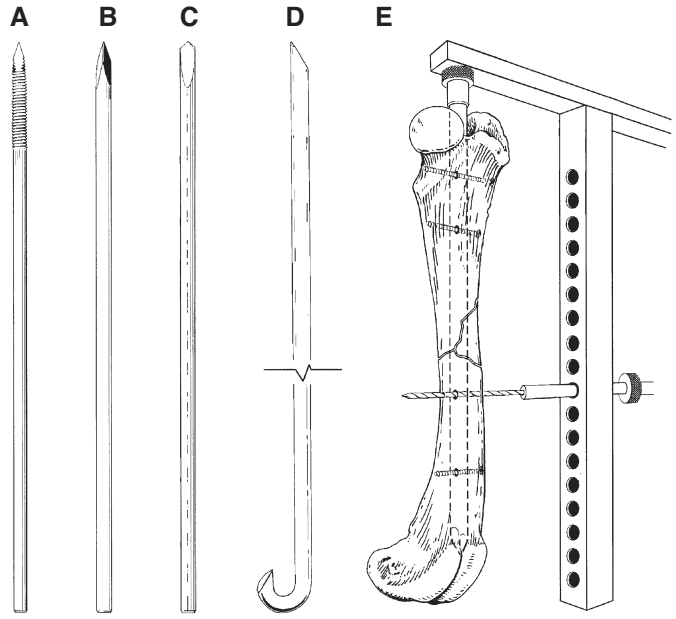


FIGURE 2-54. Intramedullary pin types. **A,** Steinmann pin, partial negative-profile-thread, trocar point. **B,** Steinmann pin, trocar point. **C,** Steinmann pin, chisel point. **D,** Rush pin. **E,** Interlocking nail and drill jig for placing bone screws through the pin.

surface (Figure 2-54, *C*). In the smaller sizes of K-wires the chisel point tends to bind and twist on itself in areas of dense cortical bone, so the trocar point is preferred in these pins. The most useful type of Steinmann pin is smooth shanked and furnished with a trocar point on one end and chisel point on the other end. This allows the choice of the most efficient point for drilling; it makes no difference which point is used once the pin is seated in the bone.

Rush Pins

Whereas Steinmann pins are passive intramedullary splints, exerting no mechanical force on the bone, Rush pins are *dynamic* intramedullary splints, exerting continuous compression forces at two or three points on the bone because they become flexed during introduction (Figure 2-54, *D*). This flexion is induced by introducing the pin at an angle of about 20 degrees to the axial axis of the bone, rather than on the axial axis as with the Steinmann pin (see Figure 2-55, *A*). As long as this flexion does not exceed the elastic limits of the metal, the pin will react to the bending by trying to return to its original shape. In this manner the Rush pin locks itself to the bone at the point of entry, where it deflects off the opposite cortex and, in some cases, where the tip comes to rest on the original cortex.

To be used in the manner just described, the Rush pin has a noncutting beveled point that glides rather than cuts when it encounters bone. The opposite end is hook shaped to allow (1) close approximation of this end with the bone and (2) positive control of the direction of the flexion during introduction.

Küntscher Nail

Although it was one of the early forms of intramedullary fixation[65] in the dog because of its wide use in human patients at the time, the Küntscher nail has never

achieved wide application in small animals. The V cross-sectional shape requires close contact of the pin through a considerable length of the bone to ensure stability. Because dog bones rarely are true cylinders, and because the cortex is too thin for reaming to a uniform diameter as is done in human bone, this device is not very useful in dogs or cats.

Interlocking Nail

The intramedullary reaming required to insert Küntscher nails in human patients was recognized as extremely nonphysiological because of the damage done to the medullary blood supply, and the unreamed interlocking nail was developed to replace the Küntscher nail.[69] An interlocking nail is basically an IM pin secured in position by proximal and distal transfixing screws that secure the bone to the nail to provide torsional and axial stability. The use of the interlocking nail has considerable advantages over the use of IM pins alone. The interlocking nail helps to prevent collapse of comminuted fractures during weight bearing, rotational instability, and pin migration.[72] As with the IM pin, the interlocking nail can be inserted through a limited surgical approach, with minimal disruption of fragment blood supply. Because this technique in humans generally involves insertion by closed technique on a distraction table under fluoroscopic control, it seemed to be beyond any practical application in veterinary orthopedics. The introduction of the IN System (Innovative Animal Products, Rochester, Minn) has provided a method for insertion of the interlocking nail without the need for specialized radiographic equipment (see Figure 2-54, *E*).[70] Considerable experience has been gained to adapt this system for large dogs and now for smaller dogs and cats.[72-79] Application of the interlocking nail was originally limited to use in femoral, tibial, and humeral fractures in large breeds, with a minimal medullary canal diameter of 6 mm. An early report indicated that 83% of fractures healed without complication.[72] Interlocking nails broke in 7% of fractures, mostly when 6-mm nails accommodating 3.5-mm screws were used.[72,74] Fatigue cycling was the likely cause of failure and developed when the interlocking nail was malpositioned so that screw holes were too close to the fracture site or nails of insufficient diameter were selected. Considerable modifications have been made in the size and number of screw holes for interlocking nails.

The interlocking nail currently is available in 4.0-, 4.7-, 6.0-, and 8.0-mm diameters, with a standard two holes proximally and distally for the interlocking screw (Innovative Animal Products, Rochester, Minn). The 4.0-mm and 4.7-mm nails accept 2.0-mm screws; the 6.0-mm nail accepts a 2.7-mm screw; and the 8.0-mm nail accepts a 3.5-mm screw. Nails are also designed with three holes instead of four, with a single screw hole in the proximal or distal positions, to avoid placement of a screw hole at the fracture site. The current sizes should accommodate use in diaphyseal fractures of the femur, humerus, and tibia in large cats and dogs of most sizes. Reduction of the fracture and insertion of the interlocking nail are typically completed through a limited surgical approach. The medullary canal may be opened with Steinmann pins of increasing diameter. The interlocking nail is adequately seated into the distal metaphysis, and the drill guide is attached for placement of the locking screws. Interlocking nails are most often used in "static" mode, in which locking screws are used in both proximal and distal positions. A "dynamic" mode can also be selected, in which locking screws are used in only the proximal or distal positions. The dynamic mode allows more axial compression at the fracture site but also affects rotational stability and must therefore be used judiciously.

One study compared the mechanical properties of the 8.0-mm interlocking nail to the broad 3.5-mm dynamic compression plate (DCP) in an unstable

fracture model.[77] Stiffness and failure limits were higher for the interlocking nail in compression testing, but not in bending. Yield load (deformation) was higher for the interlocking nail than the DCP in compression and bending tests. Rotational tests were not performed but would be highly relevant in a comparison of these systems. The superior bending and compressive mechanical properties of the interlocking nail compared to a bone plate are likely attributable to the nail's placement closer to the neutral axis of bone.

Indications for Intramedullary Fixation

Because of the variety of intramedullary devices, it is not possible to list indications without qualifying the fixation device to be used. Fracture types are listed in Table 2-1, and for discussion of the "fracture patient score" mentioned here, see Selection of Fixation Method later in this chapter.

Steinmann Pin

When used *without any ancillary fixation,* the indications for Steinmann pin fixation are limited to the following:

1. Stable fractures that do not have a tendency for axial shortening or rotation, primarily type A fractures with a high fracture patient score.
2. In skeletally immature animals, especially puppies and kittens less than 4 months of age, type B and some type C fractures can be successfully treated because of the rapid callus formation seen in these animals.

When used in combination *with ancillary fixation,* virtually all fracture types can be handled with Steinmann pins, although perhaps not as efficiently as other fixation methods in type C fractures with a low fracture patient score.

Steinmann pin fixation can be accomplished by either an open or a closed method. The closed technique is restricted to simple fractures, those of recent origin, and those that can be easily and accurately reduced. Fixation of the latter fractures is influenced by the size of the animal, time since injury, and experience of the operator.

Rush Pin

The use of Rush pins for diaphyseal fractures in dogs and cats has not been well evaluated, although one of us (DLP) has long used them in place of Steinmann pins with good results in tibial fractures. The primary application for these pins is in proximal or distal fractures, where the double-pin configuration provides good stability. When there is an intraarticular component, the Rush pin is easily combined with lag screw fixation.

Interlocking Nail

All diaphyseal fracture types in the humerus, femur, and tibia are amenable to fixation using interlocking nails as long as the medullary canal diameter is at least 4 mm.

Methods of Application

Steinmann Pins

Specific landmarks for pin insertion in the various bones are provided in later chapters covering fractures in individual bones. The following remarks are general and apply to all bones.

Pin Chucks and Power Drills

Steinmann pins are most often inserted with a hand chuck, that is, a Jacobs keyed chuck to grip the pin, which is attached to a handle. Lowering the surgery table assists in the penetration of hard bone; this allows more mechanical force to be applied to the chuck and aids in proper aiming of the pin angle. To prevent bending of small pins and to penetrate very hard cortical bone, at first only a short amount of pin should protrude from the chuck until the outer hard cortical bone is penetrated. The pin is inserted into the bone with a back-and-forth rotational motion while exerting force on the chuck. The chuck is rotated back and forth at least 120 degrees to take advantage of the cutting trocar tip. Care should be taken to avoid "wobbling" an arc with the handle, since this will cause the bone hole to be enlarged (see Figure 2-38, *C, D*).

Power drills allow easy pin insertion but do have significant drawbacks. With too much speed and forceful insertion, thermal necrosis of surrounding bone can easily occur, resulting in loosening of the implant with time. These drills can be safely used if low-speed drilling (150 rpm) is performed (see Figure 2-52). Another technique to avoid thermal necrosis is to stop the drill every 2 or 3 seconds; however, this makes it more difficult to detect when the pin has entered the medullary canal or opposite cortex. When properly used, power drills offer the advantage of less wobble during pin insertion, thus preventing enlargement of the entrance hole through cortical bone. They also significantly increase the ease of insertion of Kirschner wires, which tend to bend easily when inserted with a hand chuck. (For further discussion of power drills, see previous section on pin insertion methods for external fixators.)

Pin Diameter

It has been said that a goal of pinning is to fill the fracture site with pin or pins because this gives the most stiffness to the pin-bone construct. However, the surgeon must weigh this goal against its possible drawbacks. With a straight bone (cat), filling the cavity will still allow anatomical reduction, although an overly large pin in a straight bone does increase the risk of significant interference with reestablishment of the medullary blood supply, with resultant delayed union. In curved bones, however (most dogs), filling the fracture site with the pin will often mean inability to achieve anatomical reduction. For midshaft fractures, try to fill about 60% to 75% of the medullary cavity at its narrowest point. If in doubt, use a smaller pin, since you can always replace it with a larger pin. If you go from a large pin to a smaller pin, you will have a large hole at the entry site that does not "bind" the smaller pin. If the fracture is in the location of the narrowest diameter, you can estimate pin size directly, but if the fracture is proximal or distal to the narrowest diameter, it must be estimated from the radiograph.

Stack Pinning

This method of pinning involves the use of several pins rather than one pin to fill the cavity. It is rarely needed, except in the very big dog where the biggest pin ($^1/_4$ inch) is not large enough. As a general rule, stack pinning is necessary only for the humerus or femur. The theoretical advantages include better rotational stability and more points of bone contact; however, clinical results do not bear these out, with a 50% complication rate and generally unsatisfactory results reported in one study.[80] Another study did not find statistically significant differences in mechanical torsional strength when comparing single-, double-, and multiple-pin fixation of femoral fractures.[81] Disadvantages of stack pinning include (1) greater tendency for

pins to migrate because of the difficulty of firmly seating all pins distally; (2) potential problems with many pins exiting in one place (e.g., greater chance of hitting sciatic nerve in femoral fractures); and (3) difficulty of cutting multiple pins at the entrance site short enough to prevent soft tissue irritation.

Seating of Pin

Landmarks are given later for each bone on how far to seat a pin, but these are only "rough estimates" and variance is common. Always watch the fracture as the pin is driven; if distraction of the fracture is seen, the pin is probably engaging the distal cortex and pushing the bones apart. The pin should then be retracted, the fracture reduced again, and additional counterforce applied to resist the tendency to distract. This can be done either with manual pressure from some point distal to the fracture or with bone clamps if the fracture allows. In this situation the pin should be rotated without too much pressure, to allow it to cut into the bone without distracting the fracture. Driving the pin too far results in penetration of the distal cortex, often with resulting intraarticular pin placement. When this happens, the pin must be redirected from the fracture site into the distal fragment; simply retracting the pin often results in late migration of the pin back into the joint. As you approach final pin placement, be sure that no crepitus (pin on bone) is present in the joint (elbow, stifle, hock). Use another pin of similar length, matched to the protruding end of the working pin, to confirm the position of the point of the pin within the bone.

Cutting of Pin

The most practical method of cutting is usually with a bolt cutter or specialized pin cutter. Metal saws can be used but are awkward and deposit considerable amounts of metallic particles into the skin wound. Watch the fracture during and after the pin is cut with bolt cutters. With large pins, considerable movement of the pin occurs with resultant movement at the fracture. Except for small pins, it is often difficult to cut the pins short enough with bolt cutters. The usual goal is to cut the pin as short as possible (~5 mm) above the bone. This prevents large seromas and impingement on nearby structures (sciatic nerve, femoral condyles), lessens postoperative pain, and keeps the pins more stable by avoiding muscle and tissue action on the exposed pin end. One method of keeping pin ends short when they cannot be easily cut is depicted in Figure 19-1: (1) seat the pin to the proper depth; (2) withdraw it about 2 cm; (3) cut off as close as possible (usually about 2-3 cm from bone); and (4) impact the pin with a punch and mallet, being careful to stabilize the fracture carefully before impacting.

Pin Placement in Long Bones

Pins are placed in long bones by either *retrograding* (i.e., driving pins from fracture site, out one end of the bone and then back into opposite fragment) or *normograding,* where the pin is placed from one end of the bone, into and through the medullary canal, and into the other fragment (see Figures 17-1 and 17-2). Depending on the bone, one or both methods may be acceptable, as discussed in the appropriate chapters.

Rush Pin

Instrumentation

Rush pins are generally available in diameters from 1/16 inch (1.5 mm) to 1/4 inch (6.6 mm). The latter size is too large for any small animal application; 3/32 inch

(2.4 mm) and 1/8 inch (3.2 mm) are the most useful sizes in dogs. Pins are available in a variety of lengths proportional to their diameter (Osteo-Technology International Inc., Hunt Valley, Md) since they cannot be cut to length at the surgery table. Because these pins are often used in pairs and because they are precut in length, it is probably worthwhile, although not absolutely necessary, to have a double set of pins. The only other special equipment necessary for use of Rush pins is an impactor, which is used to seat the pin. Adequate substitutes for Rush pins can be fabricated from Steinmann pins with a metal saw and file, but this must be done preoperatively.

Technique

Unlike the Steinmann pin, which is static in the medullary canal, the Rush pin is put into the bone so that the pin is forced to bend as it is inserted (Figure 2-55, *A*). The pin is inserted at an angle of approximately 20 degrees to the long axis of the bone. If the forces produced on the bone are properly manipulated, they can be used to increase the stability of the fixation. The technique is somewhat more demanding than Steinmann pinning and will require some practice to perfect, but it is well worth doing so.

1. Because Rush pins do not have cutting points, a pilot hole must be drilled with a twist drill or Steinmann pin of the same size as the Rush pin (Figure 2-55, *B1*). With the fracture reduced, the pin is started into the bone while held at the hooked end in a pair of pliers. The hook provides a means of keeping the gliding point properly oriented to strike the second cortex. When double pins are used for proximal or distal fractures, the pin length is chosen to approximate two thirds to three fourths of the bone length (Figure 2-55, *A*). Pin diameter is based on bone size and the age of the patient. In skeletally immature animals, a pin that is too stiff (because of its diameter) will tend to break through the second cortex rather than bend and glide. For cats and small-breed dogs, 1/16 inch (1.5 mm) is appropriate; 3/32 inch (2.4 mm) is used for animals to 30 pounds (15 kg); and 1/8 inch (3.2 mm) is used for larger animals.
2. When resistance is felt as the pin contacts the opposite cortex, the pin is driven with a mallet and a special Rush pin driver or impactor, which is similar to a nail set, although the pliers will provide sufficient force to insert the smaller pins (Figure 2-55, *B2*). The double pins are alternately driven a short distance, until both are fully seated. The impactor or pliers is used to seat the hook end of the pin tightly against the entry cortex, where it provides some compression and stability against rotation of the pin. If the pin resists moderate driving force, it can be prebent slightly to relieve some bending strain and allow easier insertion without the chance of damaging the bone (Figure 2-55, *B3*). This bend must not be so severe as to preclude the pin being further bent as it is inserted; to do so would make the pin behave in a passive rather than a dynamic mode, and stability would be compromised.
3. When a Rush pin crosses an oblique fracture, its dynamic characteristics will cause either distraction or compression of the fracture line, depending on the orientation of the pin relative to the obliquity of the fracture (Figure 2-55, *C*). When driving double pins, it is important to lead with the pin that will tend to reduce the fracture, then follow with the pin that displaces the fracture.
4. Because of the hook end lying close to the bone, Rush pins are usually not removed after bone union because they create very little soft tissue irritation. When used across physeal lines, Rush pins may cause growth arrest in animals less than 5 months of age. This can be prevented by removing the pins 3 to 4 weeks postoperatively or by cutting off the hook after the pin is seated.

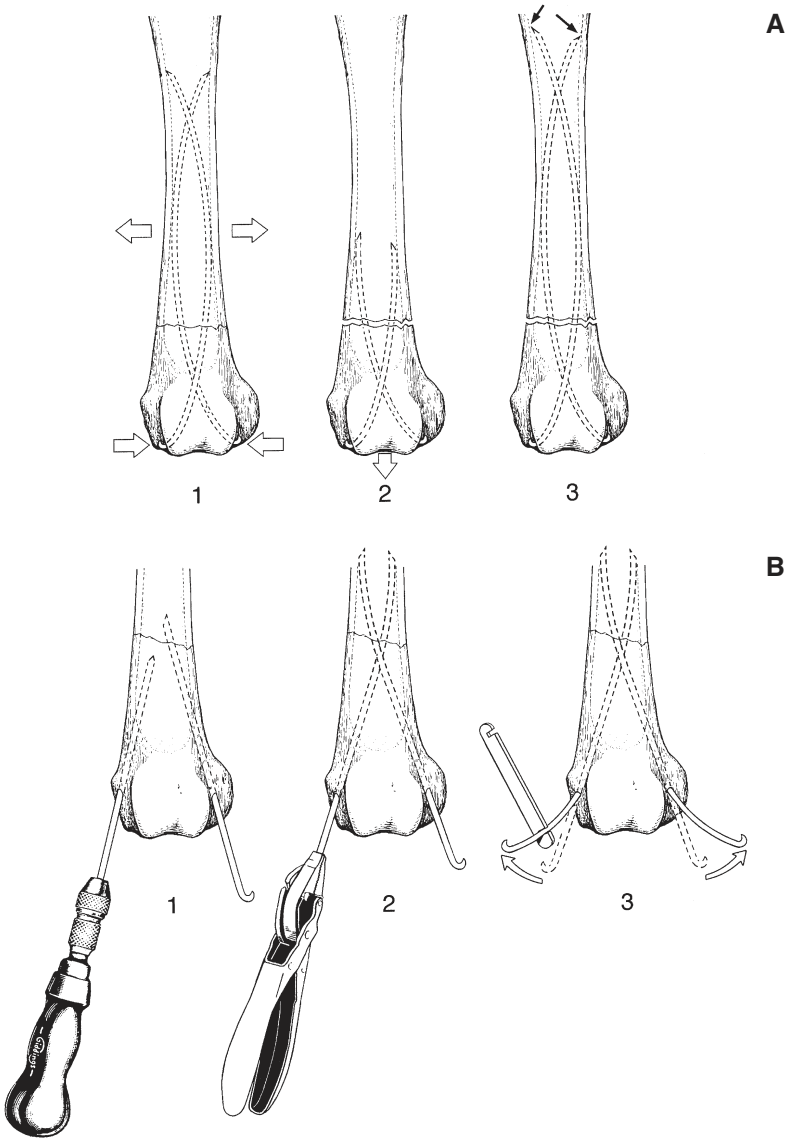


FIGURE 2-55. Rush pin principles. **A,** Proper length of pins, usually two thirds to three fourths the length of the bone, allow the pins to glide off the opposite cortex and bend back toward the cortex of insertion, as in *1*. The elasticity of the pins causes them to exert dynamic forces on the bone, as indicated by the arrows. If the pins are too short *(2)*, their elasticity will cause distraction of the fracture. If the pins are too long *(3)*, the tips of the pins may impinge the cortex sufficiently *(arrows)* to prevent complete reduction of the fracture. **B,** The pilot hole is drilled with a Steinmann pin or bone awl at an angle of approximately 20 degrees to the long axis of the bone *(1)*, and both pins are seated before being alternately driven across the fracture line *(2)*. If inserted at the correct angle, the pins will deform and glide on the opposite cortex with moderate force. If the condyle is too wide to allow insertion at the proper angle, the pins are relieved of stress by gentle bending *(3)*, to allow easier bending at the opposite cortex. If bent too far, the pin will lose its dynamic force on the bone.

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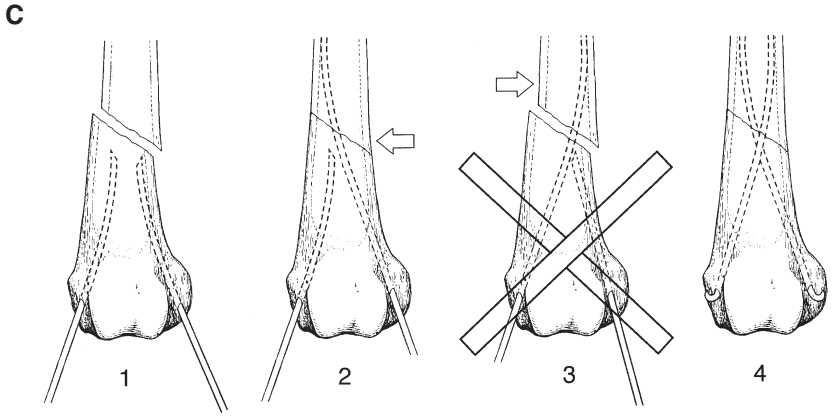


FIGURE 2-55. *Continued* **C,** When double pinning an oblique fracture *(1)*, it is important to drive and partially seat first the pin that forms a V angle with the fracture line *(2)* because this pin will create some compression force at the second cortex and will cause minimal displacement of the short distal fragment. If the pin that forms an X angle with the fracture line is seated first *(3)*, it will cause marked angular displacement of the short fragment. Alternating the advancement of the pins until they are seated close against the bone *(4)* maintains good reduction.

Interlocking Nail

The interlocking nail system is now available with 4.0-, 4.7-, 6.0-, and 8.0-mm-diameter nails, using the standard two holes proximal and distal for the locking screws (Innovative Animal Products). Each diameter size comes in different lengths. The interlocking nail has a trocar point, although IM pins of smaller diameter are often used first to open the medullary canal. Fracture reduction is accomplished through a limited surgical approach, and the interlocking nail is then driven into the intramedullary space with technique similar to the IM pin. Each nail has a machined joint proximally that allows attachment of an extension to the drill guide jig (see Figure 2-54, *E*). Nail length is therefore an important issue for preoperative planning, since cutting off the jointed end is not desirable. The location and number of the interlocking screw holes in relation to the fracture are also important preoperative considerations. Templates are available for onlay to the radiographs and to facilitate proper choices in preoperative planning. Once the drill guide jig is attached to the pin extension, drill guide inserts and sleeves are used through the jig to position the locking screws properly in the nail holes. The jig is fairly effective at blind location of the nail holes, with one report indicating only a 4% prevalence of misdirected screws.[72]

CERCLAGE WIRE

The term *cerclage* means "to encircle" or "to wrap into a bundle." This procedure refers to a flexible wire that completely (see Figure 2-59, *H*) or partially (see Figure 2-59, *I*) passes around the circumference of a bone and is then tightened to provide *static interfragmentary compression* of bone fragments. The latter method is also known as *hemicerclage*. Cerclage or hemicerclage wire is *never used* as the sole method of fixation on any type of diaphyseal fracture. To do so routinely causes a pathological fracture at the most distal wire, which acts as a stress concentrator for bending forces.

Current clinical use of cerclage wiring is based on the work of Rhinelander,[82] who showed that the small diameter of the tightly placed wire did nothing to disturb the centripetal flow of blood from medullary canal to periosteum. Recent emphasis on the concept of biological fixation suggests that fracture fragments should be left undisturbed when possible, so that remaining viable cells can contribute to callus formation. A decision to use cerclage wire to stabilize a fragment must be balanced against potential damage to fragment blood supply inherent to fragment manipulation. The surgeon must be gentle and efficient in reduction of fragments and application of cerclage wire to avoid this concern. Preserving cortical blood supply depends on soft tissue attachments to bone fragments being preserved and the wires being tight; a moving wire will disrupt the periosteal capillary network, devascularizing the underlying bone and disrupting periosteal callus formation. Inappropriate application of cerclage wire resulting in loose wire is a common cause of delayed union or nonunion in healing of fractures. Careful adherence to application fundamentals is important to avoid complications in the use of cerclage wire.

Indications

Cerclage wires are used primarily on long oblique, spiral, and certain comminuted or multiple fractures. They are used as ancillary fixation with IM pins (Figure 2-56, *A* and *B*), external skeletal fixators (Figure 2-56, *C* and *D*), and bone plates (Figure 2-57). Additionally, cerclage wires are used intraoperatively to aid in holding fracture segments in the reduced position while primary fixation is applied (see Figure 2-57).

Technique

Several fundamentals must be observed if cerclage wires are to be used with optimal success.

1. Cerclage wire fixation should be restricted to those fractures in which the length of the fracture line is at least twice the diameter of the bone or longer (see Figure 2-59, *D*). This ensures that the fracture line describes an angle of 45 degrees or less with the axial axis of the bone, and thus tensioning of the wire produces stable interfragmentary compression rather than shear forces (see Figure 2-59, *E*).
2. Restrict use of wires to areas where the cylinder of bone can be reconstructed anatomically; this means that, with rare exceptions, there should be no more than two fragments and two fracture lines in the transverse plane described by the wire. Three fracture lines/fragments should only be attempted when the fragments are large and interdigitate well, so that the compression afforded by the wire will maintain reduction (see Figure 2-59, *F*). Cerclage wires *should not be used to surround multiple unreduced fragments* (see Figure 2-59, *G*). These wires will become loose and disrupt vascular supply, and they are one of the main causes of nonunion.
3. Use monofilament stainless steel wire of sufficient strength for immobilization. Wire of 22 gauge (0.025 inch, 0.64 mm) is suitable for toy breeds and cats, 20 gauge (0.032 inch, 0.81 mm) for average dogs, and 18 gauge (0.040 inch, 1.0 mm) for large breeds. For giant breeds, 16 gauge (0.049 inch, 1.25 mm) is indicated. It is always safest to err on the side of wires that are too large rather than too small.

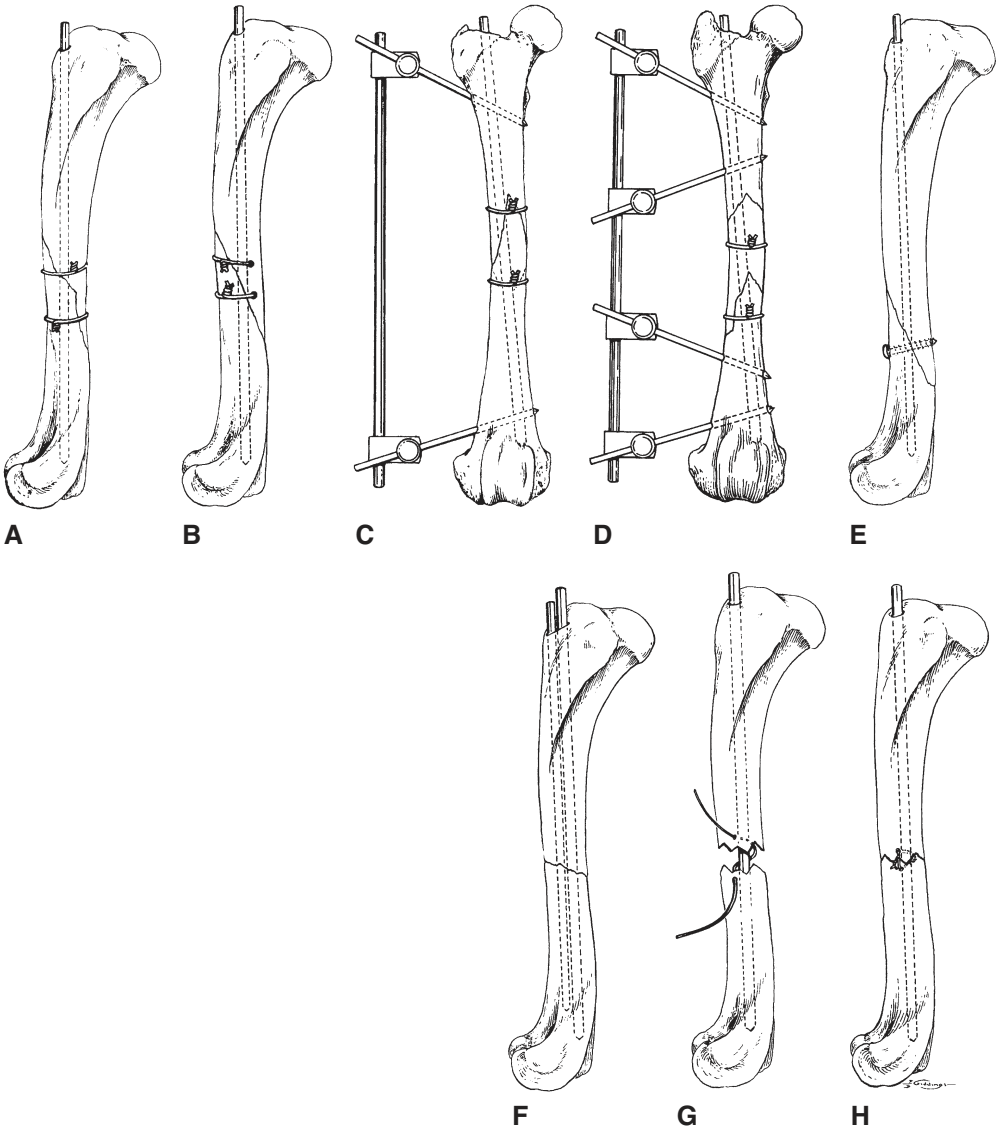


FIGURE 2-56. Auxiliary fixation used with intramedullary (IM) pin. **A,** Two cerclage wires. **B,** Two hemicerclage wires. **C,** External fixator 1/1 pin (half-Kirschner splint) and cerclage wires. **D,** External fixator, 2/2 pins, and cerclage wires used in a multiple fracture. **E,** Lag screws. Their use is usually limited to larger dogs. **F,** Two IM pins used in a serrated, short oblique fracture. **G** and **H,** Interfragmentary wire crossed around IM pin as auxiliary fixation in a serrated transverse fracture.

4. Apply all wires tightly to bring about rigid fixation of the fracture segments. Anything short of this allows movement of the implant and bone fragment, with subsequent devascularization, as well as demineralization of bone. Placement of a tight wire involves both tensioning the wire around the bone and then securing it in place. Two methods are in common use: twisting a straight wire and bending an eyelet wire (see Figure 2-59, *A* and *B*); both produce equally good clinical results when properly performed. The eyelet wire technique results in less soft tissue irritation from the bent end, is less technically demanding than the twist method, but is slightly more expensive.

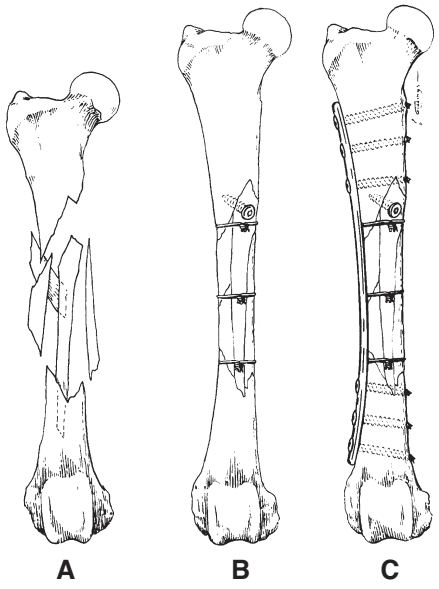


FIGURE 2-57. Cerclage wire and bone plate. **A,** Comminuted fracture of the femur. **B,** Comminuted area reconstructed and compressed using cerclage wires and a lag screw. **C,** Neutralization plate applied.

Although more tension is produced in the wire by the eyelet method, the *yield point,* where the wire begins to deform due to tension forces, is lower for the eyelet than the twisted wire.[83,84] This difference can be negated by using the next larger size of wire with the eyelet method. With either method, it is important to try moving each wire on the bone after placement. There should be no movement with the application of any reasonable force. Twisted wires can be given additional twists to further tighten them, but this is not possible with bent eyelet wires, which must be replaced if not tight enough on the first try.

Twist Method

Instruments required for placing twist wires are quite simple (Figure 2-58, *A* and *B*). Almost any type of pliers will suffice, but needle holders are only useful with the smallest wire. The threaded collar device in Figure 2-58, *A* is the most consistent and easiest to use. Wires should be twisted under tension preload so as to produce a uniform twist of both wires (Figure 2-59, *B*); this requires that the position of the twisting device be continuously adjusted to produce the correct twist. Excessive movement of the twisting instrument or twisting one wire only (Figure 2-59, *C*) results in fracture of the wire before it is tight. The twisted end either can be cut seven or eight twists from the bone and bent flat while continuing to twist slightly or can be left upright and cut three or four twists from the bone. The latter results in the least loss of tension[83] but can be done only where the wire is covered by an adequate thickness of soft tissue.

Bent Eyelet Wire Method

Although there are several types of tighteners available for eyelet wire, including those with built-in tension gauges (Figure 2-62, *D*), the simple type illustrated in (Figure 2-58, *C*) produces equally good results clinically and experimentally.[84] The tensioning and bending method is illustrated in Figure 2-60.

5. In applying the wire, avoid destruction of periosteal blood supply resulting from detachment of soft tissue in areas where muscle or ligaments attach to

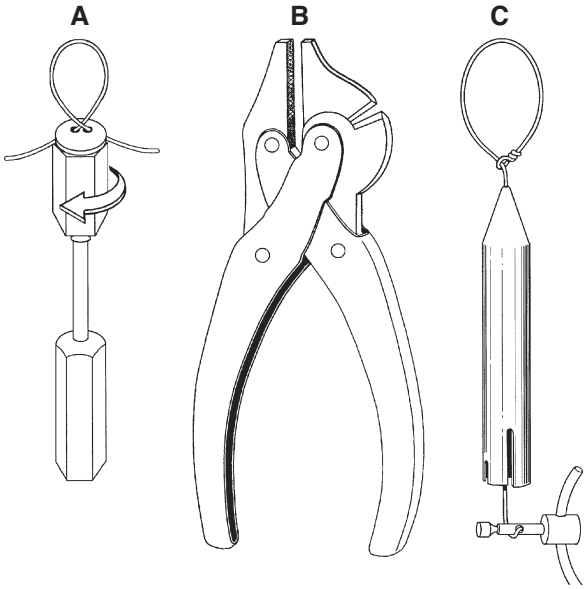


FIGURE 2-58. Wire-tightening instruments. **A,** This twisting instrument secures the wire between a fixed, double-perforated tip and a large nut that is tightened *(arrow)* on a threaded shaft. **B,** Parallel jaw pliers work well for twisting and are available at hardware stores. **C,** Eyelet wires are tightened by wrapping the long end of the wire around a rotating key inserted into a hollow bullet-nosed tube.

periosteum. Avoid entrapping muscle or nerves by passing the wire very close to the bone. The wire passer serves very well for placing the wire around the bone with a minimum of trauma (Figure 2-61). The end of the wire can also be bent into a half-circle of appropriate size and passed directly around the bone with a needle holder. This method works best with the larger wire sizes. The wire must be placed so that it will be perpendicular to the axial axis of the bone when tightened; an angled wire will loosen just as a ring that is too large on the finger will be loose. Avoid placing wire in an area where it will increase the fracture gap when tightened.

6. If a relatively long fracture area is to be covered, the cerclage wires should be placed approximately 1/4 inch (5 mm) from the ends of the fragments, then spaced approximately 1 to 1.5 cm apart. Placement closer than this may result in unnecessary devitalization of the bone (caused by detachment of soft tissue in placing the wires) and delay of union and does not increase the fixation stability. The number of cerclage wires used is in direct relation to the length of the fracture, but is never less than two. A single wire acts as a fulcrum to concentrate all bending loads but cannot supply enough interfragmentary compression to prevent bending. Single wires are used only for fissure fractures.
7. When placing a full cerclage on a bone that is conical, or tapering, (e.g., proximal femur), precautions need to be taken to prevent the wire from slipping toward the smaller diameter and thus becoming loose. Often the natural surface irregularities of the bone accomplish this, but it may be necessary to notch the bone or drive a small K-wire perpendicular to the bone to trap the wire. One end of the K-wire is bent 90 degrees to discourage late migration of the implant.
8. Above all, stabilize the main bone fragments with stable, uninterrupted primary fixation. Depending on the type of fracture, this may be accomplished with an IM pin, an external fixator, or a bone plate.

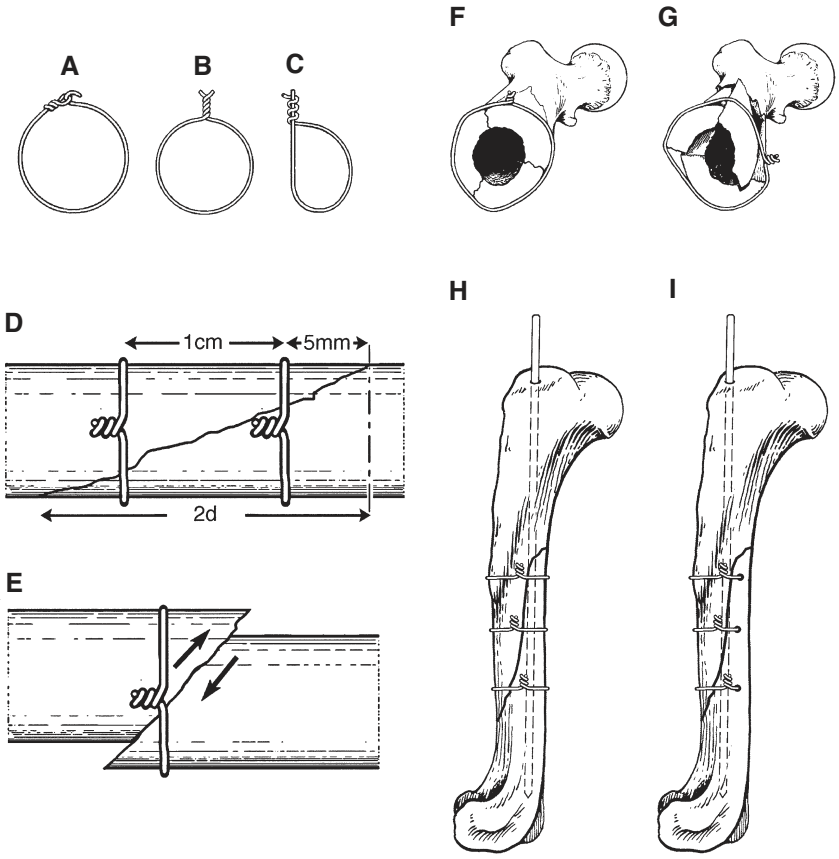


FIGURE 2-59. Cerclage wire principles. **A,** Tightening and securing an eyelet wire. See also Figure 2-60. **B,** Tightening and securing a twisted wire. Note that each wire is equally twisted at a uniform angle and that there are at least three twists below the cut ends. **C,** An improperly tightened twisted wire. This wire will loosen when loaded and will quickly fatigue and break with continued attempts to tighten it. **D,** For compression to be produced by a cerclage wire, the length of the oblique fracture line must equal at least twice the bone diameter. Wires are placed approximately 5 mm from the end of the fracture and spaced about 1 cm apart. There is no mechanical advantage to closer spacing (*d,* diameter). **E,** If the length of the fracture line is less than twice the bone diameter, tightening the wire produces shearing rather than compression forces. **F** and **G,** Stability of cerclage fixation requires that the tubular shape of the diaphysis be reconstructable and that a maximum of three fragments be included. If the fragments are not completely reduced or do not interlock when compressed, the wire will become loose as the fragments move. **H,** An ideal cerclage wire fixation: a long oblique two-piece fracture, used in support of a Steinmann pin. **I,** Placing part of the wire through a bone tunnel does not change the mechanical function of the wires, and this is a good method of preventing displacement of wires in a tapering bone.

Modifications of the eyelet and twist methods are described to use double-loop, double-wrap, or loop/twist techniques to generate superior tension and resist greater loads before loosening than single twist or eyelet methods.[85]

Double-Loop Cerclage

Double-loop cerclage is formed from a single length of wire, folded near its center (Figure 2-62, *A* and *D*).[85] Both free ends of the wire are passed through the center

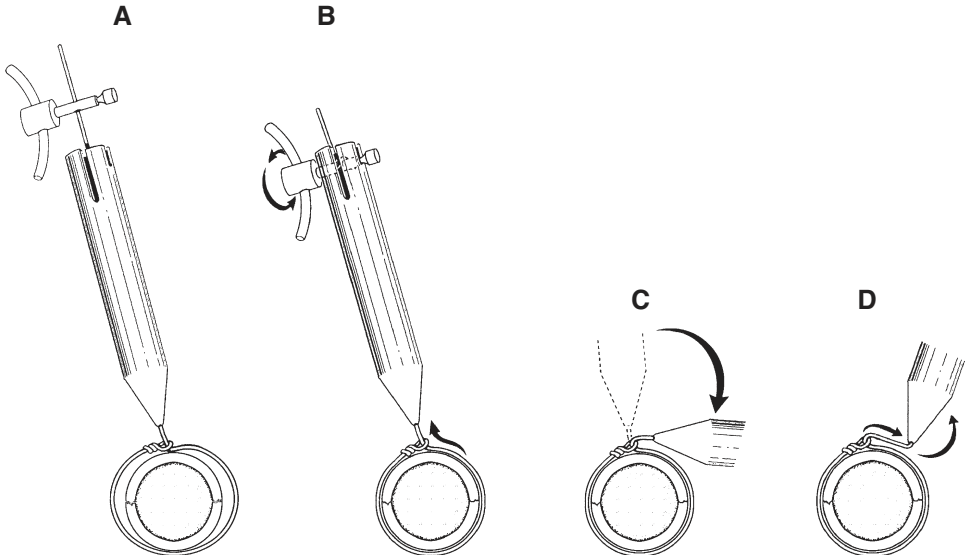


FIGURE 2-60. Tightening and securing eyelet cerclage wire. **A,** The free end of the wire is secured in the rotating key of the tightener. **B,** Tension is produced in the wire as the key is turned. The angular bend of the wire, indicated by the arrow, must not be too acute or the wire will fatigue and easily break. **C,** After attaining sufficient tension, the tightener is rotated 90 degrees to secure the wire. **D,** Loosening the tightener and rotating it back to the upright position allows the bent wire to be pressed closely to the bone and then cut.

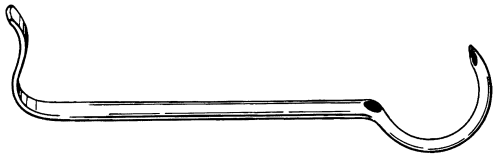


FIGURE 2-61. AO/ASIF wire passer. This instrument makes it possible to insert the cerclage wire around the bone with minimal soft tissue detachment. (Courtesy Synthes, Ltd, Paoli, Pa.)

fold and tightened with a single-eyelet tightener with two cranks or a double-loop tightener (Synthes, Ltd., Paoli, Pa).

Double-Wrap Cerclage

Double-wrap cerclage is formed from a single-eyelet cerclage (Figure 2-62, *B*). The wire is of sufficient length to encircle the bone twice before placing the free end through the eyelet.[85] The wire is tensioned and bent over with a wire-tightening instrument.

Loop/Twist Cerclage

Loop/twist cerclage is formed by folding a single wire in half, thereby constructing a small loop in the fold (Figure 2-62, *C*).[85] Both free ends of the wire encircle the bone. One end is passed through the loop but enters the tightener and is attached to the second crank. The first end is tightened and bent over, but not cut. The second crank is tightened to take up the slack, and the instrument is rotated on its axis to complete the twist.

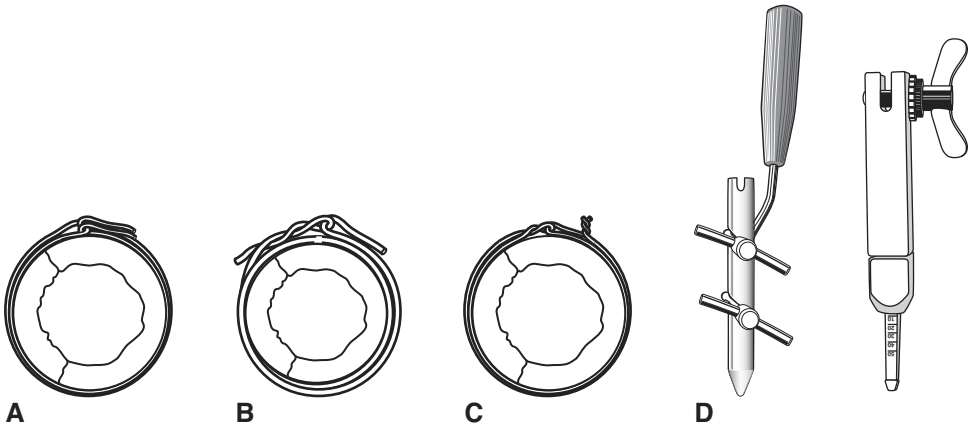


FIGURE 2-62. Double cerclage wire patterns. **A,** Double-loop cerclage has both free ends of the wire passed through the center fold and tightened. **B,** Double-wrap cerclage is formed from a single-eyelet cerclage with sufficient length to encircle the bone twice before placing the free end through the eyelet. **C,** Loop/twist cerclage is formed by folding a single wire in half, thereby constructing a small loop in the fold. Both free ends of the wire encircle the bone. One end is passed through the loop but enters the tightener and is attached to the second crank. The first end is tightened and bent over, but not cut. The second crank is tightened to take up the slack, and the instrument is rotated on its axis to complete the twist. **D,** *Left,* Single-eyelet tightener with two cranks. *Right,* Double-loop tightener. (Courtesy Synthes, Ltd, Paoli, Pa).

INTERFRAGMENTARY WIRE

These techniques are typically utilized to prevent rotation of short oblique or transverse fractures, to secure bone fragments, and to stabilize fissure fractures. As the name "interfragmentary" wire implies, the wire does not encircle the bone, but rather passes through and partially around the bone. This is the *least secure and consistent* form of internal fixation and should not be depended on for long-lasting stability when subjected to high dynamic loading forces. It should be reserved for smaller dogs and cats, or for immature animals that can be expected to form callus early and abundantly. Interfragmentary wires are difficult to tighten because of the acute bends introduced during placement of wire in the bone. If the fracture line is suitable for cerclage wiring, this is always a better choice relative to stability produced.

The most common patterns using interfragmentary wire are shown in Figure 2-63. The holes in the bone are made with K-wires or twist drills, and the wire is passed through the holes. If the wire enters the medullary canal, it is best to drill the bone first, place the wire into both bone segments, reduce the fracture, then seat the pin and tighten the wire. It makes little difference if the pin is encircled, as in Figure 2-63, *B* and *C,* unless the pin is small enough to deform and be brought into contact with the cortex. The cruciate and horizontal mattress patterns shown in Figure 2-63, *D, E*, and *F,* are more effective in preventing rotation than are simple patterns (Figure 2-63, *A*).[86] Even so, they are not very efficient, merely changing the rotational point from the central axis of the bone to the cortex secured by the wire. The opposite side of the bone remains unstable unless the fracture lines interdigitate sufficiently. Maximum rotational stability is provided by the transfixation pin and

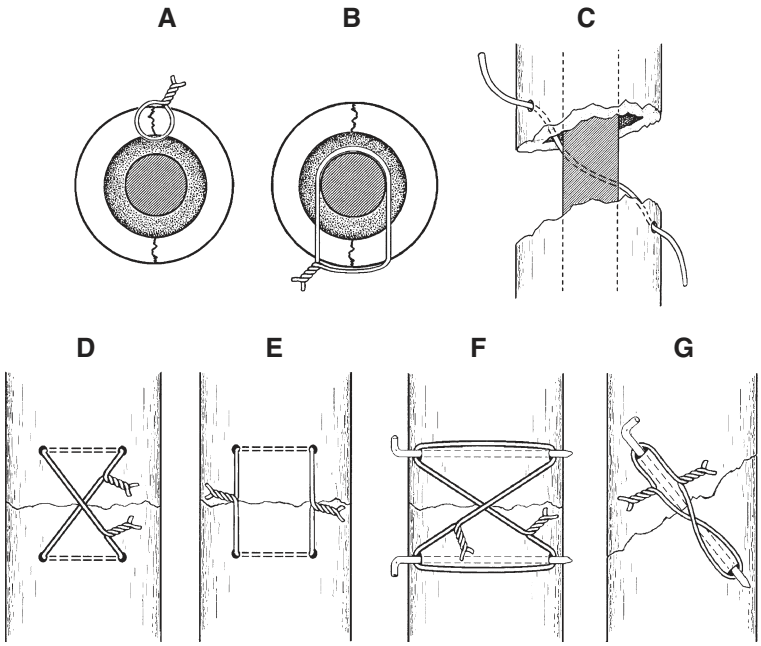


FIGURE 2-63. Various interfragmentary wire patterns. **A,** Simple interfragmentary "suture" placed through holes drilled from the cortex to the medullary cavity. The wire must be positioned before the fracture is reduced. **B** and **C,** Wire placed around the pin. In some situations this may pull the pin tightly against the cortex, which increases stability of the fixation. **D** and **E,** Interfragmentary wires placed through bone tunnels tangential to the medullary cortex. These patterns offer increased rotational stability and can be placed after the fracture is reduced. **F** and **G,** Combining interfragmentary wires with K-wires may be simpler than drilling bone tunnels. Crossing the fracture line with the K-wire, as in *G*, adds considerable rotational stability.

wire technique shown in Figure 2-63, *G*. Application of additional pins and wire to the transfixation device has been described to increase the strength of the configuration; however, additional manipulation of the fragments may cause soft tissue and vascular damage that could compromise healing.

TENSION BAND WIRE

According to the tension band principle, active distracting forces are counteracted and converted into compressive forces.[87] The tensile forces exerted by contraction of muscles on fractures such as those involving the olecranon process, trochanter major, tuber calcis, or detached tibial tuberosity can be overcome and converted to compressive forces by inserting two K-wires and a tension band wire (Figure 2-64). The K-wires are needed to neutralize shear forces at the fracture line, and the tension band wire not only neutralizes bending loads, but actually converts them to compressive forces. The cortex that forms the bending point must be intact for this method to work. The wire is usually placed in a figure-of-8 fashion to ensure that the longest possible lever arm, between the bending point and the wire, is maintained. This fixation device is more stable when the animal is weight bearing than when at rest, which is a useful situation for the veterinary surgeon.

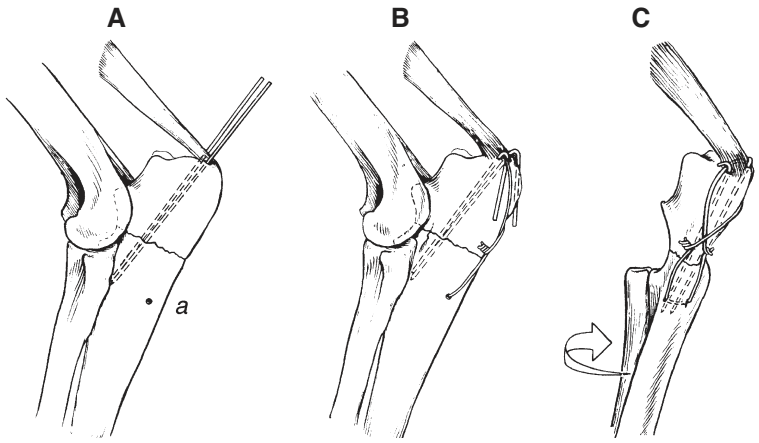


FIGURE 2-64. Tension band wire and Kirschner wire (K-wire) fixation. **A,** Olecranon fracture. The K-wires are placed at caudomedial and lateral corners of triceps tendon insertion. Ideally, the pins contact the cranial ulnar cortex distal to the coronoid process. A transverse hole *(a)* is drilled through the caudal cortex. **B,** The tension band wire is positioned and twisted tight on both sides of the figure-of-8. The wire should pass through the triceps tendon close to the olecranon proximally. The K-wires are bent caudally, cut, and, **C,** rotated 180 degrees so that the ends are buried in soft tissue. If the fragments of this fracture do not interlock or if comminution is present, plate fixation is indicated.

Technique

The tension band technique described and illustrated here is on the olecranon, one of the most common applications. The usual procedure in repairing a fracture or osteotomy of the olecranon process requires first reducing the fracture, then inserting two pins that are started on the caudomedial and caudolateral areas of the tuber. Such placement interferes less with the triceps tendon, and bending of the pins can be accomplished more effectively. If the pins can be inserted diagonally to engage the cranial cortex distally, they do a better job of securing the fragments and countering rotational and shearing forces than if they just go down the medullary canal. The pins should be as parallel to each other as possible to allow for compression of the fracture line as the wires are tightened. Note that the olecranon is concave on the medial side, and that pins tend to exit the cortices prematurely unless aimed carefully in a direction parallel with the lateral cortex.

A transverse hole is then drilled through the diaphysis distal to the fracture site (Figure 2-64, *A*). This hole is positioned to place the crossing point to the figure-of-8 wire near the fracture line and thus maintain the lever arm. The wire is inserted in a figure-of-8 manner and tightened by twisting each side of the figure-of-8. Avoid overtightening, because this will create a gap at the articular notch if the fracture is in this area (Figure 2-64, *B*). Note that the wire is passed through the triceps tendon close to the bone to avoid cutting the tendon when tightening the wire. Alternatively, the wire can be placed through a second hole in the bone to prevent interference with soft tissues, as is done in the tuber calcis (Figure 2-65, *D*). Use monofilament stainless steel wire of sufficient strength for immobilization. As listed earlier for cerclage wire, wire diameter of 22 gauge (0.025 inch, 0.64 mm) is suitable for toy breeds and cats, 20 gauge (0.032 inch, 0.81 mm) for average dogs, and 18 gauge (0.040 inch, 1.0 mm) for large breeds. Giant breeds place considerable stress on an olecranon repair and are the most likely

breeds to have loosened fixation. For giant breeds, 16 gauge (0.049 inch, 1.25 mm) and the largest possible pins are indicated. Again, it is always safest to err on the side of wires that are too large rather than too small. Eyelet wires can be used in place of twisted wire, but because of the stiffness of the wire, some difficulty will be noted in the 1.0- and 1.25-mm sizes in making both halves of the figure-of-8 equally tight.

The K-wires are then bent down the caudal surface of the ulna, cut, and rotated so that the ends are buried in soft tissue (Figure 2-64, *C*). If properly inserted, these implants do not interfere with movement of soft tissue and usually do not need to be removed after healing. If removal is desired because of lameness or seroma formation, the knot is untwisted a few turns to allow a pin cutter to cut each side of the knot. The wire is then twisted around a needle holder as it pulls through the tissues. It may have to be cut several times during this maneuver depending on wire length.

Other situations in which the tension band wire principle can be used to advantage include the following:

1. Avulsion fracture or osteotomy of the trochanter major of the femur (Figure 2-65, *A*)
2. Avulsion fracture of the tibial tubercle (Figure 2-65, *B*)
3. Fracture or osteotomy of the medial malleolus of the tibia (Figure 2-65, *C*)
4. Fracture of the tuber calcanei (Figure 2-65, *D*)
5. Fracture or osteotomy of the acromial process of the scapula, usually in large dogs (Figure 2-65, *E*)

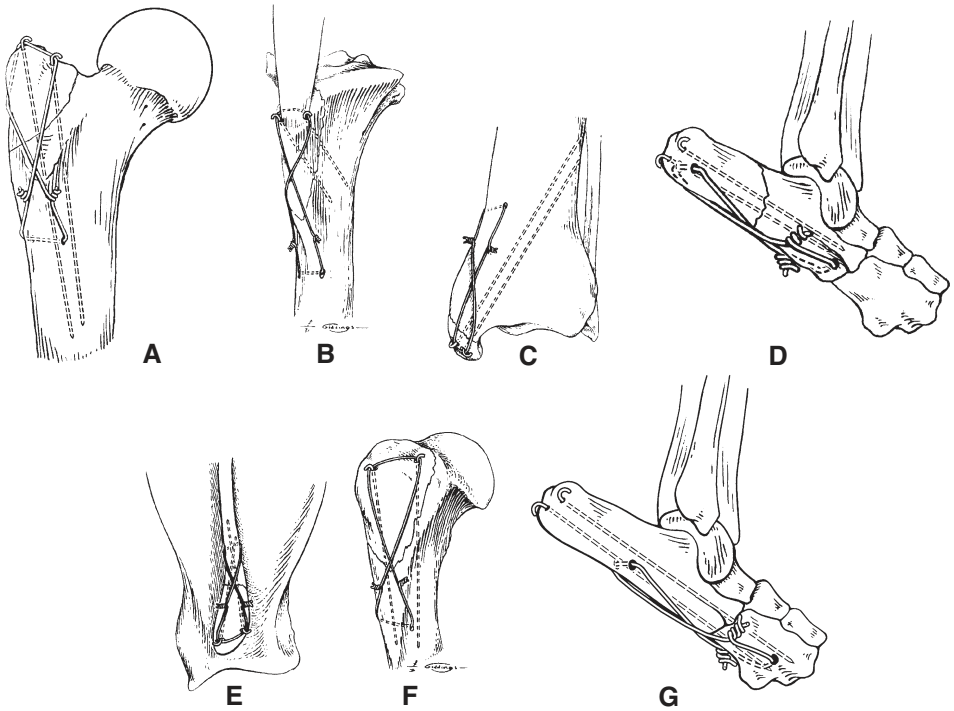


FIGURE 2-65. Conditions in which the tension band wire principle can be used to advantage. **A,** Avulsion fracture or osteotomy of trochanter major of femur. **B,** Avulsion fracture of tibial tubercle. **C,** Fracture or osteotomy of medial malleolus of tibia. **D,** Fracture of tuber calcanei. **E,** Fracture or osteotomy of acromion process of scapula. **F,** Fracture or osteotomy of greater tuberosity of humerus. **G,** Arthrodesis of intertarsal joint.

6. Fracture or osteotomy of the greater tuberosity of the humerus (Figure 2-65, *F*)
7. Arthrodesis of the proximal intertarsal joint (Figure 2-65, *G*)

BONE SCREWS

There are two basic types of bone screws: cancellous (Figure 2-66) and cortical (Figure 2-67).[87,88] Figure 2-68 details the typical assortment of bone screws available to the veterinary surgeon. Bone screws are usually employed to provide static interfragmentary or plate/bone compression by means of the *lag screw* principle. Interfragmentary compression is produced when the head of the screw bears on the first cortex and the threads of the screw are engaged only in the second cortex. Tightening of the screw converts that torque force to interfragmentary compression. Partially threaded screws automatically function as lag screws if their threads do not cross the fracture line (Figure 2-66, *B* and *C*). Fully threaded screws require special insertion technique to function as interfragmentary lag screws (Figure 2-67, *B* and *C*). Fully threaded screws provide plate/bone compression because the screw threads do not engage the plate and are anchored in the bone only, usually in two cortices. A secondary function of bone screws is to hold fragments in a fixed position without interfragmentary compression, where it is called a *position screw.* Such use is rare, usually being applied to prevent a small bone fragment or graft from displacing into the medullary canal.

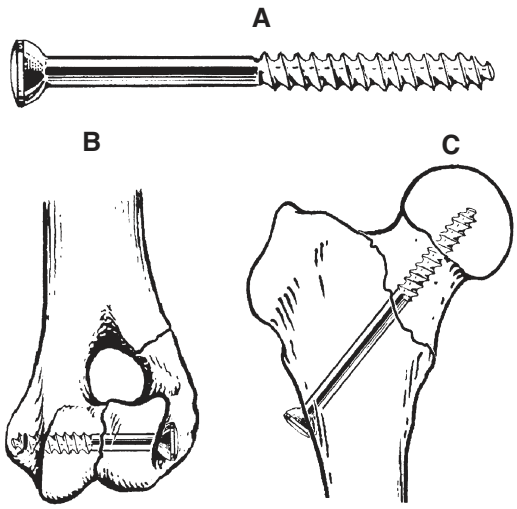


FIGURE 2-66. Partially threaded lag screws. **A,** Partially threaded screws most often have a thread designed for cancellous bone. The junction of the smooth shank and the threads is a potential "stress raiser," where bending loads concentrate. Both fragments are drilled the diameter of the screw shank. This will allow tapping of the screw threads in the second fragment. **B,** Lateral part of the humeral condyle stabilized by lag screw fixation. In order for compression to be produced, it is critical that all the threads be across the fracture line from the screw head. This may position the shank/thread junction close to the fracture line and predispose to breakage of the screw. **C,** In this femoral neck fracture, it can be seen that the shank/thread junction is some distance from the fracture, with little chance of screw breakage.

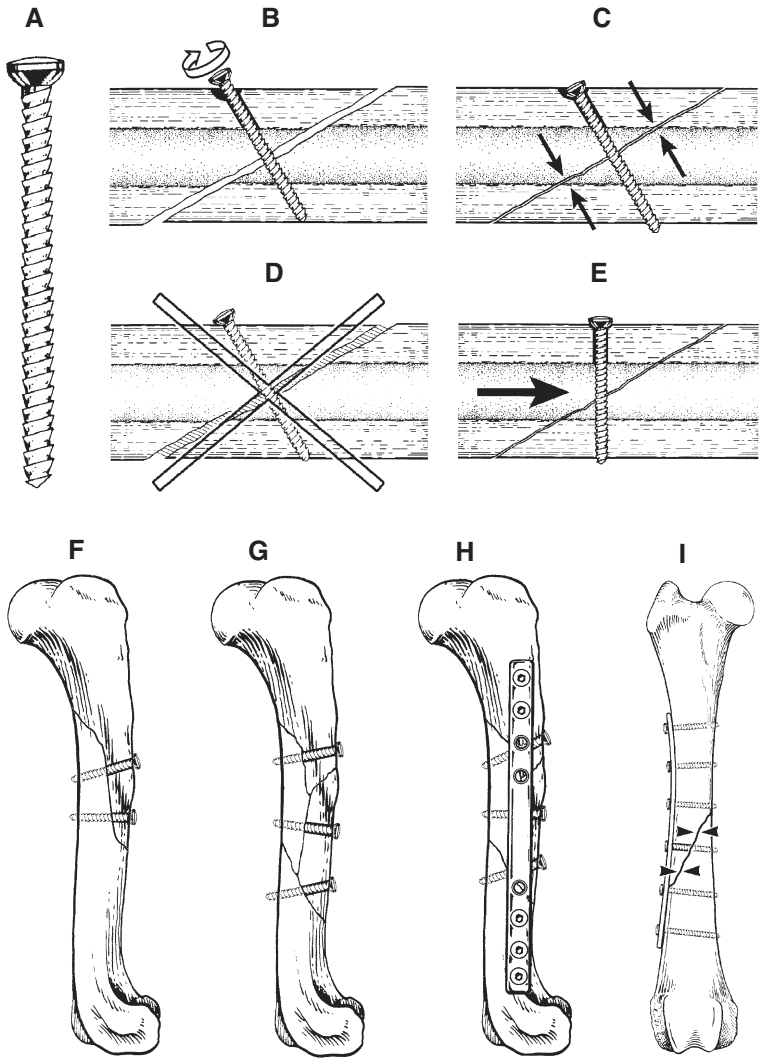


FIGURE 2-67. Fully threaded lag screws. Although these illustrations show diaphyseal bone, the same principles apply in metaphyseal fractures, as shown in Figure 2-66. **A,** Fully threaded screws typically are designed for use in cortical bone, although this does not diminish their usefulness in canine and feline metaphyseal regions. **B,** For fully threaded screws to function as lag screws and produce interfragmentary compression, the hole in the first cortex (fragment) must be equal to the diameter of the screw threads, allowing the screw to glide within the hole. The hole in the second cortex is the diameter of the core of the threads, allowing the threads to engage or tap into the bone. **C,** Because of the glide hole in the first cortex, the bone is pulled into compression between the screw head in the first cortex and the distal threads engaged in the second cortex. **D,** If both cortices are threaded (or tapped), the bone cannot glide on the screw, and no compression is generated. Continued tightening of the screw will strip the threads in the bone. **E** and **F,** Although a lag screw perpendicular to the fracture line, as in **C,** produces maximal interfragmentary compression, a screw perpendicular to the cortex is better able to resist axial loading. In shaft fractures, it is ideal to combine both positions if the fracture line is long enough to accommodate two screws. **G** and **H,** This complex fracture was completely stabilized by interfragmentary lag screw compression, then a neutralization plate was applied to protect the screw fixation from bending, rotational, and axial forces. **I,** When the plane of the fracture line allows, interfragmentary compression can be applied by a lag screw placed through a plate hole. As in *G* and *H*, the plate functions as a neutralization plate.

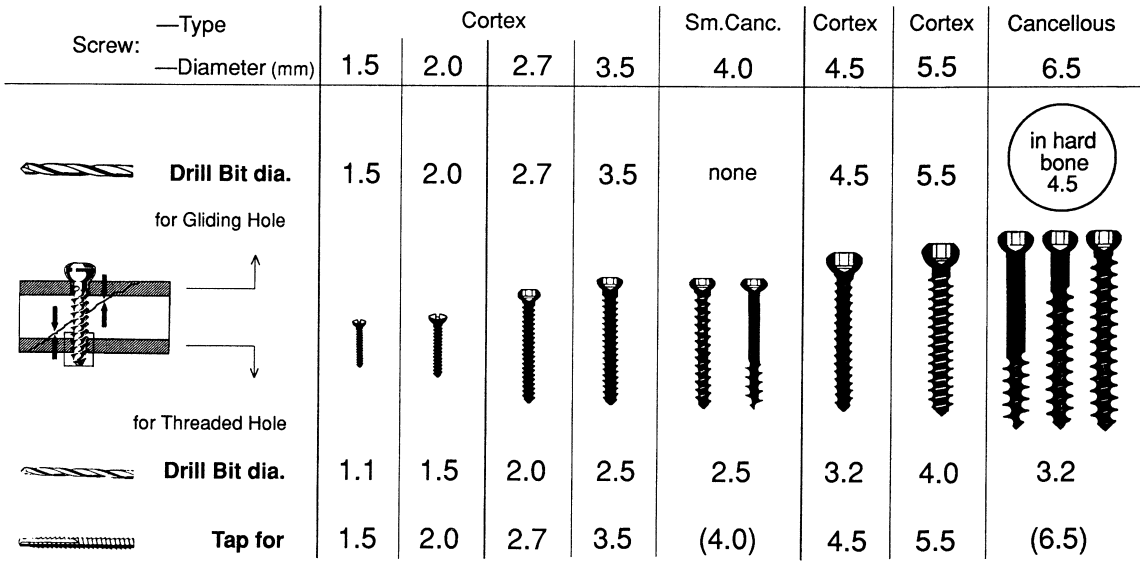


FIGURE 2-68. Screw, drill bit, and tap sizes. (Courtesy Synthes, Ltd, Paoli, Pa.)

Cancellous screws are used to compress fragments of epiphyseal and metaphyseal bone. The screw may be partially or completely threaded with relatively few threads per unit length; threads are quite deep, and the pitch of the threads is relatively high. Although very useful in human osteoporotic bone, there is much less need for this type thread in canine and feline bone, since even the metaphyseal zones are covered in dense cortical bone, where cortically threaded screws hold well. Partially threaded screws are inherently weak at the junction of the threaded and unthreaded zones, where there is a dramatic change in stiffness of the screw shaft. This produces a stress-concentrating effect and makes this area subject to stress fracture when subjected to repetitive bending loads. Therefore the surgeon should try to ensure that this junction is as far from the fracture line as possible.

Cortical screws are designed to be used primarily in the dense diaphyseal bone (see Figure 2-67). The screw is fully threaded, with more threads per unit length than cancellous screws; threads are shallower and more flatly pitched than cancellous screws. With proper application, these screws can be made to function as lag screws (see Figure 2-67, *B* through *I*). Because fully threaded screws are of uniform diameter throughout their length, they are not subject to the stress-accumulating effect just described for partially threaded screws. Also, fully threaded screws are less prone to breakage when used in heavily stressed fractures such as the lateral aspect of the humeral condyle.

Indications and Principles of Insertion

Primary Fixation in Certain Fractures

The fractures fixed with bone screws are usually in the metaphyseal or articular areas of the bone rather than in the diaphysis. Either partially threaded cancellous screws or fully threaded cortical screws can be used. To accomplish interfragmental compression, cancellous screws are inserted so that the thread of the screw does not

cross the fracture line (see Figure 2-66, *B* and *C*). The fracture segments are first reduced; after the appropriate-diameter *tap hole* (equivalent to the screw core diameter in the threaded area; Figure 2-68) is drilled, the thread is cut using the appropriate tap. Some cancellous screws are self-tapping and thus do not require pretapping. Tightening the screw produces compression of the fracture segments as the near fragment glides on the smooth shank of the screw.

A cortical screw will bring about interfragmentary compression when it is inserted to accomplish a lag effect, and it can also be used to repair these fractures when inserted in the manner described later (see Figure 2-67). This requires that (1) an oversized hole equal to the outer diameter of the screw threads *(glide hole)* be drilled in the near cortex and (2) a tap hole be drilled in the far cortex and tapped so that the screw thread becomes engaged on insertion. The latter step can be omitted if the screw is self-tapping. Precise centering of the tap hole with the glide hole is best accomplished by placing an insert drill sleeve in the glide hole. Alternatively, the tap hole is first drilled through both cortices, and then the first cortex hole is enlarged to glide hole diameter. Tightening the screw allows compression to be exerted between the two cortices, since the first cortex can move on the screw because the glide hole is not engaging screw threads (see Figure 2-67, *C*). When threads are engaged in both cortices, no gliding can occur, and thus no compression is produced (see Figure 2-67, *D*). Maximum interfragmentary compression is secured when the axis of the screw is perpendicular to the fracture line; therefore an attempt is always made to orient the screw as close to this axis as bone contour and exposure will allow.

Screws are *never* used as the primary fixation in shaft fractures. They are always supplemented with a plate, pin, or external skeletal fixator. Primary fixation of shaft fractures with screws always results in fracture at a screw hole or failure of the screw unless the limb is immobilized in an external splint/cast, thus negating the advantages of internal fixation.

Aid in Reduction and Auxiliary Fixation

With long oblique, spiral, or multiple fractures of the diaphysis, cortical bone screws inserted with a lag effect to accomplish interfragmentary compression may be used as an aid in accomplishing reduction and serve as auxiliary fixation (see Figure 2-67, *F*). The recent emphasis on the concept of biological fixation would encourage that fracture fragments be left undisturbed when possible, so that remaining viable cells can contribute to callus formation. A decision to use lag screws to stabilize a fragment must be balanced against the potential for damage to fragment blood supply inherent to fragment manipulation. The surgeon must be gentle and efficient in the reduction of fragments and application of lag screws to avoid this concern.

Two adjoining fragments are reduced and usually held in the reduced-compressed position during drilling, tapping, and insertion of the bone screw. The bone screw should be inserted at a distance from the fracture line at least equal to the screw diameter, so the center of the hole must be 1.5 diameters from the fracture line. When the fracture is multiple in nature and the bone segments are of sufficient size, the entire bone or portions of it may be reconstructed anatomically by reducing and fixing two fragments at a time until reconstruction is complete (see Figure 2-67, *G*). A neutralization plate (see next section) is one choice for final fixation (see Figure 2-67, *H*). Plate screws can also be inserted for lag effect when the fracture line is properly oriented to the plate (see Figure 2-67, *I*). Whenever possible, lag screws should be used in preference to cerclage wire to accomplish interfragmental compression and to aid in reduction and auxiliary fixation. Lag screws are more reliable than cerclage wires in producing interfragmentary compression because fewer

potential technique errors are possible during insertion. Additionally, insertion of a lag screw causes less disruption of soft tissue and periosteal blood supply than does placement of a cerclage wire, and if a screw should loosen, it does not cause the vascular disruption attributed to a loose cerclage wire.

BONE PLATES

One of the primary objectives in the treatment of fractures is early return to full function of the injured limb. Bone plates are ideal for accomplishing this goal because they have the potential to restore rigid stability to the reconstructed fractured bone when properly applied.[87-89] Bone plates are adaptable to many situations, as follows:

1. Most long-bone fractures
2. Multiple and complex fractures
3. Fractures in larger dogs (especially the femur) because postoperative complications are less frequent and postoperative care is reduced when the fixation apparatus is covered with soft tissue

Although many designs and sizes of plates are available, the ASIF (Association for the Study of Internal Fixation, Synthes Ltd., Paoli, Pa) system is used here to illustrate the principles because it is the system with which the authors are most familiar (Figure 2-69). Several manufacturers now produce plates and screws very similar in design and function to the ASIF implants. For optimum results in the use of bone plates, a scientific understanding of the following areas is a prerequisite:

1. Anatomy (e.g., structure of bone; location of blood and nerve supply; muscle separations; attachments of muscles, tendons, and ligaments)
2. Principles of active forces (knowledge of compression, tension, and torsional and bending forces as they affect the bone)
3. Understanding of the mechanics of fixation in detail, and viewing and planning its application in three dimensions
4. Proper selection of a surgical approach and method of internal fixation best suited for the individual fracture
5. Bone-healing patterns (see also previous discussion in this chapter)

It is important to be able to interpret the biological response with *rigid fixation,* where primary or direct bone union is anticipated. Development of a "cloudy" irritation callus is a warning sign and indicates some movement occurring at the fracture site and the potential for delayed union or nonunion. When two vascular, anatomically reduced bone fragments are rigidly fixed under compression so that no shearing or torsional forces can act on them, no resorption of bone at the fracture line takes place, and a direct bony union occurs without any radiologically visible periosteal callus.[90,91] On the other hand, if a *bridging osteosynthesis* approach was adopted to stabilize the fracture, considerable periosteal and endosteal bridging callus is anticipated, and its absence would be cause for concern.

Terminology

Plates may be inserted to function as a compression plate, a neutralization plate, bridging plate, or a buttress plate. Such names do not imply anything about the physical characteristics of the plate, but only its function.

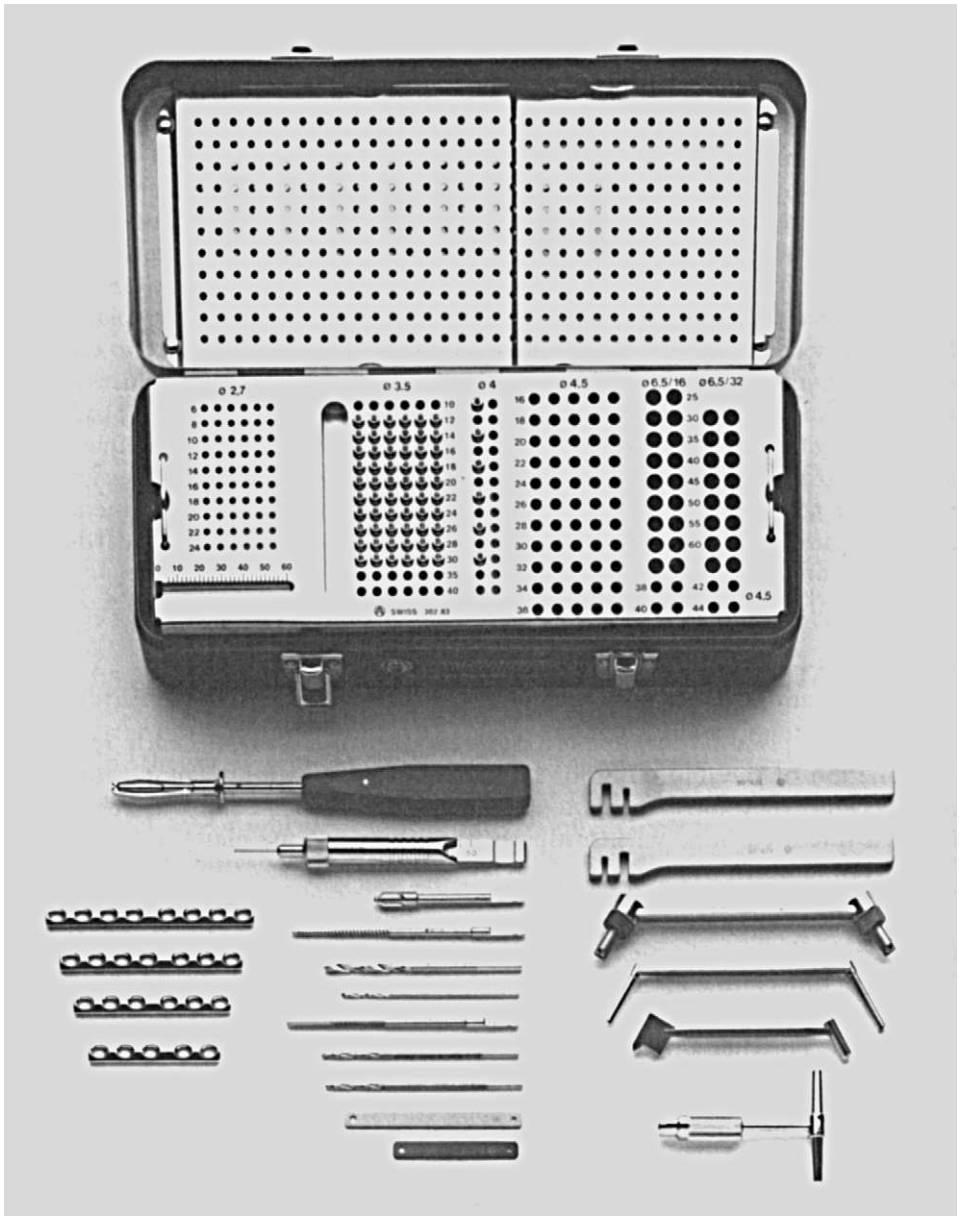


FIGURE 2-69. Basic bone-plating equipment and plates. (Courtesy Synthes, Ltd, Paoli, Pa.)

Compression (Tension Band) Plate

When the plate is applied so that it is under tension and the fracture fragments are under compression, it is referred to as a compression plate or a tension band plate. Long bones (e.g., the femur) are subject to eccentric loading and may be compared to a bent column. The lateral side is subject to distracting or tension forces; the medial side, to impacting or compressive forces (Figure 2-70, *A* and *B*). It is vital that the plate be applied on the side of the bone that is most frequently under a distracting or tension force (Figure 2-70, *C*). Clinically, these surfaces are the lateral surface of the femur, medial or cranial surface of the tibia, cranial or lateral surface of the humerus, and the craniomedial or cranial surface of the radius.

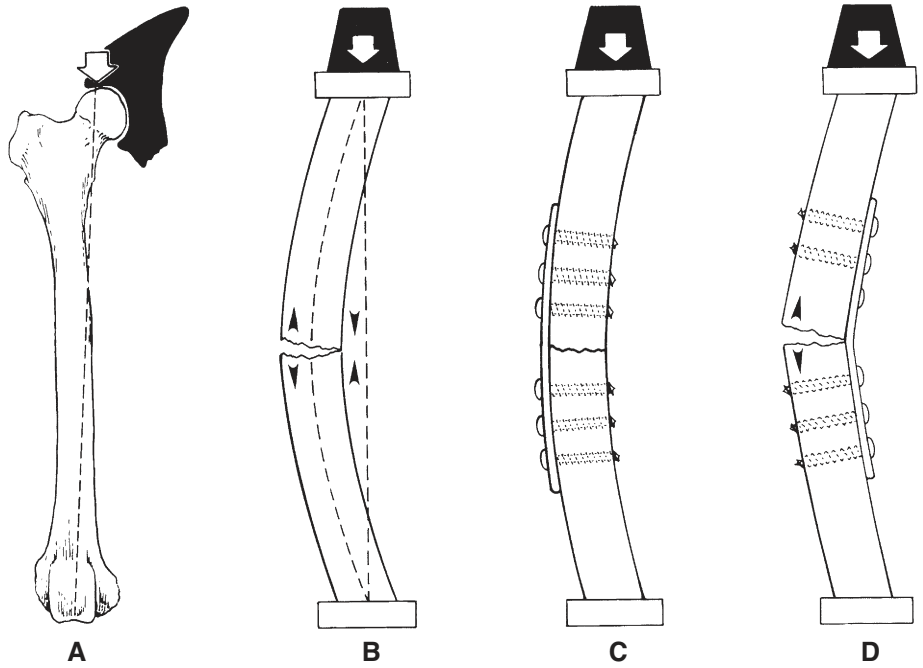


FIGURE 2-70. Principle of a compression plate. Insert the plate only on the tension side of the bone so that the bone will receive compressive forces. Because long bones are subject to eccentric loading, the side of the bone to be under tension must be known to determine where to apply the plate. The femur (**A**), for example, can be compared with a bent column (**B**). The plate that is applied to the outer or convex side can then counteract all tension forces (**C**) and provide rigid internal fixation. If applied on the inner or concave surface, the plate would not provide fixation (**D**); such a plate would come under excessive bending stresses and would soon show a fatigue fracture.

When a plate is applied to the lateral surface of the femur, it counteracts all tension forces and creates compressive forces along the fracture line, thus providing rigid internal fixation (Figure 2-70, *C*). If the plate were applied on the medial surface, it would not give long-lasting fixation because the plate would be under excessive bending stress and subject to fatigue fracture (Figure 2-70, *D*). It is also critical to long-term stability and prevention of plate failure that the cortex opposite the plate be intact to prevent compression forces on that cortex from becoming bending forces being applied to the plate (Figure 2-70, *B*). The cortex opposite the plate in this situation acts as a buttress against the compression forces.

Production of tension in the plate was originally accomplished by use of a tensioning device (see Figure 2-71, *D*) that was temporarily applied to the plate and attached to the bone, but the self-compressing plate has totally replaced the tension device in practice. Axial compression is accomplished at the fracture site with these plates, and the dynamic compression plate (introduced by Synthes and discussed later) has been the pattern for these plates (Figures 2-71 and 2-72).[92] Compression plates are used on type A stable fractures, osteotomies, and arthrodeses.

Neutralization Plate

The neutralization plate is applied on the tension side of the bone to neutralize or overcome torsional, bending, compressive, and distraction forces on fracture lines

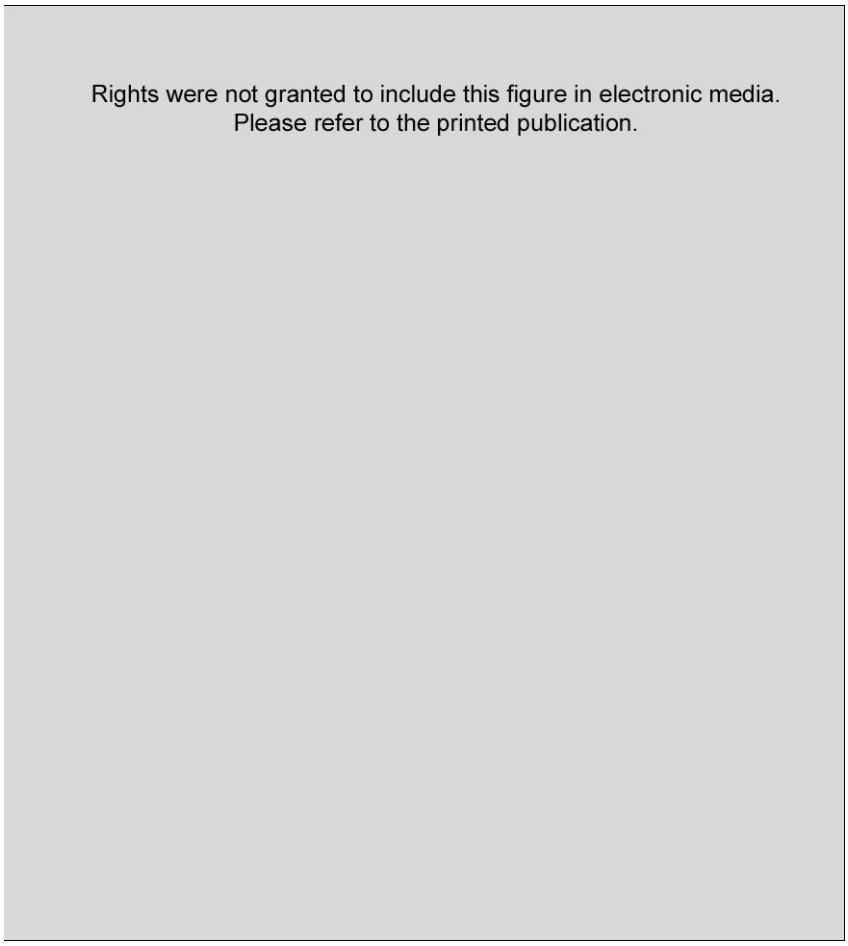


FIGURE 2-71. Self-compressing plate (dynamic compression plate, DCP). **A** and **B,** Sagittal sections of a screw and screw hole in a DCP show the mechanical principle. **C,** The first screws on either side of the fracture line are inserted eccentrically (load position) and alternately tightened to produce compression. **D,** If there is a wide fracture gap, additional compression can be accomplished by the use of a tension device. (From Müller M et al: *Manual of internal fixation,* ed 2, New York, 1979, Springer-Verlag [Translated by J Schatzker].)

that have been stabilized by interfragmentary compression supplied by lag screws and cerclage, hemicerclage, or interfragmentary wire (see Figure 2-67, *C*). If possible, the plate is applied to exert some axial compression. Neutralization plates are used on osteotomies or type B and some type C unstable fractures that can be anatomically reconstructed using lag screws or cerclage wire.

Buttress or Bridging Plate

This nomenclature can be somewhat confusing because the term "bridging plate" was developed to signify a buttress plate used for bridging osteosynthesis of diaphyseal fractures. The buttress plate functions to shore up a fragment of bone, thereby maintaining length and the proper functional angle in fractures such as those involving the proximal tibial plateau (Figure 2-73, *A* and *B*). The bridging plate may be considered a buttress plate used to splint or bridge the fracture area to maintain length of the bone when the fragments are left unreduced or are missing and



FIGURE 2-72. Drill guides for insertion of the self-compressing plate (DCP). **A,** Load guide. The guide is inserted in the screw hole of the plate with the arrow pointing to the fracture line. The screw is located eccentrically so that in tightening, it moves 1 mm (it also moves the bone fragment 1 mm). **B,** Neutral guide. The screw is located slightly eccentrically so that in tightening, it moves 0.1 mm. **C,** For oblique fractures, a lag screw may be inserted at an angle through the plate. *Continued*

replaced with cancellous bone graft (Figure 2-73, *C*). The advantage for use of a buttress plate is that the plate is applied with minimal manipulation of the bone fragments and disruption of remaining blood supply. The disadvantage of this plate function is that the plate must completely absorb all bending, torsional, and compressive forces of weight bearing and is more likely to fatigue and fail compared with compression or neutralization plate constructs. Hulse and colleagues have

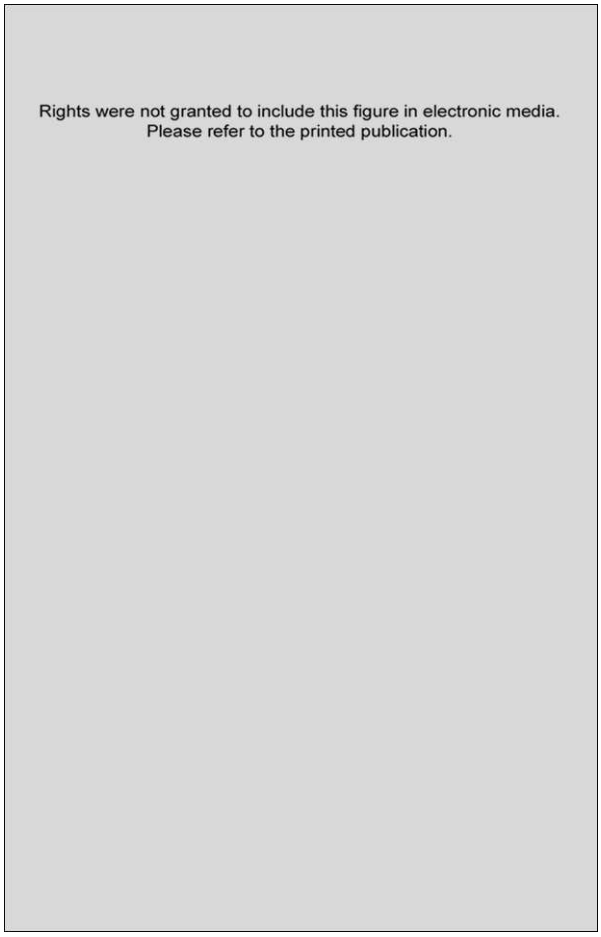


FIGURE 2-72. *Continued* **D, E,** and **F,** When multiple fracture lines are present, the first fracture line is compressed as the second screw in the load position is tightened. The second fracture line is compressed as the third screw in the load position is tightened. (From Allgöwer M et al: *The dynamic compression plate,* New York, 1973, Springer-Verlag, pp 15, 24, 34.)

suggested and described the use of an intramedullary pin, in conjunction with a buttress plate, to reduce stress on the plate used with buttress function.[93] The details of intramedullary pin/buttress plate combination fixations are discussed later in this chapter.

Application of Bone Plates

Number of Screws

Clinical data indicate that an absolute minimum of two screws (four cortices) should be used in the bone segments on each side of the fracture in small animals. However, a minimum of three or four screws (six or eight cortices) is ideal for compression and neutralization plates and is mandatory for bridging plates in small animals (Figure 2-74). These numbers do not vary much with the size of the animal,

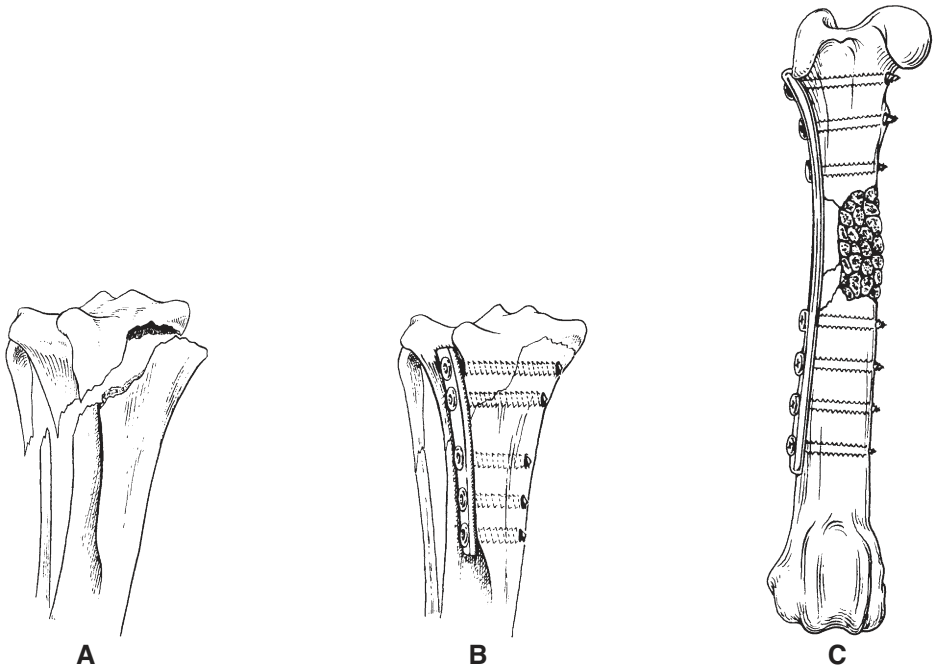


FIGURE 2-73. Buttress plate. **A,** Fracture of the proximal tibial plateau. **B,** Buttress plate fixation shores up the fragment, maintaining length and proper functional angle. **C,** Bridging plate bridges a defect, filled with bone graft in this case.

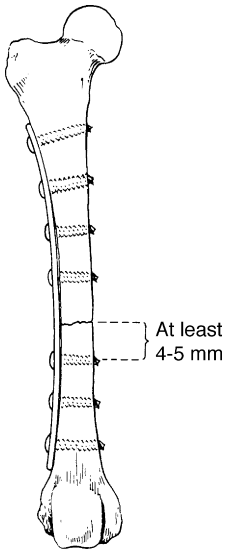


FIGURE 2-74. Plate fixation: number of screws and screw placement. Although two screws (four cortices) are an absolute minimum on each side of the fracture line, three or four screws (six or eight cortices) are more ideal and are mandatory for larger breeds. Minimal distance between fracture lines and screws is 4 to 5 mm.

since the plate sizes vary to allow approximately the same number of screws per unit of bone length. The number of screws is a function of plate length.

Placement of Screws

Clinical and experimental data indicate that the minimal distance between screw hole and fracture line should be 4 to 5 mm, or at least equal to the diameter of the screw used[87,88] (see Figure 2-74).

Length and Size of Bone Plate

Bone plates are made in a variety of sizes to mate with the various diameters of bone screws (see Figure 2-69). Both length and thickness are proportional to the size screw intended for use with the plate. A long plate is much more effective than a short plate in neutralizing forces to which the fractured bone may be subjected, because it increases the working length of the implant and distributes destabilizing forces over a larger surface. The ideal approach in most cases is to use a plate that is just short of the entire length of the bone (see Figure 2-74). See Figure 2-75 for plate size guidelines relative to the bone involved and the size of the animal. Because the number of screw holes is directly proportional to the length of the plate, more screws can be used with the longer plate.

Contouring the Plate

If anatomical reduction of the bone fragments is to be maintained during application of the bone plate, it is mandatory that the plate be contoured to closely fit the bone surface to which it is to be applied. In some cases, this is accomplished by bending; in others, by a combination of bending between the screw holes (Figure 2-76, *A*) and twisting (Figure 2-76, *D*). Prestressing (underbending) the plate is advisable in most cases because it aids in minimizing the gap on the far cortex and assists in compression when the screws are finally tightened. This usually amounts to a 1-mm gap between the bone and plate at the fracture site (Figure 2-76, *B* and *C*).

Insertion of a Lag Screw through the Plate

In some cases the fracture line lends itself to interfragmentary compression by inserting the lag screw through the bone plate (see Figure 2-67, *A*).

Dynamic Compression Plate

The design of the screw holes in the dynamic compression plate (DCP) is based on the spherical gliding principle developed by the ASIF and patented by Synthes. As the screw is tightened, the spherical screw head glides toward the center of the plate until the deepest portion of the hole is reached (see Figure 2-71, *A* and *B*). The result is that the bone fragment into which the screw is being driven is displaced at the same time and in the same direction, that is, toward the center of the plate and the fracture line. By alternate tightening of the screws on each side of the fracture line, the fragments are compressed (see Figure 2-71, *C*). The tension device may be used for additional compression, although it is rarely needed (see Figure 2-71, *D*). Two drill guides (neutral and load) are used in drilling the holes in the proper position. The *load guide* has the potential for moving the fragment 1.0 mm and the *neutral guide* 0.1 mm in the 4.5-mm plate (see Figure 2-72, *A* and *B*). In general, all the principles that apply to the insertion of regular plates apply to the DCP; however, the DCP has the following additional advantages[87,88]:

1. Cancellous bone screws may be inserted in any plate hole.
2. Plate screws may be applied at varying angles when used as lag screws (see Figure 2-72, *C*). The interaction between the screw head and screw hole of the plate permits angulation of the screw to a maximum range of 25 degrees in either direction longitudinally and 7 degrees sideways.[94] Exceeding the recommended angulation of the screw in any plate may cause interference of the screw head on the edge of the plate hole and may prevent proper seating of the screw into the plate hole and to the far cortex of the bone.

Veterinary plate and screw chart

A guide for the selection of plates with respect to animal weight and fracture location

DCP	Dynamic compression plate	LC. DCP	Limited contact dynamic compression plate
Br. DCP	Broad dynamic compression plate	RCP	Reconstruction plate
AP	Veterinary acetabular plate	MP	Mini plate
Na. DCP	Narrow dynamic compression plate	VCP	Veterinary cut-to-length plate

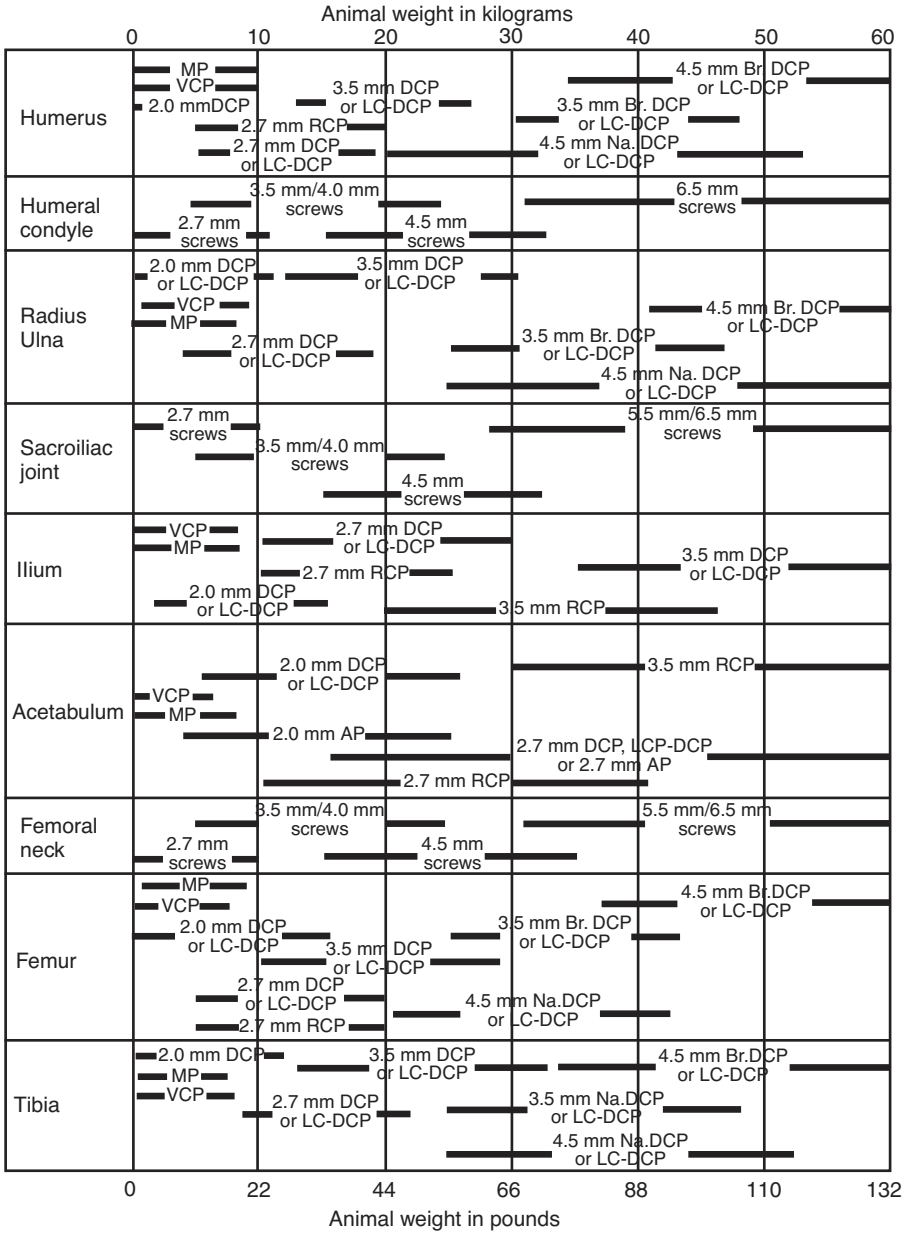


FIGURE 2-75. A guide for selection of plates with respect to animal weight and fracture location. (Courtesy Synthes, Ltd, Paoli, Pa.)

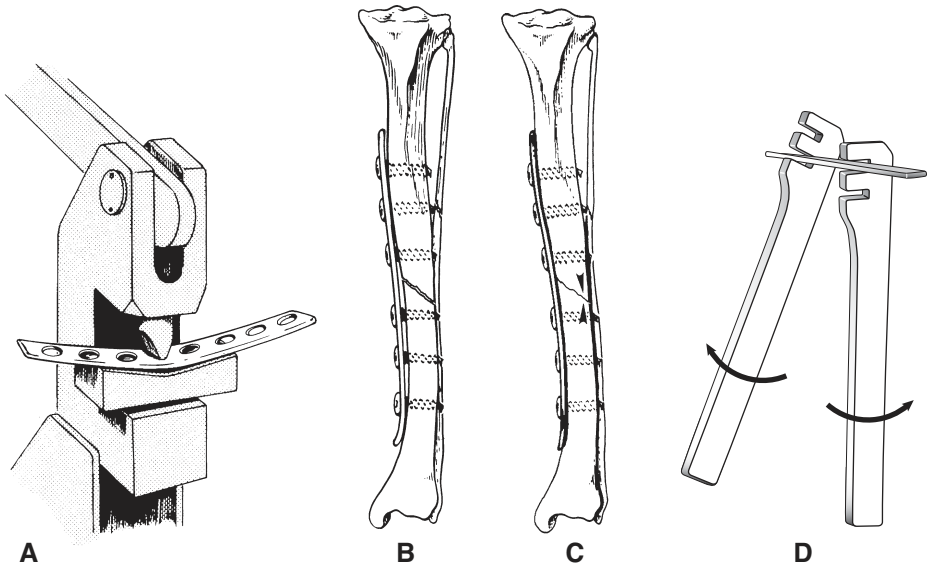


FIGURE 2-76. Plate fixation: contouring the plate. **A,** The plate must be contoured so that it approximately fits the bone surface to which it is applied. Using the bone plate-bending press, gently bend the plate between the screw holes. **B,** Prestressing (underbending) the plate supplies added compression to the far cortex. In a curved bone the plate is contoured to leave a 1-mm gap between plate and bone at the fracture site. In a straight bone the plate is bowed slightly to produce the 1-mm gap. **C,** Tightening the prestressed plate causes added compression on the cortex opposite the plate. **D,** Twisting irons may be used to contour a plate around its central axis.

3. With a fracture of three or more segments, the plate has the potential for compression at each of the fracture lines (see Figure 2-72, *D, E,* and *F*).

Selection of Proper Bone Plate and Screw Sizes

One of the problems confronting the surgeon is the choice of the size of implant to use on the various fractures in patients of different sizes. Various factors may be considered in choosing the size of implant, such as type and location of the fracture, age, activity, size of bone, weight of animal, and condition of soft tissue.[88,95,96] However, when the basic fundamentals of implantation are observed, the most consistent factor in choosing the size of the implant is the *weight* of the patient. To provide guidelines in selecting proper bone plate and screw size, data were compiled on approximately 1000 bone plate cases and 300 screw fixation cases in which plates and screws were used as the primary method of fixation.[95] The summation of data collected is presented in Figure 2-75. Corrections have been made and included for implants that were too weak (resulting in breaking or bending) or too large. As expected, there is some overlapping of appliance sizes for given weights. In addition to the size of the implant, some of the more common causes of failure include bone plates that are too short in length, an insufficient number of bone screws, vascular impairment, infection, and failure to use bone graft.

Special Plates and Plate Applications

Because most plates are manufactured for use in humans, there are many anatomical areas in small animals where no suitable plate exists. Thus a variety of bone plates have been designed for application in small animals in special circumstances

(Synthes Ltd., Paoli, Pa). These include C-shaped plates for use on the dorsal acetabular rim; T-shaped mini DCPs for 1.5- to 2.0-mm screws for use on distal radial fractures; straight mini DCPs for 1.5- to 2.0-mm screws; hook plates for intertrochanteric osteotomy (see Chapter 16), and cuttable plates. Other manufacturers have similar devices available. A useful plate in severely comminuted fractures is the lengthening plate, which has no screw holes in the middle; this minimizes plate failure over unstable regions.

Veterinary Cuttable Plate

Although a fairly recent development, veterinary cuttable plates (VCPs) have rapidly become popular in small animal use because they fill a very real gap in previously available implants for long-bone fractures in small breeds and for small-bone fractures in larger breeds. The previously available miniplates for 1.5- to 2.0-mm screws are often too weak or too short, whereas the 2.7-mm plate either is too thick or does not have enough screw holes per unit of length. Additionally, the 2.7-mm-diameter screw may exceed 25% of the bone diameter and thus weaken the bone. The VCP is 300 mm in length, 7 mm wide, and either 1.0 mm thick (1.5- or 2.0-mm screws) or 1.5 mm thick (2.0- or 2.7-mm screws) (Figure 2-77). The screw holes are all round, and the spacing of the holes is identical in both size plates, allowing the stacking or sandwiching of two plates to increase stiffness as required for the situation. The plates are easily cut at a screw hole with a small pin or wire cutter, allowing one plate to be used for several cases, and are very economical compared with other plates. A small amount of bone compression can be obtained by drilling the screw holes slightly eccentric (away from the fracture line) to the plate hole.

Stacking of plates allows for a total of five thicknesses: 1.0, 1.5, 2.0, 2.5, and 3.0 mm. Two identical length plates are stacked if the increased stiffness is desirable over the full length of the plate. In some cases it may be desirable to allow slightly more flexibility at each end of the bone, and the top plate can be shortened to between half and three fourths the length of the base plate.[97] Stacked plates should be contoured simultaneously by placing a screw through both plates at each end of the plates to prevent sliding of the plates relative to each other during contouring. Mechanical studies have demonstrated that the VCP is more resistant to bending force than 1.5- to 2.0-mm miniplates and is less resistant than 2.7-mm plates.[98] Stacking plates yielded a stiffness slightly less than the sum of

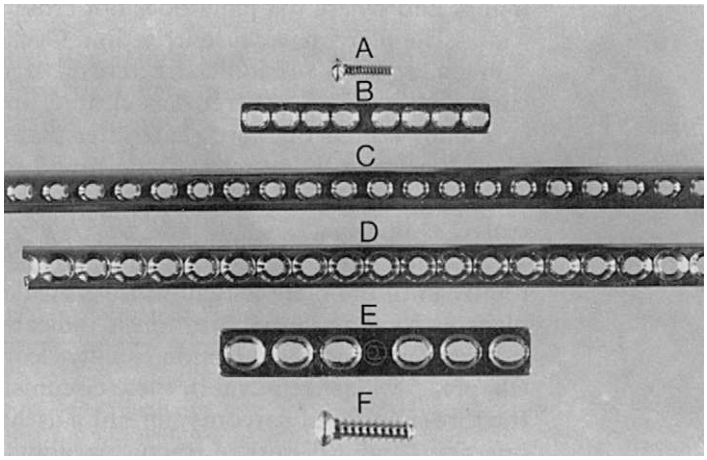


FIGURE 2-77. Miniplates and screws. **A,** 2.0-mm screw. **B,** 2.0-mm DCP. **C,** 1.5-mm/2.0-mm cut-to-length plate, 1.0 mm thick. **D,** 2.0-mm/2.7-mm cut-to-length plate, 1.5 mm thick. (Note increased number of screw holes available compared with standard 2.7-mm DCP in **E.**) **F,** 2.7-mm screw. (Courtesy Synthes, Ltd, Paoli, Pa.)

stiffness for each plate, and two thick plates had a stiffness of approximately two thirds that of the 2.7-mm plate. Screw size did not have a pronounced effect on stiffness.

Reports of clinical application of the VCP have been uniformly encouraging.[97,99,100] Primary use has been in multifragmental type C long-bone fractures in small breeds, pelvic fractures, and metacarpal-metatarsal fractures in large breeds. The ability to place many screws within a short distance is very useful in multifragmental fractures and often makes the bone-plate construct stronger than a larger plate with fewer screws.

Limited-Contact Dynamic Compression Plate

The limited-contact DCP (LC-DCP) is used in the same manner as the 3.5-mm narrow and 4.5-mm narrow DCP; however, additional design features have been incorporated to enhance its application and function in diverse fractures (Synthes).[94] The LC-DCP is designed with a structured undersurface, with oblique undercuts at both ends of each screw hole (Figure 2-78, *A* and *B*). The purpose of the undercuts is to reduce contact of the plate with the cortical surface and therefore to improve periosteal blood supply and efferent blood flow from the cortex. Improved blood flow should reduce plate-related osteoporosis. A second benefit of the undercuts at each screw hole is to distribute stiffness more evenly throughout the plate and reduce stress concentration and failure of the plate through unfilled screw holes. Each screw hole has been redesigned to improve angulation of the screw and versatility in direction of compression. Oblique undercuts at each end of the screw hole allow a screw to be angled up to 40 degrees in either direction of the long axis of the plate. This is especially useful in the application of lag screws through the plate. The screw may be angled 7 degrees sideways in the plate, similar to the DCP. The spherical gliding principle of the screw hole has been redesigned to be present at both ends of the hole, which allows compression in either longitudinal direction. This feature is especially useful in complex fractures, in which it may be desirable to compress different components of the fracture. Specific "universal" drill guides are designed for use in the LC-DCP (Figure 2-78, *C*). Screw holes are now evenly spaced throughout the plate, with elimination of the middle open segment. This feature allows greater versatility in shifting the plate in the long axis of the bone in relation to the fracture.

The original LC-DCP is made of commercially pure titanium and should be used with titanium screws. Titanium achieves 90% of the strength of stainless steel, with slightly less stiffness. Pure titanium is biologically inert and therefore has better tissue tolerance and fewer low-grade immunological complications than stainless steel. Titanium implants cost more than stainless steel, however, and thus few veterinary practices are using the LC-DCP. An LC-DCP is now being made in stainless steel, so veterinary application is expected to increase.

Reconstruction Plates

Compression plates and LC-DCPs may be contoured with a bending press or twisting irons around their longitudinal axes, but they cannot be bent in the plane of their flat surface without structural damage to the screw holes. Reconstruction plates (Synthes) have been designed to develop three-dimensional contours for complex bony anatomy. Notches are designed into the sides of the plate to allow the surgeon greater freedom to contour the plate in the plane of its flat surface (Figure 2-79). Special bending pliers and twisting irons are available to contour the plate with minimal distortion of the screw holes. These plates are available in 4.5-, 3.5-, and 2.7-mm configurations. They are useful in selected fractures of the humerus, pelvis, and mandible; however, caution must be exercised in selection and use of this plate type. Reconstruction plates are significantly less stiff than the DCP

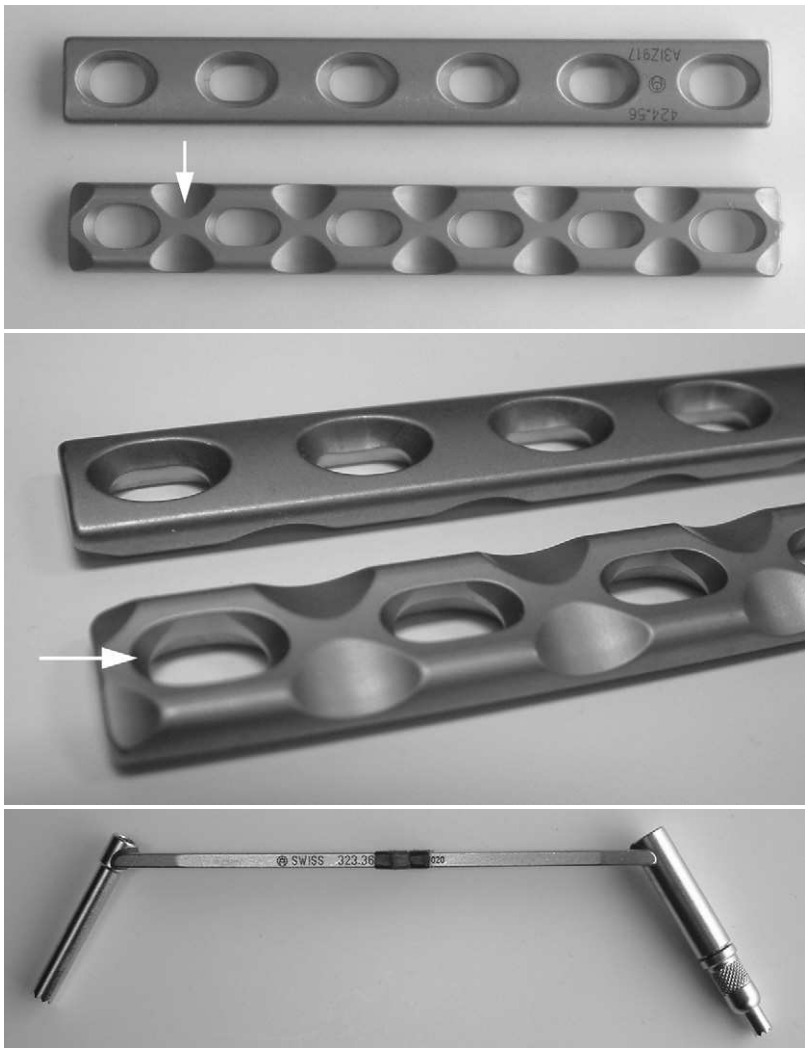


FIGURE 2-78. Limited-contact dynamic compression plate (LC-DCP). **A,** LC-DCP has been designed with a structured undersurface, with undercuts *(arrow)* at both ends of each screw hole. The purpose of the undercuts is to reduce contact of the plate with the cortical surface and to distribute stiffness more evenly throughout the plate. **B,** Each screw hole has been redesigned to improve angulation of the screw; oblique undercuts *(arrow)* at each end of the screw hole allow a screw to be angled up to 40 degrees in either direction of the long axis of the plate. The screw may be angled 7 degrees sideways in the plate, similar to the DCP. **C,** Universal drill guide may be used in either end of the redesigned screw hole to allow compression of a fracture in either longitudinal direction of the plate. (Courtesy Synthes, Ltd, Paoli, Pa.)

or LC-DCP. If significant bending forces are expected in weight bearing at a fracture site, this plate may deform, resulting in loss of fracture alignment.

Plate and Intramedullary Pin Combination for Bridging Osteosynthesis

The concept of biological osteosynthesis emphasizes that bone fragments be left undisturbed to reduce manipulation of the soft tissue envelope surrounding fracture fragments and, therefore, to prevent disturbing the healing potential of the bone.

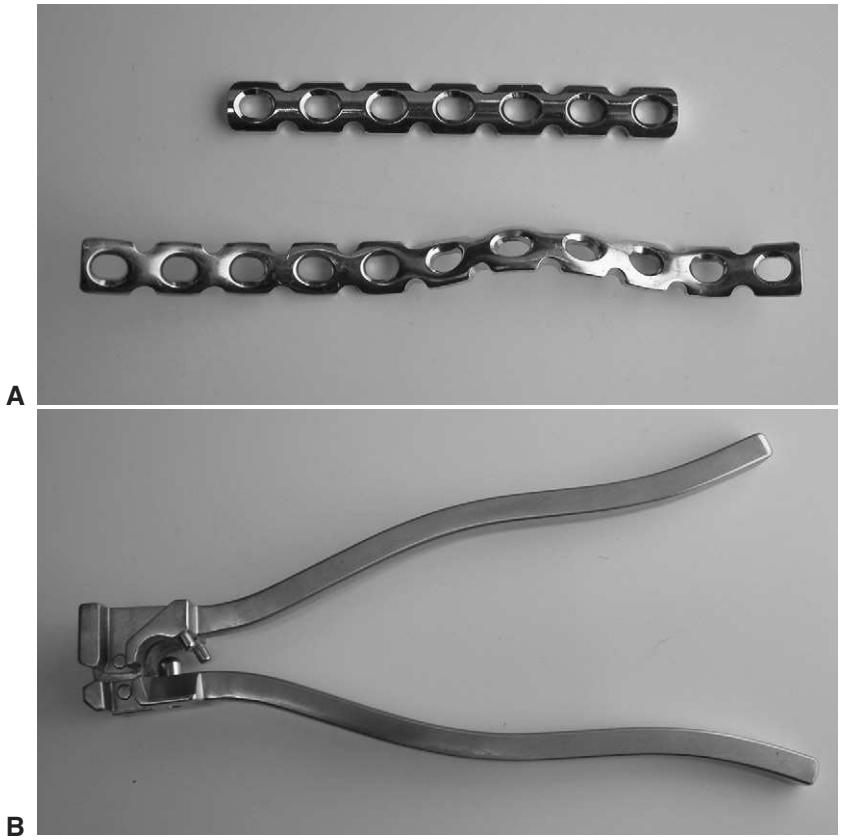


FIGURE 2-79. Reconstruction plates. **A,** Notches are designed into the sides of the plate to allow contouring the plate in the plane of its flat surface. **B,** Special bending pliers allow contouring the plate with minimal distortion of the screw holes. (Courtesy Synthes, Ltd, Paoli, Pa.)

A buttress plate applied correctly to a comminuted fracture achieves the goals of a bridging osteosynthesis strategy. A disadvantage of a bone plate applied with buttress function is that the plate must withstand all weight-bearing forces until fracture healing is achieved and is typically subjected to major bending stresses. There is no early load sharing between the plate and the bone because fragments remain aligned, but unreduced. The plate is subjected to considerable bending stress and may fatigue and fail earlier than a comparable plate used with neutralization or compression function. The combination of an intramedullary (IM) pin with a buttress plate has been described to help overcome some of the disadvantages of use of the buttress plate alone[93,101,102] (Figure 2-80).

When an IM pin is used in combination with a plate, the pin is placed first and fulfills two functions. Placing the IM pin allows easy and efficient alignment of the major bone fragments of a fracture. The smaller fragments are not disturbed, and the healing potential of the bone is protected. The pin also functions during healing to share loading and protect the plate from the bending forces of weight bearing. Stress reduction in a plate/pin system is twofold compared with the buttress plate alone, and fatigue life of a plate/pin system is increased tenfold over a plate alone.[101] Mechanically, the pin and plate are acting as parallel beams, to shield each other from diverse weight-bearing forces. A disadvantage of the combination of pin and plate for fracture repair is that the IM pin may interfere with placement of plate screws through the intramedullary space (see Figure 2-80). A larger IM pin will

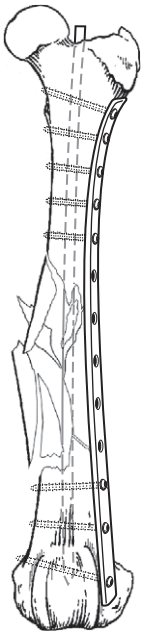


FIGURE 2-80. Plate and intramedullary pin combination for bridging (biological) osteosynthesis. The pin will function during healing to share loading and protect the plate from the bending forces of weight bearing.

make this problem more likely. A pin size that occupies 35% to 40% of the diameter of the medullary space has been proposed to provide adequate stiffness at the fracture site when used with a plate.[101] A pin of this size generally allows adequate space for placement of bicortical screws through the plate. If significant interference with the pin is encountered, unicortical screws may be placed. The pin size can be adjusted for different comminution patterns. A pin size of 50% of the medullary diameter may be chosen for severely comminuted fractures that involve a large proportion of the diaphysis, because this selection will provide greater stiffness. A lesser comminuted fracture may require a pin size of 30% of the diameter of the medullary space. A minimum of three monocortical and one bicortical screw above and below the fracture is recommended for plate/pin combinations.[93] However, sufficient intramedullary space often is present in many bones for several bicortical screws above and below the fracture.

A pin/plate combination allows efficient alignment and fixation of the major fragments of a fracture. Comminuted fractures are seen with great variation in fragment size, number, and spacing. The surgeon applying a pin/plate combination must also carefully assess, radiographically and by gentle inspection, the minor fragments at the fracture site. If significant fracture gaps remain after application of the pin/plate combination, the use of autogenous cancellous bone graft is highly recommended at the fracture site. If a large fragment remains severely displaced and cerclage or other auxiliary fixation is not indicated, a loop of absorbable monofilament suture material around the fragment and bone can be used to gently draw the fragment closer to the fracture site, without disrupting soft tissue attachments. This reduces the size of the fracture gap. If ignored, large fracture gaps, regardless of the stiffness of the fracture fixation system, may contribute to delayed fracture healing.

Pin removal may be completed at 4 to 6 weeks postoperatively, if some destabilization of the fracture is desired. Removal of the pin at an appropriate time will increase strain at the fracture site and contribute to healing. The pin may be maintained for a longer period if protracted healing is expected. Pin removal can be expected to be difficult in some pin/plate combinations because the threads of screws

may be etched into the side of the pin. Forceful extraction of the pin may be required, or the pin may be left in place, as long as it is sufficiently seated within the bone.

Removal of Bone Plates in Small Animals

Indications for Removal

In general, plates are not removed. Previous concerns in human medicine that implants might stimulate bone tumors have been unfounded. However, bone plates should be removed under the following conditions[88,103]:

1. When the plates become nonfunctional (e.g., loose, broken, or bent), they are no longer serving a useful purpose, and some cause discomfort.
2. The plate may be acting as a thermal conductor. A small number of owners have observed that their animals show some favoring of the leg after being outside in cold weather for a time. However, normal function returns after the animal comes back into the house. Lameness has been most frequently noted with plate fixation of the radius and tibia. This is thought to be caused by a difference in expansion and contraction of the plate and bone when subjected to change in temperature, as well as by the thermal mass of the plate chilling adjacent periosteum. Removal of the bone plate, after clinical union, has corrected this temporary lameness.
3. The bone plate may cause bone beneath the plate to become osteoporotic as a result of remodeling associated with vascular interference by the plate on the bone surface. These changes are the result of a local periosteal circulatory disturbance caused by plate-bone contact.[104] We have not seen these changes to be as severe as in human patients, probably because the surface of the dog bone is quite irregular, and plate-bone contact is not close over large areas of the bone. Serious problems can arise from remodeling osteoporosis in the situation in which a rather stiff plate ends in the middiaphyseal region, as with plating of a proximal femoral fracture or plate fixation of a stifle joint arthrodesis. Under these circumstances the end of the plate acts as a stress concentrator, focusing all bending loads that the bone normally distributes over a much larger area. Concentrating these loads where there is a dramatic transition from normal bone to osteoporotic bone can cause pathological fracture.
4. Interference with bone growth may occur in the young animal. Many shaft fractures in young animals can be treated by closed reduction and fixation or simple intramedullary pinning, since they heal rapidly and most axial deformities correct themselves by the active remodeling present during bone growth. Nevertheless, open reduction and internal fixation are indicated when congruent articular surfaces or leg length cannot be obtained and maintained by these means. In our experience, altered bone growth in young animals has not been a problem when bone plates have been removed at the time of clinical union and where the plate does not cross a growth plate.
5. The plate may cause irritation. Occasionally, an implant just beneath the skin gives rise to a lesion characteristic of a lick granuloma. Plate removal after clinical union has cleared up the condition. Late lameness is occasionally seen 1 or more years after plate fixation. Radiographic signs of implant loosening (bone resorption around screws, evidenced by a black halo) or infection are absent. Plate removal causes the lameness to disappear, but the reason is unclear.

6. Infection may occur. If infection is present, it is difficult to clear it up totally until the plate is removed. As a rule, if the plate is not loose, it is left in place as long as immobilization is indicated. When clinical union is achieved, the plate is removed, and the infection usually clears up with appropriate treatment (see Chapter 5). Plate removal in these circumstances is also indicated because most fracture-associated sarcomas in animals have a history of a metallic implant, infection, and a disturbed fracture-healing pattern.[105]
7. The plate may also impede full functional performance in field and racing animals, for reasons that are not entirely clear. This situation may be similar to the late lameness described in condition 5.

Suggested Policy in Regard to Plate Removal

1. Leave all pelvic plates in place unless specific complications indicate removal. Relatively small plates are used, and to date, no evidence of stress protection has been noted.
2. Leave plates in place in skeletally mature animals that have undergone uncomplicated healing. Those that have experienced complications, such as infection, delayed union, or nonunion, probably should have plates removed.
3. In skeletally immature animals, remove all plates on the long bones at the time of clinical union.
4. Ideally, it is best to remove all plates on long bones, although the economic realities of veterinary practice make this difficult to accomplish. Call the owner's attention to the potential reasons for removal at discharge, and give an approximate time for recheck and plate removal. Needless to say, it is difficult to have an animal return for plate removal when all appears well. If complications occur after clinical union, it is best to have talked to the owner about recheck and plate removal. Stress protection problems and implant-stimulated osteosarcoma occur only rarely in small animals.

Suggested Timing of Plate Removal

Data were collected covering patient age and plate removal time in more than 300 cases[103] and are collated in Table 2-5, which suggests timing of bone plate removal. The time until removal may need to be increased in more complex cases or problem cases.

Surgical Removal of Implant

Radiographs should be taken before and after plate removal. This will add to the clinician's knowledge of bone healing and radiographic interpretation and will help to avoid repeating surgical errors. The procedure is performed as follows:

1. A standard approach is made to the bone involved.
2. The cicatrix encasing the plate is opened over its entire length.

TABLE 2-5. REMOVAL OF BONE PLATES

Age	Postoperative Time for Plate Removal
Under 3 months	4 weeks
3-6 months	2-3 months
6-12 months	3-5 months
Over 1 year	5-14 months

3. In some animals a portion of the plate will be covered with a layer of bone. An osteotome is usually required for its removal over the surface of the plate. Bone filling empty screw holes will usually fracture if the plate can be levered away from the bone.
4. After bone plate removal, active hemorrhage (which is usually minimal) is controlled, the wound is closed in layers, and a pressure dressing is applied. Cerclage wires and lag screws are routinely left in place unless they are associated with infection or other abnormal healing.

Refracture

Refracture is a fracture of normal bone occurring in the region of a previous fracture that appears to have undergone sound union both clinically and radiographically.[88,96,103,105,106] An incidence of less than 1% has been encountered in our fracture cases. Most refractures result from premature implant removal, poor anatomical reduction, or osteoporotic bone. Refractures can be kept very minimal if the basic fundamentals of applying and removing implants are followed, with particular emphasis on anatomical reduction, proper implant size, and bone grafting of architectural defects.

Plate removal from the radius of toy and miniature dogs is somewhat worrisome because of the delicate nature of this bone and the tendency for these breeds to jump off of furniture. The holes left after screw removal may be large enough relative to the bone to weaken it. Autogenous cancellous bone grafting of the screw holes is one way to hasten return of normal bone strength. The limb can also be lightly splinted for 3 weeks, with provisions to leave the foot exposed to allow active weight bearing while protecting the bone from excessive bending loads.

Postoperative Care after Plate Removal

The appearance of the radiographs and the activity of the patient are usually the determining factors in postoperative care. Treatment usually involves the following:

1. Application of a compression bandage over the operative area for 2 to 3 days to help prevent possible hematoma or seroma formation.
2. Supportive measures (e.g., coaptation splint, external fixator, IM pin) if bone healing on the radiograph after plate removal appears to be less than adequate, or if the bone appears to be extremely osteoporotic under the plate. If the thickness or density of the bone in the fracture area is greatly altered, bone grafting may be indicated.
3. Restriction of activity for 1 to 4 weeks. This may range from confinement to the kennel or house, walking on a leash, or restricting play.

SELECTION OF FIXATION METHOD

Fracture Treatment Planning

Decision making regarding an appropriate method of treatment for a specific fracture in a specific patient can be either straightforward or very difficult, depending on many factors. As in many other areas of veterinary practice, the decision is partly science and partly art. One cannot simply look through the following chapters to find a fracture that looks like the one under consideration and then blindly copy the

method of fixation depicted. To do so ignores the fact that the fracture is attached to an animal that is part of a milieu composed not only of its fracture but also other injuries, body weight, general health, physical environment, animal disposition, economic constraints, owner's care, and the owner's expectations for the long-term function of the animal.

Most often, it is with diaphyseal/metaphyseal fractures that we must make choices between several possible methods of fracture fixation. As discussed earlier, there is little choice of fixation method for treating intraarticular fractures, whereas many possibilities seem to exist for treatment of shaft fractures. Furthermore, the basic indications for many of these methods overlap considerably, leading to varying degrees of uncertainty about the best choice. Regarding the overlap of indications, we must remember that many roads may lead to the same point and that there probably is no single way to treat a given shaft fracture. There is nothing wrong with choosing a particular approach to a specific situation as long as the decision is rationally based and good results are obtained.

Factors to consider in choosing a fixation method cover a wide gamut. The answers to many of these questions are self-evident, but some will require considerable probing before the repair is attempted. The *type of bone* involved determines the healing pattern and relative stability needed for healing. Cortical bone is the most demanding of stability and is represented by fractures of the shaft of long bones, the mandible, the tuber calcis, and the olecranon. In corticocancellous bone, as in flat bones and metaphyseal bone, stability is less critical.

Location of fracture in the bone determines the forces acting on the fracture and fixation device. In the shaft the primary forces are bending and shear (rotation and shortening). The femur is the most highly loaded bone during weight bearing. In the metaphysis the primary loads are bending and shear. This is also the area of insertions of ligaments/tendons, and these create their own shear and tension forces. Articular fractures are usually subjected primarily to shear and tension. Location of the fractures also determines the potential suitability of various classes of fixation. Coaptation is only suitable for long-bone fractures distal to the elbow/stifle, fractures of the scapular body, and some fractures of the metacarpal/metatarsal bones. Internal fixation is the best choice for all other fractures.

The *type of fracture* is critical in determining fixation methods, because many methods are very limited in their ability to neutralize forces acting on the fracture fragments (see later discussion in this section).

Concurrent injuries of either the musculoskeletal system or soft tissues may dictate more rigid forms of internal fixation to achieve early ambulation of the patient and thereby ease the problem of postoperative care for the animal. Open and infected fractures need early stabilization with rigid internal fixation.

Age of the patient determines stability and the length of time that fixation may be needed to achieve healing. Skeletally immature animals produce abundant and early periosteal/endosteal callus, which means early stability. Aged animals typically produce minimal periosteal/endosteal callus, and clinical union is slower. Therefore, types of fixation that do not achieve long-lasting stability (IM pins, casts) may become unstable before clinical union is achieved.

Size, *breed*, *and temperament* are secondary factors in fixation choice, in the sense that exactly the same basic principles will govern the choice, but the surgeon should always favor the most stable of the range of choices when dealing with a large, active, or excitable animal. Likewise, when considering the fracture type, the surgeon should score it conservatively in these animals.

The *degree of function* needed is also important in choosing a fixation method. The activity levels of patients vary considerably. Consider the functional demands on the bone in the large, working or sporting breed versus the small, sedentary pet. Likewise, the owner's expectations of function are critical. We would be more likely to use a very stable form of fixation when a high level of function is mandatory.

The animal's *environment* and its *expected control* by the owner may influence the choice of fixation. An external fixator may not be a good choice for an animal kept on a chain in the yard or for an owner who will not follow instructions for care and rechecks faithfully. Inquire carefully into the housing conditions of the animal and the owner's attitudes *before*, not after, the repair.

Equipment available and experience level of the surgeon must be considered, and surgeons must be scrupulous in their self-evaluation. When possible, a timely referral may be in order to ensure the best outcome for the patient and owner.

Economic constraints are a fact of life that must be faced in veterinary medicine and may tend to override other concerns. This must be handled on a case-by-case basis, but we must not be forced into doing a procedure that we know will fail simply because it is what the client can afford. It is a commonly held opinion that external casts and splints are less expensive to apply than internal fixation. Although this may be true in some cases, it is not uniformly so. If we rigorously evaluate costs of coaptation in terms of cost of materials, time involved in not only application but also rechecks and replacement, and most importantly in results achieved, we will often see that simple forms of internal fixation are very competitive with coaptation.

Choice of Fixation

An elegant method of compiling many of the considerations just discussed has been devised by Palmer and colleagues.[107,108] (Table 2-6). The routine use of this or a similar method of evaluation will force the surgeon to consider the "mechanical, biological, and clinical variables affecting fracture healing and return to function in

TABLE 2-6. FRACTURE PATIENT SCORING SYSTEM*

Score	1	2	3	4	5	6	7	8	9
MECHANICAL FACTORS									
Non–load sharing	Neutralization possible				Good load sharing				
Large, obese patient	Medium patient				Small patient				
Multiple limb injury/disease					Single-limb injury				
BIOLOGICAL FACTORS									
Local Factors									
High-energy fracture: wedges	Two-piece fracture				Low-energy fracture: greenstick				
Long open reduction					Short open reduction; closed reduction				
Open fracture—degree 3	2				1				
Gunshot fracture—grade 3	2				1				
Systemic Factors									
Geriatric	Mature				Immature				
Debilitated/ill					Healthy				

*Data from Palmer RH: Decision making in fracture treatment: the Fracture Patient Scoring System. In *Proceedings of (Small Animal) ACVS Veterinary Symposium*, Washington, DC, 1994, pp 388-390; and Palmer RH, Hulse DA, Aron DN: A proposed fracture patient score system used to develop fracture treatment plans. In *Proceedings of 20th Annual Conference of Veterinary Orthopedic Society*, 1993.

a given patient."[107] Each line should be scored if applicable and the results totaled and divided by the number of scorable factors to obtain an average. With practice the clinician will be able to assess the score mentally without the arithmetic, but the exercise will force consideration of all the factors listed. This type of evaluation is of value primarily in diaphyseal fractures, where many fixation methods might be considered. It is of less use in most other fractures, where the choices of fixation are much more pragmatic because of anatomical and mechanical considerations; the best examples involve articular fractures, where the fixation method for a specific fracture will not vary much from patient to patient.

Scores from Table 2-6 can be correlated with fixation methods as follows:

- Score 9 or 10

Fracture—transverse or short oblique; type A:

1. Cast/splint
2. IM pins in many, but not all cases; may be combined with interfragmentary wires.
3. Compression plate
4. External fixator, type IA
5. Interlocking nail

- Score 8 (7) to 9

Fracture—long oblique or spiral; type A and B1 one reducible wedge:

1. IM pins/cerclage-hemicerclage wires
2. Neutralization plate
3. External fixator, type I, II (may be combined with cerclage wires/lag screws)
4. Interlocking nail (may be combined with cerclage wires/lag screws)

- Score 4 (3) to 7

Fracture—wedge; type B:

1. Neutralization plate
2. External fixator, type IA double bar or IB, II (may be combined with cerclage wires/lag screws)
3. Interlocking nail (may be combined with cerclage wires/lag screws)

- Score 1 to 3

Fracture—complex; type C:

1. Buttress/bridging plate, or plate and IM pin combination
2. External fixator, type II or III
3. Interlocking nail

OPEN FRACTURES

Open fractures usually occur in about 5% to 10% of the total fracture cases seen. The term "compound fracture" is obsolete in North America but is still widely used in other areas. An open wound overlying a fracture almost always means (1) contamination, (2) reduction in local host defense mechanism by the presence of foreign material and debris, (3) devitalized necrotic tissue, and (4) dead space. All these factors increase the potential for infection in the open wound, and prevention of such infection is the overriding concern in animals with these injuries. Aggressive *early internal fixation* of the fracture is key to controlling infection.

Classification

Degree I. The skin is penetrated from the inside by a sharp bone fragment, which then usually retracts under the skin and is no longer visible. The wound

typically is less than 1 cm in diameter, and surrounding tissues are only mildly contused.

Degree II. Wounding of the skin occurs from the outside, leaving a variably sized soft tissue deficit and more severe contusion of surrounding tissues (Figure 2-81, *A*). Foreign material may be carried into the wound at the time of injury or later.

Degree III. Extensive skin, subcutaneous tissue, and muscle injury from the outside is present, and the bone is usually fragmented as a result of high-energy injury (Figure 2-81, *B* and *C*). There is often soft tissue avulsion, degloving, and neurovascular injury. High-velocity bullet wounds and traumatic partial amputations are common examples.

Prognosis for first- and second-degree open fractures differs little from similar closed fractures, but third-degree injuries carry a less favorable outlook. Treatment of these injuries is both extensive and expensive, but if aggressively managed, these approaches represent an acceptable risk for most owners, since amputation is often the only alternative.

Treatment

Principles

The following principles apply to the treatment of open fractures[88,109,110]:

1. Prevention or minimization of contamination from time of occurrence of injury until initiation of surgical treatment.

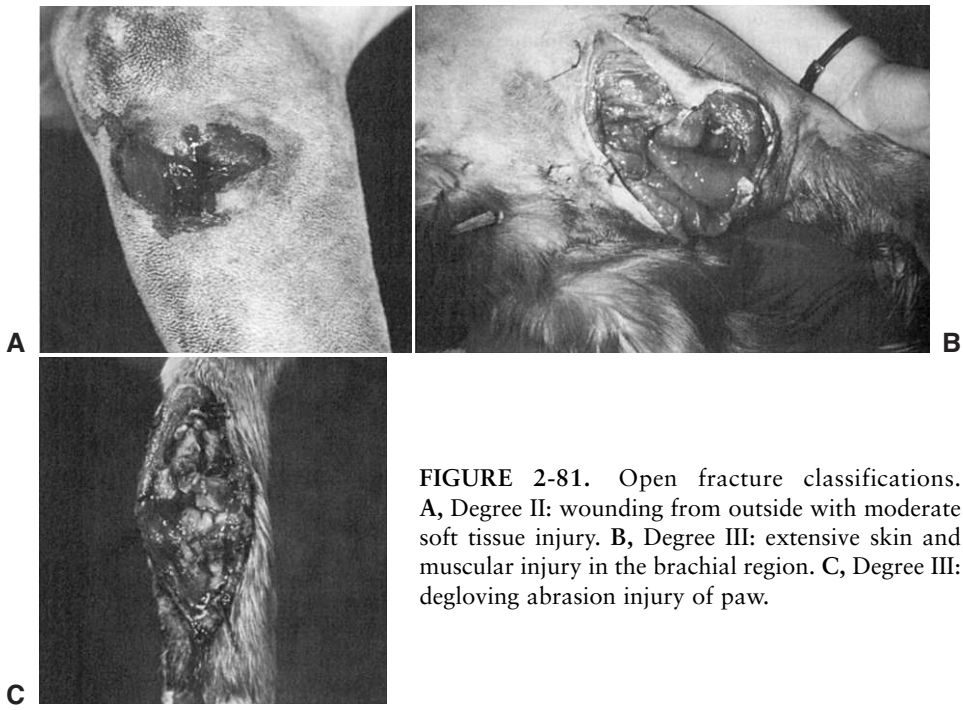


FIGURE 2-81. Open fracture classifications. **A,** Degree II: wounding from outside with moderate soft tissue injury. **B,** Degree III: extensive skin and muscular injury in the brachial region. **C,** Degree III: degloving abrasion injury of paw.

2. Thorough cleansing and aseptic surgical debridement to remove nonviable and devitalized tissue.
3. Preservation of vascularity to both soft tissue and bone.
4. Stable fixation.
5. Early active mobilization of the limb.

Emergency Treatment

First aid by the owner should be directed toward stopping hemorrhage and preventing contamination. Covering the area with a clean bandage applied with minimal pressure usually accomplishes this objective. An open fracture is always considered an emergency and is treated as such. At the hospital the open fracture should be covered immediately with a large sterile dressing, which should remain until debridement is possible. A soft splint is useful in the distal limbs.

After and during thorough physical and orthopedic examination to expose and evaluate concurrent injuries, particular attention is given to the cardiovascular system regarding perfusion and circulating red blood cell volume. The animal is stabilized as necessary with fluids and other supportive therapy. A good general rule is to take chest radiographs of all fracture patients as soon as their general condition permits. A thorough physical and radiographic orthopedic examination is essential for diagnosis, prognosis, and determination of the type of fracture treatment.

It may be necessary to clip hair to appreciate the presence of a first-degree injury. Cultures should be taken from the wound at this time for sensitivity testing. Systemic antibiotics (usually a cephalosporin) should be started immediately. Staphylococci account for 60% of the infections at our hospitals, with most of the remaining infections equally divided between *Streptococcus* and *Escherichia coli. Pseudomonas, Proteus,* and *Klebsiella* are found rarely. For many first-degree injuries, clipping of hair, cleansing the wound, and bandaging are all that is necessary before fracture stabilization. For second- and third-degree injuries, adequate surgical debridement and primary fracture fixation are urgent and are done as soon as the animal will tolerate general or regional anesthesia.

Definitive Surgical Treatment

Cleansing and Debridement

Utmost care in aseptic technique is indicated because most strains of bacteria found in wounds are indigenous to the hospital in which treatment was performed rather than to the scene of the accident. Cleansing and debridement are carried out under general anesthesia. Caps, masks, and gloves should be worn to clip and wash the area. The open area is covered with sterile lubricating jelly, and the surrounding surgical area is clipped and surgically scrubbed. Loose hair from the clippers will be trapped in the jelly and rinsed away. Debridement should be done in the operating room or a clean area using aseptic technique. Careful removal of obviously dead tissue and foreign material is aided by copious lavage with saline or Ringer's solution. Addition of chlorhexidine to make a 0.5% solution, or 100 ml of 10% povidone-iodine solution (or whirlpool concentrate) per liter of irrigating fluid, is advocated by some for added disinfection. If the wound must be enlarged to allow for adequate debridement, some thought must be given to blood supply, since additional compromise could predispose to infection.

Debridement must be meticulous to remove all devitalized tissue and not damage vessels and nerves. Very large wounds present difficulties in this regard and need to

be left open to allow progressive debridement over several days. It is best initially to be conservative in evaluating skin viability because skin is easily removed in later sessions if it does not survive. Nonviable muscle is a good culture medium, and its recognition is difficult; loss of contractility, lack of bleeding when cut, and pale color are the most useful criteria. Cortical bone fragments stripped of their soft tissue attachments are removed unless they are part of a joint surface or essential for stabilization of the fracture. Resulting bony defects are filled with autogenous cancellous bone graft. Large devascularized cortical fragments left in situ may become sequestra and require removal if the wound becomes infected.

The importance of removal of all dead or devitalized material in the prevention of deep-seated wound infection cannot be overemphasized.

Fracture Fixation

Stabilization of the fracture must be addressed following debridement. It is critical to success to do the fracture fixation at this point because stabilizing the fracture also stabilizes soft tissues, preserving existing blood supply and allowing capillary invasion to establish new blood supply. Thus, stabilizing the fracture is the best defense against infection of both the bone and the soft tissues. Open reduction can be performed through the wound, if it is correctly placed, or through a separate incision. Consideration must be given to a second incision's effect on skin blood supply.

First-degree injuries are treated as closed fractures. Second-degree injuries require different initial care, but stabilization and poststabilization care is similar to closed fracture treatment. Stabilization of third-degree injuries is primarily done with external skeletal fixation, although the interlocking nail may prove to be an important method. The following types of fixation may be used; each has its indications and limitations.

1. Splints and casts are usually reserved for animals with minor puncture wounds; those treated within the first 6 to 8 hours; and those with stable fractures of the distal half of the radius and ulna, carpus, tarsus, and foot.
2. Internal fixation involves the following methods:
   a. Intramedullary pins are usually restricted to stable, first-degree fractures treated within 6 to 8 hours. Secondary fixation (e.g., external fixator) may be added for more stability.
   b. Bone screws and plates have the advantage of stable uninterrupted fixation; however, an extensive open approach is required for application. They are particularly applicable when the fracture involves an articular surface, as well as on the femur of dogs, where postoperative limb function is not optimal with the external fixator.
   c. Interlocking nails may be applied through a minimal open approach and provide stable fixation, but they are less likely to be used for the highly comminuted fractures.
   d. External skeletal fixation has the advantage of minimal application time, and the fixation pins can usually be applied proximal and distal to the fracture and skin wound area, leaving the traumatized area freely accessible for treatment as an open wound. This type of fixation is particularly adaptable to infected fractures, gunshot fractures, and the more severely traumatized cases. Because of its ease of application on

the tibia and radius/ulna, external fixation is the first choice for open fractures of these bones.

Whatever type of fixation is used should remain in place until clinical union is achieved, as long as it is secure and accomplishing stabilization of the fracture segments. Healing is routinely delayed in third-degree fractures, and fixation should be chosen with this in mind. Loose implants should be replaced if clinical union has not been achieved.

Bone Grafting

Bone grafting is usually indicated in open fracture cases when bone is missing and in some of the more severely fragmented fractures (see Chapter 3). Autogenous cancellous grafts can be used at surgery, after debridement, reduction, and fixation. If the graft cannot be covered with soft tissue, it is usually covered with petrolatum-impregnated gauze. If infection, suppuration, and questionable vascularity are present, however, it is usually advisable to delay grafting until suppuration has ceased and healthy granulation tissue is present. The granulation tissue is elevated and the graft packed into the bony deficit.

Cortical grafts should not be used in an infected area because they are slow to become vascularized and usually become sequestered. If a cortical graft is indicated, the procedure should be delayed until the infection has cleared.

Wound Closure

Closure of the wound should only be considered in first- and second-degree injuries in which the minimal soft tissue injury can be adequately debrided and the skin closed without tension. It is important to cover vessels, nerves, and tendons, but bone can be left exposed if necessary, as can bone plates. Transposition of muscle bellies often allows soft tissue coverage of vital structures when skin is not available. Theoretically, contaminated wounds do not become infected for 6 to 8 hours—the "golden period"—and can be successfully closed after debridement without the need for drainage. However, some wounds are so heavily contaminated or devitalized that the golden period is considerably shortened. *When in doubt, leave the wound open,* which is more successful than surgical placement of drains in our experience. If no suppuration develops, delayed primary closure can be done in 4 to 5 days. If there is suppuration, secondary closure can be done after healthy granulation is established, or the wound can be left to heal by second intention.

Aftercare

Systemic antibiotics are continued several days postoperatively, or as long as there is suppuration, and may be changed to suit the sensitivity report. Open wounds are kept under sterile dressings, with saline-soaked sterile natural gauze sponges packed into the wound. Dressings are changed daily until secretion and suppuration slows, then as needed. Once granulation has become well established, the frequency of bandage changes can be reduced. Keeping the wound covered during the epithelialization period will keep the tissue moist and prevent overgrowth of granulation tissue. (See Chapter 5 for further details regarding infected fractures.)

Early active, but limited, use of the limb stimulates both soft tissue and bony repair. Radiographic evaluation of bone healing is done at monthly intervals until healing is obvious. External fixator removal can often be staged to allow a more gradual return to normal stress patterns in the bone.

Case Studies

Case 1

Figure 2-82, *A,* shows a grade 2, open, type B wedge fracture in a 1-year-old, 55-pound dog that was struck by a car bumper. The open area was covered with a clean bandage immediately and presented for treatment within 8 hours. Fixation was performed using an IM pin and a two-pin, type I external fixator (Figure 2-82, *B*). The wound was treated as an open lesion with nitrofurazone dressings. The skin lesion closed within 2 weeks (Figure 2-82, C). The external fixator was removed in 1 month, and the IM pin was removed at clinical union (2 months).

Case 2

Figure 2-83, *A,* shows a grade 2, open, type C complex gunshot fracture, in a 2-year-old, 60-pound dog. Fixation was done using a bone plate (Figure 2-83, *B*). The fracture healed; however, minor fistulous tracts opened up intermittently during the healing period (Figure 2-83, C). These cleared up promptly after removal of the bone plate and a sequestrum 11 months after injury. The defect in the shaft was the sequestrum site (Figure 2-83, *D*).

Case 3

Figure 2-84, *A,* depicts a grade 3, open, infected, type B wedge fracture in an 8-month-old, 15-pound dog 6 days after trauma. The end of the distal segment was still protruding from the skin; the dog's temperature was 105° F. A type I external fixator was applied (Figure 2-84, *B*), and the local area was treated with numerous nitrofurazone dressings. The animal was started on a systemic antibiotic regimen. The local and systemic infection cleared, and healing was delayed, although without sequestrum formation (Figure 2-84, *C* and *D*). The fixator was removed at 4 months.



A **B** **C**

FIGURE 2-82. **A,** Grade 2 open comminuted fracture that resulted when a 55-pound, 1-year-old dog was struck by a car bumper. Open area was covered with a clean bandage immediately, and the dog was presented for treatment within 8 hours. **B,** Fixation using an intramedullary (IM) pin and unilateral external fixator, 1/1 pin. **C,** IM pin shown at time of clinical union (7 weeks). The external fixator was removed at 4 weeks and the IM pin at 7 weeks.

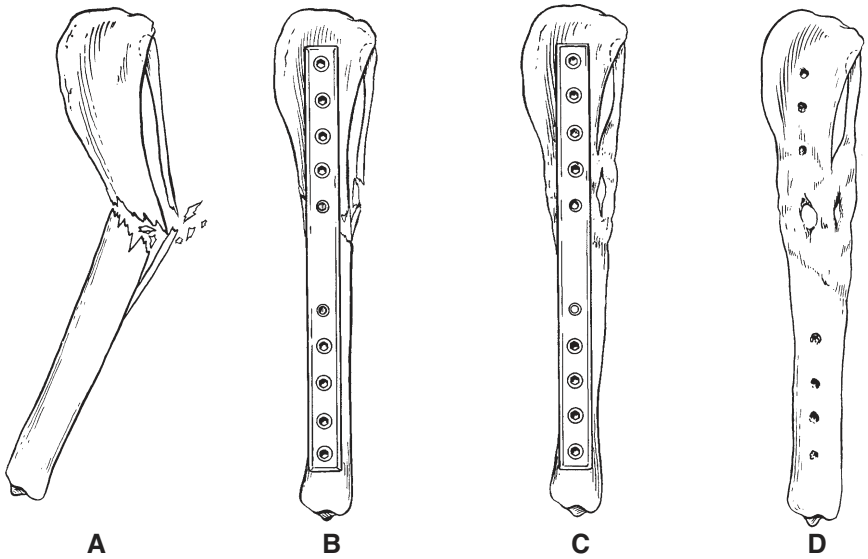


FIGURE 2-83. **A,** Grade 2 open gunshot fracture in a 60-pound dog. **B,** Fixation using a bone plate. **C,** Fracture had healed (11 months after injury); however, intermittent minor draining tracts were still present. **D,** After removal of the plate and sequestra, the draining tracts disappeared. The defect in the diaphysis was the site of sequestra. In retrospect, a better choice of stabilization would have been a unilateral external fixator.

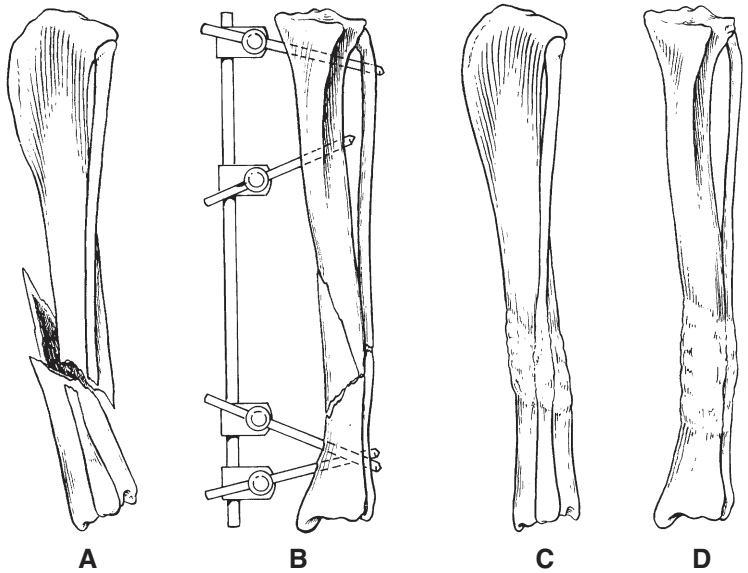


FIGURE 2-84. **A,** Grade 3 open infected fracture, 6 days after trauma, in a 15-pound dog 8 months of age. End of distal segment still protruding from skin, temperature 105° F. **B,** Unilateral external fixator was applied. **C** and **D,** Local and systemic infection cleared; healing was delayed, although without sequestrum formation. Splint was removed at 4 months.

GUNSHOT FRACTURES

Gunshot fractures of the limbs cause multisystem wounding that can lead to massive destruction of soft and hard tissues and result in complicated and delayed healing of both. With judicious treatment, the success and complication rates are very acceptable for the less complicated fractures, whereas more guarded prognoses are indicated for the most difficult fractures.[111] Although the treatment of gunshot fractures shares much with that of open fractures, it is important to have knowledge of the type of wounding missile, specifically, the ballistics of the bullet or pellet. No knowledge of firearms is necessary, and the information needed is gained from physical examination of the wound and examination of the radiographs.

Pathophysiology

When tissues are struck by a missile, whether a bullet or an automobile bumper, the kinetic energy of the wounding object is converted into work on the tissues and results in plastic and elastic strain (deformation) and dissipative energy in the form of heat. This kinetic energy is described by the formula $KE = MV^2/2$. Because the energy developed is greatly influenced by the velocity raised to the second power, most attention has been devoted to the muzzle velocity of the bullet. Although it is true that when the bullet weight is constant, raising the velocity is a good way to increase the wounding energy available, it is also true that sheer mass can have a significant effect.[112] Table 2-7 illustrates that the kinetic energy of the 30-06 Springfield bullet (common hunting rifle) is almost double that of the M16 (current military weapon), although the square of its muzzle velocity is only 72% of the M16. The kinetic energy of the small bullet of the M16 is highly dependent on its high muzzle velocity, whereas the bullet of the 30-06 has sufficient mass to be a significant contributor to the wounding energy. The effect of mass is most dramatically illustrated by the shotgun: as seen in Table 2-7, the 12-gauge shotgun has a muzzle velocity of only 1300 ft/sec, but because of the tremendous mass of the pellets (700 grains) the kinetic energy available is 2700 foot-pounds. Although this amount of energy is only available in short-range situations, where the pellets are still tightly enough grouped to act as a single missile, the shotgun does have a tremendous wounding potential. The terms *high energy* and *low energy* are used here in place of the commonly used "high velocity" and "low velocity" descriptors.

The location of gunshot injuries of the dog varies with the environment in which the pet lives. In metropolitan settings, the dog is typically an apartment dweller who confronts an intruder. In these cases, head wounds with mandibular and maxillary fractures are common, almost always caused by handguns at short range. In suburban and rural settings, wounds are more often inflicted by hunting rifles at longer range, and the location of fractures is much more random. It is interesting to note the relatively high incidence of humeral fractures, probably because the heart/chest is a common aiming point. Fortunately, the incidence of short-range shotgun

TABLE 2-7. KINETIC ENERGY OF COMMON BULLETS AND SHOTGUN SHELLS

Type Cartridge/Shell	Weight Bullet/Shell (grains)	Muzzle Velocity (feet/sec)	Kinetic Energy (foot-pounds)
12-gauge, 3-inch magnum	701	1315	2726
M16 (AR-15)	55	3250	1290
30-06 Springfield	150	2750	2519

injuries is low. Long-range shotgun injuries are usually confined to shallow wounding by a few pellets.

A classification system to characterize the various types of gunshot fractures is helpful in developing a treatment protocol. Such a scheme is described in Table 2-8. *Low-energy type 1 fractures* produce predictable penetrating wounds of the soft tissues, and there is often no exit wound (Figure 2-85, *A*). Soft tissues are disrupted along the path of the missile, and fracture patterns are simple. The severity of bone damage varies with the location of the bone; much more of the initial energy of the bullet is already expended by the time the bullet strikes the midshaft of the femur as compared with the tibia, so tibial fractures typically are more complicated. Most of the bullet fragments remain in situ and are usually quite large, although some smaller, dustlike fragments are present.

High-energy type 3 fractures are much more complicated, with both an entry and an exit wound present (Figure 2-85, *C*). The exit wound is often not on line with the entry wound if the bullet ricochets off a bone. As the bullet's energy is transferred to the soft tissues, they expand around the missile, creating a temporary cavity that then immediately collapses. Hydrostatic shock waves are created that injure tissues within a radius as much as 30 times the diameter of the bullet.[111] Bone is shattered into small pieces, and the bullet is reduced to myriad dustlike fragments; most of the bullet probably continues through the exit wound, where it can produce a secondary injury in adjacent tissues. Extensive devascularization of bone is produced not only by fragmentation but also by soft tissue detachment and thrombosis of canaliculi in cortical bone. The exact type of bone injury varies with the location of the impact and the type of bone (cortical vs. metaphyseal) involved.

Type 2 fractures exhibit characteristics of both types 1 and 3, depending on the specific wounding missile (Figure 2-85, *B*). These wounds are generally produced by low- to medium-velocity bullets that are relatively heavy; the lead fragments seen radiographically are a combination of the large type 1 fragments and the dustlike type 3 fragments. Similarly, the fracture patterns are more fragmented than in type 1 fractures, but the fragmentation is neither as severe nor as extensive as with the type 3 injuries.

Surgical Protocol[111]

Initial Evaluation and Wound Treatment

Treatment of gunshot fractures is basically the treatment of type 2 and 3 open fractures. All are considered contaminated, and type 3 injuries have the greatest potential for infection to become established. Antibiotic therapy should be started immediately after culturing the wound for antibiotic sensitivity testing. After stabilization of the patient, as indicated by clinical signs, and performing a complete physical and neurological examination, definitive fracture treatment can be considered. Radiographic examination, preferably under general anesthesia, is necessary to establish the exact fracture type and plan further treatment.

TABLE 2-8. CLASSIFICATION OF GUNSHOT FRACTURES

	Kinetic Energy	Fracture Type	Soft Tissue Injury
Type 1	Low	A, few B	Minimal
Type 2	Medium	A, B, few C	Moderate
Type 3	High	C	Extensive

Modified from Schwach RP, Park RD, et al: *Vet Surg* 8:57-62, 1979.



FIGURE 2-85. Gunshot fracture classification. **A,** Type 1, low energy. **B,** Type 2, intermediate energy. **C,** Type 3, high energy.

Wounds are cleansed and debrided as described earlier for open fractures. Extensive debridement is not needed in type 1 and 2 injuries, but type 3 injuries require more attention to removing dead tissue, especially muscle that is completely devitalized (see previous debridement guidelines). Short-range shotgun wounds result in massive soft tissue injuries and require extensive debridement. Hair, small detached bone fragments, and lead fragments that are readily accessible are all removed. It is not strictly necessary to remove lead fragments, so extensive probing and dissection is to be avoided; however, intraarticular lead should always

be removed. Leave all bone fragments with soft tissue attachments and all large fragments regardless of soft tissue integrity. As with open fractures, be cautious about primary closure of the wounds; it is much safer to allow open drainage until a determination can be made about the presence of infection. Delayed primary closure or healing by granulation is always preferable to wound disruption caused by exudation.

Fracture Fixation

As with open fractures, immediate stabilization of the gunshot fracture is helpful in treating the soft tissues. Except for a few type 1 fractures of the radius/ulna and the tibia, the remaining gunshot fractures require internal fixation.

Type 1 and 2 Fractures

Treatment is similar to closed fractures of type A, B, or C. Either an anatomical reconstruction with stable internal fixation or a biological osteosynthesis approach may be taken with these fractures.

Type 3 Fractures

Because of the extensive bone devascularization involved in these complex type C fractures, very delayed healing is to be expected. The fixation must therefore be capable of long-lasting stability, and because of the fragmentation, the fixation must be capable of acting as a bridging or buttress device. The choices are thus limited to bone plates, interlocking IM nails, or external fixators. Experience has shown that the bridging osteosynthesis approach is preferable in these fractures; they are reduced either closed or with a minimal open approach. No attempt is made to reduce fragments; rather, the emphasis is on restoring axial and rotational alignment and maintaining as much length as possible. To attempt extensive manipulation and stabilization of small fragments not only further devascularizes them, but also rarely results in adequate stabilization. The severe nature of the wounding process is actually helpful in establishing the cascade of humoral and local factors needed for early callus formation, and to the extent that the area is invaded and further disturbed, we can slow this healing reaction.

These criteria for reduction and fixation are ideally met *in the dog* by the external fixator for fractures of the humerus, radius/ulna, and tibia (see the section on external skeletal fixation for the splint types appropriate to these bones). Because dogs often do not function well with external fixators on the femur, the interlocking IM nail, bone plate, or bone plate/IM pin combination may be a better choice for this bone. As previously stated, the goal is restoration of axial and rotational alignment and maintaining length to the extent possible. In placing the bridging plate, the emphasis is on simply attaching it proximally and distally, with minimal disturbance of the fracture site and fragments. This is facilitated by contouring the plate from a radiograph of the contralateral bone. Likewise, with placement of the interlocking nail, the open approach is only sufficient to allow guiding the nail across the fracture area into the distal fragment. The availability of cinefluoroscopy would eliminate the need for any open approach, as is common in human applications.

If bone plates or interlocking nails are not available, there should be no hesitation to use the external fixator on canine femoral fractures, but there is a tendency to delayed bone healing and soft tissue tie-down problems in the stifle joint. Aggressive physiotherapy during the healing period may minimize these problems. *Cats* do not exhibit the tendency toward poor limb function with the external fixator applied to the femur, so it can be readily used on all bones in this species.

Healing Time and Prognosis

Type 1 and 2 fractures generally heal similar to closed fractures of the same type, that is, between 6 and 10 weeks. Type 3 fractures routinely exhibit delayed healing times of 12 to 20 weeks. Progressive destabilization of external fixators starting at 8 weeks is helpful in producing more vigorous callus formation. Schwach and colleagues[111] reported overall prognosis as good to excellent for type 1 fractures, fair to good for type 2 fractures, and fair to poor for type 3 fractures. The prognosis for type 2 and 3 fractures has certainly improved since this report because of the increased sophistication of external fixator applications, but we have no firm figures available.

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3

Bone Grafting

Bone grafting was introduced into general surgical practice early in the twentieth century, and the principles of grafting have been well established for more than 75 years.[1] *Banked bone* (frozen, freeze-dried, and irradiated) came into general use in the late 1940s.[2] Infection associated with bone grafting in animals has been minimal when aseptic procedures have been used and when the bone has not been introduced into a contaminated, infected, or unstable area. We have not encountered outright rejection by the body or bone sequestrum formation when autogenous or frozen allografts are used, although bone does have an antigenic potential.[3] Freezing decreases the antigenic stimulation of the graft. Introduced bone undergoes varying degrees of osteoconduction (creeping substitution) and is completely or partially replaced by host bone.

INDICATIONS FOR GRAFTING

Bone grafting is recommended in the following circumstances:

1. To enhance healing in delayed unions, nonunions, osteotomies, and arthrodeses of joints by stimulating early formation of bridging callus
2. To bridge major defects in multifragmentary fractures by establishing continuity of bone segments and filling cortical defects, thereby stimulating and enhancing early formation of bridging callus
3. To replace entire cortical segments lost from fracture fragmentation or from excision caused by neoplasia
4. To fill cavities or partial-thickness defects resulting from excision of cysts or neoplasms

CHARACTERISTICS OF BONE GRAFTS

Sources and Terminology

Grafts originate from the following three sources:

1. *Autograft* or *autogenous graft*—from the same animal. Autografts have maximal osteogenetic potential and earliest response, but their collection increases operative time and risk, and the bone available may be insufficient in quantity, shape, and size or may be mechanically unsuitable.

2. *Allograft*—from the same species. Formerly known as "homografts," these grafts are collected from donor animals and either used fresh or held in a bone bank (freezer) for future use. Experimentally and clinically, an allograft has about the same enhancing effect as autogenous bone; however, no direct osteogenesis occurs, and there is an initial delay in response of about 2 weeks compared with the response of an autograft. Availability in sufficient quantity, shape, and size is the main advantage. Additionally, allografts are the only feasible source for large cortical grafts.
3. *Xenograft*—from a different species. This graft has the least osteogenetic potential and is most likely to cause a foreign body reaction. There is little clinical application for this type of graft. The term "heterograft" is obsolete.

Structure

Grafts may be either *cancellous, cortical,* or a combination of both—*corticocancellous.* Cancellous grafts are usually collected from the host's metaphyseal bone and used as fresh autografts. Cortical grafts are most often used as frozen allografts. Corticocancellous grafts can be either fresh autografts or fresh or frozen allografts and are usually collected from the ribs or dorsal iliac crests.

FUNCTIONS OF BONE GRAFTS

Bone grafts serve as a source of osteogenesis and may also serve as a mechanical support.[2,3] Rapid formation of bridging callus is important when fracture fragmentation creates a situation in which the bone cannot assume any weight sharing with the implant. Under these circumstances, callus can stabilize the fracture sufficiently to relieve the implant of some of these forces and thus minimize chances of premature failure or loosening of the implant. When placed in large deficits resulting from trauma or resection of neoplastic bone, cortical bone grafts can serve as a weight-bearing strut or buttress that resists weight-bearing forces, again sparing the implant of some of these loads.

New bone that is formed on or about a graft can be of graft origin (i.e., *directly from osteoblasts or osteoprogenitor cells* that survive the transfer). At best, survival of cells from the graft is estimated at 10% when a fresh autogenous cancellous graft is used and handled under optimum conditions. The second way in which the bone graft may function as a source of osteogenesis is by recruitment of mesenchymal or pluripotential osteoprogenitor cells in the area, which then differentiate into cartilage-forming and bone-forming cells, a process called *osteoinduction.* A third osteogenic function of grafts is *osteoconduction,* the three-dimensional process of ingrowth of sprouting capillaries, perivascular tissue, and osteoprogenitor cells from the recipient bed into the structure of a graft. The graft acts as a scaffold or template for new-bone formation, then undergoes varying degrees of osteoclastic resorption and replacement *(creeping substitution)* by host bone.

Cancellous grafts have many advantages, such as rapid stimulation of direct bone formation, early osteoinduction, and early vascularization. Autogenous cancellous bone is the only bone graft that can be safely applied in contaminated areas. Vascular invasion and osteoconduction occur much more slowly in cortical grafts, but these grafts have the advantage of affording some immediate stability to the area. They are prone to sequestration in infected areas.

CLINICAL APPLICATION OF BONE GRAFTS

Collection of Bone for Grafting

Strict aseptic technique is mandatory in grafting procedures that do not involve ethylene oxide (ETO) sterilization.

Autogenous Cancellous Bone

Figure 3-1, *A* through *D*, shows the most common areas for collection in small animals: the lateral tubercle of the humerus, the subtrochanteric region or medial condyle of the femur, the proximomedial tibia, and the craniodorsal iliac spine. The selected area is approached through a 2- to 3-cm skin incision. The cortical bone is opened with a trephine or a trocar-pointed Steinmann pin ($^3/_{16}$-$^1/_4$ inch; 4.8-6.5 mm), and cancellous bone is scooped out with an oval curette (Figure 3-1, *E*). The graft is usually held in a small container (covered with a gauze sponge moistened with Ringer's or saline solution) until time for transfer to the new area (Figure 3-1, *F*). Do not immerse the graft in the fluid, and do not apply antibiotics. A blood-soaked surgical sponge can be substituted for the container. The graft should be implanted immediately after it is collected.

Because of their accessibility, the proximal humerus and tibia are the most frequently used collection sites. One or more of these areas is prepared preoperatively, and draping should allow access to them if needed during fracture repair. The proximal humerus yields more bone than the tibia, and cancellous bone is restored more completely than in the tibia, where fibrous tissue fills the graft site.[4]

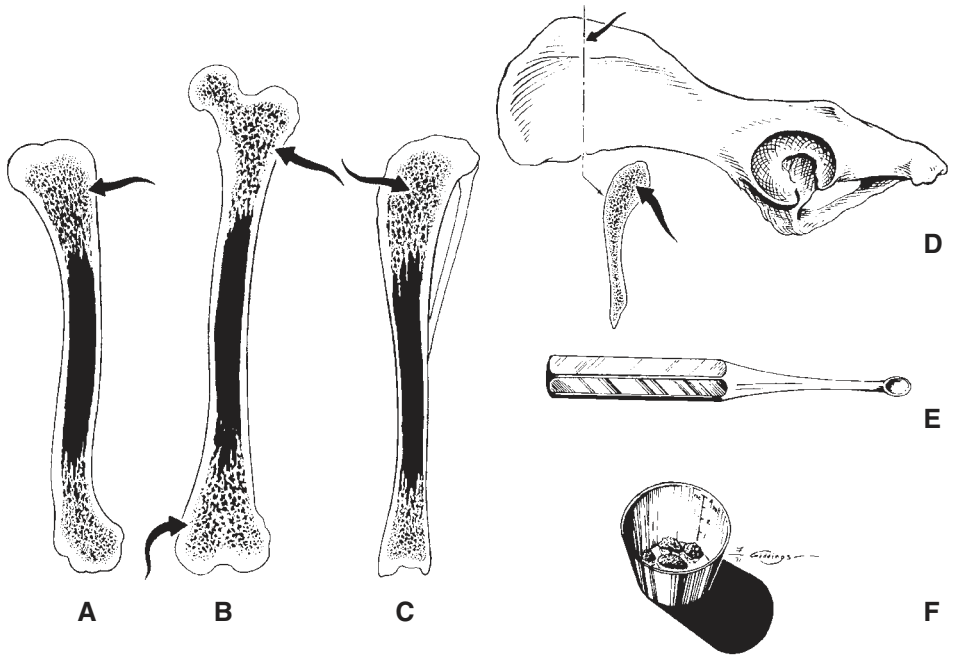


FIGURE 3-1. Collection of autogenous cancellous bone for grafting. **A** through **D,** Sections of a humerus, femur, tibia, and ilium indicating location for collection of bone graft. **E,** Curette used to scoop out cancellous bone. **F,** Receptacle used for temporarily holding collected graft.

Postoperative hematoma is not uncommon at the donor site, but can be minimized by careful layered closure of the site.

Autogenous Corticocancellous Bone

The ribs and craniodorsal iliac spine are the usual donor sites. The rib collection technique is similar to that illustrated in Figure 3-2 for allografts. An incision through skin and muscle is made directly over the chosen rib. The periosteum is incised and carefully elevated to avoid opening the pleural cavity, and the rib is freed by cutting at both ends. The iliac spine is also approached directly by a dorsal incision of skin and muscle. It is not necessary to elevate periosteum, and a suitable block of bone is freed by osteotome or bone saw. The graft can be either just the lateral cortex or a full-thickness piece of the iliac spine/crest containing both cortices.

Allograft/Bone Banking

Collection technique varies with the method chosen for preservation. The graft can be collected aseptically and preserved by freezing or collected under clean conditions, sterilized by ETO, and preserved by freezing.[2,3,5]

Bone is collected from a healthy donor animal of the same species, under strict aseptic procedure if ETO sterilization is not used. For corticocancellous bone, it is preferable to use a donor from one of the large breeds approximately 4 to 6 months of age. Ribs are the most common source of bone because they have a relatively high proportion of cancellous bone (Figure 3-2, *A*). If more cortical content is desirable, the craniodorsal iliac spine is used as previously explained. All periosteum and other soft tissue are removed from the bone by scraping with a scalpel blade or periosteal elevator at collection. The harvested bone is placed in a sterile test tube or similar container. A small amount of Ringer's solution may be added to keep the bones moist and to prevent freezer burn (dehydration) in storage. Each bone is usually

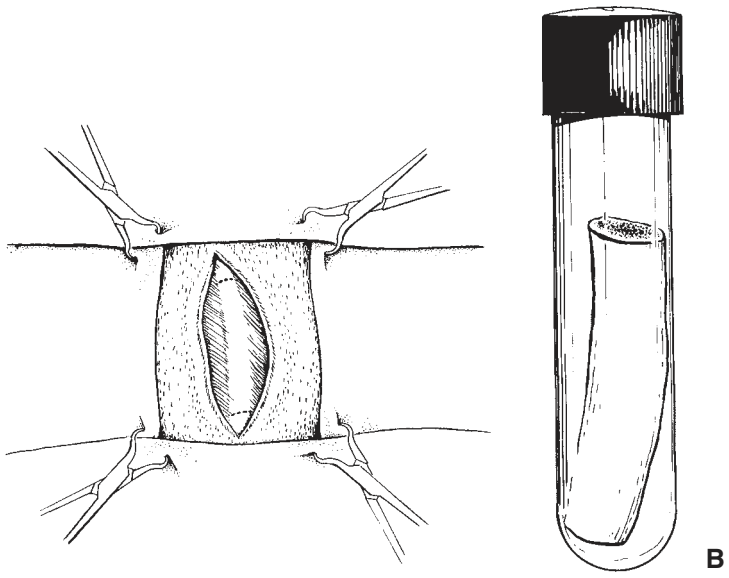


FIGURE 3-2. Collection of rib grafts for bone bank. **A,** Ribs are aseptically collected from a donor animal and cleaned of all soft tissue. **B,** Each rib is placed in a sterile test tube or similar container.

placed in an individual sterile container or wrap for convenient use (Figure 3-2, *B*). The sealed and labeled containers are placed in a home-type deep freezer and held at 0° F (–18° C) or lower. Bone preserved in this manner may be held for approximately 1 year.

Cortical diaphyseal grafts are collected from all the long bones, cutting the diaphyseal portion free at each end with a bone saw. The medullary canal is curetted and flushed to remove soft tissue elements. Packaging and freezing are done as described earlier. Because these grafts will need to match the recipient site quite closely in size, they should be labeled as to size of donor, and it is also helpful to radiograph the specimen to allow easier matching to the recipient.

ETO sterilization simplifies the collection process in that aseptic technique does not have to be used, although the conditions should be made as clean as possible. After the bones have been cleaned of soft tissue, they are double-wrapped in polyethylene instrument sterilization pouches or tubing. Sterilization is by 84% ETO (Anprolene, H.W. Anderson Products) for 12 hours, followed by 72 hours of aeration, all at room temperature. After this sterilization the bones are deep-frozen as previously described.[5] Such sterilization and storage up to 1 year appear to have no effects on cortical bone resistance to compressive, bending, and torsional loads when compared with fresh bone.[6]

Types of Grafts and Placement

The graft types most often used are pure cancellous fragments, corticocancellous bone chips, cortical or corticocancellous onlay or inlay, and cortical tubular intercalary grafts (Figure 3-3).

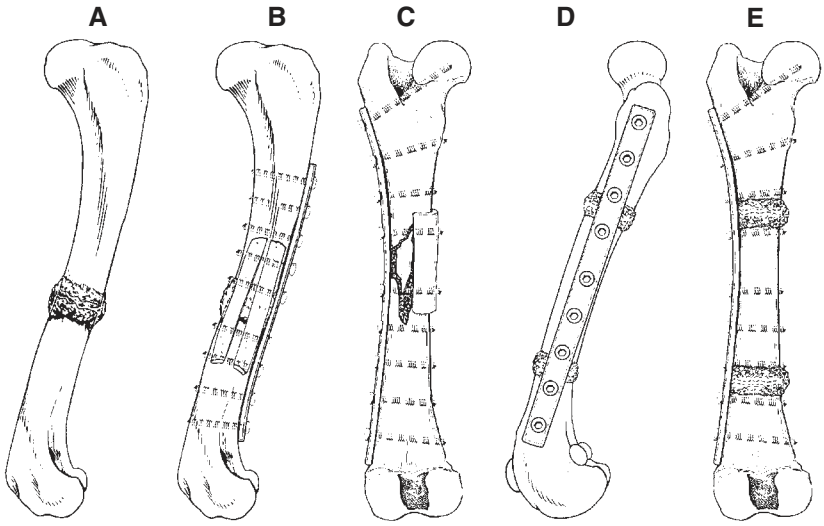


FIGURE 3-3. Types of bone grafts. **A,** Pure cancellous fragments or bone chips created by use of a rongeur are packed around the fracture site. **B,** Onlay graft (usually a split rib) spans the fracture, and cancellous fragments or chips are packed around the fracture site. **C,** Inlay cortical graft acts as a buttress to replace missing cortical bone in the compression cortex opposite the plate. The fragmented area under the plate is grafted with cancellous bone. **D** and **E,** Tubular intercalary allograft used to replace a section of the diaphysis. Autogenous cancellous bone is used at the graft-host junctions.

Pure Cancellous Fragments

The graft of pure cancellous fragments is used immediately after collection by packing the fragments into the desired area and then gently compressing the material. Any graft left after packing into the defect can be spread around the surface of the defect and adjacent bone (Figure 3-3, *A*). The graft site should be cleaned of tissue fragments and blood clots before insertion of the graft. Avoid irrigation of the graft before closing the soft tissues, which should be done immediately. In delayed unions or nonunions, the sclerotic tissue and periosteum are peeled off the host bone segments at the fracture site. This is usually accomplished by using a periosteal elevator or osteotome and mallet (see Figure 4-3). The bone segments are stabilized by a compression plate, and the graft is placed around the fracture site between the elevated periosteum and cortex.

Corticocancellous Bone Chips[2]

The graft using corticocancellous bone chips is usually prepared from banked allograft rib bone. Bone chips of 2 to 5 mm in diameter (see Figure 3-3, *A*) are used in a manner identical to pure cancellous bone and are useful to increase the volume of graft over that available from pure autogenous cancellous bone, or when an autogenous donor site has not been prepared. The chips are created by using a rongeur to "nibble off" small bone pieces.

Onlay Bone Graft[2]

Figure 3-3, *B,* shows an onlay graft used in treatment of a nonunion fracture. The sclerotic tissue and periosteum are elevated and reflected off the host area. The bone segments are stabilized by a compression plate. The graft is created by splitting a rib bone to expose the cancellous interior, and this side is placed against the recipient bone. One or more onlay grafts are placed on the bone, spanning the fracture site. The graft may be secured in place by bone screws, by cerclage wires, or by suturing the patient's tissue over the area. Rigid fixation of bone segments in the host is much more important than fixation of the transplant. It is usually a good procedure to place autogenous cancellous bone or bone chips around the remaining uncovered portion of the fracture site. Onlay grafts can be used in a similar manner in fresh fractures.

Inlay Bone Graft

The inlay graft is most often cortical bone used as a buttress to replace a portion of missing cortex on the compression side opposite the bone plate (Figure 3-3, *C*). Its use has declined with the advent of the concept of "bridging osteosynthesis" (see Chapter 2). In many cases its use is interchangeable with the tubular graft explained below. The graft must be securely stabilized, preferably by bone screws placed through the plate.

Tubular Intercalary Diaphyseal Graft[5,7-9]

Tubular grafts (Figure 3-3, *D* and *E*) are indicated chiefly for the following:

1. Severe multiple or comminuted shaft fractures that do not lend themselves to anatomical reconstruction
2. Fractures with missing bone segments; bone length can be restored
3. Replacement of surgically removed segments of neoplastic bone
4. Reconstruction of certain atrophic nonunion fractures
5. Correction of malunion

Good clinical results have been reported for this method. Twenty-five cases followed a mean of 2.1 years yielded normal function in 96% of the dogs.[9]

Despite these results, the use of this type of bone graft in fracture repair has declined with the advent of the concept of bridging osteosynthesis (see Chapter 2), and intercalary grafts are presently used primarily in limb-sparing surgery for bony neoplasia.

The procedure usually consists of squaring off the ends of the viable bone segments, attaching the proper size and length of cylindrical diaphyseal allograft to the center section of the plate, and immobilizing it under compression at both ends by using a dynamic compression plate. Autogenous cancellous graft is used at each end of the graft. There may be an advantage to perforating the graft with small drill holes to encourage vascularization of the medullary canal. Screws should secure a minimum of four cortices in the graft and six cortices in each end of recipient bone to secure adequate stability. Functionally, most animals respond in the same way as the patient with an average, multiple or segmental fracture stabilized with a bone plate. Replacement of the allograft by host bone is slow and incomplete, with areas of dead graft still present at 8 years in one patient.[10] New bone deposited on the surface of the graft creates clinical union, and plates can be removed in 18 to 25 months if indicated.

Autogenous Free Vascularized Bone Graft

The advent of microsurgery in veterinary orthopedics has resulted in the description of successful autogenous free vascularized bone grafts, with donor sites of the distal

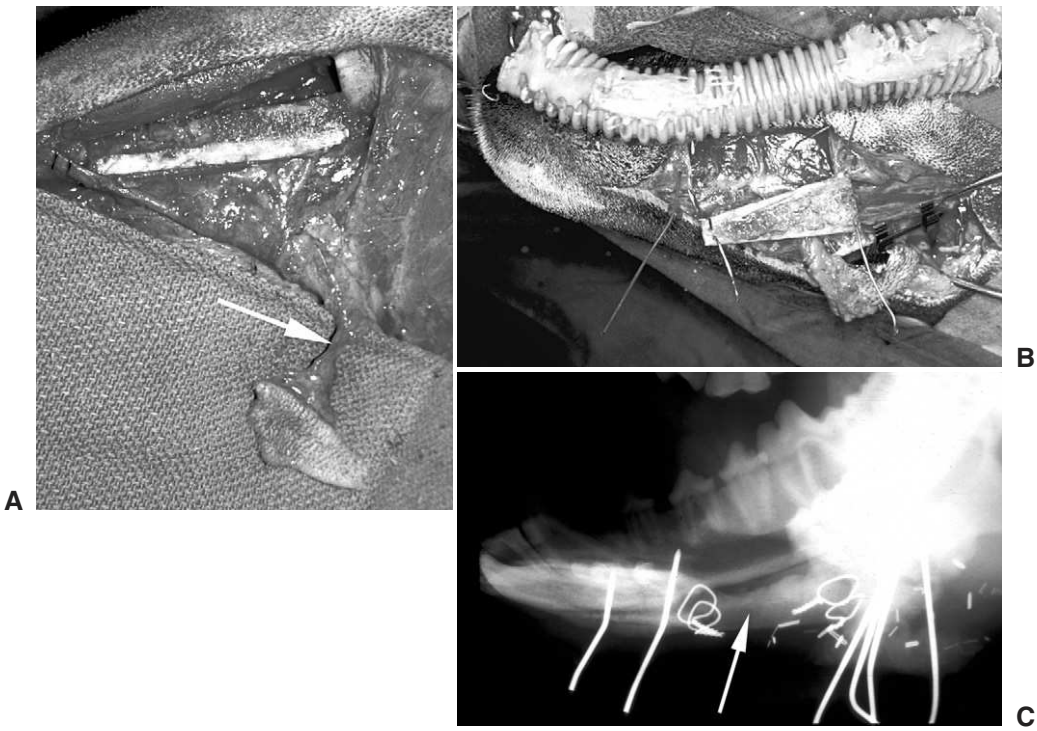


FIGURE 3-4. Free autogenous vascularized bone graft. **A,** Medial tibial cortex harvested from donor site with vascular pedicle *(arrow)*. **B,** Graft is fixed to mandibular defect with hemicerclage wire. An acrylic type I fixator is used to stabilize the mandible. The graft vessels have been anastomosed with microsurgical technique. **C,** Radiograph shows healing of the graft *(arrow)* to host bone. (Images courtesy Dr. Trevor Bebchuck.)

ulna, coccygeal vertebrae, fibula, and medial tibial cortex.[11-15] Maintaining vascular supply to the bone graft requires successful microsurgical anastomosis of the vascular pedicles of the graft to the recipient site vessels. A successful anastomosis yields excellent graft survival and incorporation of the graft into the host bone, with resistance to infection and sequestration. Distal ulna has been used to reconstruct tibial diaphyseal defects.[11,12] Medial tibial cortical free grafts have been used to bridge contaminated mandible defects successfully (Figure 3-4).[13] These techniques require advanced training and experience in microsurgical techniques and are used currently on a very limited basis. They may become more relevant to clinical practice as veterinary orthopedic specialization progresses.

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4

Delayed Union and Nonunion

The speed of reunion of bone is in direct ratio to the rigidity with which the two pieces are placed together.

—Richard VonVolkmann (1830-1889)

Delayed union refers to a fracture that has not healed in the usual time for that particular fracture. Table 4-1 details average healing times anticipated for small animals.[1] *Nonunion* refers to a fracture in which all evidence of osteogenic activity at the fracture site has ceased, movement is present at the fracture site, and union is no longer possible without surgical intervention. The term *pseudoarthrosis* is sometimes applied indiscriminately to all nonunions, but it should be reserved for those nonunions in which sclerotic bone ends are united by a fibrous "joint capsule" filled with serum (Figure 4-1, *A*). The most common causes of these conditions are local factors, as follows:

1. Inadequate immobilization, or failure to maintain immobilization for a sufficient length of time.
2. Inadequate reduction with a large fracture gap and interpositioning of soft tissue.
3. Impairment of the blood supply resulting from the original trauma or surgical trauma.
4. Infection. A fracture may heal in the presence of infection; at best, however, healing is delayed. Implant loosening is common in infected bone.
5. Loss of bone or bone fragments from open trauma or surgery.

General factors such as age, high-dose corticosteroid therapy, and metabolic alteration of osteoblastic activity (e.g., rickets) may affect the rate of bone healing. However, observations of delayed union or nonunion fractures attributed to these factors are uncommon in dogs or cats.

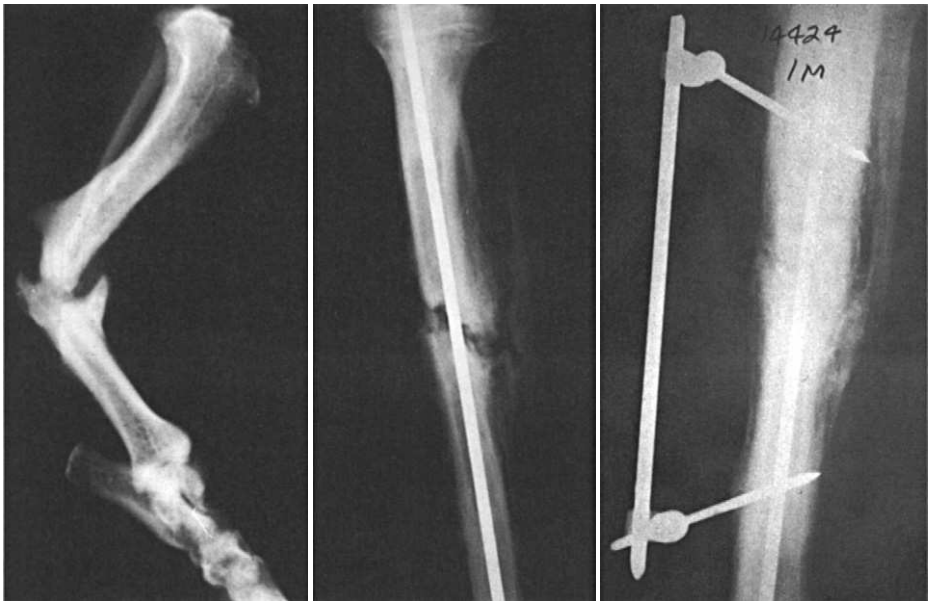
DELAYED UNION FRACTURES

The most common cause of delayed union is inadequate or interrupted fixation of the fracture segments. On radiographic examination (Figure 4-1, *B*) the fracture line remains evident and has a feathery or woolly appearance, and there is no sclerosis of the bone ends. Evidence of osteogenic activity (callus) is visible, but this is minimal and may not bridge the fracture line.

TABLE 4-1. AVERAGE TIMES TO CLINICAL UNION

Age of Animal	ESF (type I, some II) IM Pin	Plate Fixation ESF (type III, some II)
<3 months	2-3 weeks	4 weeks
3-6 months	4-6 weeks	6-12 weeks
6-12 months	5-8 weeks	12-16 weeks
1 year	7-12 weeks	16-30 weeks

Modified from Hohn RB, Rosen H: Delayed union. In Brinker WO, Hohn RB, Prieur WD, editors: *Manual of internal fixation in small animals,* Berlin, 1984, Springer-Verlag, pp 241-254.
ESF, External skeletal fixation; *IM,* intramedullary.



A B C

FIGURE 4-1. Delayed union and nonunion fractures. **A,** Chronic nonunion of the pseudoarthrosis type. The sclerotic bone ends are united by a fibrous "joint capsule" containing serum. **B,** Delayed union tibial fracture caused by rotational instability. The fracture line is prominent, with a feathery or woolly appearance. Some nonbridging callus is evident laterally. **C,** Four weeks after closed application of an external fixator, the fracture has reached clinical union.

Treatment of delayed union fractures may be approached by various means, as follows[2]:

1. If reduction is satisfactory, rigid uninterrupted fixation should be ensured and maintained for an extended time. If the original fixation is still deemed adequate, this may involve simply reducing the animal's activity through better owner cooperation or may require the use of non–weight-bearing slings (see Chapter 2). The use of external coaptation splints or casts should be avoided in animals with long-bone fractures.

If the original fixation is suspect, it should be augmented or replaced. A common scenario is a long-bone fracture (often the femur) treated by intramedullary fixation,

with or without cerclage or interfragmentary wire, that is not totally stable in rotation or perhaps is in shear resulting from collapse with weight bearing. Under these circumstances, closed application of an external fixator is useful and usually provides sufficient stability to allow healing to proceed (Figure 4-1, *C*). Type I fixators are most often used in this situation. Delayed union femoral fractures in large-breed dogs are probably better treated by application of a bone plate (Figure 4-2, *A* and *B*) because better limb function can be anticipated than with external fixators.

Bone plate fixation is not immune to problems with delayed union, usually because of instability at the fracture site. Loose screws in bone plates can be salvaged by the following means:

a. Replace with larger screws if the plate holes will accept them, or replace cortical threads with cancellous threads.
b. Add a nut to the protruding end of the screw.
c. Fill screw holes with methyl methacrylate. Use liquid cement in a syringe, fill the holes, and insert the screws. After the cement hardens, tighten the screws to normal tightness. Do not allow any cement into the fracture area.
d. Substitute cerclage wires for screws. This is the least desirable method and is used only as a last resort.

2. If there is good end-to-end bone contact, but with malalignment or bending at the fracture site, the bone should be straightened and rigid uninterrupted fixation applied. This situation is most often a sequel to closed reduction and coaptation fixation. Usually, straightening can be accomplished by careful but forceful pressure with the hands or by applying pressure over a fulcrum point.

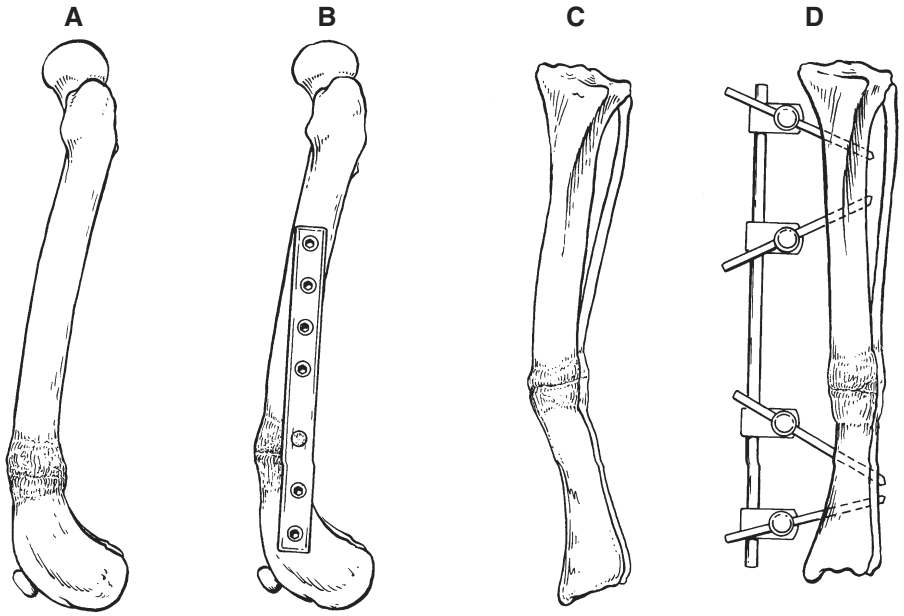


FIGURE 4-2. Delayed union fractures. **A,** Satisfactory reduction of delayed union femoral fracture previously treated with an intramedullary pin. **B,** Rigid internal fixation provided by a compression plate. **C,** Delayed union fracture of a tibia with good contact of bone fragments but with valgus deformity. **D,** Bone straightened manually, without surgical exposure. A unilateral external fixator consisting of 2/2 pins was applied for fixation.

This is preferable to doing an open surgical correction because it saves many weeks of healing time (Figure 4-2, *C* and *D*). Again, external fixators are often the technique of choice.

3. If reduction is unsatisfactory, surgical intervention is indicated to correct the deficiencies of reduction and fixation. In the absence of vigorous callus formation, autogenous cancellous bone grafting of the fracture site is always indicated (Figure 4-3).

NONUNION FRACTURES

Two basic types of nonunion fractures—viable and nonviable—as classified by their biological characteristics, were proposed by Weber and Cech[3] and remain the most useful system for the clinician. All these types may be complicated by the presence of infection.

1. *Viable* (reactive, vascular). This is a biologically active fracture, characterized by a variable degree of proliferative bone reaction with interposed cartilage and fibrous tissue that is evident radiographically and histologically (Figure 4-4). There are three subtypes within this category, representing the types most often seen in small animals:
   a. *Hypertrophic*, or "elephant foot" (Figures 4-4, *A*, and 4-5, *A*). There is an abundant bridging callus that has not ossified because of motion at the

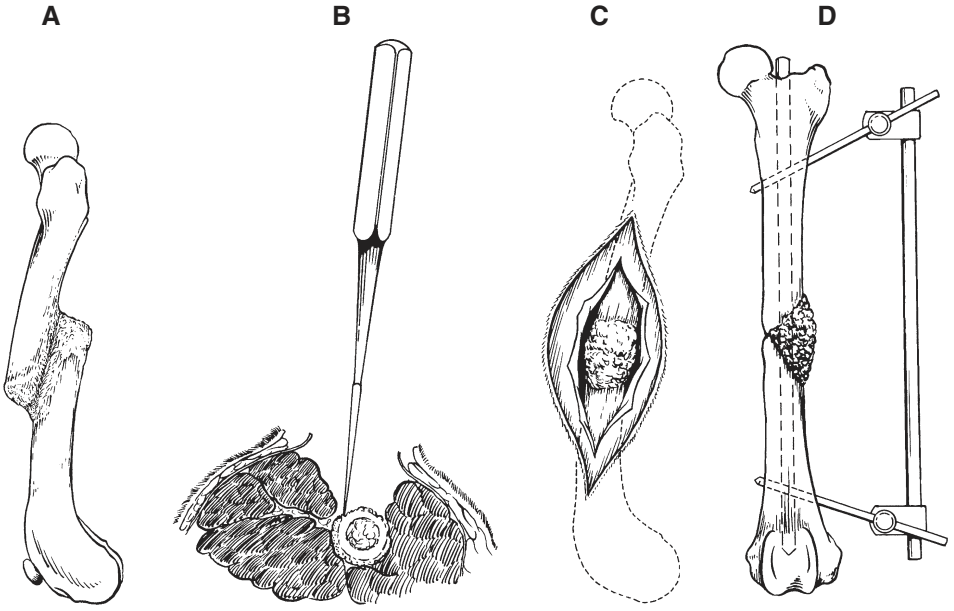


FIGURE 4-3. **A,** Delayed union fracture with evidence of osteogenic activity, movement at fracture site, overriding of fracture segments, shortening, and favoring the leg. **B** to **D,** Open approach; modified periosteal callus layers were reflected away from the cortex as one layer. Reduction and stabilization were achieved by inserting an intramedullary (IM) pin and unilateral external fixator (1/1 pin). A cancellous bone graft was added around the fracture site. In cases such as this, the medullary space is filled with internal callus; thus the IM pin fits snugly and affords excellent stability. The external fixator was added to stabilize against rotation. The other alternative is to use a plate for fixation.

fracture site. What appears to be sclerosis of the bone ends is actually abundant appositional bone being deposited that is unable to bridge the fracture gap due to motion.

b. *Moderately hypertrophic,* or "horse hoof" (Figures 4-4, *B,* and 4-5, *B*). Callus is present, but it is not as florid as the hypertrophic nonunion fracture.

c. *Oligotrophic* (Figure 4-4, *C*). This type is sometimes difficult to distinguish from the nonviable types. Callus is absent or minimal, and the fracture gap may simply be bridged by fibrous tissue. The radiographic key is the continued fuzzy or hazy appearance to the bone ends, even if they have become smooth or rounded in outline. This haziness is caused by vascularity of the area, as opposed to the sclerotic appearance of devascularized bone.

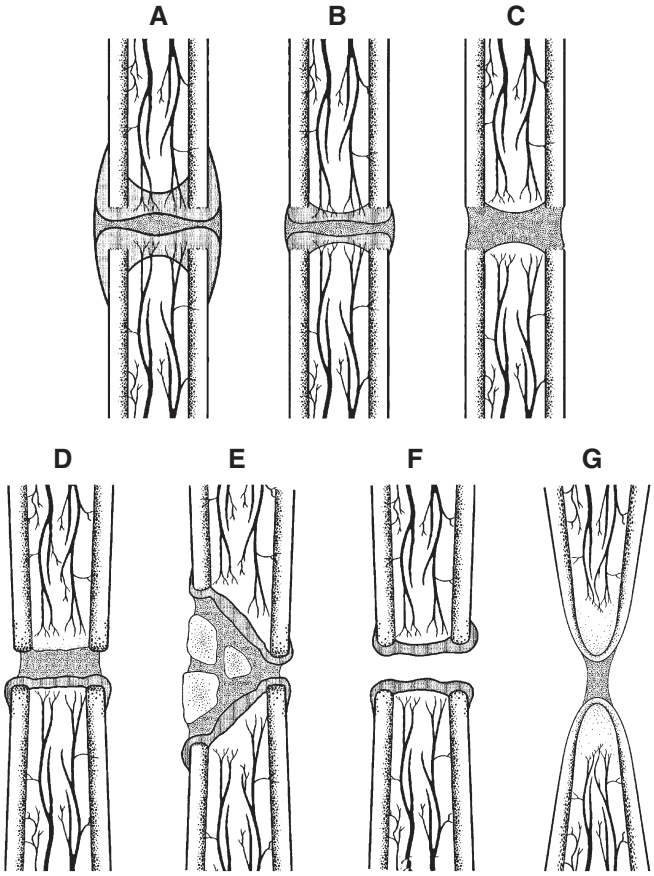


FIGURE 4-4. Classification of nonunion fractures, according to Weber and Cech.[3] **A** to **C,** *Viable,* or biologically active, nonunions. **A,** Hypertrophic; elephant foot callus. **B,** Moderately hypertrophic; horse hoof callus. **C,** Oligotrophic; callus minimal or absent. **D** to **G,** *Nonviable,* or biologically inactive nonunions. **D,** Dystrophic; one or both sides of the fracture line are poorly vascularized. **E,** Necrotic; devascularized bone fragments (sequestra) remain in the fracture gap. **F,** Defect; bone fragments missing from the fracture gap. **G,** Atrophic; resorption and rounding of bone ends and complete cessation of osteogenic activity.

2. *Nonviable* (nonreactive, avascular). These types of nonunion fortunately are not common because they represent a much more difficult situation to achieve clinical union.
   a. *Dystrophic* (Figure 4-4, *D*). One or both sides of the fracture line are poorly vascularized, sometimes because of a fragment that has healed to one end but has too little blood supply to unite to the other end. Radiographic characteristics include a visible fracture gap, rounded and distinct edges to the bone, and sclerosis extending several millimeters from the bone edges. The dystrophic type is seen most often in distal radius/ulna fractures in toy and miniature dogs.
   b. *Necrotic* (Figure 4-4, *E*). If bone fragments are not "captured" by invading callus, as a result of motion or more often infection, they may never become vascularized and remain in the fracture gap as sequestra. These fragments will have the same sharp jagged edges as they had in the immediate postfracture radiographs and will appear more sclerotic with time. The main fragment edges will smooth off as a result of remodeling and will exhibit variable degrees of sclerosis.
   c. *Defect* (Figure 4-4, *F*). Large fragments may be missing from open fractures, especially high-energy gunshot fractures. If this gap is more than 1.5 times the bone diameter, osteogenetic potential in the local area may be insufficient to bridge the gap with callus, no matter how good the stabilization. This is most common in areas in which vascular recruitment is limited because of inadequate soft tissue (e.g., distal tibia, radius/ulna) or local soft tissue and vascular damage.
   d. *Atrophic* (Figures 4-4, *G,* and 4-5, *C*). This is the end point of most nonviable nonunions, with resorption and rounding of the bone ends, with or without disuse osteoporosis, and complete cessation of osteogenic activity.



A **B** **C**

FIGURE 4-5. Radiographic appearance of nonunions. **A,** Hypertrophic. **B,** Moderately hypertrophic. **C,** Atrophic.

Treatment

Viable Nonunion

If *reduction is satisfactory,* most patients will respond to stable fixation of any type. Compression at the fracture site (e.g., with a compression plate) is especially efficacious. Callus should be disturbed as little as possible when applying fixation, even to the point of contouring the plate to accommodate the callus. Type II and III external fixators can also be employed, especially in the radius/ulna and the tibia. These fixators are the best choice if the nonunion is infected. Type I external fixators combined with intramedullary (IM) pins can be applied in some situations (Figure 4-6).

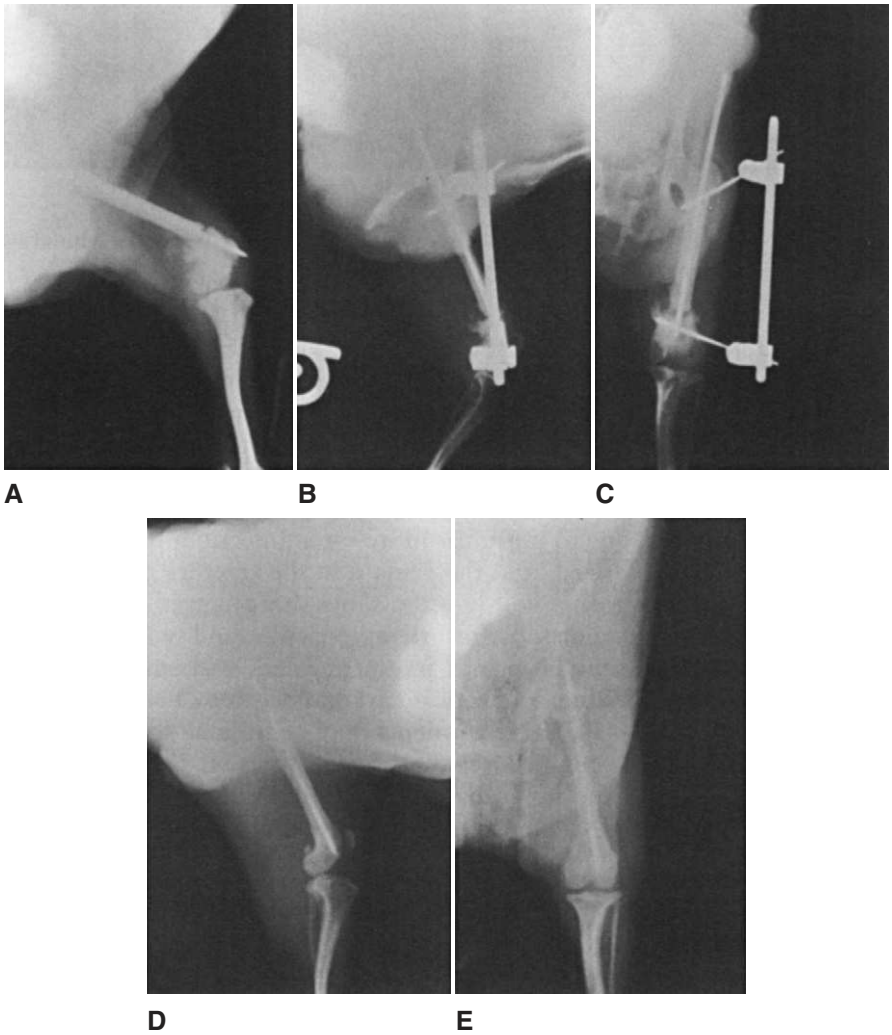


FIGURE 4-6. Moderately hypertrophic nonunion of a supracondylar fracture in a small Yorkshire terrier immobilized by use of an improperly placed intramedullary (IM) pin. There was rotation at the fracture site. **A,** Radiographic appearance at 3 months. Clinically, the area was very painful, and the animal refused to use the leg. **B** and **C,** A lateral open approach was used, and an IM pin and unilateral external fixator (1/1 pin) were applied for stabilization. The external fixator was removed in 6 weeks because there was sufficient callus to stabilize against rotation. **D** and **E,** Clinical union was present at 3 months, and the IM pin was removed. The animal regained a full range of movement and function.

If *reduction is unsatisfactory*, the callus must be divided at the fracture site. Some callus may need to be resected to achieve bone-to-bone contact and to open the medullary canal with an IM pin, allowing speedy reestablishment of the medullary blood supply. Appropriate fixation is then applied. Bone grafting is not needed, although pieces of resected callus can be packed around the fracture site.

Nonviable Nonunion

An open approach is made to allow reflection of the covering of thickened periosteum with a periosteal elevator or osteotome and removal of the fibrous soft tissue between the bone ends. Sclerosed bone is removed from the bone ends with rongeurs until bleeding is observed from the periosteum and endosteum; however, excessive bone length should not be sacrificed to achieve this. Additionally, a suitable diameter of Steinmann pin or a twist drill is used to open the medullary canal. The space between the reflected periosteum and bone is packed with cancellous bone chips, and stable fixation is applied (e.g., bone plate, external fixator, or IM and external fixator) (Figure 4-7; see also Figure 4-3, *B, C,* and *D*). Healing is slow, and the fixation will need to remain in place for a prolonged period (4-6 months). Some of the more indolent conditions may necessitate grafting procedures a second or third time.

Future Treatment Possibilities

Bone morphogenetic proteins (BMPs) function to induce transformation of undifferentiated mesenchymal cells into chondroblasts and osteoblasts and have been shown to induce new bone formation in vivo and in vitro.[4] BMPs have been isolated from a variety of mammalian tissues and are on the verge of becoming commercially available through recombinant DNA technology in quantities sufficient for

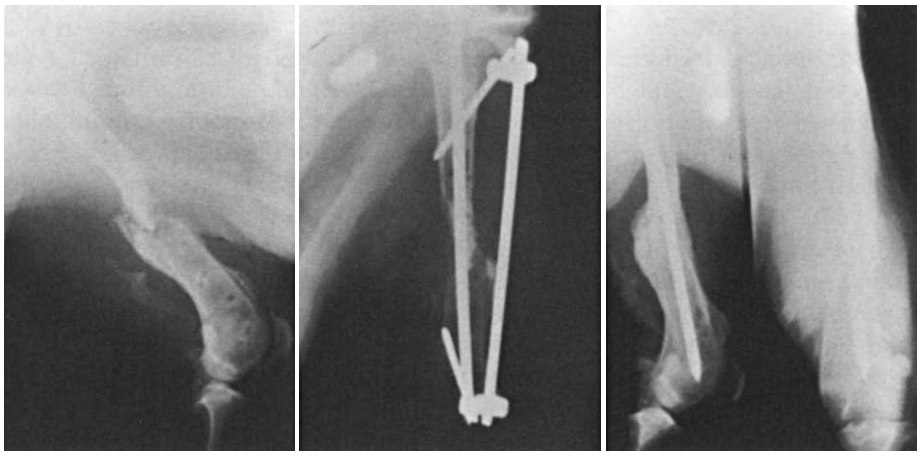


FIGURE 4-7. Nonunion of a fracture of the femur. The extremely comminuted fracture was originally fixed by use of a plate; however, the fracture site deficits were not filled with bone graft. At 15 months, when the animal returned for plate removal, it was favoring the leg. **A,** Radiograph of femur after plate removal, lateral view. **B,** After reflection of the modified periosteum in the fracture site area, an intramedullary (IM) pin and a unilateral external fixator (1/1 pin) were applied for fixation, lateral view. A bone graft was applied in the fracture area. **C,** Clinical union at 4½ months, lateral view. Demineralized bone such as this responds faster if subjected to stresses; therefore the IM pin and external fixator were chosen for stabilization.

clinical application. Potential applications include use as alternatives to bone grafts, promoters of osteointegration of implants, and treatment of nonadaptive bone disease such as stress fractures. Thus, BMPs would appear to have value in the treatment of delayed union and nonunion fractures, but their role in this area remains to be defined through clinical trials.

Microsurgical technique has allowed the use of autogenous free vascular bone grafts as treatment for nonunion fractures in dogs. The distal ulna and the medial tibial cortex have been described as potential donor sites, with external fixators used for graft stabilization. Successful experimental vascular bone transplantation also has been described.[5-7] Microvascular anastomosis of a bone graft blood supply has a demonstrated experimental advantage over avascular grafts in a bacteria-contaminated graft site.[7] Avascular bone becomes an infected sequestrum in the presence of bacteria, whereas vascularized autogenous bone (see Figure 3-4) quickly incorporates with local bone and hypertrophies to accept a load during weight bearing.[5-7]

Bone transport osteogenesis, with the use of circular-frame external fixators, has been described as a possible treatment for large segmental defects, as seen with nonunion fractures.[8-10] A circular-frame external fixator is applied to the bone, and an osteotomy is performed distant to the nonunion site. Serial distraction is used to transport autogenous bone slowly across the bone defect until the defect is closed and the fracture has healed. New bone forms in the distracting osteotomy site and rapidly remodels into lamellar bone. The transported bone provides vascularized autogenous bone at the site of the poor healing environment of the nonunion gap. Use of this technique has been very limited for nonunion fractures in animals, and further clinical and scientific studies are needed to define its use in veterinary orthopedics.

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5

Treatment of Acute and Chronic Bone Infections

Osteitis or *osteomyelitis* is defined as a bone inflammation involving the haversian spaces, Volkmann canals, and generally the medullary cavity and periosteum. Bone infection is usually associated with open fractures, bone surgery (especially involving metallic implants), and systemic illness. Bite wounds are common causes of osteomyelitis in the lower limbs, mandible, and maxilla in dogs and the coccygeal vertebrae in cats.

Acute infection is characterized by a supportive history, localized pain, swelling, erythema, and elevation of body temperature (≥103° F [39.5° C]). In most early cases, radiological signs are not evident. Persistent fever is the most reliable early sign of infection. Postsurgical osteomyelitis signs are usually evident 48 to 72 hours after surgery, but during this period it is difficult to distinguish between incipient osteomyelitis and deep wound infection. Wound disruption and drainage takes several days to develop.

Chronic infection is characterized by a supportive history; draining sinus tracts (±); muscle atrophy, fibrosis, and contracture; variable lameness; and positive radiographic changes. These changes may include cortical resorption and thinning; osteoporosis; periosteal new bone formation that may be smooth, expansile, or spiculated[1]; formation of sequestra and involucra; sclerosis; and soft tissue swelling (Figure 5-1). A *sequestrum* is a piece of dead bone that has become separated from normal bone during the process of necrosis and is surrounded by a pool of infected exudate. Because it has not undergone any resorptive process and is not vascularized, its radiographic density is high, giving the appearance of a very white piece of bone that has very sharp and ragged edges. Most sequestra are found within the medullary cavity or beneath a bone plate. An *involucrum* is a covering or sheath of new bone formation and fibrous tissue covering a sequestrum.

Most often, osteomyelitis implies bacterial infection; however, fungi or viruses can also infect bone and marrow. Staphylococci cause 50% to 60% of bone infections in dogs,[1] and historically the organism most frequently reported has been *Staphylococcus aureus*; however, one report indicates that *Staphylococcus intermedius* is more common.[2] The significance here is that most of these were resistant to penicillin because of β-lactamase production. Other common organisms include *Streptococcus, Escherichia coli, Proteus, Klebsiella, Pseudomonas,* and *Pasteurella* when bite wounds are present. The importance of anaerobes, especially in bite wound osteomyelitis, has been emphasized by Muir and Johnson,[3] who reported a 64% incidence of anaerobic bacteria isolated from such cases. Such isolates include *Actinomyces*, *Clostridium*, *Peptostreptococcus, Bacteroides,* and *Fusobacterium*.



FIGURE 5-1. Radiographic signs of osteomyelitis. **A,** Postoperative film of revision by bone plate fixation of an infected nonunion fracture. Hazy nonbridging callus is seen at the distal edge of the fracture gap, and periosteal new bone is distal to the plate. **B,** Postoperative day 19. Note resorption of bone under the center of the plate, increased periosteal new bone distally, and sclerosis of the ulna. The ulnar fragment is a sequestrum. The plate is loose, as indicated by bone resorption around the distal screws. **C,** Two months after intramedullary (IM) pin fixation, this humerus shows classic signs of chronic infection and nonunion characterized by extensive, mature periosteal bone formation.

About 50% of infections are caused by a single organism; others are caused by multiple organisms.

ROUTES OF INFECTION

The routes of infection, in order of occurrence, are as follows:

1. Direct contamination from open fractures, surgical intervention in treatment of a fracture, and puncture wounds. The highest percentage of infected fractures follow either open fracture repair or open repair of closed fractures. The presence of a metallic implant is usually involved.
2. Direct extension from infected adjacent soft tissue.
3. The bloodstream, from such conditions as vertebral osteomyelitis, discospondylitis (*Brucella, Nocardia, Staphylococcus*), and bacterial endocarditis.[4] Compared with other routes, this source of osteomyelitis is rare and is not discussed here.

TISSUE CHANGES

Bone is normally as resistant to infection as any other tissue. Clinical infection is always a result of more than simple bacterial contamination and usually implies concurrent soft tissue injury (and thus compromised bone vascularity), sequestration,

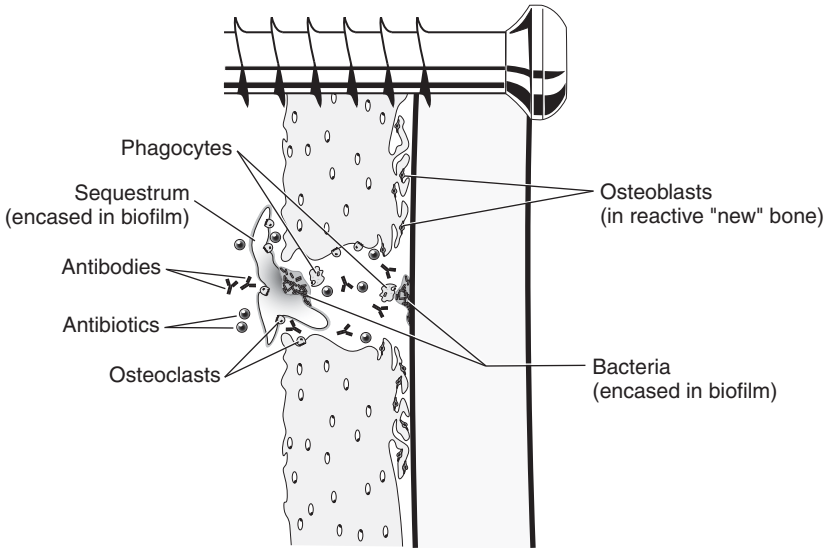


FIGURE 5-2. Bacteria produce a biofilm (glycocalyx) that promotes bacterial survival and growth by protecting the bacteria from the host immune responses.

implants, instability of fracture fragments, or alteration of local tissue defenses.[1] Indeed, 72% of open fractures and 39% of closed fractures have bacterial contamination at surgery, but only a small percentage become clinically infected.[5] The role of metallic implants in bone infection has been elucidated in a variety of studies that have explained how these implants create low-grade inflammation by depressing host defenses, thus providing a nidus for infection. Infective bacteria produce a biofilm *(glycocalyx)* that promotes bacterial growth by protecting bacteria from phagocytosis and antibodies and causing adherence to implants (Figure 5-2) or other foreign material.[1,6]

Infection in bone produces vascular congestion, edema, and an inflammatory exudate that spreads through the bone, killing osteocytes and marrow cells. Polymorphonuclear cells release proteolytic enzymes, causing tissue necrosis, a decrease in local pH, and demineralization of bone matrix and breakdown of trabeculae. Sometimes the involvement is confined to a localized area; in other cases, large areas are involved. Spread of infective exudate occurs most easily along the medullary canal; however, it also occurs beneath the periosteum and in the cortex through vascular channels. As the quantity of exudate increases, intraosseus pressure increases and further compromises blood flow. Areas of bone served by the involved vascular channels become anoxic and die.

With subsidence of the acute phase, pyogenic granulation tissue attacks and absorbs dead spongiosa and separates as sequestra those parts of the cortex that are necrotic. Pus accumulating in the subperiosteal space may separate periosteum from the outer cortex. The periosteum responds by laying down new bone in an attempt to bridge and surround the involved area, the so-called involucrum. This process is not unlike the classic formation of an abscess. The involucrum is usually fenestrated, leading to the eventual drainage of pus through multiple sinus tracts, which are accompanied by extensive scar tissue formation in the surrounding soft tissue and distortion and thinning of overlying skin. These events are worsened by fracture instability, since interfragmentary motion discourages vascularization of the bone. The opposing surfaces become more widely separated because of bone resorption, leading to further instability.

Timely and aggressive surgical or medical intervention can arrest infection, leading to its elimination, followed by gradual remodeling of the involucrum into cortical bone that may look surprisingly like the original bone. This process of healing can be discussed by considering (1) changes in necrotic bone; (2) formation of new bone; and (3) changes in old, living bone.

Necrotic Bone

Dead bone is absorbed by the action of granulation tissue that develops about its surface. If the dead bone is cancellous, it may be removed entirely, leaving a cavity behind. Dead cortex in any appreciable amount is gradually detached. After sequestration, the bone is less readily attacked and more slowly absorbed because of the physical barrier imposed by the scar tissue walls of the cavity surrounding the sequestrum. Cortical sequestra may take years or even the lifetime of the animal to be completely absorbed. Some sequestra are never absorbed and will continue to cause drainage until they are surgically removed.

New Bone

New bone forms from primitive mesenchymal cells in the surviving portions of periosteum, endosteum, and cortex. Recurrence of infection may result in the formation of superimposed layers of involucrum.

Old, Living Bone

In osteomyelitis, surviving bone usually becomes osteoporotic during the active period of infection because of disuse atrophy and decalcification resulting from inflammatory hyperemia. After subsidence of infection and resumption of function of the part, bone density increases again.

CLINICAL APPROACH

History, signs, and radiographic findings are essential in making a diagnosis and in determining the extent of the lesion. Treatment is based on the principles of appropriate antimicrobial drugs, open wound drainage and lavage, fracture stabilization, sequestrectomy, and grafting of bone deficits.[1] The first step is to culture and determine the antibiotic sensitivity of the causative organisms. Culturing for anaerobes is particularly important in chronic infection and those associated with bite wounds. It is imperative that the culture be taken from the infected area and *not* from the draining sinus tracts, which are typically contaminated with skin organisms. In acute cases, it is best to perform fine-needle aspiration from the infected area. In chronic cases, culture at the time of sequestrectomy is indicated. Fractures will heal in the presence of infection, although healing will be delayed.

Acute Infection

Treatment for acute infection must be aggressive and appropriate to forestall chronic disease, as follows:

1. Place the animal on a regimen of systemic antibiotics, initially based on either hospital epidemiology (previous iatrogenic infections) or on the knowledge that

most infections are caused by β-lactamase-producing staphylococci; thus, cefazolin, clindamycin, cloxacillin, or amoxicillin-clavulanate is indicated. Culture and sensitivity testing will indicate the best choice for long-term treatment, which should be continued for 4 to 6 weeks.
2. Perform complete and careful debridement of wound, if indicated.
3. Establish surgical drainage to the area if exudate is present. This may necessitate leaving the wound open after debridement or using drains with or without suction or irrigation. Because of the difficulty in maintaining drains in animals, it is much safer and easier to manage the patient if the wounds are left entirely open, even if this means leaving the implants exposed.[7] In this method the open wound can be covered with a wet to dry bandage that is changed daily until the defect has stopped draining exudate or is filled with healthy granulation tissue. In a healthy wound, granulation tissue will quickly cover a metallic implant. At this time, filling the bone defect with an autogenous cancellous bone graft may be indicated by simply elevating granulation tissue and packing the cancellous graft beneath it (see Chapter 3).

A common technique in human patients involves primary closure of the wound over drains to allow irrigation and suction. The drains are placed into the wound bed and exit the skin at a distant site. The tubes are used to flush the wound bed with fluids containing the appropriate antibiotic, based on culture and sensitivity results. The difficulties of managing such a system almost preclude its use in animals. Open drainage is much more successful in completely evacuating exudate and preventing chronic infection.

4. Evaluate and modify, if necessary, the internal fixation to ensure stability of the fracture.

Chronic Infection

Treatment of chronic infection usually involves the following:

1. Administer antimicrobial therapy as outlined for acute infection and continue for 5 to 7 weeks. Anaerobic infection is much more likely in chronic cases, and metronidazole and clindamycin are the most useful drugs. Aminoglycosides and quinolones are the most useful drugs against gram-negative infections.
2. Remove sequestra if present. In most cases it is advantageous to follow the same surgical approach used in open reduction of the fracture rather than following the sinus tract, if one is present. As a rule, it is not necessary to curette the area of the sinus tract or to use chemical or proteolytic enzymes after removal of sequestra that are walled off with granulation tissue. It is useful to remove sclerotic bone involved in the involucrum, since this may be necrotic bone that will form a secondary sequestrum. Remove bone only until point bleeding is seen from the cortex to avoid creating a large cavity. If a draining tract persists, all sequestra probably have not been removed, and a second or even a third attempt may be in order. A common site for sequestra is beneath a bone plate, which may require removal of the plate to remove the sequestrum.
3. Critically evaluate fracture stability. If the fracture is healed and implants are present, they are removed. If implants are secure and stabilizing the fracture, they should be left in place until the fracture is healed. If instability is present

and implants are loose, they should be removed and replaced by suitable fixation. Use of the external fixator or plates and screws is preferred over intramedullary pins. Once the fracture is healed, removal of implants is generally required to completely clear the infection because of the persistence of bacteria around the implant.

There is an exception to the rule that dead bone should be removed as soon as it is separated. This occurs when the sequestrum involves the whole thickness of the shaft of a long bone. If these large fragments are removed at the original surgery—shortly after injury or within a few weeks—the surrounding tube of periosteum may collapse, and the subperiosteal hematoma may be obliterated. There is no longer a continuous hematoma between the fragments, and the fracture cannot unite. In such a case it is better to defer sequestrectomy for several months until the surrounding involucrum of subperiosteal bone has been laid down, thereby ensuring continuity

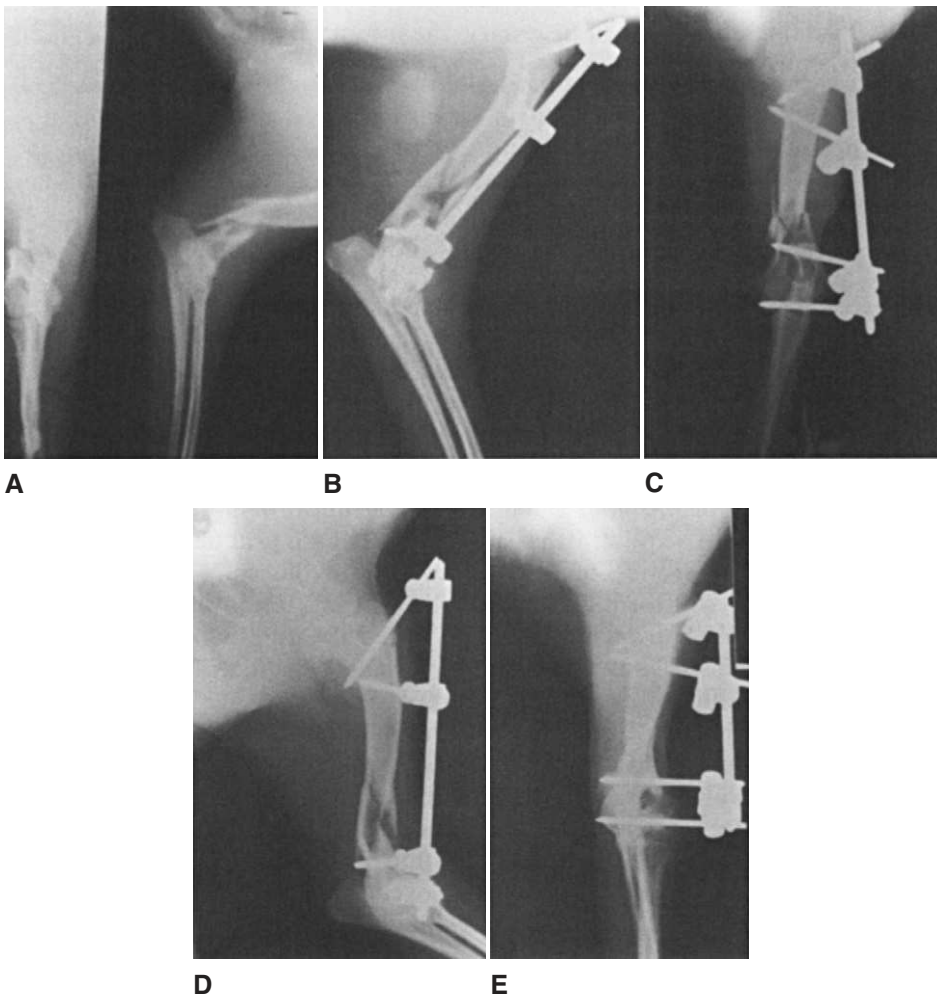


FIGURE 5-3. **A,** Radiographic views of a distal humeral fracture, 5 days' duration, with an open suppurating wound. The dog's temperature was 104.5° F. **B** and **C,** Lateral and craniocaudal views of the unilateral external fixator, consisting of 2/2 pins applied for fixation. The draining area was treated as an open wound and closed in about 2 weeks. **D** and **E,** Lateral and craniocaudal views at 9 weeks; clinical union was present, and the splint was removed.

of the shaft. Bone grafting with autogenous cancellous bone is usually indicated after removal of sequestrum of this magnitude.

4. Leave the wound open and treat as described for acute infection.[7]

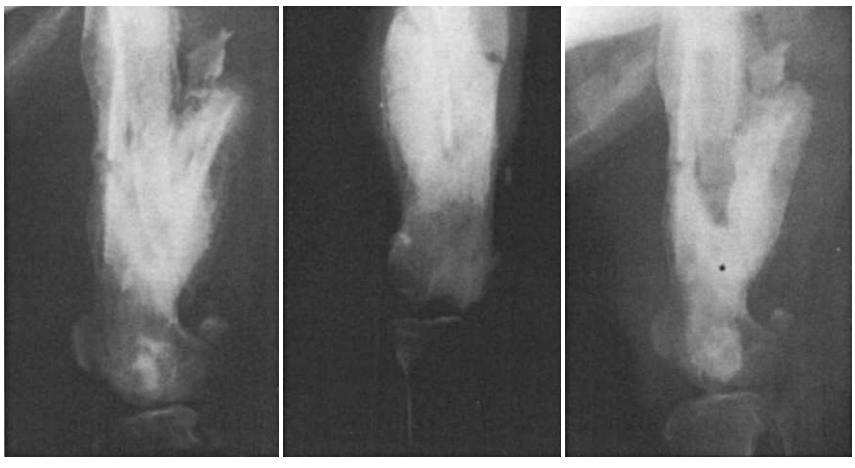
Case Studies

Case 1

Figure 5-3 depicts acute bone infection. A cocker spaniel struck by a car 5 days previously presented with an open draining area with bone protruding on the medial surface and a temperature of 104.5° F (Figure 5-3, *A*). The immediate objectives in treatment were to flush the area with Ringer's solution, apply rigid fixation, and place the animal on a regimen of systemic antibiotics. The area was prepared for surgery, which included flushing it. Fixation was accomplished by application of a unilateral external fixator, 2/2 pins (Figure 5-3, *B* and *C*). Because the distal bone segment was too short for placement of two pins proximal to the supracondylar foramen, the distal pin was placed in a transcondylar position. The proximal pin was inserted next, followed by application of the connecting bar and clamps, then the two center pins. This arrangement allowed full use of the leg during the healing period. The draining area was treated as an open wound, and it closed in about 2 weeks. Healing was uneventful. Clinical union was present at 9 weeks, and the external fixator was removed (Figure 5-3, *D* and *E*).

Case 2

Figure 5-4 depicts the history of a fractured femur, which was originally treated 5 months previously. Infection had been a constant problem from the time of surgery. Several draining tracts were present in the region of the popliteal lymph nodes, and a walled-off sequestrum was present (Figure 5-4, *A* and *B*). Culture and sensitivity testing indicated *Staphylococcus pyogenes*, which was sensitive to chloramphenicol, oxytetracycline, and chlortetracycline. In Figure 5-4, *C,* one large



A **B** **C**

FIGURE 5-4. Fractured femur treated 5 months previously; draining sinus tracts were present near the popliteal lymph nodes. **A** and **B,** Lateral and craniocaudal views indicating a walled-off sequestrum. **C,** One large and two small sequestra were removed surgically using a lateral approach to the femur. The sinus tracts disappeared in 1 week.

and two small sequestra have been removed surgically by a lateral approach to the femur. The bone was well healed, and the infection was walled off in the local area. The animal was placed on systemic antibiotics, and the draining tract disappeared in 1 week.

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6
Arthrology

STRUCTURE AND FUNCTION OF JOINTS

The purpose of joints is to afford the greatest stability to the body during weight bearing and motion. Painless and full range of joint motion are needed for normal ambulation and performance of daily living chores. Interruption of normal joint mechanics leads to painful osteoarthritis and physical incapacity, thereby reducing an individual's quality of life and increasing the burden on others. This is an increasing problem in human and animal geriatric populations because of longer life spans. Proper diagnosis and management of joint disease depend on understanding the basic anatomy and physiology of the musculoskeletal system. Cures for stopping or reversing osteoarthrosis are on the horizon. The material presented in this chapter should guide clinicians in understanding and arriving at rational treatments for joint diseases.

Connective Tissues

The "workhorse" of the musculoskeletal system is connective tissue. Its components are outlined in Table 6-1 and are mentioned throughout this chapter and Chapter 7. It is extremely important that clinicians understand the relationships among these components of joint tissue.

Classification of Joints

Joint classification[1,2] is summarized in the following way. Joint diseases of animals usually involve diarthrodial joints.

- **Fibrous joints (synarthroses).** These joints have little motion.
  1. Syndesmoses. These have considerable intervening connective tissue (e.g., temporohyoid joint).
  2. Sutures (e.g., skull).
  3. Gomphosis (e.g., tooth socket).
- **Cartilaginous joints (amphiarthroses).** These joints have limited motion, which permits compression and stretching.
  1. Hyaline cartilage (synchondrosis) (e.g., costochondral junction, epiphyseal plate of long bones of growing animals).
  2. Fibrocartilage (amphiarthrosis) (e.g., mandibular symphysis).
- **Synovial joints (diarthroses).** These joints allow the greatest amount of movement and are of primary concern to the orthopedic surgeon.

TABLE 6-1. COMPONENTS OF CONNECTIVE TISSUE IN JOINTS

Cell Types	Fibers (Proteins)	Matrix (Ground Substance)
Fibroblast	Elastin	Proteins
Chondrocyte	Reticulin	Mucopolysaccharides (proteoglycans),
Osteocyte	Collagen (hydroxyproline)	hyaluronic acid, chondroitin sulfate,
Synoviocyte		keratosulfate
Myocyte		Water

Components of Synovial Joints

All synovial joints have a joint cavity, joint capsule, synovial fluid, articular cartilage, and subchondral bone (Figure 6-1). Some joints, in addition, have intraarticular ligaments, menisci, and fat pads.

The articular surface of bone is covered by hyaline cartilage. The bones are united by a joint capsule and ligaments. The joint capsule is composed of an inner synovial membrane that produces synovial fluid and an outer fibrous layer that aids joint stability. The range of motion in joints is limited by muscles, ligaments, joint capsule, and bone shapes.

Any mechanical system wears out with time, and animal joints are no exception. Wear and tear occur with aging but may be hastened or exaggerated by trauma, disease, and structural and biochemical changes in the articular cartilage. Lubrication, which decreases friction, is vital in keeping the "machine" in proper working condition. This lubrication can be affected by the nature and geometry of the articulating surfaces, the synovial membrane, the physical and chemical properties of the synovial fluid, the load on the joint, and the type of joint movement.

Synovial Membrane

The synovial membrane is highly vascular, blends with the periosteum as it reflects onto bone, and covers all structures within the joint except articular cartilage and menisci. The synovial lining may extend beyond the fibrous layer and may act as bursae under tendons and ligaments. Basically, the *synoviocytes* (cells of synovial membrane) have two functions: phagocytosis and synovial fluid production.

Synovial Fluid

Synovial fluid is a dialysate of blood to which glycosaminoglycan (GAG) has been added by the synoviocytes. Its chief function is lubrication, which decreases friction, thereby decreasing wear and tear to articular cartilage. The synovial fluid also provides nutrition to the articular cartilage and maintains electrolyte and metabolite balance.

The chief GAG of synovial fluid is *hyaluronic acid*, which is highly polymerized and prevents serum proteins of high molecular weight from entering the fluid. Joint fluid proteins increase with inflammatory conditions either because of a decrease in this polymerized state of hyaluronic acid or as a result of an increase in the capillary permeability of the subsynovium. Both situations cause joint effusion. Corticosteroids are thought to interfere with production of hyaluronic acid.

Inflammatory joint conditions may be distinguished from noninflammatory conditions by analysis of joint fluid (see Table 6-2). In inflammatory conditions, the protein electrophoretic pattern of synovial fluid is altered, sugars are decreased, the cell population increases, and cell type ratios change. The polymerized state of

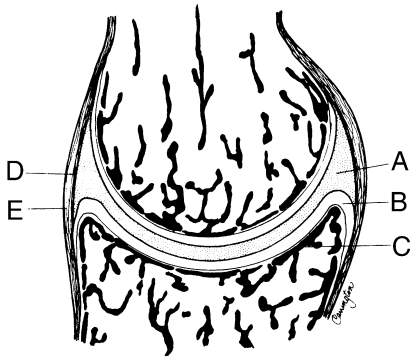


FIGURE 6-1. Schematic drawing of joint components: *A*, joint cavity with joint fluid; *B*, articular cartilage; *C*, subchondral bone; *D*, synovial lining; *E*, fibrous joint capsule.

hyaluronic acid can be estimated using the glacial acetic acid precipitate test.[3] The quality of GAG decreases rapidly in the presence of some infections and can slowly decrease in chronic osteoarthritis.

The viscosity of the synovial fluid is related to this mucoprotein; it is higher in small joints and at low rates of shear and use (walking, standing). A decrease in viscosity during more rapid joint movement causes less drag and therefore less friction of the joint surfaces. Cold temperatures may cause increased viscosity and therefore drag to joint surfaces. This partly explains the necessity for "warming up" before athletic pursuits.

Articular Cartilage

Joint cartilage allows gliding action of joints. It is the recipient of most blows and jolts to the skeleton. Its resilience buffers these blows, preventing erosion of the subchondral bone with subsequent shortening. The subchondral bone absorbs shock and in turn protects cartilage from damage.[4]

Grossly, normal adult articular cartilage is white, smooth, glistening, and translucent. It lacks blood vessels, lymphatic vessels, and nerve endings.[5] Nutrients must pass the synovial barrier and the cartilage matrix barrier before reaching the chondrocytes. Thus a mechanical or chemical joint injury is not recognized by the animal until a synovial reaction occurs. Some agents used to treat synovial disease may be deleterious to the articular cartilage (e.g., corticosteroids in rheumatoid arthritis) but are not detected by cartilage cells because of this lack of nerve endings in the cartilage. Because cartilage lacks blood vessels, the inflammatory repair process after trauma is impossible until deep lesions invade subchondral bone[6] (Figure 6-2).

The thickness of the articular cartilage is generally greater when the following are present[5]:

1. The joints are larger.
2. The joints are under considerable functional pressure.
3. Friction is increased.
4. The joints are not very congruent.
5. The joints are greatly used.
6. The animals are younger.
7. The joints are exercised.

Histologically, articular cartilage is composed of chondrocytes, fibers, and ground substance. Eighty percent of cartilage is water, 10% is collagen, and 10% is proteoglycan.[6]

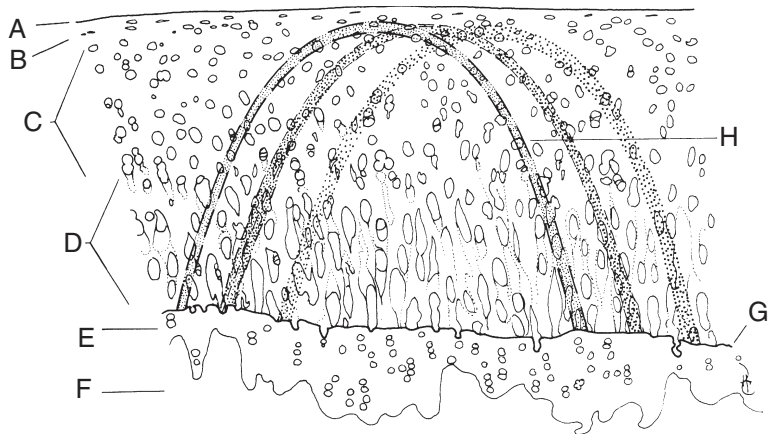


FIGURE 6-2. Schematic drawing of articular cartilage histology showing its layers and fibril arrangement: *A,* surface membrane; *B,* tangential zones; *C,* intermediate zones; *D,* radial zone; *E,* calcified zone; *F,* subchondral zone; *G,* tidemark; *H,* fibrils, or "wickets."

There are four layers of articular cartilage, not including a surface membrane (lamina splendens), based on fiber orientation and shape of chondrocytes, as follows[5]:

1. Tangential (surface layer)
2. Transitional (intermediate layer)
3. Radial (deep layer)
4. Calcified

The chief nourishment for the cartilage comes from the synovial fluid, with 7% to 10% coming from the blood vessels of the subchondral bone.[7]

Cells

Chondrocytes in mature cartilage are sparse but are metabolically quite active despite their appearance on light microscopy. The intermediate-zone cells are active in synthesizing protein and other components of matrix, as well as collagen. In immature cartilage, *mitoses* occur in the surface zone (resulting in growth of the cartilaginous mass during adolescence) and in the basilar layers (accounting for growth of the bony epiphysis). At skeletal maturity, however, mitoses are absent under normal conditions and cartilage cells are incapable of division. There is evidence that under certain situations, such as cartilage laceration and osteoarthritis, the chondrocyte can reinitiate cell synthesis and multiple division of a single cell (clone).[6]

Fibers

Collagen fibers are imbedded in matrix. They are not normally visible by light microscopy because the refractive index is the same as that of the ground substance.[2] They may be seen by phase-contrast microscopy or electron microscopy.[5] Freyberg[8] has postulated that the fibers form hoops, or "wickets" (see Figure 6-2). The surface arrangement of the cartilage fibrils provides a slightly irregular surface that prevents adhesions of opposing articular surfaces when lubricated by synovial fluid.[2] This superficial layer of tightly packed fibers resists shear forces during joint movement.[9] When pressure is applied at the surface, the fibrils expand laterally while the thickness decreases. When the pressure is released, the fibrils rebound

as a result of their elasticity.[8] This elasticity decreases with continuous compression or with age. The resiliency of cartilage also depends on the fibrils being supported by matrix proteoglycans.[9] The intermediate layer has the greatest shock-absorbing capacity because of the high content of bound water.[9]

If the superficial layers of fibers are lost through erosion (trauma), the matrix comes into closer contact with joint enzymes, leading to further degradation. This layer can then be considered like the integument as a first line of defense for the rest of the cartilage.

Matrix

The matrix, or *ground substance,* of articular cartilage is composed of bound water and proteoglycans. Subunits of proteoglycans are called *glycosaminoglycans* (GAGs), such as chondroitin 6-sulfate, chondroitin 4-sulfate, and keratosulfate. These macromolecules are stiffly extended in space as a result of their strong negative charges, repelling one another. They are hydrophilic and bind to the collagen fibers, thereby creating a barrier to absorption of substances from synovial fluid. Only substances having a low molecular weight permeate normal articular cartilage. The barrier to outward flow of organic components is thought to be the factor for its resiliency and resistance to deformation of the articular cartilage.[6]

The health of cartilage matrix may be measured by using metachromatic histochemical stains such as toluidine blue O or safranin O. Loss of metachromasia (and thus chondroitin sulfate) is characteristic of degenerating cartilage and is directly proportional to the severity of the disease. Staining is thus an excellent research tool.

Significant softening of the articular cartilage has been seen in dogs undergoing experimental stifle immobilization for 11 weeks.[10] Rabbit knees immobilized for 6 days underwent extensive loss of metachromatic staining.[11] Mobilization is therefore critical to the health of articular cartilage.

Diseases, injuries, or toxic agents affecting matrix or fibers result in changes that can be permanent, painful, and crippling. Understanding these mechanisms may elucidate a cure or reversal of these changes.

Healing of the Articular Cartilage

In normal situations, mitotic figures are not seen in the articular cartilage of adult animals. In lacerations to the articular cartilage or in osteoarthrosis, however, the chondrocyte can reinitiate DNA synthesis and cell division, possibly by release of biological suppression of the replicatory apparatus.[6]

If lacerations in adult animals are confined to the upper layers of the avascular articular cartilage, no inflammation or effective healing can occur. Mitotic activity does occur but ceases 1 week after initial injury. In rabbits, these superficial lacerations neither healed nor progressed to more serious disorders within 1 year of injury. When lesions were deep and invaded the subchondral vascular bone, reparative granulation tissue invaded the defect, which then changed to fibrocartilage by metaplasia. The end result, years after injury, is a discolored, roughened pit surrounded by smooth hyaline cartilage.[6] Allowing this vascularity to reach the surface is the theoretical reason for curetting or drilling a defect that results from osteochondritis dissecans. Continuous passive motion[12,13] (in which the animal is placed in a confining apparatus with the affected limb attached to a machine that moves the leg at preselected rates and ranges of motion for 2 to 4 weeks) has shed new light on articular cartilage healing. However, it remains to be seen if there are practical applications in veterinary medicine.

CARTILAGE AND JOINT ABNORMALITIES

Pain, deformity, and limb malfunction can result from improper joint physiology. Many acute joint conditions progress to chronic osteoarthrosis. The aim of the orthopedist is to minimize or stop these changes. In chronic osteoarthrosis the objective is to minimize patient discomfort and improve limb function.

Definitions

Arthritis. The simple definition of arthritis is inflammation of a joint. Many chronic orthopedic conditions in veterinary medicine do not have any long-lasting appreciable inflammatory component of the synovial lining. Therefore the term "arthritis" is a misnomer but so ingrained in the general population that this term will unfortunately persist.

Arthrosis. The term arthrosis refers to a noninflammatory degenerative joint condition characterized by a lack of inflammation in the synovial lining and the presence of normal or near-normal synovial fluid.

Osteoarthritis (osteoarthrosis). The common arthritis seen in veterinary medicine is a slowly progressive cartilage degeneration with osteophyte production, usually caused by trauma or microtrauma (abnormal wear). There is very little inflammation of the synovial lining (and therefore few changes in the synovial fluid) compared with the more inflammatory joint diseases. The synovial response is the basis for classifying joint disease. Because it is degenerative and not inflammatory, a more proper term for osteoarthritis is osteoarthrosis, or *degenerative joint disease* (DJD).

Classification of Joint Disease

Joint diseases are classified in the following way[14]:

I. Noninflammatory joint disease
   1. Degenerative joint disease (DJD), osteoarthritis, osteoarthrosis
      a. Primary
      b. Secondary
   2. Traumatic
   3. Neoplastic

II. Inflammatory joint disease
   1. Infectious
   2. Noninfectious: immunological
      a. Erosive
      b. Nonerosive

NONINFLAMMATORY JOINT DISEASE

Osteoarthrosis

Primary Degenerative Joint Disease

Primary DJD is a degeneration of cartilage in elderly individuals occurring for no known reason other than the wear and tear that comes with aging. Mankin,[15] however, points out that aged cartilage does not show the same changes as osteoarthrotic cartilage.[15] Consequently, contradictions in various histochemical

and biochemical data exist because of the types of abnormal cartilage that are analyzed and not identified as to source.

Most people older than 40 years of age have some degree of degeneration in the hip, knee, or interphalangeal joints of the fingers (Heberden's nodes). Much interest in this phenomenon has been generated in human medicine. Animals are useful as research models for osteoarthrosis. Bentley[16] has stated that a suitable model is valuable in facilitating further study of the pathogenesis of the disease and the effects of various treatments on it. The ideal model for DJD should start with the loss of cartilage matrix and should progress to fissuring, fibrillation, erosion of cartilage, subchondral sclerosis, osteophyte production, and mild synovial inflammation.

Secondary Degenerative Joint Disease

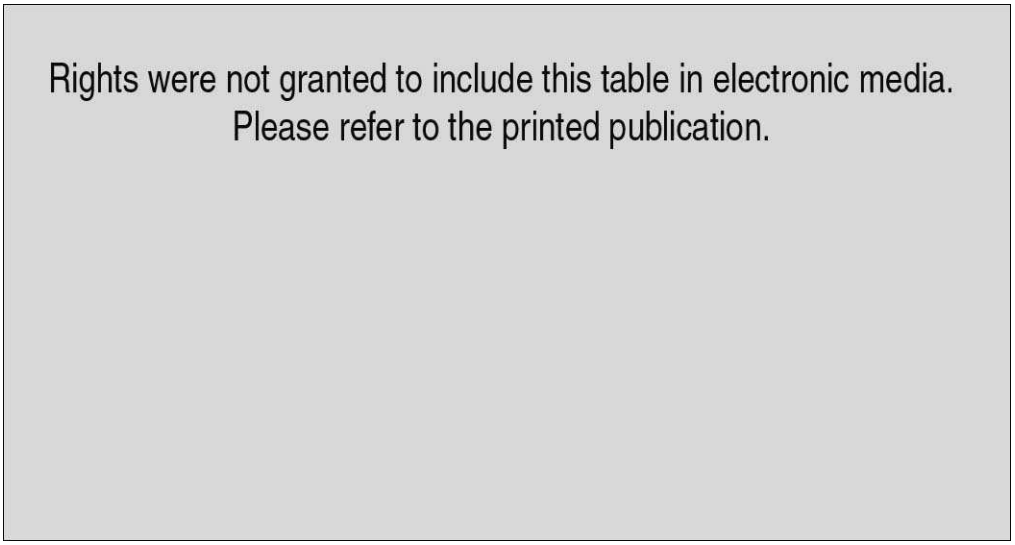
Secondary DJD develops secondarily from known conditions that affect the joint and supporting structures. This is perhaps the most common type observed in small animals. Those conditions predisposing animals to secondary DJD are outlined by Pedersen[14] (Table 6-2).

Degeneration of the Articular Cartilage

Bentley[16] states that the cartilage breakdown starts when compression or shear stresses cause cell damage, releasing cathepsin, which in turn induces loss of proteoglycans and water. This decreases cartilage resiliency and leaves collagen exposed so that fissuring (fibrillation) occurs. Additional chondrocyte damage then occurs, additional cathepsin is released, and the cycle continues (Figure 6-3).

Other investigators hypothesize that excessive wear occurs in this damaged cartilage with normal physical stresses, and that the degradation products released into the joint space produce secondary synovitis and sometimes inflammation (thus pain and effusion in acute flare-ups of a chronic situation). There are attempts at repair in the forms of granulation tissue, chondrocyte proliferation, clones, increased proteoglycan production, and osteophytes. However, with degradative enzymes, lack of

TABLE 6-2. CONDITIONS PREDISPOSING TO SECONDARY DEGENERATIVE



From Pedersen NC: Canine joint disease. In *Scientific Proceedings of 45th Annual Meeting of the American Animal Hospital Association,* 1978, pp 359-366.

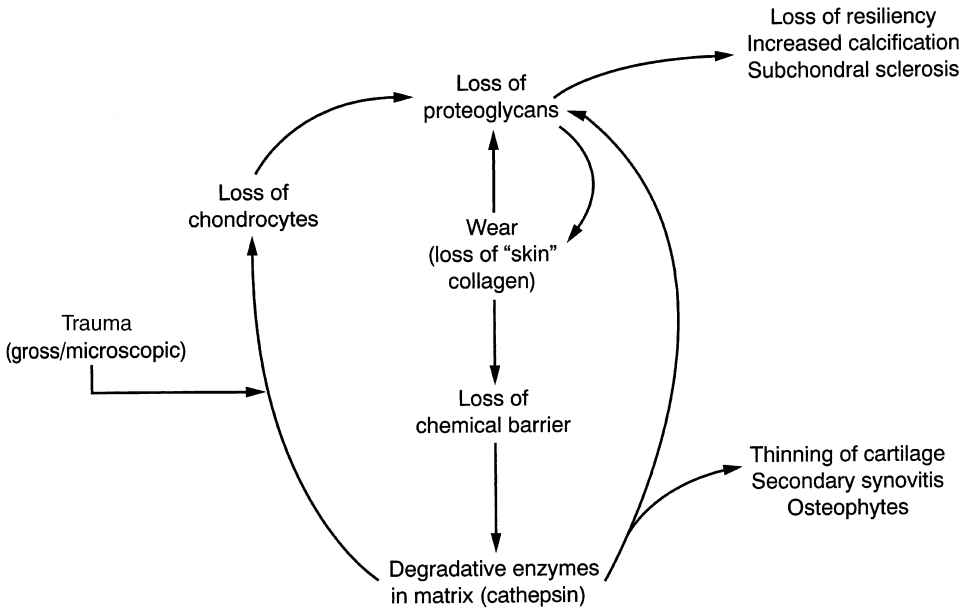


FIGURE 6-3. The vicious cycle of progressive degenerative joint disease.

orientation in regenerating tissue, and abnormal stress caused by these unstable joints, physiological repair attempts are usually negligible. Two reported cases, however, may show some reversibility of osteoarthrosis.[17]

In a case of hip osteoarthrosis, devitalized tissue was removed and a metal device interposed between the acetabulum and femoral head. Imperfect hyaline articular cartilage formed under the prosthesis. The implication is that the prosthesis protected the reparative granulation tissue from mechanical abrasion.[17]

In another case of osteoarthrosis of the hip, wedge osteotomies of the femur with reangulation of the femoral head were performed. Subsequently, radiographs showed regression of the osteoarthrosis.[17] Wilson[18] stated that there was an increase in the joint space and more reformation of cartilage.

Changes in Bone

Two changes in bone occur in the presence of osteoarthrosis: the production of marginal osteophytes and the appearance of subchondral sclerosis.

Osteophytes

Marginal osteophytes may protrude into the joint or may develop within capsular structures or ligamentous attachments to joint margins. Their shape is determined by mechanical forces and the surface contour from which they protrude.[15] McDevitt and colleagues[19] showed that histologically this begins 7 days after experimental rupture of the cranial cruciate ligament in dogs. At first, there was an accumulation of fibroblast-like cells at the synovial membrane-articular cartilage junction, which by 4 weeks had changed to woven bone with a few chondrocytes. By 8 weeks, trabecular patterns were seen in the early osteophyte along with resorption of the femoral cortex underneath, allowing some communication of bone marrow from each area. By 16 weeks after the rupture, the osteophytes consisted of trabecular bone covered by thick cartilage. By 48 weeks, the trabeculae and marrow of the

osteophyte and distal femur were confluent. Some investigators have proposed that hyperplasia of the cartilage margin is invaded by vascular granulation tissue with subsequent bone formation.[20] The reason for these osteophytes is unclear, and the theories are contradictory.[8,20-22]

Sclerosis

Under areas of cartilage erosion, sclerosis *(eburnation)* occurs. The denuded bone becomes polished and grossly resembles ivory or marble and represents advanced cartilage destruction. Turek[22] believes that an early stage of this condition results from endochondral ossification of the lower layers of cartilage, which histologically are detected by double "tidemarks" (wavy hematoxylin-staining lines demarcating the interface between calcified and noncalcified hyaline cartilage).

Changes in Synovial Membrane

The synovial membrane in DJD generally appears normal. The surface may show some hyperplasia, but minimal inflammatory response, except in certain forms of hip osteoarthritis in humans and large animals. With some partial cruciate ligament tears, however, we have noticed a red, proliferative synovial lining consistent with Griffen and Vasseur's suggestion that immune mechanisms may play a role in the development of spontaneous cruciate ligament rupture.[23]

Changes in Cartilage

Early gross changes in articular cartilage consist of a localized, soft or velvety area that changes to a yellow to dull-white color with pits, and with depressions and linear grooves becoming apparent. In advanced disease the cartilage may be soft and spongy. In areas where subchondral bone is exposed and subjected to wear, a highly polished eburnated surface may be present. In joints with apposing articular surfaces, "kissing" or mirror-image lesions develop. Osteophytes develop at joint margins where the synovium reflects off the chondral-perichondral junction. Osteophytes sometimes form in an area not covered by synovium. Bone spurs that form outside joints where tendons insert are termed *enthesiophytes*.

Histological Changes

Collins[24] has defined the histological progression of osteoarthrosis as follows:

1. Loss of surface cartilage layers.
2. Diffuse increase in numbers of cells.
3. Moderate decrease in metachromatic staining, indicating loss of proteoglycans. In experimental sectioning of the cranial cruciate ligament in dogs, McDevitt and associates[19] found this loss 16 weeks after the rupture.
4. Ingrowth of subchondral vessels through the tidemark.
5. Vertical clefts beginning at the surface (flaking).
6. "Fibrillation" when clefts extend to the calcified zone.
7. Further loss of metachromatic staining.
8. Cloning or clumping of chondrocytes.
9. Focal areas of erosion down to the subchondral bone, leaving exposed sclerotic bone.
10. Subchondral cyst formation.
11. Patches of new cartilage seen over eroded areas and osteophytes.

The stages just enumerated are not always present and do not always occur in the order given. In some cases, extensive erosions and eburnation occur without marginal osteophytes, whereas in other cases, many osteophytes may be seen without

appreciable change in the articular cartilage, such as in many spontaneous cruciate ligament ruptures in dogs. Dogs infrequently have subchondral cyst formation.

Biochemical Changes

In osteoarthrotic cartilage, collagen is renewed with a different type of collagen that is larger in diameter than the type found in skin and bone. The synthesis of protein and glycosaminoglycans is greatly increased—although the total quantity found is decreased—and is proportional to the disease severity in mild or moderate cases. In severe cases, there is a failure of this reparative process. This irreversibility suggests that treatment should be instituted at a relatively early stage of the disorder while there is still a capability of providing cells and matrix for repair of minimal to moderate defects.[25] Lacerations and chemical lesions do not show this reparative reaction. It may be feasible to treat lesions of cartilage with agents that decrease enzymatic degradation or with materials that could enhance repair (salicylates, uridine diphosphates).[25]

The interchange between the terms "osteoarthrosis" and "degenerative joint disease" are somewhat confusing at times. Human orthopedists frequently stress the decreased thickness of articular cartilage (with decreased joint space and sclerosis seen on radiography), whereas small animal clinicians usually are referring to marginal osteophytes. Often with cruciate rupture, severe osteophytosis may occur, but the articular surfaces look fairly normal rather than yellow, pitted, or eburnated. This joint performs better than when the cartilage is lost. Joint replacement in humans is considered when the surface articular cartilage is gone. Judging the severity of the arthritis based solely on osteophytes may be incorrect.

Clinical Signs

Osteoarthrosis in Humans

Because subjective patient descriptions are lacking in veterinary medicine, the clinical signs and symptoms of osteoarthrosis in people are reviewed.[26]

Pain. The prominent sign is pain that occurs on use of the part and that is relieved by rest. The pain is usually described as aching and poorly localized. With more advanced cases, pain may occur with minimal activity or even at rest. At times, pain may awaken a person after tossing and turning during sleep because of loss of joint "splinting," which limits painful motion during the waking hours. Pain may be exacerbated by changes in the weather, such as temperature, humidity, and barometric pressure.

This pain may originate from the following factors:

1. Elevation of normally sensitive periosteum because of marginal osteophytes
2. Pressure on exposed subchondral bone
3. Trabecular microfracture
4. Pinching or abrasion of synovial villi
5. Mild synovitis
6. Capsular inflammation

According to Gardner,[27] pain in capsules and ligaments is stimulated by twisting or stretching. There are pain fibers in the capsule and ligaments but few in the synovium. However, there are pain fibers in the adventitia of blood vessels supplying these areas. Gardner theorizes that increased sensitivity during weather changes is caused by reflex blood flow to the area of joints. In addition, the pain may be referred from one area of the limb to another as a result of reflex spasms of the flexor muscles.

Pain is often nonexistent in osteoarthrosis. In one study, only 30% of people with radiographic or pathological evidence of osteoarthrosis had any symptoms.[26] Generally, when symptoms were present, there was little correlation between degree of pathology and severity of pain.

Stiffness. Stiffness on arising from a resting position is common and usually lasts less than 15 minutes. The stiffness is caused by a change in the elasticity of periarticular structures. Loss of joint range of motion (ROM) may result from joint surface incongruity, muscle spasm and contracture, capsular contraction, or mechanical block from osteophytes or joint "mice."

Crepitation. On palpation, the human joint may show localized tenderness. Pain elicited by passive motion may be prominent. Joint crepitation (grating, crackling) from erosion or incongruity may be palpated; however, normal joint cracking or snapping is believed to be a slipping of tendons or ligaments over a bony prominence when the joint is flexed. The examiner may note loss of ROM. Bony ankylosis (fusion) of joints is very uncommon with osteoarthrosis. The joint may be swollen because of synovial reaction, increased joint fluid, or the presence of osteophytes. Although not a true crepitus, the noise that is made when knuckles can be "cracked" is caused by a negative resting pressure (−4 mm Hg) that becomes more negative (> −117 mm Hg) with distraction forces. This causes gas to go out of solution, resulting in a "crack."[28]

Obesity. It is still unresolved whether obesity is a contributing causative factor in osteoarthrosis.[26] Logically, it appears that a heavier weight would mechanically abrade a damaged joint more quickly. In mice with a genetic predisposition for primary degenerative joint disease, obesity did not alter the course of the disease. Epidemiological studies in humans, however, indicate that osteoarthrosis is more common in obese, rather than nonobese, individuals. In one study of 105 obese (≥50 kg) patients with chronic musculoskeletal pain, significant weight reduction was achieved by surgery on the stomach.[29] Eighty-nine percent of patients had complete relief of pain in one or more joints. Two patients regained their weight and their pain as well.

Osteoarthrosis in Dogs

Most of our experience with osteoarthrosis deals with the dog; the cat rarely has osteoarthrosis except after obvious injury. Hip dysplasia has been diagnosed sporadically in cats.[30] In the dog or cat, osteoarthrosis is usually not idiopathic or primary. It is usually secondary to trauma, unstable joints, malalignment or conformation defects, or congenital conditions such as osteochondritis dissecans and hip dysplasia. Exceptions may occur in very old or obese dogs. The clinician should try to discover the cause of the arthrosis in order to intervene in situations in which treatment may decrease the amount of discomfort and future osteoarthrosis an animal will have.

Pain. A discussion of pain is noteworthy, since our clients usually complain that their pet is in pain, or they may ask whether the animal is in pain when known osteoarthrosis exists. First, many dogs, as with some people, are stoic and do not let their pain bother them. Because they cannot tell us they are in pain and even though they may not cry or yelp, it is difficult to advise an owner whether an osteoarthrotic animal is experiencing pain, especially since we know that human patients with osteoarthrosis often are without pain.

An example of stoicism in a dog occurs in the event of fresh fractures. Many times, a dog will allow gentle palpation, radiographic positioning, and body movement without wincing, cringing, gasping, crying, yelping, or biting. Is this dog in pain? The answer is believed to be "yes."

Another finding is that excitement or nervousness may override the dog's sensitivity to pain. For example, a client may say, "He limps all day except when he goes out chasing rabbits," or lameness may disappear as the pet approaches the veterinary environment.

The most prominent sign of limb pain with osteoarthrosis is lameness. Limping or unusual gait can occur with other conditions, such as shortened limb (without pain), mechanical dysfunction (i.e., patellar ectopia, contracture of infraspinatus muscle), a stiff leg (usually from previous fracture), neurological problems, and neuromuscular weakness. After examination of the limb, shortening or mechanical problems can be eliminated. Therefore, limping is usually caused by pain. This is contradictory to a client's comment that the limping dog "doesn't seem to be in any pain." Clients fail to understand that dogs are more tolerant and less vocal than humans.

Other signs of pain—besides crying out, yelping, sensitivity on palpation, and favoring a limb—include loss of tolerance to exercise and reluctance to play, jump on furniture, or go up and down stairs. When rear legs are involved, the dog may "bunny hop," take short, mincing steps, sit with the painful leg cocked to the side rather than underneath the body, or show pacing, irritability (especially with children), and personality change. When the owner or veterinarian has judged that the dog has a "shoulder" or "hip" lameness, the clinician must keep an open mind. In our experience, locating the source of pain based on gait observation is difficult. The astute clinician should not make preconceived diagnoses based on other opinions.

Pain elicited on palpation is variable. Many dogs with known osteoarthrosis of a joint will not react to palpation. Identifying the area where pain has been elicited can be challenging at times. It is difficult to isolate and move one joint without moving other tissues or without pressing on a sensitive area during the manipulation. For example, in a young dog with panosteitis of the radius or ulna, the area may be grasped tightly while the shoulder joint is examined. When the dog cringes, the examiner is thinking about the shoulder joint and forgets that the elbow is extended and the forearm tissues are compressed.

The osteoarthrotic dog is similar to humans in regard to the pain worsening with cold, damp weather or a change in physical activity. This altered physical activity may include taking longer walks or runs than usual; slipping on ice and stretching contracted tendons, joint capsules, and other parts; or climbing stairs that have not been part of the daily routine. Although pain may be increased, it usually does not persist for more than 1 or 2 weeks. If it does, the clinician should be alerted to further problems, such as a ruptured cranial cruciate ligament with hip dysplasia, fracture of osteophytes, or further progression of pathology (e.g., meniscal damage occurring with chronic cruciate ligament disease). However, some chronically osteoarthrotic dogs progress to the stage where lameness or pain is continual.

The fact that in humans the radiographic signs may not correlate with the severity of the symptoms may help the veterinary clinician understand why a dog with severe osteoarthrosis of the hips may act totally normal without clinical signs, or why the dog may be more lame on the less arthritic hip, as shown by radiography.

Certain questions arise about the theorized origin of pain from osteoarthrosis. If osteophytes stretch sensitive periosteum, does debridement of these proliferations alone help the patient? Experimental data are lacking. If reflex muscle spasms from osteoarthrosis accentuate pain in people, can this be one of the benefits of pectinotomy for hip dysplasia in dogs? In cranial cruciate ligament rupture or partial rupture, the synovium is frequently reddened and corrugated. Can synovectomy in dogs relieve pain by eliminating hypertrophied synovial villi that can become pinched or contain immune complexes?

Stiffness. On arising from a resting state, an arthritic dog experiences stiffness. As with people, in earlier stages, this stiffness disappears as dogs "warm out of it." As time passes, this stiffness may become continual as fibrosis and decreased joint ROM occur. Decreased ROM is not as common or as great as in people, probably because of increased use a dog would have compared with a person, whose pain threshold is probably lower.

Crepitation. Crepitation is palpated on dogs with severe osteoarthrosis. The examiner must be careful at times in determining the source of crepitation because, if great, it can resound throughout the limb. If the stifle is palpated and crepitation originates from the hip, the examiner may wrongly assume the stifle is the origin of the crepitation. Sutures beneath the skin from previous surgery may also give a feeling of crepitation; however, this sensation will be of a quality different from the type that comes from bone rubbing on bone.

Obesity. The question of whether obesity contributes to the development of osteoarthrosis is pertinent in veterinary medicine. Most arthritic dogs that we see are overweight. Common sense tells us that extra stress on the joint contributes to abrading and degenerating cartilage more quickly. For example, hypernourished puppies with hip dysplasia potential have shown more DJD than those whose diets were restricted[31]; however, this does not indicate that the diet was the cause of hip dysplasia. In cases of ruptured cruciate ligaments, our clinical impression is that larger dogs develop osteophytes more quickly than smaller dogs. This may also be related to the fact that smaller dogs may "carry" or favor the leg, thus resulting in less damage from weight bearing. In some cases, dogs with chronic pain from osteoarthrosis seem to improve with weight reduction alone.

Age. Osteoarthrosis rarely is seen (radiographically or pathologically) in very immature animals compared with adults, except for cartilage diseases such as Legg-Calvé-Perthes or osteochondrosis. For example, a mature, large dog with cruciate disease would begin to develop osteophytes within 7 to 10 days after the rupture. Although the literature is sparse concerning natural rupture in young dogs, a few cases have been seen in which young dogs with chronic lameness (i.e., ≥2 months) associated with cruciate disease do not have remarkable cartilage change.

Treatment

The best treatment for osteoarthrosis is prevention. When a known disease condition is present with a potential for osteoarthrosis, the clinician should advise corrective measures or environmental changes to lessen the problem (e.g., surgery for cruciate ligament rupture, diet for overweight dogs with hip dysplasia, slinging for early Legg-Calvé-Perthes disease of femoral head). Interestingly, Murray states that excessive athletic activity in children is likely an important cause (especially in males) of subsequent DJD of the hip.[32] This contradicts those veterinarians and owners who believe that young dogs with hip dysplasia or with a potential for hip dysplasia should be heavily exercised to develop muscle mass and prevent or minimize osteoarthrosis.

Objectives

The objectives of treatment for osteoarthrosis in animals are (1) to relieve pain, (2) to maintain function and range of motion (unless undertaking arthrodesis), and (3) to maintain or regain normal activity.

Nonsurgical Methods

Rest. During flare-ups of osteoarthrosis, mild inflammation exists as debris is being absorbed and removed by the synovium. Weight-bearing activities tend to

aggravate and prolong this inflammation. Rest includes short walks on leash and elimination of running and jumping. Total disuse, however, may lead to excessive muscle atrophy and joint stiffness. In most animals, total limb inactivity is unusual. If inactivity seems to be a problem, gentle passive ROM exercises may be warranted. When the animal is overusing a joint affected by early osteoarthrosis, or in cases of early traumatic arthroses, coaptation splints, casts, or slings for 2 to 3 weeks may be useful.

Heat. Heat is very beneficial in relieving muscle spasm and pain. This may be accomplished by soaking a facecloth or towel in fairly warm water and applying it around the joint for 10 minutes, two or three times per day. Therapeutic ultrasound is an effective method of applying heat in animals. The dose range depends on the depth of penetration desired and ranges from 5 to 10 watts (total dose) twice daily for 5 to 10 days. In acute joint injuries, however, cold rather than heat is indicated to decrease pain, swelling, and hematoma formation.

Exercise. Our usual recommendation concerning degree of exercise is rest during acute flare-ups and moderate, self-regulated activity during remission. Encouraging an animal to overexert behind a bike or car or on an exercise treadmill is not advised. A dog will often not "feel" (until later) its limitations when excited to please an owner, chase a rabbit, or follow another dog in a race. Swimming is an excellent exercise for osteoarthrosis of joints because non–weight-bearing ROM exercise decreases joint capsule adhesions. If the animal has an athletic function (hunting, performance), permanent reduction of strenuous activity may need to be instituted to achieve a good quality of life for the pet.

Medications. Most medications do nothing to reverse osteoarthritis. Animals are medicated for the most part to decrease pain and discomfort. In recent years, more medications are available to the pet owner, and a general discussion is warranted. It must be remembered that drug interactions vary between species. Drugs proven to be safe and effective in humans are not necessarily safe in dogs or horses or cats. All animal owners should be warned to observe for the occurrence of vomiting, diarrhea, melena, anemia, edema, inappetence, abdominal pain, septicemia (perforation), or renal problems. The drug should be stopped if any of these signs occur.

By eliminating the animals' own defense mechanism (pain), overexertion and aggravation of joint degeneration are possible. Therefore, any pain-reducing drugs should be accompanied by rest. Medication should be used as determined by the animal's discomfort or decreased function, not by radiographs. The minimum amount of drug should be used to reach the desired effect, and the drug should be stopped when no longer needed. Masking pain may also delay proper diagnosis and management of some orthopedic conditions (e.g., osteochondritis dissecans of various joints, cruciate instability).

Nonsteroidal antiinflammatory drugs (NSAIDs) are antiinflammatory, analgesic, and antipyretic. Gastrointestinal (GI) side effects are still a major concern in animals and humans, even with the modern COX-2 inhibitors.[33] In the Vane model, the inflammatory cascade has been simplified, as follows[34]:

Tissue damage (→) Prostaglandin synthase (cyclooxygenase) (→) Prostaglandin (→) Inflammation

Prostaglandins are important normal substances in the body. The NSAIDs block the cascade from cyclooxygenase (COX) to prostaglandin, thereby decreasing inflammation. COX-1 is in many tissues and performs a variety of important homeostatic mechanisms, including manufacture of prostaglandins that protect the GI tract.[35] COX-1 inhibitors can lead to GI erosions and ulceration. COX-2 is not normally

found in most tissues and helps transmit pain and accelerates inflammation. Its absence is theoretically not harmful to the body. Therefore, although COX-1 and COX-2 inhibitors are helpful with decreasing pain, the COX-2 inhibitors are *theoretically* a better choice of drug with fewer undesirable side effects.

Aspirin in humans is reported to inactivate COX permanently (until new cells are formed), whereas other NSAIDs are competitive inhibitors and reversible.[34] In our hands, buffered aspirin along with food intake used judiciously and intermittently has not proved to cause problems in dogs. Aspirin in cats can be quite toxic (platelet dysfunction), but administration every third day in low doses is a widely used prophylaxis treatment for thromboembolism.[36] Aspirin also may occasionally be used for pain.

The following agents have been accepted, by U.S. Food and Drug Administration (FDA) approval or by common usage, for use in the dog. A drug that may be effective in some osteoarthritic individuals may not be effective in others. Positive clinical response is usually found by "trial and error."

- Etodolac (Etogesic, Fort Dodge): more selective inhibition of COX-2 than COX-1. Dose is 5 to 15 mg/kg orally once daily; supplied in 150- and 300-mg tablets; dogs only.
- Deracoxib (Dermaxx, Novartis Animal Health): COX-2 inhibitor. Dose is 3 to 4 mg/kg once daily orally for up to 7 days to control postoperative orthopedic pain; doses of 1 to 2 mg/kg/day can be administered long term for osteoarthrosis and inflammation; supplied in 25- and 100-mg scored chewable tablets; dogs only.
- Carprofen (Rimadyl, Pfizer Animal Health): selective inhibition for COX-2 than COX-1. Dose is 2 mg/lb once daily or 1 mg/lb twice daily; supplied in 25-, 75-, and 100-mg scored chewable tablets or nonchewable caplets; dogs only.
- Carprofen (Rimadyl, Pfizer Animal Health): injectable. May be used to control postoperative pain at a dose of 2 mg/lb daily for a maximum of 4 days postoperatively.
- Meloxicam (Metacam, Boehringer Ingelheim Vetmedica GmbH): 1.5 mg/ml oral suspension; supplied at 1.5 mg/ml in 10-, 32-, and 100-ml dropper bottles with measuring syringe. Dose is 0.2 mg/kg once daily orally for the first day, then 0.1 mg/kg daily orally thereafter; dogs only. For dogs weighing less than 5 pounds, it is recommended to use a dropper bottle at the rate of 1 drop for each pound of body weight, dropped directly on the food, not into the mouth. Dogs more than 10 pounds may be given the suspension directly in the mouth with a measuring syringe provided, or the agent may be mixed with food.
- Buffered acetylsalicylic acid (aspirin): COX-1 and COX-2 inhibitors. Dose is 10 to 25 mg/kg two or three times per day (preferably with food). Cats may be given 10 to 20 mg/kg every 2 or 3 days.

"Chondroprotective agents," more appropriately termed *disease-modifying osteoarthritic agents,* ideally enhance chondrocytic macromolecule synthesis, enhance hyaluron synthesis by synoviocytes, inhibit inflammatory modifiers, and remove or prevent formation of fibrin, thrombi, and plaque in synovium or subchondral vessels. No known agent performs all these objectives at this time. Cartilage is produced by chondrocytes, which synthesize matrix, giving cartilage its resilience and tensile strength. This matrix consists of collagen (supplying tensile strength) and proteoglycans (mainly hyaluronic acid and glycosaminoglycans), which provide the compressive resilience to cartilage.[37-39]

DJD is characterized by a slow, progressive loss of cartilage matrix molecules, called *polysulfated glycosaminoglycans* (PSGAGs). Intuitively, resupplying the body with these macromolecules could lessen or reverse osteoarthrosis.

Injectable PSGAGs (Adaquan, approved for use in dogs in the United States; Arteparon, used in Europe) have had conflicting efficacy studies. Although some *experimental* studies have shown efficacy, at this time there are no *clinical* data proving symptomatic relief or disease modification from administration of these drugs.[38] It appears, however, that the best results occur if PSGAGs are given early, before the development of significant DJD, at a dose of 5 mg/kg twice weekly for 4 weeks and then as needed. These products are fairly expensive to administer and are not available orally.[37-39]

Hyaluronic acid (Hyaluron) is a nonsulfated glycosaminoglycan (GAG) and a major component of synovial fluid. It is used intraarticularly or intravenously in horses. This product is postulated to help synovial fluid function by increasing viscosity, reducing inflammation, and scavenging free radicals.

Oral products supply building blocks for producing GAG and hyaluronic acid. "Neutraceuticals" do not require FDA approval, and some claim these products have the same parenteral effect as PSGAGs. Neutraceuticals are readily available over the counter, and there is no control as to their exact content or their ability to be absorbed (bioavailability). Fortunately, no significant side effects have been reported.

Chondroitin sulfate is the predominant GAG in articular cartilage. Its oral absorption rate in dogs has been shown to be 70%. *Glucosamine* is a building block of GAG in cartilage and hyaluronic acid in synovial fluid. Its bioavailability is good (87%). Gycoflex (Vetrascience Lab) is a mollusk exoskeleton and contains glucosamine and chondroitin sulfate. Cosequin (Nutramax Laboratories) contains glucosamine and chondroitin sulfate, as well as manganese and ascorbate. Its bioavailability is uncertain.

In conclusion, these disease modifiers have shown conflicting results. Results in humans are not necessarily comparable to those in dogs. Although these drugs clearly do not, at this time, reverse osteoarthrosis, they may have some benefits, especially the injectable products, when used early. Good long-term, blinded, placebo-controlled studies are needed to document their efficacy.[37] Oral products, which are less expensive, lack good scientific evidence that they modify osteoarthritis. Anecdotal reports at times claim "success," but this may only be the result of an antiinflammatory effect.

Diet. Although it has not been conclusively proved that obesity causes osteoarthrosis, common sense and positive clinical results lead us to recommend weight loss in overweight animals. Weight reduction alone has been very effective for some animals in reducing pain from osteoarthrosis.

Acupuncture. Some animal owners are interested in alternative therapies for osteoarthritis. Because anecdotal reports have shown promise,[40] we performed a double-blind prospective study of 19 dogs with clinical signs of hip dysplasia treated by gold bead implantation or placebo performed by an experienced, certified veterinary acupuncturist.[41] We failed to show any clinical improvement based on owner questionnaire or veterinary physical examination. Objective measurements using force plate and kinematic gait analysis showed no statistical differences between treatment and placebo groups.

Surgical Methods

Surgery for osteoarthrosis should be considered when pain or function is not helped by reasonable conservative measures. Procedures include debridement of osteophytes and joint surfaces, soft tissue or muscle release, arthrodesis (bony fusion of a joint), arthroplasty, osteotomy, pseudoarthrosis, neurectomy, and limb amputation.

Debridement. The removal of osteophytes may decrease the "tugging" on the joint capsule and therefore prevent pain, although the real efficacy is unknown. Regrowth of osteophytes may occur, especially if the inciting cause (e.g., instability) is not corrected. Removal of fractured osteophytes has also provided some pain relief in elbow, shoulder, and stifle joint osteoarthrosis. Debridement of "joint mice," cartilage flaps, proliferative synovium, and degenerative ligaments is also performed. Debridement is often used in conjunction with other procedures. Smoothing joint surfaces may enhance joint congruency and improve stability and joint fluid lubrication.

Muscle Release. A prime example of decreasing pain and restoring function involves cutting the pectineus muscle or tendon in the dog with hip dysplasia. The exact effect is uncertain, but improvement may result from destroying a painful spastic muscle, decreasing the forces between the painful femoral head and acetabulum, or reangulating an eroded area in the coxofemoral joint to allow weight bearing on a less-damaged area of cartilage.

Arthrodesis. Fusion of the carpal and tarsal regions is a fairly common procedure in dogs and is effective in relieving instability and pain. The canine limb functions satisfactorily with these fusions. Shoulder, elbow, and stifle fusions are attempted less often; these fusions have a slightly greater chance of failure, and greater gait impairment results than with fusion in the more distal areas. When arthrodesis is performed properly, however, a remarkable degree of function is obtained. At times, amputation results in a better ambulation function for the animal but is often unpalatable for the owners.

Arthroplasty. Arthroplasty means any plastic or surgical reconstruction of a joint. A synovectomy may fall into this category.[42] It is helpful in synovial chondrometaplasia and early cases of rheumatoid arthritis. Total hip replacement is another example of an arthroplastic procedure. This is now a fairly common procedure in small animal referral centers. Other prosthetic joints are not commercially available at present.

Osteotomy. In humans, wedge osteotomy on the proximal femur is an accepted treatment for coxofemoral arthritis. The reangulated femoral head is nailed or plated in a more varus precalculated position, which brings immediate relief of pain and can increase the joint space radiographically as some re-formation of surface cartilage occurs. Wilson[18] stated that simply breaking the bones is what brings relief, possibly because of a decongestive effect by altered venous drainage; mere trochanteric osteotomy without altering the femoral angle also gave immediate pain relief. It was not clear whether re-formation of cartilage is possible. With unicompartmental osteoarthrosis of the knee in people, tibial osteotomy is successfully used. In small animals, however, osteoarthrosis typically involves the entire joint, and osteotomy is an impractical option.

Bentley[16] produced osteoarthrosis in rabbits by injecting papain into coxofemoral joints. He then studied the effects 3 and 6 months after osteotomy. Results showed an increased blood supply to the femoral head and acetabulum, increased bone formation in the femoral head, and increased marrow activity. These changes can result in the clearance of bone cysts and subchondral sclerosis. The subchondral marrow cells produce fibrocartilage, and coupled with a more favorable redistribution of forces in the hip, a continuous surface layer is re-formed.

Wedge osteotomy of the proximal femur in dysplastic dogs has been performed in North America after encouraging results with its use in Switzerland.[43] Our experience is that, although dogs are helped clinically, osteoarthrosis is still progressive.[44] Pelvic osteotomy (see Chapter 16) is another example of an osteotomy usually used to *prevent* rather than treat osteoarthrosis.

Pseudoarthrosis. A good example of pseudoarthrosis is resection of the femoral head and neck in dogs and cats. It is a simple, effective technique for relieving pain in dogs and cats. With congenital luxation of the radial head in canine elbows, resection has resulted in good limb function. Pseudoarthrosis can also be useful for treating problems with the digits, if necessary.

Neurectomy. Sectioning a sensory nerve to relieve pain has been used in large animals but not in companion animals. The diffuse nerve supply to an area is one reason why neurectomy may fail in dogs. In humans lacking nerve supply to a joint (e.g., Charcot's joint, often caused by syphilis or diabetes), joint destruction is massive because of the absence of normal body responses in protecting a painful area.[22] Pursuing therapies along this line seems unwarranted.

Amputation. A final treatment that should be avoided but still considered is amputation of a limb or toe. In a few cases, however, such as a chronically infected, destroyed joint caused by a resistant organism, or when arthrodesis would result in a severe mechanical gait impairment, amputation may be in the patient's best interest.

Conclusion

Treatment of osteoarthrosis should include a proper balance of client instruction, moderate medication, and surgery if applicable.

Traumatic Joint Disease

Obvious traumatic joint conditions involve dislocation (luxation), instability from ligamentous disruption, and fracture. These conditions are categorized under "acquired degenerative joint disease." There are some general guidelines for selecting a rational treatment.

Dislocation (Luxation)

Dislocations result in obvious mechanical dysfunction. Normal nourishment and lubrication of the articular cartilage are lacking, and weight bearing on incongruent surfaces leads to further traumatic injury to the cartilage surfaces. In some cases, open reduction is less traumatic than prolonged, abortive attempts at closed reduction (e.g., elbow dislocated ≥5 days). Therefore, gentle closed reduction should be attempted as soon as possible before muscle spasticity prevents easy relocation or before the animal tries to bear weight too soon on an unstable joint. Most joints should be immobilized from 1 to 4 weeks after reduction, depending on the degree of instability remaining after reduction. A relocated elbow may not need any support, whereas a relocated hock may require 4 weeks of support. When the joint is so unstable that immobilization will not maintain reduction, some form of internal stabilization may be needed, such as capsular or ligament repair, pinning across joints, and other techniques that assist coaptational support.

Fracture

A fracture through a joint is serious when it affects a major movable joint. The hip, stifle, and elbow joints are most frequently involved. The aim of repair is to reduce the fracture line perfectly in order to decrease incongruency and subsequent degree of osteoarthrosis. Another objective in surgery is to stabilize fractures well enough to allow early weight bearing, which helps decrease joint stiffness and maintain range of motion. In general, pins, wires, and screws should not be placed through articular cartilage unless absolutely necessary. If necessary, non–weight-bearing areas of cartilage should be selected, if a choice is possible.

Instability

Instability from ligament rupture often involves the stifle joint. The ligament or its function should be repaired as soon as possible so that instability does not cause osteophytes, erosion, or possible discomfort from the resulting arthritis. Instability seen with congenital laxity, such as in hip dysplasia or patellar luxation, causes microtrauma of articular surfaces, deformity of bony contours, eventual erosion of cartilage surfaces, and osteoarthrosis. Simple "reefing" or imbrication of the joint capsule does not result in a permanent stability in these hips or patellas, in luxating patellas, or in cruciate rupture instability.

Thus, early repair of joint injuries is indicated to minimize the irreversible changes that may occur. Usually some osteoarthritis will form, and the surgeon attempts to minimize these changes so that the animal may lead a comfortable life. With cruciate ligament rupture, however, the client should be advised that the joint will never be as normal as it was before injury, despite the best efforts made. This may change the performance of a working dog. When performance must be maximal (e.g., in police, tracking, or sled dogs), the dog's function in life may need to be changed. In some cases, however, strenuous activities were resumed and the animal performed well.

Neoplastic Joint Disease

Neoplasms in joints are rare. From 1952 to 1978, there were only 29 cases in dogs and three in cats reported in the literature.[45] Primary tumors are termed *synoviomas, synovial sarcomas,* or *giant cell tumors*. These tumors are characterized by slow-growing swellings about a joint that occasionally cause pain on joint movement. Initially on radiography, only a soft tissue mass may be seen. There may be calcium deposits within the soft tissue. Later, destruction of the adjacent cortical bone occurs, followed by cancellous bone destruction. The tumor may appear encapsulated, but often there are extensions into fascial planes and surrounding tissues, resulting in a high rate of recurrence after extirpation.[45]

Wide surgical resection is advisable. Postoperative radiation therapy results in the dogs are unknown. In humans, there is a decreased frequency of local recurrence after postoperative radiation. If recurrences appear, amputation may be the best course to follow.

INFLAMMATORY JOINT DISEASE

Inflammatory joint diseases caused by infection or immunological factors are not rare in pet practice, but they occur infrequently. These conditions are characterized by inflammation of the synovial membrane with resultant changes in the synovial fluid (Table 6-3).[14] Lameness and gait impairment are the signs seen most frequently. Systemic signs may include fever, lethargy, anorexia, and leukocytosis. In-depth discussion of systemic inflammatory joint disease is beyond the scope of this text, and readers are referred to internal medicine textbooks for more detailed information.[46]

Infectious Disease (Arthritis)

Joint infections are usually caused by bacteria that enter the joint either through penetrating wounds or through the bloodstream. Fortunately, these infections are rare, but when an infection occurs, it can be devastating to the joint. Our experience with pets (other than neonates) differs from that of other investigators[14] in that joint

TABLE 6-3. SYNOVIAL FLUID CHANGES IN VARIOUS TYPES OF CANINE ARTHRITIS

Rights were not granted to include this table in electronic media.
Please refer to the printed publication.

From Pedersen NC: Canine joint disease. In *Scientific Proceedings of 45th Annual Meeting of the American Animal Hospital Association,* 1978, p 365.

infections usually have been caused by external wounds (e.g., surgery, gunshot, abrasion, laceration). The severity of joint destruction depends on the type of bacteria and the duration of infection. *Corynebacterium pyogenes* infection causes severe pannus formation (granulation) over cartilaginous surfaces, whereas *Clostridium* species can elaborate collagenase. *Streptococcus* and *Staphylococcus* produce kinases that activate plasminogen and result in plasmin, which removes chondroprotein from cartilage matrix. All these infections result in severe and widespread cartilage damage. Other bacteria may not produce destructive enzymes, and widespread permanent damage may not occur.

Signs

Pain and lameness are consistent findings with joint infections. The joint is swollen, warm, and tender on palpation. If the soft tissue trauma is extensive, the former signs may be present without infection.

Diagnosis

It is expedient to perform synovial fluid analysis and Wright's staining of the centrifuged exudate. This staining technique is more helpful than a Gram stain in picking up the presence of bacteria. Culture and sensitivity of this fluid are mandatory, although synovial biopsy culture is better. Early radiographs may show capsular distention, and subchondral lysis may appear later. Bacteria readily attach to the synovium. Therefore, it may be helpful to massage and "pump" the joint before joint tap so that the bacteria may be liberated into the fluid.

Treatment

In acute joint infections, treatment should be undertaken immediately. The exudate should be evacuated (by aspiration or by arthrotomy), the synovium cultured, the fluid smeared on a slide, and Wright's stain applied. High levels of appropriate antibiotics, depending on the results of the smear, are given systemically. However, antibiotics given before the culture is taken may prevent bacterial growth of the culture. Antibiotics should be given before receiving the culture and sensitivity results because of the disaster that may result if protection is withheld while awaiting test results. Choice of antibiotics may be changed when the sensitivity results are known. Penicillin G in high doses (30,000 IU/lb twice a day) is good initial drug. Ampicillin and the cephalosporins are also useful. These antibiotics should be continued for 2 to 4 weeks.

Early infections (within first 24-48 hours) may respond to joint aspiration and systemic antibiotics without arthrotomy. Arthrotomy, however, allows debridement of necrotic material; removal of fibrin clots, which may serve as a nidus for infection; and subtotal synovectomy, if joint motion is restricted by the thickened

joint capsule encroaching on the articular cartilage. Local instillation of antibiotics is contraindicated for two reasons: systemic antibiotics achieve adequate levels in the joint, and chemical synovitis may be created, enhancing the inflammation.[47]

Initially, the joint should be supported by a soft splint or bandage to reduce pain and inflammation. When clinical signs regress, gentle ROM exercise and minimal weight bearing may be allowed. If the joint is destroyed, arthrodesis may be indicated after the infection clears.

Noninfectious Diseases (Immunological Joint Disease)

Joint conditions believed to be the result of the immune mechanism can be divided into those that erode cartilage (e.g., rheumatoid arthritis) and those that do not (e.g., systemic lupus erythematosus). These conditions are becoming better known in veterinary medicine as the literature describing clinical cases and our diagnostic tools expand. Most of our knowledge comes from human medicine, where these diseases are common and potentially crippling or life threatening.

Erosive Inflammatory Disease

Rheumatoid Arthritis

Rheumatoid arthritis (RA) is defined as a severe, often progressive, polyarthritis of unknown etiology. It was first described in the dog in 1969,[48] and other cases have been described since then.[46,49,50]

Pathogenesis. The exact pathogenesis of RA is unknown but has been summarized as follows.[51] Endogenous immunoglobulin G (IgG) protein becomes altered for some unknown reason and stimulates IgG and IgM antibodies (called *rheumatoid factors*), which then combine to form immune complexes in the joint. These complexes activate the complement sequence, resulting in leukotaxis. Leukocytes phagocytize the immune complexes, thereby releasing lysosomal enzymes that alter the components of the joint. These enzymes contain collagenase; cathepsins, which disrupt basement membranes; and proteases, which can cleave glycoproteins.[52] The more prolonged the synovitis, the more prominent is the joint damage.[53] This succession of events is the basis for using antiinflammatory drugs. Surgical synovectomy removes the immune complexes and can be effective in humans if performed early.[54]

Signs and Symptoms. The clinical signs and course of RA may vary in dogs, as in humans. Depression, fever, and anorexia may occur with or without lameness. Joint swelling may be subtle or obvious. Often, more than one joint may be affected. With severe and chronic involvement, cartilage erosion may be detected by palpating crepitation. Erosions may be explained by the proliferative granulation tissue arising from the synovium, which crosses the articular surface (pannus) or invades the subchondral bone at the synovial attachments. Erosions in cartilage not covered by pannus may be caused by granulation tissue arising from the epiphyseal marrow, which erodes the subchondral bone.[55] Joint instability of the carpus and tarsus may be apparent while the dog is ambulatory. Drawer movement from stretching or tearing the cruciate ligaments may be palpated. Toes may dislocate. Spontaneous exacerbations and remissions occur.

Diagnosis. The diagnosis of RA is not provable. In humans, there is no pathognomonic characteristic or test. The American Rheumatism Association has established seven criteria (Table 6-4),[56] and a definitive diagnosis is made if a patient shows at least four of seven characteristics. Subcutaneous nodules (criterion 5) have not been reported in the dog.

TABLE 6-4. DIAGNOSTIC CRITERIA FOR RHEUMATOID ARTHRITIS*

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Please refer to the printed publication.

The rheumatoid factor test in humans yields false-positive and false-negative results. The latex particle rheumatoid factor test using human IgG, as performed in clinical laboratories, has given poor results in the dog.[57] In institutions using canine antigen, if the titer is high and other clinical signs are compatible with RA, a presumptive diagnosis of RA can be made because few diseases can cross-react. A negative rheumatoid factor test, however, does not exclude the diagnosis. Synovial histopathology reveals lymphoid and plasma infiltrates and is nonspecific.

Radiographic changes occurring in RA can include soft tissue swelling, increased joint fluid, decreased joint space, and lytic areas in the subchondral bone and juxtaarticular bone. Disuse osteoporosis appears at a later stage, and osteophytes form when instability occurs. The joint space decreases as cartilage becomes thinner, and it is seen especially in the carpal and tarsal joints.

In one report, four of 10 cases of RA occurred in the Shetland sheepdog.[49] In our experience the Shetland sheepdog and collie have been prone to this condition. Often the presenting signs are breakdown of the ligaments and tendinous support of the carpus or tarsus. Minimal trauma (e.g., fighting, jumping from a truck) may have alerted the owner suddenly to the lameness or joint angulation. The cartilage change seen on radiographs (i.e., lysis) or arthrotomy may be minimal. The inflammatory response may cause necrosis within bundles of collagen, leading to weakening and rupture of tendons and ligaments.[46,58]

Joint infections may be difficult to differentiate from RA. History and clinical course help to distinguish the two conditions.

Other inflammatory diseases have joint fluid analyses as well as systemic signs similar to those characteristic of RA. In bacterial endocarditis there may be a heart murmur, electrocardiographic changes, and little erosion of the cartilage.

Systemic lupus erythematosus (SLE) may be difficult to distinguish from RA in the early stages. SLE does not tend to cause erosions of cartilage, and it can have a high antinuclear antibody (ANA) titer.

Other diseases that may mimic clinical signs of RA include traumatic arthritis and DJD. History of sudden onset and involvement of only one joint help to distinguish these conditions from RA. Usually, synovial fluid analysis is valuable. Shifting leg lameness is seen with hypertrophic pulmonary osteopathy (HPO); however, careful limb palpation for swelling and radiography can usually elucidate HPO. Panosteitis causes a shifting leg lameness in young dogs, with some systemic signs (fever, inappetence), but can be differentiated by age, presence of bone pain, and lack of joint swelling.

Treatment. Antiinflammatory agents are used to block the production or action of the local mediators of the inflammatory response. Immunosuppressant drugs may be tried.[55] In general, it is wise to start treatment with the least toxic drug and to change therapy only when the maximum tolerated dose is ineffective.[59] In veterinary medicine, economics may play a considerable role. Salicylates (e.g., aspirin) are considered very effective in their antiinflammatory and analgesic effects and are still considered the first form of therapy for humans.

The most common cause of aspirin failing to achieve therapeutic results in humans is administration of an inadequate dose.[58] The dose for dogs with RA is 25 to 35 mg/kg (5 grains/20 lb body weight) every 8 hours. Aspirin should be buffered and given with food to decrease gastric irritation. It is debatable whether salicylates impede the disappearance of cartilage,[60] whereas corticosteroids hasten it.[61] Corticosteroids, such as prednisolone, 1 to 2 mg/lb acutely for 2 to 3 weeks, tapered over 3 to 4 months to 0.1 mg/lb every other day,[46] can be used as necessary if aspirin fails to decrease the active inflammation. Intraarticular injections of corticosteroids are seldom indicated. If the patient is not responsive to high levels of aspirin and is nonambulatory, the clinician may be forced to consider joint injections. However, multiple joint injections cause cartilage degeneration and cyst formation and thus should be used as a last resort.[6,62] Other drugs used with some success are the cytotoxic drugs (cyclophosphamide, azathioprine) and gold (sodium aurothiomalate).[46]

Other aspects of treatment consist of weight reduction, rest during flare-ups, mild exercise (swimming is excellent), synovectomy, and arthrodesis. Synovectomy and arthrodesis are practical only if one or two joints are involved.

Lyme Arthritis

Lyme arthritis is a relatively new disease caused by the spirochete *Borrelia burgdorferi*. It has been diagnosed mainly in northern California, the upper Midwest, and the Northeast. It can cause recurrent joint lameness, fever, inappetence, and lethargy. Conditions and signs less frequently associated with Lyme arthritis include lymphadenopathy, central nervous system (CNS) disorders, and renal and cardiac disease. The diagnosis is presumptive and should be based on a history of tick exposure and clinical signs, which include the presence of inflammatory joint fluid. Serological tests have a high proportion of false-positive and false-negative results and generally are not helpful.[63] Treatment is usually successful with the administration of antibiotics (tetracyclines, penicillins) for 3 to 4 weeks.[46] The use of preventive vaccines is controversial at this time and is not recommended except where Lyme arthritis is endemic.

Nonerosive Inflammatory Disease

Nonerosive inflammatory joint conditions involve three categories of disease: SLE, those associated with chronic infectious processes, and idiopathic conditions.

The symptoms can mimic rheumatoid arthritis, but erosions are rare and systemic involvement occurs. Lameness and weakness are common.

Systemic Lupus Erythematosus

The distinguishing feature of SLE is its serological abnormalities (LE cell or ANA positive). In humans, glomerulonephritis caused by aggregation of immune complexes in the kidney may cause death. Aspirin may control the joint aspects of SLE, but not the kidney changes.[59] Therefore, prednisolone is recommended and may be combined with cytotoxic drugs such as cyclophosphamide or azathioprine.[64] Polymyositis has been reported in the dog.[65]

Arthritides with Concomitant Chronic Infectious Disease

The presenting symptomatology of these arthritides is the same as for SLE, except that a disease process (*dirofilariasis,* or chronic fungal or bacterial infections of the heart, ears, or genitourinary system) is concurrent. Reversal of inflammation has occurred on resolution of the primary problem.[64] Rheumatic fever in humans (preceded by *Streptococcus* pharyngitis) may result in polyarthritis that is sterile, probably because of circulating immune complexes.

OSTEOCHONDROSIS

Osteochondrosis is a disturbance of cell differentiation in metaphyseal growth plates and joint cartilage. If this condition results in a dissecting flap of articular cartilage with some inflammatory joint changes, it may then be termed *osteochondritis dissecans* (OCD). This condition is very common in many species. In the dog, medium, large, and giant breeds are affected. By understanding the origins of these lesions, the veterinarian can devise a rational treatment for osteochondrosis at various stages and degrees of severity.

After a general discussion of osteochondrosis, each major joint is covered as to clinical signs, pertinent physical findings, radiographic diagnosis, treatment, and prognosis.

Pathology

Olsson[66] has characterized osteochondrosis as a generalized skeletal disturbance of endochondral ossification in which either parts of the physis (epiphyseal plate) or lower layers of the articular surface fail to mature into bone at a symmetrical rate. This results in focal areas of thickened cartilage that are prone to injury.

Bone growth (osteogenesis) in the metaphyseal area of the long bones occurs at the physis (growth plate) through endochondral ossification (bone formation following a cartilage precursor). The end of the bone—the epiphysis—must also grow. This occurs by endochondral ossification of the deeper layers of the surface articular cartilage. Osteochondrosis in the physeal area can result in an *ununited anconeal process* (UAP), retained cartilaginous cores at the distal ulna, and genu valgum (knock-knee). Osteochondrosis of the articular surface can lead to OCD in several joints (shoulder, stifle, hock, elbow, vertebral articular facets[67]) and possibly to a fragmented coronoid process and ununited medial epicondyle of the elbow.[66,68,69]

The form of osteochondrosis seen most frequently in the United States is OCD of the scapulohumeral joint. OCD and *fragmented coronoid process* (FCP) of the elbow are rapidly becoming a common concern, especially in the Labrador retriever and Rottweiler breeds. In our practice, they outnumber the cases of OCD

of the shoulder. UAP, OCD of the talus (hock), and OCD of the stifle are seen in lesser numbers. In Studdert's study of 1247 Labrador retriever puppies in an Australian breeding colony for producing guide dogs, 15% had osteochondrosis of the elbow.[70] In Grondalen's study of Rottweiler dogs in Norway, 50% of 1423 dogs screened radiographically for elbow arthrosis had positive results.[71] In our experience and that of others, the cause of the arthrosis is some abnormality of the coronoid (fragmented or fissured) process and less often OCD of the humeral condyle.[72,73]

Histopathology

Cordy and Wind[74] describe a histological sequence for the various stages of osteochondrosis. They studied the "normal" histology of the humeral heads from 14 dogs of large breeds 3 to 18 months of age. The predilective site for OCD had thicker-than-normal subchondral trabeculae that contained calcified cartilage until the dogs were 8 months of age. Nonpredilective sites of the humeral head showed ossified cartilage remnants in the trabeculae, which remained only until the animal reached 5 months of age. In three of these "normal" control animals, however, tongues of unossified cartilage extended into the subchondral bone region (Figure 6-4, *A*).

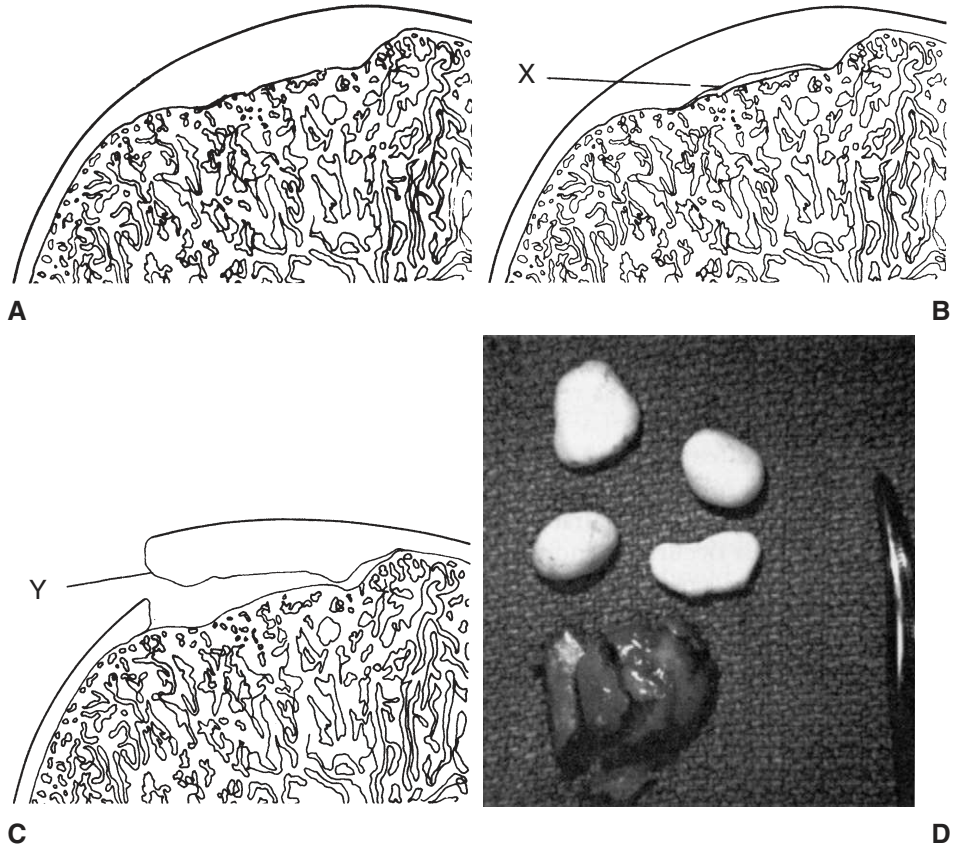


FIGURE 6-4. **A,** Schematic diagram of thickened cartilage representative of osteochondrosis. **B,** Osteochondrosis with a horizontal cleft that may heal or turn into osteochondritis dissecans. (*X* represents a crack in the calcified cartilage zone.) **C,** Osteochondritis dissecans with flap formation. (*Y* represents the flap.) **D,** Specimens from the radiograph shown in Figure 6-5, *E*. Note the color difference between the fractured osteophyte and the four white "joint mice."

The cartilage in the oldest of these three dogs contained necrotic chondrocytes. These three dogs probably had osteochondrosis, which might have progressed to the clinical lesions of OCD had they been allowed to live.

In the control animals, the "tidemark" (wavy hematoxylin-stained line demarcating junction of calcified and noncalcified layers of cartilage) was faint in younger animals but was dark-stained in those animals 6 to 7 months of age. In the predilective site, however, the tidemark was not prominent until the animals were 9 months old. The tidemark can be compared to a cementing substance. It may be that the predilective site has a weaker attachment (until the animal is 9 months of age) to the calcified cartilage zone than other areas of the humeral head.

A greater degree of asymptomatic pathology was seen in two other dogs.[72] On gross visualization of the smooth humeral head, a yellowish discoloration was seen bilaterally at the predilective sites. Histologically, there were debris-filled horizontal clefts along the tidemark region with thickened cartilage above it (Figure 6-4, *B*). This thickened cartilage superficial to the horizontal cleft contained some unorganized and necrotic chondrocytes.

When osteochondrosis progresses so that a vertical cleft breaks through the surface, the disease can then be termed OCD. It is at this point that lameness may occur. According to Pedersen and Pool,[75] if the subchondral capillary bed is able to surround, bridge over, and bypass this area of chondromalacia, then endochondral ossification can occur without a clinical lesion developing. If the vertical cleft radiates and becomes more extensive than in one linear spot, the cartilage can form a movable flap (Figure 6-4, *C*). These flaps, at this stage, are twice the normal cartilage thickness. Histologically, the surface appears normal, whereas the deep layers contain disorganized chondrocytes with some necrosis and calcification.[74] Bone was not found in these flaps except in two of 31 cases. In these cases, vascularized connective tissue extended to the flap from the underlying bone marrow of the bed. This vascularized cartilage then underwent endochondral ossification, allowing bone to form within the flap. In our experience, OCD of the hock usually contains bone. The cartilage flap is usually attached to the synovial lining and therefore receives nourishment. It can later undergo endochondral ossification after detachment from the subchondral region.

The bed of the defect formed a saucer-shaped depression covered by a granular, grayish white material that histologically represented the calcified cartilage zone. Beneath this zone, there was a thin layer of new fibrous tissue or fibrocartilage. Deeper to this, trabecular bone was normal, and no necrosis, comminution, or eburnation was present, at least in the early stages of this condition.

After the flap forms (usually 5 to 7 months of age), it cannot heal back down to the bed of the lesion. It undergoes further dystrophic calcification and may either stay in place with gradual degeneration or become dislodged. Often, there is a "kiss" lesion on the articular surface touching the loosened piece. When free, these "joint mice" migrate to pockets within the joint or in tendon sheaths that communicate with the joint. These joint mice may be engulfed by synovium, or they may remain free within the joint. They may grow in size because they are nourished by synovial fluid. Often they become rounded (Figure 6-4, *D*, and Figure 6-5, *E*).

Pathogenesis

The pathogenesis of OCD can be considered as a thickened area of articular cartilage that is not cemented down well to the underlying subchondral bone. Some chondrocytes may die. A tangential force, such as the scapula hitting the humerus during running and jumping, can crack this weakened area horizontally. If the



FIGURE 6-5. **A,** Flattening of subchondral bone, resulting from thickened, nonvisible cartilage superior to it, in a 5-month-old German shorthair pointer. **B,** Saucer-shaped defect in a 6-month-old Great Dane. **C,** Dystrophic calcification of the cartilage in a 7-month-old Great Dane. **D,** Elevated calcified flap in a 17-month-old German shorthair pointer. **E,** Calcified joint mice, roughened articular surface, and fracture of an osteophyte from the caudal glenoid of the scapula in a $2^1/_2$-year-old Great Dane.

trauma is continued, it may crack vertically through the articular surface, allowing synovial fluid to bathe the deep layers of degenerating cartilage, which in turn causes a synovitis. If there is no further stress (e.g., the stress of walking or running), the lesion may have a chance to heal. With further stress, the crack becomes circumferential, forming a nonhealing flap. The flap will continue to stimulate synovitis until removed. The cause of the thickened cartilage is unknown; however, a hereditary predilection is suspected.

Feeding the dog three times the recommended calcium intake has also produced osteochondrosis.[76]

Radiographic Appearance

Normal cartilage is not visible on plain radiography unless significant dystrophic calcification or bone formation has occurred. Because OCD lesions consist of thicker cartilage than the surrounding cartilage, the lesion is observed as a flattening, "divot," or saucer in the bone. Each characteristic lesion is described next.

Treatment

When recognized early (4 to 6 months), some syndromes (OCD of the shoulder, hock, and stifle, retained cartilaginous cores) may be treated with rest and restricted diets. Diet restrictions consist of decreased caloric intake of a well-balanced cereal dog food and cessation of calcium supplementation. Decreased activity may decrease shear forces and prevent flap formation. Once flap formation or separation has occurred, however, healing will not take place. Healing, or nonseparation of the thickened cartilage, should occur by 6 months of age, and it has been our experience that dogs remaining lame after $6^1/_2$ months of age have formed a nonhealing lesion and are surgical candidates at this point. Removal of the irritating flap or loose piece should be performed as soon as possible.

The first objective of surgery is to remove the flap or joint mouse that is irritating the synovium and gouging the opposite cartilaginous surfaces. A second objective is to remove any cartilage in the periphery of the bed that is not adherent to the underlying tissue. A third concern is whether the bed should be curetted. Curettage is sometimes recommended because granulation tissue from the bleeding subchondral bone invades the defect and fills it more quickly with fibrocartilage. This is especially true if the defect has dense sclerotic bone lining it. Often, however, a grayish material is already lining the defect (calcified cartilage layer) and may contribute to natural healing. Therefore, curettage may be unnecessary and even contraindicated. Another alternative is to use a Kirschner drill wire to drill a few holes in the

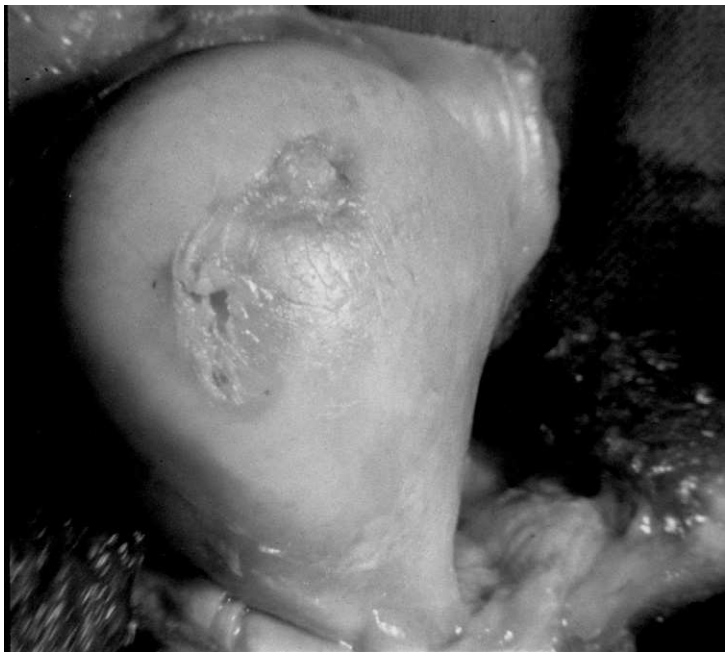


FIGURE 6-6. Humeral head of aged, stray coonhound dog with bilateral involvement of its shoulder joints. Note the degenerative-looking fibrocartilage, which may represent the "healing" of a flap that never detached (see Figure 6-5, *B*), or healing of the bed once the flap had detached.

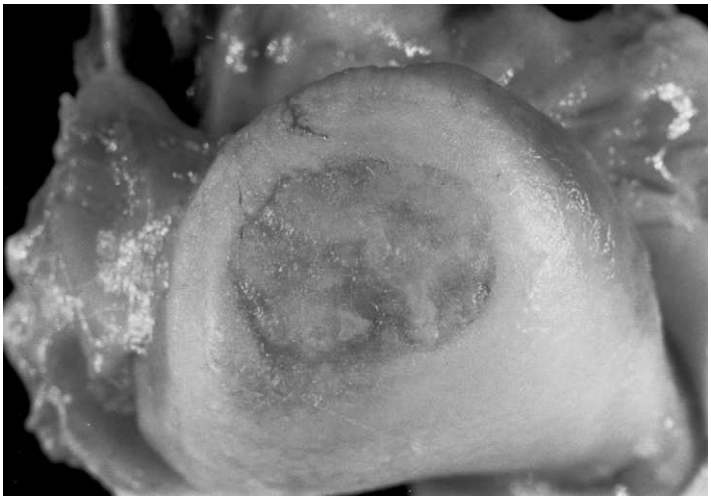


FIGURE 6-7. Humeral head of a 7-year-old Irish setter presented for forelimb amputation of an osteosarcoma of the radius. The dog had been lame all its life. A rounded joint mouse 1 inch in diameter was also found.

defect ("forage") to allow neovascularization without disturbing some of the cartilage elements already there.

Controlled experimentation using cases of natural disease is needed to provide guidance as to the proper therapy of the bed. Currently, we do not agree on recommending routine curettage of the bed.

Figure 6-6 shows the appearance of a humeral defect several years after natural flap detachment. Figure 6-7 provides an example of an incompletely "healed" lesion (unoperated).

Panosteitis (Chapter 24) is a common condition of large young dogs and may coexist with osteochondrosis. Care must be taken to rule out panosteitis (moderate to severe lameness, pain on long-bone palpation, characteristic radiographic lesions) as the source of pain to avoid surgery on an osteochondrosis that has not formed a flap.

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7

Principles of Joint Surgery

The structure and function of joints, discussed in Chapter 6, should be well understood as a basis for surgery. An ever-increasing percentage of small animal orthopedics cases have involved disorders of the joints, since stringent leash laws have limited the number of fractures seen in many urban practices. This chapter presents a few basic concepts necessary for success in arthroplastic procedures and defines some terms used in later chapters.

In small animals, diseases of the joints should be repaired as soon as possible to avoid permanent changes. Clinicians must adhere to strict asepsis to avoid devastating infection. Hemostasis is of utmost importance.

The objective of the orthopedic surgeon is to minimize the amount of uneven wear and abnormal stress across joint surfaces. This is accomplished by realigning joint fractures perfectly, removing loose bone (e.g., ununited anconeal process, fragmented coronoid process), correcting angular deformities, stabilizing instability (e.g., cruciates, patellar luxations), reducing dislocations, removing repetitive microtraumata (e.g., meniscal tears), reconstructing joints with diseases of cartilage (e.g., osteochondritis dissecans, Legg-Calvé-Perthes disease), and performing arthrodesis on nonreconstructible joints, such as those with rheumatoid arthritis, severe osteoarthrosis, and chronic instability.

Correct diagnosis and understanding of the disease process are paramount in good patient care. All too often, the "grand old panacea" (cortisone or any pain medication) is given without diagnosing the problem correctly, sometimes at the expense of permanently crippling the animal. In other cases, when a correct diagnosis is made, eliminating the animal's signs may bring immediate relief to the owner and veterinarian; however, this may shorten the life span as the animal approaches old age and develops crippling arthritis as a result of misuse of the limb.

There are many treatments for any given disease, some directly contradictory. The veterinarian must bear in mind the client, the economic situation, the home care, the use and function of the animal, and the veterinarian's facilities and surgical abilities and ability to refer to specialists. The veterinarian needs to adapt to these variables and may treat the same disease differently in different animals, depending on the circumstances.

Proper postoperative management is vital in achieving success. If the client is not advised on how to restrict the animal's activity for a certain length of time, how to take care of a splint (e.g., if a plaster of Paris cast gets wet), and how to look for complications, hours of the veterinarian's work may be wasted. If the patient or owner is uncooperative, longer hospitalization may be necessary. In all conditions in which osteoarthrosis is present or a potential for osteoarthrosis exists, lean body weight should be the goal. To check for optimal weight, the owner should be

advised to palpate and individualize each rib. When these ribs are palpable, and the abdominal area shows a discernible "waist," the animal has lost sufficient weight.

PRINCIPLES OF ARTHROTOMY

Surgical approaches to joints must be carefully planned to avoid damage to muscles, tendons, and major ligaments. Ideally, none of these structures would be incised, but in practice this is not always possible. It is very important, therefore, that these structures be properly sutured to maintain joint stability. Degenerative joint disease secondary to surgically induced instability of the joint is an unfortunate sequel to many otherwise successful procedures. Large ligaments and tendons should be detached, when necessary, by osteotomy of their bony origin or insertion rather than by incising and suturing. It is important to achieve adequate exposure for the proposed procedure; excessive retraction causes soft tissue trauma, and poor visualization of the joint usually results in an inadequate repair.

Incision into a joint often involves severing one or more fascial or fibrous tissue planes that function to stabilize the joint. These tissues are collectively known as the *retinacula*. The lateral retinaculum of the stifle, for example, is composed of the fascia lata, the aponeurosis of the vastus lateralis and biceps femoris muscles, and the lateral patellar ligament. The fibrous joint capsule could also be considered part of the retinaculum. In some cases these structures can be sutured collectively, and in some instances they need to be closed in layers to ensure normal function. The reader is referred to *An Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat*[1] for a discussion and illustration of specific approaches.

The actual incision into the joint capsule must be planned and executed to avoid damage to articular cartilage and to provide adequate tissue margins to allow suturing. Intraoperatively, damage to articular cartilage with retractors, knives, electrocautery, and other devices should be avoided. Frequent irrigation with saline or balanced electrolyte solution is valuable in maintaining superficial layers of articular cartilage in good condition. It is important to postoperative healing to maintain hemostasis to the extent possible and to remove large clots before closing the joint. Although the capsule is usually sutured, complete closure of the synovial layer is not necessary to prevent synovial fluid leakage. As with the peritoneum, the synovial membrane quickly seals itself by fibrin deposition and fibroplasia. Before a joint is closed, the joint space should be thoroughly irrigated to remove tissue debris and clotted blood.

Selection of suture material for joint capsule closure is the subject of a wide variety of opinions. Our general rules are provided here.

1. When the closure can be made without tension and the capsule is not important in stabilizing the joint (e.g., shoulder osteochondritis dissecans [OCD] surgery, medial approach to elbow for OCD), use continuous sutures of small-gauge (sizes 2-0 to 4-0) absorbable material or an interrupted pattern with nonabsorbable materials. The synthetic absorbable materials such as polyglycolic acid (Dexon, Davis and Geck, Wayne, NJ) and polyglactin (Vicryl, Ethicon, Inc., Somerville, NJ) are more satisfactory than surgical gut, being initially stronger and more uniformly absorbed. The more slowly absorbed monofilament synthetic materials such as polydioxanone (PDS, Ethicon) and polyglyconate (Maxon, Davis and Geck) are also excellent materials for use in these applications.

2. If the capsule must be closed under tension or if it is being imbricated to add stability, use interrupted sutures of nonabsorbable material in sizes 3-0 to 1. The choice of material is not critical; however, monofilament materials such as nylon or polypropylene are not as prone to becoming infected as are the braided materials. Polydioxanone and polyglyconate sutures provide the long-lasting strength needed for healing of the capsule under tension as well as the advantage of ultimately being absorbed. This greatly reduces the potential for long-lasting, suture-based infections. For these reasons, we are using these materials increasingly in joint surgery.

It is important with any nonabsorbable material that the suture not penetrate the synovial membrane in an area that would allow the suture to rub on articular cartilage. Such contact can cause erosion of the cartilage. Lembert and mattress patterns allow slight imbrication because of eversion, whereas the simple interrupted pattern allows edge-to-edge apposition. The cruciate interrupted pattern is excellent for holding the tension on the first throw of a knot and thus is very useful with suture material that is "slippery" to tie under tension.

The question is often raised regarding the usefulness of debridement of osteophytes in the arthritic joint. Experimental work has indicated that this procedure probably has questionable value.[2] In experimental dogs, osteophytes returned to 60% of predebridement level within 24 to 28 weeks, and there was no measurable clinical difference between treated and untreated dogs. However, because of experimental conditions (i.e., minimal production of osteophytes after severance of anterior cruciate ligament), the research cases had far fewer osteophytes than we typically see in clinical cases. Consequently, the results in this research protocol may not mimic clinical conditions. Therefore, we remove osteophytes when they mechanically interfere with joint motion, as is often seen at the proximal trochlear sulcus of the stifle joint; however, partial synovectomy of hyperplastic synovial membrane is indicated to reduce inflammation within the joint. Osteophytes are also removed when they are rough and protrude into the overlying, sensitive synovial lining. Fracture of osteophytes occasionally accentuates clinical signs of lameness.

LIGAMENTOUS INJURIES

A great deal of joint surgery in the dog and cat consists of treating various forms of ligamentous injury. We tend to think in terms of "luxations" or "ruptured ligaments" rather than in terms of *sprain injury* to ligaments. A brief review of the pathophysiology of sprain injury should help the clinician deal more confidently with these injuries.

Sprains

Although commonly used interchangeably, the terms "sprain" and "strain" have distinct definitions. A *strain* is an injury of the muscle-tendon unit, whereas a *sprain* is a ligamentous injury.

Ligaments are composed of longitudinally oriented bundles of collagen fibers that are so oriented as to have a much greater tensile strength in tension than in shear or torsion. Ligaments are very inelastic, however, and if tensile load exceeds the ligament's elasticity, the collagen fiber bundles will become permanently deranged at about 10% elongation. Damage to a ligament caused by external force is called a sprain (Figure 7-1).

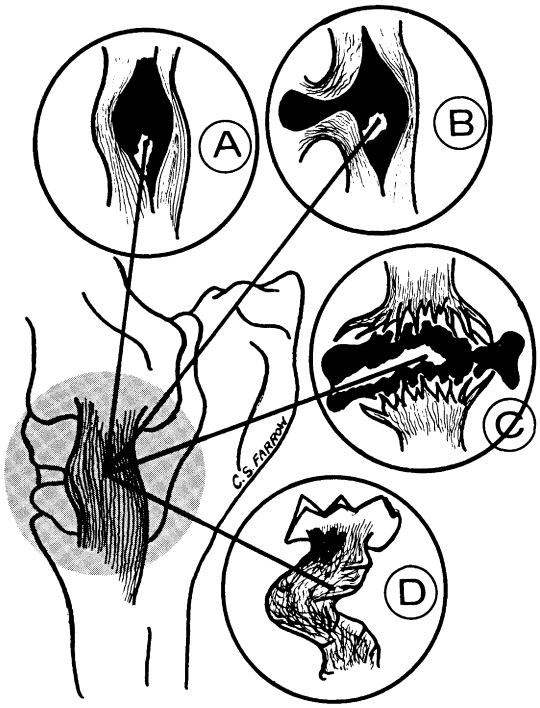


FIGURE 7-1. Sprain classification schemes generally focus on the qualitative aspects of the ligamentous injury. **A,** First-degree sprain injury involves minimal tearing of ligament and associated fibers, as well as a varying degree of internal hemorrhage. **B,** Second-degree sprain usually results in definite structural breakdown, as a result of partial tearing. Hemorrhage is both internal and periligamentous, with inflammatory edema being moderately extensive. **C,** Third-degree sprain is most severe and often involves complete rupture of the ligament body. **D,** Avulsion at the points of origin or insertion usually results in one or more small bone fragments, which may often be identified radiographically. (From Farrow CS: *Vet Clin North Am* 8:169-182, 1978.)

Sprains are conveniently categorized into three classes: first degree (mild), second degree (moderate), and third degree (severe)3 (Table 7-1).

1. *First-degree sprains,* or *mild sprains,* result from very-short-lived application of moderate force. Relatively few collagen fibers are damaged, and minimal functional change results. Hematoma formation and edema occur in the parenchyma with rapid fibrin deposition. Invasion of the fibrin by fibroblasts results in rapid healing, with normal anatomy being restored and no functional deficit. Minimal or no treatment is needed.
2. Second-degree sprains, or moderate sprains, are characterized by increased numbers of damaged collagen fibers, more extensive hematoma, and marked functional deficit (Figure 7-2). The ligament is grossly intact. Long-term restoration of normal function is unlikely without treatment.
3. Third-degree sprains, or severe sprains, are characterized by actual interstitial disruption (partial or complete) or avulsion of the ligament from bone (Figures 7-3, 7-4, and 7-5). Avulsion fractures of the ligamentous origin or insertion may also be present. Function is completely lost, and vigorous treatment is needed to restore function. Spontaneous healing by fibroplasia is virtually certain to result in an unstable joint.

Treatment

First-Degree (Mild) Sprains

Immediately after the first-degree injury, icing will reduce hemorrhage and minimize pain. Veterinarians rarely see the patient this early. Initial application of ice should be followed within a few hours by application of heat. External support is not necessary, although an elastic bandage may provide some comfort. Treatment is primarily directed at enforced rest for 7 to 10 days, followed by another 7 to 10 days of light exercise, such as leash walking or the freedom of a small kennel-run.

TABLE 7-1. CHARACTERISTIC FINDINGS IN *SPRAIN* INJURY IN THE DOG

Disorder	Physical Findings	Radiographic Findings
Chronic sprain	Regional soft tissue alterations, lameness, and variable degrees of limb deformity unaccompanied by signs of inflammation. There is almost always a history of prior trauma.	Regional soft tissue alterations often accompanied by signs of old bony trauma, osteoarthritis, and heterotopic bone formation.
Acute sprain		
Mild (first degree)	1. Minimal lameness. 2. Mild to moderate regional soft tissue swelling, which may be confined to the intracapsular location. 3. Tenderness on palpation. 4. Pain variable on manipulation.	1. Minimal regional soft tissue swelling; may be entirely absent. 2. No bony lesions. 3. No apparent instability; stress radiographs fail to identify spatial derangement.
Moderate (second degree)	1. Obvious lameness. 2. Obvious swelling. 3. Frank pain on palpation. 4. Pain readily elicited on minimal manipulation.	1. Prominent regional soft tissue swelling, usually both intracapsular and extracapsular in origin. 2. Bony lesions rarely present. 3. No apparent instability; stress radiographs may demonstrate spatial derangement (see Figure 7-2).
Severe (third degree)	1. Severe lameness, often resulting in no weight bearing by the affected limb. 2. Gross swelling, which may extend well into the proximal metacarpus and digits of the affected paw (see Figure 7-3). 3. Extreme pain on palpation or manipulation, frequently accompanied by crepitus or abnormal mobility.	1. Gross regional soft tissue swelling. 2. Bony lesions frequently present. Avulsion fractures are common and are often associated with subluxation. 3. Instability often apparent and readily demonstrable with stress radiographs (see Figures 7-4 and 7-5).

From Farrow CS: *Vet Clin North Am* 8(2):169-182, 1978.

Nonsteroidal antiinflammatory drugs (NSAIDs) may be useful for a few days but may also encourage the animal to be overactive. By the end of the third week, most animals with mild sprains can be allowed unrestricted activity, although extremely vigorous exercise should be approached gradually.

Second-Degree (Moderate) Sprains

More aggressive and definitive therapy is required in second-degree injuries to ensure full return to function. It is extremely important to realize that 6 to 10 weeks may be required for initial healing and that full stability may not be achieved until 3 to 6 months after injury. If no instability can be demonstrated, the limb is splinted for 2 to 3 weeks, followed by 2 weeks in a firm elastic bandage, if possible. Light activity is started at the removal of the splint and slowly increased toward normal between 6 and 8 weeks after injury, although maximal-effort activities should be delayed until at least 12 weeks.

If instability can be demonstrated either by palpation or radiography, the best chance of success lies with early surgical repair of moderate sprains (see following section on surgical repair). Because the ligament is basically intact, the technique of suture *imbrication* or plication is employed to make the ligament taut in its functional position and to support it during the healing phase. The joint capsule and retinaculum can also be imbricated for additional support. The limb must be immobilized postoperatively, with the affected joint at a functional angle in some manner that will protect the ligament from severe stress initially. However, it is important not to stress-shield the ligament completely for too long; 4 to 6 weeks



FIGURE 7-2. Second-degree sprain. The stressed radiograph *(closed arrow)* demonstrates slight instability on the medial site *(open arrow)* of the carpus, evidenced by excessive valgus deformity of the metacarpus. This view should be compared with a similar view of the contralateral limb to confirm the spatial derangement.



FIGURE 7-3. Third-degree sprain, showing marked swelling of the carpus and metacarpus and non–weight-bearing lameness.

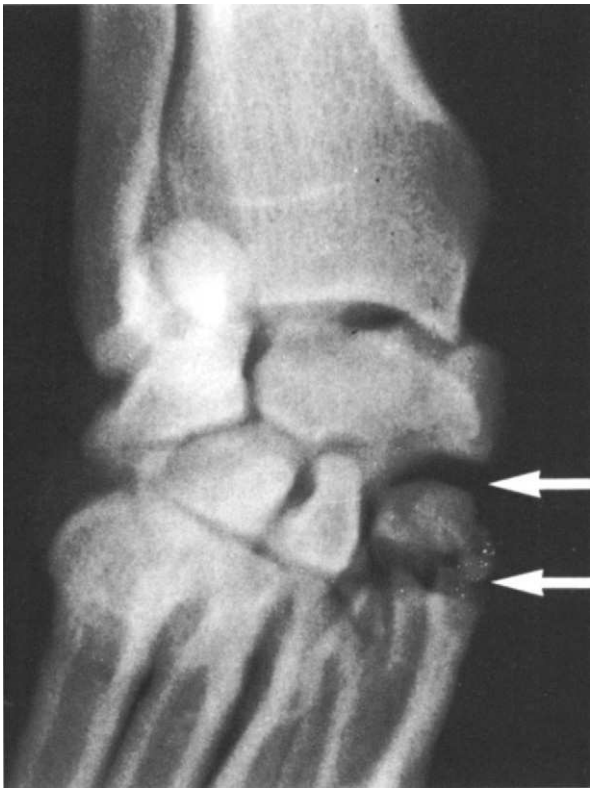


FIGURE 7-4. Third-degree sprain. Stressing the metacarpus in the lateral direction indicates severe valgus deformity caused by complete rupture of ligaments at the midcarpal and carpometacarpal joints *(arrows)*.

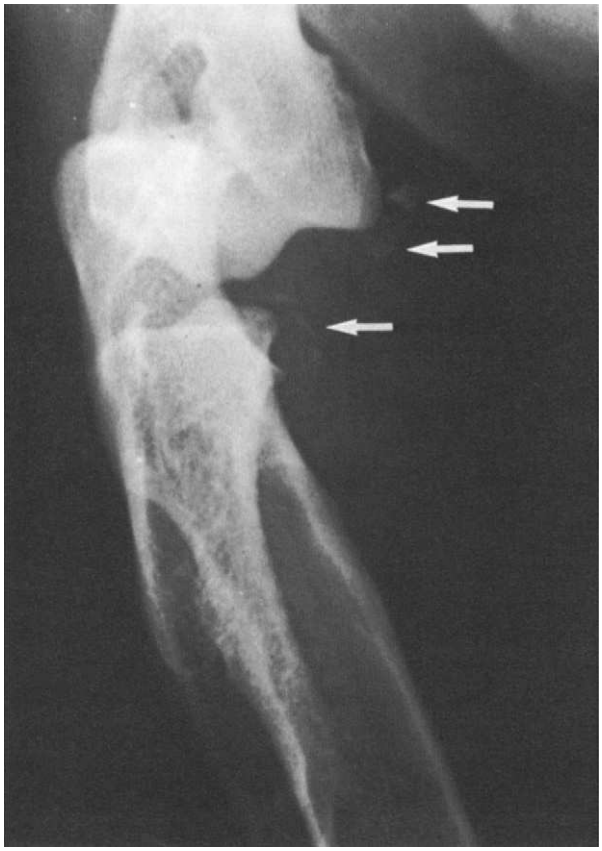


FIGURE 7-5. Third-degree sprain with avulsion of ligaments (*arrows*) on the medial aspect of the humeral condyle.

in the splint/cast is adequate. (See the discussion of splints and casts in Chapter 2 for more details.) On removal of the cast, it is critical that the animal be closely confined until 8 weeks postoperatively. Motion without undue stress will stimulate reorganization of collagen and produce more normal structure than prolonged, complete immobilization. An elastic padded bandage may be useful for the first 2 weeks after splint/cast removal.

Between 8 and 12 weeks after the second-degree injury, a slowly progressive exercise program should be started. This may consist of short periods of leash walking or being turned loose in the yard for a few minutes. The activity level is gradually increased for another 4 to 6 weeks, at which point most patients will be able to return to near-normal activity.

Delayed surgery in the presence of instability is not as successful as early repair for second-degree sprains. The necessity of early surgical repair is directly related to the size and activity level of the patient. Small, sedentary animals may have a successful outcome when treated nonsurgically, whereas in the same type of situation, a large athletic dog would end up with a permanent instability and degenerative joint disease.

Third-Degree (Severe) Sprains

Suture repair of the torn ligament is the primary method of treatment for this class of injuries (see following section on surgical repair of ligaments). The locking-loop (Kessler)[4] and pulley suture patterns[5] have proved most reliable. Monofilament nylon or polypropylene in size 0-4/0 is most often used. Shredding of the ligament (a crabmeat-like appearance) may make it difficult to reappose the severed ends. In these cases the ligament is augmented with strong suture material to support the joint while fibroplasia envelops the suture and ligament. This fibrous tissue reorganizes in response to tension stress because of loosening or stretching of the suture and eventually can provide a functional substitute for the original ligament. Materials that can be used include braided polyester sutures in size 0-2, monofilament nylon, and wire. These sutures are usually anchored by means of bone screws or bony tunnels. It is important to make these anchor points of the ligament correspond to the normal origin or insertion point to allow a full and unrestricted range of motion. If a pedicle of nearby fascia or tendon can be harvested, it can be sutured to the remaining ligament to act as a source of fibroblasts and as a lattice for fibroplasia in the same manner that a bone graft functions.

If the ligament is avulsed close to a bony attachment, it can often be reattached with a screw and plastic spiked washer or a bone staple with a special insert. Likewise, it may be possible to anchor suture material in the ligament and then use the suture to pull the ligament into contact with the bone, after which the suture is tied around a screw or anchored through a bone tunnel.

Bony avulsions of ligaments can be reattached by small screws with or without spiked washers, by multiple Kirschner wires driven through the fragment at divergent angles, by tension band wire with or without a Kirschner wire, or by stainless steel wire anchored through bone tunnels. Regardless of the method of fixation, reduction must be accurate to restore joint stability. If the joint is unstable after reduction, the ligament may need imbrication, as described for second-degree injuries. Postoperative management is also provided as described for second-degree injuries.

Surgical Repair of Ligaments

Conservative treatment of many second-degree and most third-degree injuries with instability is discouraged because permanent joint laxity often results.[3] Ligamentous

tissue shows little tendency to contract during healing, and very minor elongation, perhaps as little as 10%, causes loss of effective function and joint laxity. Additionally, scar tissue does not stand tension forces well and does not adequately substitute for ligamentous tissue.

Several basic methods are used in ligamentous reconstruction.

1. Stretched ligaments (second-degree injury) are imbricated by suturing (see Figures 7-1 and 18-23, *G* and *H*).
2. Torn ligaments are united by suturing, as shown in Figures 7-6, 7-7, and 7-8. Small, flat ligaments are repaired by incorporating sutures with the fibrous joint capsule and by use of the "prosthetic ligaments" (see Figure 18-23, A and B) if necessary.
3. Avulsed ligaments are reattached as closely as possible to their original point of bony origin or insertion. If the ligament is pulled away from the bone cleanly, it can be reattached by a lag screw and plastic spiked washer (see Figure 18-23, *D*) or a suture placed in the ligament and then attached to either a bone screw (see Figure 18-23, *F*) or a tunnel through an adjacent bony prominence (see Figure 20-12, *B* and *C*). Suture anchor devices (see Figure 14-24, *D*) may be used as an alternative to bone screws and washers to attach suture to bone for synthetic ligaments (IMEX Veterinary, Longview, Texas).
4. When bony avulsion of a ligament occurs, a lag screw with or without a plastic spiked washer is ideal if the fragment is large enough (see Figure 18-23, *C* and *D*). Smaller fragments can be attached with stainless steel wire (see Figure 18-20, *C*) or with three diverging Kirschner wires drilled through the fragment (see Figure 18-20, *D*).

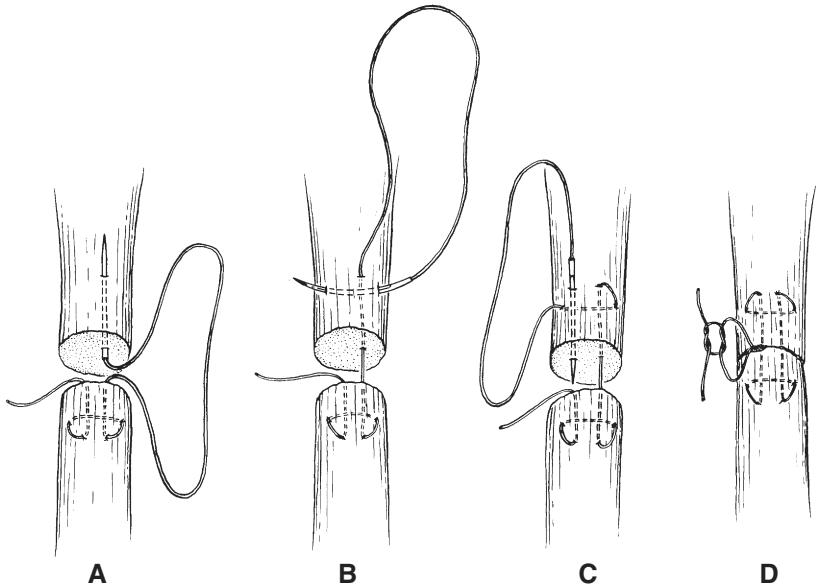


FIGURE 7-6. The locking-loop tendon-ligament suture.[4] **A,** The second half of the suture pattern is placed by entering the cut end with the suture needle and exiting the tendon at a distance from the cut end about equal to the width of the tendon. **B,** A transverse bite is made superficial to the first bite. **C,** The needle is passed deep to the transverse bite. The two corner loops surround and lock against a group of ligament-tendon fibers. **D,** The suture is tied.

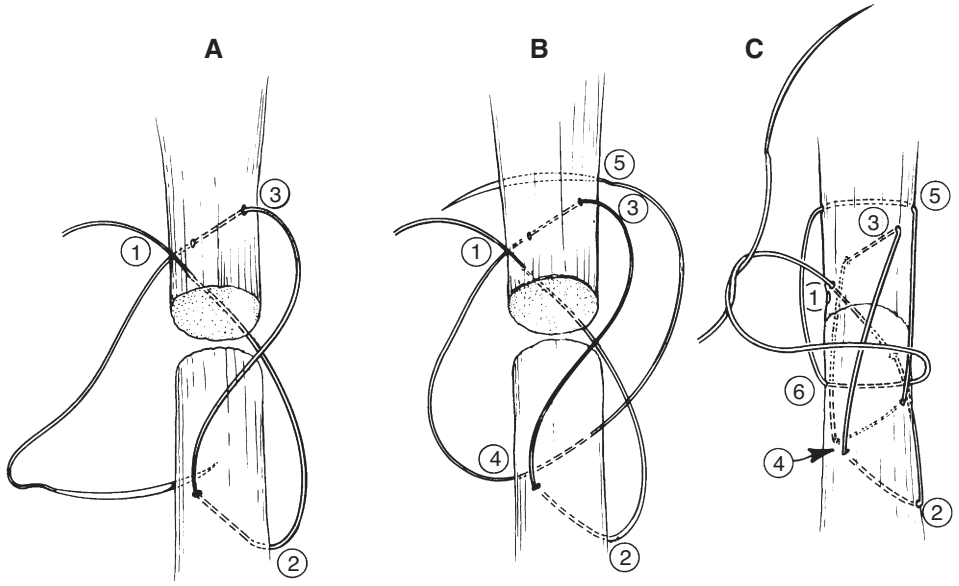


FIGURE 7-7. The pulley tendon-ligament suture. A monofilament material such as nylon or polypropylene must be used to obtain proper tightening of this suture. In theory, bites *1, 3,* and *5* are rotated 120 degrees from each other. In practice, as much rotation as possible is obtained. **A,** The first bite is made in a near-far pattern. **B,** The second bite is midlength between the near-far pattern; the third bite is made in the far-near pattern. **C,** The suture is tied. (From Berg RJ, Egger EL: *Vet Surg* 15:107, 1986.)

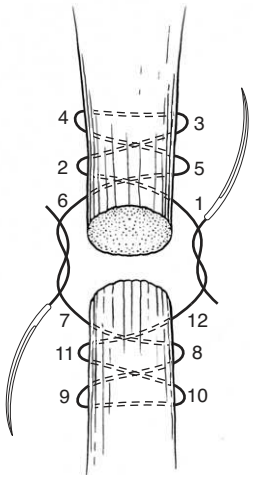


FIGURE 7-8. Modified double Bunnel-Meyer suture. This suture weaves through large tendons and obtains its main holding strength from the outer peritendinous tissue. *1,* The suture is placed on the outside end of the tendon, angled away from the cut edge, and exits. *2,* An $^1/_8$-inch bite of peritenon is pierced as the needle is again angled away from the cut edge. *3,* Another $^1/_8$-inch bite is taken as the needle is passed parallel to the cut tendon edge. *4* and *5,* Two more bites are taken while the needle is angled toward the cut edge and, *6,* emerges just proximal to the cut edge. The process is repeated on the other side of the cut tendon. The first half of a surgeon's knot is tied on one side of the paired suture and temporarily grasped with a smooth-jawed needle holder while the opposite side *(1* and *12)* is tied. The needle holder is released as the second throw of the knot is placed.

5. When the ligament is completely destroyed, as in shearing injuries of the carpus and tarsus, or in chronic injuries, the ligament must be prosthetically replaced. Such reconstruction is illustrated in Figure 20-4, *C* and *D,* and 14-24, *B* and *C*. Large sizes of braided polyester suture and tape (Polydek, Tevdek-Deknatel, Queens Village, NY; Mersilene, Ethicon), sizes 0 to 2, and monofilament nylon size 0-3 or 10-30# leader have often been used for this purpose, but polyester arterial grafts may be stronger. Carbon and stainless steel filaments show promise as extraarticular ligamentous replacements because fibrous tissue infiltrates them well and can result in formation of a functional pseudoligament. However, carbon fibers have little initial strength.
6. Any type of repair may be augmented by transposition of adjacent fascia to add strength and more fibroblastic elements for repair (see Figure 18-23, *I*, *J*, and *K*).

Protection of the ligament during healing is necessary to prevent the sutures from tearing out and to prevent elongation of healing ligamentous fibers. None of the repair techniques available is able to withstand full weight-bearing stresses for several weeks. In some cases, internal support is supplied by prosthetic materials, as just described (see Figure 18-23, *A*). External skeletal fixators are often useful to support ligamentous repairs, particularly in the presence of open wounds (see Figures 14-24, *E,* and 20-5). Other cases are best supported by external casts and splints, as detailed in Chapter 2. Casts and splints are generally maintained for 4 to 6 weeks, followed by 6 to 8 weeks of very gradual resumption of activity. Swimming is an ideal form of physiotherapy.

MUSCLE-TENDON INJURIES

Injuries of the muscle-tendon unit are termed strains (Figure 7-9). Strains can be chronic and multiple or acute and singular in nature, can occur anywhere in the

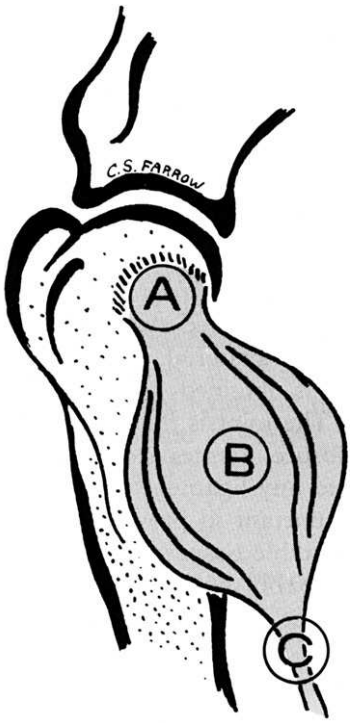


FIGURE 7-9. Strain injuries should always be considered in the context of all anatomical components associated with a muscle-tendon unit (MTU): origin or insertion (A), muscle belly (B), and muscle-tendon junction or tendon body (C). Injury to any part of the MTU is typically reflected by dysfunction of the unit as a whole. (From Farrow CS: *Vet Clin North Am* 8:169-182, 1978.)

muscle-tendon unit, and can vary in their severity from mild to complete rupture (Table 7-2). Milder forms produce minimal changes in gait and are often overlooked except in animals such as the racing greyhound, in which a slight falling off of speed may be noted. The affected muscles can be located by deep palpation of muscle bellies and tendons. Digital pressure in these areas evinces pain in the patient.

The majority of strains resolve with conservative management consisting of rest and confinement for several days. Complete rupture of a muscle-tendon unit can occur in the muscle belly, in the musculotendinous junction, or in the tendon. Such injuries are usually characterized by an inability to actively flex or extend the associated joints and to support weight. Because the affected muscles undergo spasm and contract, such injuries in the large muscles require surgical repair and external coaptation until primary healing can occur. Techniques for suturing tendons and for aftercare closely follow those described for ligaments (see Figures 7-6, 7-7, and 7-8). Deficits in muscle tissue heal by unorganized scar tissue and, if large enough, can seriously interfere with function. In such cases it may be possible to resect the scar tissue and reappose the muscle tissue. In other cases the muscle is so extensively replaced by scar tissue and so severely restricts motion of the affected joint(s) that the only recourse is to section the tendon, thus freeing the bone. Contracture of the infraspinatus muscle is one of the more common clinical conditions of this nature (see Chapter 10).

OPEN WOUNDS OF JOINTS

An open wound into a major joint is a surgical emergency and requires vigorous and early treatment to prevent the inevitable contamination from becoming an established infection. Septic arthritis is a devastating injury, often totally destroying articular cartilage.

The animal should be sedated or lightly anesthetized to allow surgical debridement under aseptic conditions. The wound is covered by sterile lubricating jelly while surrounding hair is clipped, after which the jelly and embedded hairs can be

TABLE 7-2. CHARACTERISTIC FINDINGS IN *STRAIN* INJURY IN THE DOG

Disorder	Physical Findings	Radiographic Findings
Chronic strain	Comparatively nonspecific; lameness often accompanied by localized muscle spasm. Often there is little patient response to palpation of the affected muscle-tendon unit.	A generalized decrease in regional muscle mass, which depends on both severity and longevity of the injury. Disuse osteoporosis may be present in advanced cases.
Acute strain	Comparatively specific lameness usually associated with signs of localized inflammation. The area of involvement is often painful to touch and manipulation.	Regional soft tissue swelling.
Mild (first degree)	Minimal lameness, which may be imperceptible to all but the owner.	Usually no radiographic abnormalities.
Moderate (second degree)	Easily perceived lameness, which appears to be the result of localized discomfort as opposed to frank, persistent pain.	Mild, often deceptively generalized regional soft tissue swelling, frequently associated with abnormality of associated fascial planes.
Severe (third degree)	Obvious lameness, which is often rapidly progressive. Pain is easily elicited.	Mild to moderate regional soft tissue swelling with distinct discrepancies of regional fascial planes.

From Farrow CS: *Vet Clin North Am* 8(2):169-182, 1978.

washed away. The wound is enlarged to allow removal of intrasynovial foreign material, and devitalized tissue is excised. A culture and sensitivity sample is obtained.

The joint is flushed copiously with sterile Ringer's or saline solution before closure. Tissues are closed in layers with fine-monofilament interrupted sutures, and any ligament damage is repaired at this time. Stabilization of the joint is important in preventing infection because better blood supply is maintained in stable tissues. Drain tubes in the joint are not necessary in most cases and probably do more harm than good. Daily drainage and Ringer's or saline lavage by arthrocentesis are preferable. Antibiotic therapy is initiated with ampicillin and gentamicin and changed if indicated by culture results. The joint should be immobilized for 7 to 10 days, or longer if ligamentous damage is present.

IMMOBILIZATION OF JOINTS

Immobilization of major joints, especially of the elbow and stifle, is a double-edged sword. Although it can be very useful in protecting both bony and soft tissue during healing, it is also capable of producing undesirable side effects.

The most common side effect of joint immobilization is fibrosis and contracture of periarticular soft tissues, resulting in loss of range of motion (ROM). Articular cartilage is poorly nourished during periods of immobilization and will degenerate to a variable degree. Immobilization in rapidly growing animals, especially dogs of the large and giant breeds, often results in laxity of ligaments in the immobilized limb and in stretching (thus laxity) in the contralateral ligaments as a result of increased stress.

Despite these problems, the greater good is often done by immobilization of the joint after certain arthroplastic procedures. We specifically identify these situations and recommend appropriate immobilization devices in the procedures described in the applicable chapters. Most veterinarians probably tend to overuse, rather than underuse, external immobilization after joint surgery. The theoretical ideal would be *never* to immobilize a joint because all the periarticular structures, muscles, tendons, and joint cartilage thrive better in the presence of motion. Therefore, we should examine each situation to see if immobilization can be omitted or at least minimized, rather than slavishly adhering to any specific regimen. Remember, our patients are four-footed and get along quite well on three legs. It is often possible to delay immobilization until the animal shows signs of recovering from the initial pain and swelling and begins to touch the foot tentatively to the ground. Such delay can shorten the period of immobilization by 2 to 10 days in most cases. Ideally, many conditions and postoperative management would be best handled by ROM exercises without weight bearing. On the other hand, certain animals will overuse the limb and abuse the surgical repair, especially if the owners are not able to confine an active animal adequately. The intended athletic demands placed on the dog along with owner compliance will determine the balance of immobilization versus mobilization. Good judgment is necessary in evaluating these situations. (See Chapter 2 for a discussion of casts, splints, and slings.)

Transarticular Skeletal Fixation

The external fixator can be used to immobilize joints. It is particularly useful for open wounds, which make the use of casts and splints very difficult. In the case of multiple limb injuries, the pin splint provides rigid enough fixation to protect the joint, yet allows the animal to bear weight directly on the foot.

No standard patterns have evolved for the use of the external fixator in this matter. Two such applications are illustrated in Figures 14-24 and 20-5.

Arthrodesis

Surgical fusion of a joint to form a bony ankylosis is termed an *arthrodesis*. Spontaneous ankylosis rarely results in bony fusion of a joint in small animals; more often, it simply causes severe periarticular fibrosis and contracture. Arthrodesis and total loss of motion relieve pain originating in articular and periarticular tissues, whereas ankylosis often does not.

Arthrodesis is a salvage procedure and an alternative to amputation in the following situations:

1. Irreparable fracture of the joint
2. Chronically unstable joint
3. Chronic severe degenerative joint disease from any cause
4. Neurological injury causing partial paralysis of the limb, especially of the carpal and tarsal joints. For arthrodesis to succeed, there must be cutaneous sensation in the palmar-plantar foot region, or self-mutilation may result.

Functioning of the limb after arthrodesis is never normal, but in most cases, it is adequate to allow a reasonably active life for a pet. The more proximal the fusion, the more pronounced is the disability. Stifle and elbow fusion produces severe disability, and in most situations the animal would probably function better with an amputation. The shoulder is an exception to the basic rule because the scapula becomes more mobile on the trunk and thus allows considerable movement to replace normal shoulder motion. Arthrodesis of the more distal tarsal and carpal joints, on the other hand, produces almost no visible change in gait. The hip joint is never fused, since excision of the femoral head and neck and total hip replacement are more useful procedures. Ensuring that the joint is fused in the proper angle is fundamental to success because the angle chosen is the primary means of producing correct leg length. Although a quadriped can make considerable compensation for lengthening or shortening of a single limb, function is still compromised.

Surgical Principles of Arthrodesis

To achieve rigid and functional arthrodeses, the following principles should be observed:

1. Arthrodesis should be performed only on a noninfected or a noncontaminated joint. Infection would lead to implant failure, loss of bone stock, and eventual loss of limb function.
2. Articular cartilage must be removed and subchondral bone exposed on what will be the future contact surfaces at the fusion site (see Figure 14-20, *A*). Cartilage in noncontract areas can be left intact. Curettage, power-driven burs, and power saws are all useful tools.
3. Contact surfaces may be cut flat to produce the proper joint angle and to increase the contact area, or they may be prepared by following the normal contours of the joint (see Figure 20-21, *A* and *B*). The former approach provides more stability against shear stress but creates more shortening, with potential rotation, and is difficult to accomplish without power bone saws. Following the normal contour is the much easier method if working with hand instruments such as curettes and rongeurs.

4. Proper joint angle is ensured by preoperative measurement of the opposite limb. Published ranges for each joint are only averages and may not fit any specific animal (e.g., crouched, flexed stifle angle of German shepherd vs. straight-legged Akita). Intraoperative use of a goniometer will allow the chosen angle to be duplicated. In the absence of a goniometer, a short piece of splint rod can be bent to the contour of the normal limb, sterilized, and used intraoperatively as a template. In some fusions, such as that of the stifle (see Figure 18-31), debridement of cartilage causes loss of limb length, which is fortuitous. During running movements, the contralateral limb flexes and "shortens" body height. The arthrodesed limb may become relatively too long, requiring abduction of the limb or knuckling of the toes.
5. Fixation of the bones must be rigid and long lasting, with compression of the contact surfaces preferred. Bone plates, lag screws, and tension band wire fixation techniques are most useful. When the fixation device is being attached to the bones, care must be taken to maintain the chosen angle and rotational alignment of the limb. Temporary Kirschner wires may be driven across the joint to help maintain normal relationships of the two bones (see Figure 18-31, *C*) while the permanent fixation device is applied.
6. Bone grafting is useful to speed callus formation. Most often, autogenous cancellous bone is used to pack into and around the contact surfaces (see Chapter 3).
7. External cast/splint support is needed for 6 to 8 weeks in certain cases, when the internal fixation device is not able to withstand weight-bearing loads before partial fusion has occurred.

PRINCIPLES OF JOINT FRACTURE TREATMENT

Intraarticular fractures are potentially devastating injuries that require prompt and aggressive surgical treatment. Open reduction and rigid internal fixation offer the best hope for uninterrupted function.

Failure to stabilize joint fractures adequately leads to malarticulation. Irregularities in the articular surface cause grinding of cartilage from the opposing surfaces. Liberation of intracellular proteoglycans is followed by inflammatory and degenerative changes within the joint, and varying degrees of degenerative joint disease (DJD, arthritis) follow. A certain amount of instability is also present as a result of malarticulation, which further adds to the DJD.

Principles of Surgical Treatment

Treatment of specific fractures is covered in succeeding chapters. Several general principles apply to all articular fractures, as discussed here.

Intraarticular Surgery

1. Wide surgical exposure is needed. Consider osteotomy of ligamentous/tendinous attachments to allow generous exposure.
2. In the presence of open wounds, it may be necessary to enter the joint through the wound, after appropriate debridement. If possible, however, enter through normal tissues.
3. Make a general inspection of the joint to assess the damage and to correlate it with the radiographs. Identify all fracture lines and bony fragments.

4. Remove cartilage chips without bone attachment and foreign bodies, and debride nonviable tissue.
5. Save cartilage fragments that have subchondral bone attached.
6. In reconstructing/reducing the fracture, handle cartilage gently. Use pointed reduction forceps, Schroeder vulsellum forceps, or Kirschner wires to hold pieces in reduction. Small gaps are better tolerated than "stair-step" defects.
7. Size of fragments may dictate the fixation method. Some fragments are too small for anything but a small Kirschner wire. Where these are placed on gliding surfaces, they should be countersunk beneath the cartilage surface. Lag screw fixation is generally the most versatile and reliable method of fixation. The interfragmentary compression produced generally is the most effective method of preventing shearing forces from disrupting the reduction. Very small screws, 1.5 to 2.0 mm, can be valuable for fixation of small fragments. In some cases it is possible to countersink the heads of these small screws sufficiently that they can be used on gliding surfaces. This is recommended only as a last resort, however, because late damage to the opposing cartilage surface is possible.

Use of plastic spiked washers (Synthes, Ltd., Wayne, Pa) can be helpful in distributing the compression load of the screw head more evenly over small, thin fragments (Figure 18-23, *D*). When tension loads are the primary consideration, the pin/tension band wire technique may be useful, especially with small fragments. Lag screws are useful in large, tension-stressed fragments if the screw can be positioned so that it is loaded only in the axial direction and is not subjected to bending loads (see Figure 8-5, *B*). Positioning of lag screws may be influenced by the type of fixation required when extraarticular fractures are present (see following discussion).

8. Know anatomy well. It is easy to misdirect a screw and not secure adequate fixation. The use of an aiming device (Synthes) can be very helpful. In some cases, it may be better to excise small fragments that cannot be adequately reduced and stabilized. For example, fractures of the distal one third of the patella are best treated by excision of the fragments and reattachment of the patellar ligament to the remaining patella.

Extraarticular Surgery

Many intraarticular fractures have an extraarticular component, such as the T-Y fractures of the distal humerus (see Figure 11-22) and femur (see Figure 17-29). Fixation of the extraarticular fracture should be completed at this time. Plates and external skeletal fixators are most widely applicable in these situations, although occasionally, certain forms of pinning, especially with Rush pins, are applicable.

Cancellous Bone Grafting

Both intracapsular and extracapsular bone deficits may be present after reduction and fixation. Such defects can lead to loss of stability as a result of delayed bony bridging by callus formation. Autogenous cancellous bone grafts will greatly speed callus formation (see Chapter 3). Do not place the graft where it is exposed to synovial fluid or where graft fragments could become free floating within the joint.

Repair of Soft Tissue Injuries

Ligamentous instability caused by fracture-producing trauma is the most common soft tissue problem. Appropriate reconstructive surgery should be done at this time because the instability is deleterious to the joint, and any additional insult to the

fractured joint is definitely not needed at this point. Examine carefully for musculotendinous injuries, especially in gunshot fractures and those produced by sharp trauma.

Aftercare

Aftercare varies with the joint involved, the security of fixation achieved, and the size and activity level of the animal. The major question to be resolved is the necessity for cast or sling immobilization. Often, the fixation is less than adequate to allow weight bearing before some degree of fracture union is achieved.

As a general rule, immobilization of the elbow and stifle joints is best avoided. Both these joints are susceptible to periarticular fibrosis and intraarticular cartilaginous degeneration, leading to loss of motion. If the fixation is so tenuous as to require external immobilization, try to delay applying the cast or splint for several days postoperatively until the animal starts to use the limb. Even the slight passive portion involved in non-weight-bearing activity gives the joint a chance to clear some of the hemarthrosis and inflammatory debris. Flexion bandages of the carpus and tarsus are often effective in allowing some motion while preventing weight bearing (see Figures 2-30, 2-31, and 2-32). The shoulder and hip joints and the joints of the carpus and tarsus tolerate immobilization better and can be safely supported in the appropriate cast, splint, or sling. Generally, 3 to 4 weeks of external support is sufficient to allow restricted activity throughout the rest of the healing period. Most animals can be returned to moderate levels of activity by 12 weeks postoperatively.

The determination of implant removal must be approached on a case-by-case basis. If bone plates have been used, they are often relatively short and end in the middiaphysis. In rare instances, pathological fractures have occurred where the plate ends in the middiaphyseal region, usually at the distal end of the plate, which is an argument for plate removal at about 6 months postoperatively or whenever radiographs confirm healing. We do not remove plates routinely and have seen more problems with fracture after plate removal than when plates are retained. Screws can usually be left in place with no adverse effects. Pin and tension band wire fixation, unless carefully applied, may cause irritation of overlying soft tissues and will need to be removed as soon as practical, especially if lameness or seroma is present. Twelve to 20 weeks is usually adequate to allow good healing in this situation.

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8

Arthroscopy in Joint Surgery

Arthroscopically assisted surgery is minimally invasive joint surgery that uses specialized rigid endoscopic and surgical equipment through small incisions to directly view and provide treatment for intraarticular pathology. The evolution of small animal arthroscopy has been slow since the first report of its use by Siemering[1] in 1978. Early arthroscopic equipment was less efficient than current equipment because visualization was by direct sight through the scope rather than with video camera–assisted technology. Combined with the difficulty of working with the small joints of dogs and the protracted learning curve of arthroscopy, many veterinary surgeons were initially discouraged.

The development of more refined equipment and the perseverance and dedication of surgeons reporting therapeutic successes throughout the 1980s and 1990s have resulted in arthroscopy evolving into a common and successful surgical modality in dogs (Figure 8-1, *A*). The most important rationale for use of arthroscopy versus open surgery in dogs is reduction of postoperative pain and improved early function of the joint after surgery. Improved visualization of the articular surface and its supporting ligaments and capsule is achieved with the magnification and lighting capabilities of the arthroscope, and therefore the surgeon's diagnostic capability is improved in many canine joints (Figure 8-1, *B, C,* and *D*).

Although most canine articular diseases are amenable to successful treatment by conventional open surgery, arthroscopy has added a new and useful dimension to the diagnosis and surgical treatment of many lesions. For example, osteochondritis dissecans (OCD) of the humeral head is treated in a practical and highly successful manner with conventional open surgery. Arthroscopically assisted surgery of OCD not only allows atraumatic removal of the cartilage flap from the humeral head, but also allows more of the joint to be explored through the arthroscope. Loose pieces of cartilage may be removed from the cranial aspect of the joint near the sheath of the biceps tendon (see Figure 8-1, *C* and *D*). Articular damage to the humeral head and glenoid surface and coincident ligament and capsular injury can be documented better with arthroscopy than with open surgery.

Canine arthroscopy is now recognized as state-of-the-art therapy for many orthopedic conditions, and clients more frequently request this service of veterinary surgeons. Despite documented therapeutic success and the more common use of arthroscopy in surgical specialty referral centers, numerous factors inherent to arthroscopy may limit its development for use in general practice. Arthroscopy equipment, including the arthroscopes, light source, video camera technology, specialized surgical instrumentation, fluid ingress system, image capture equipment,

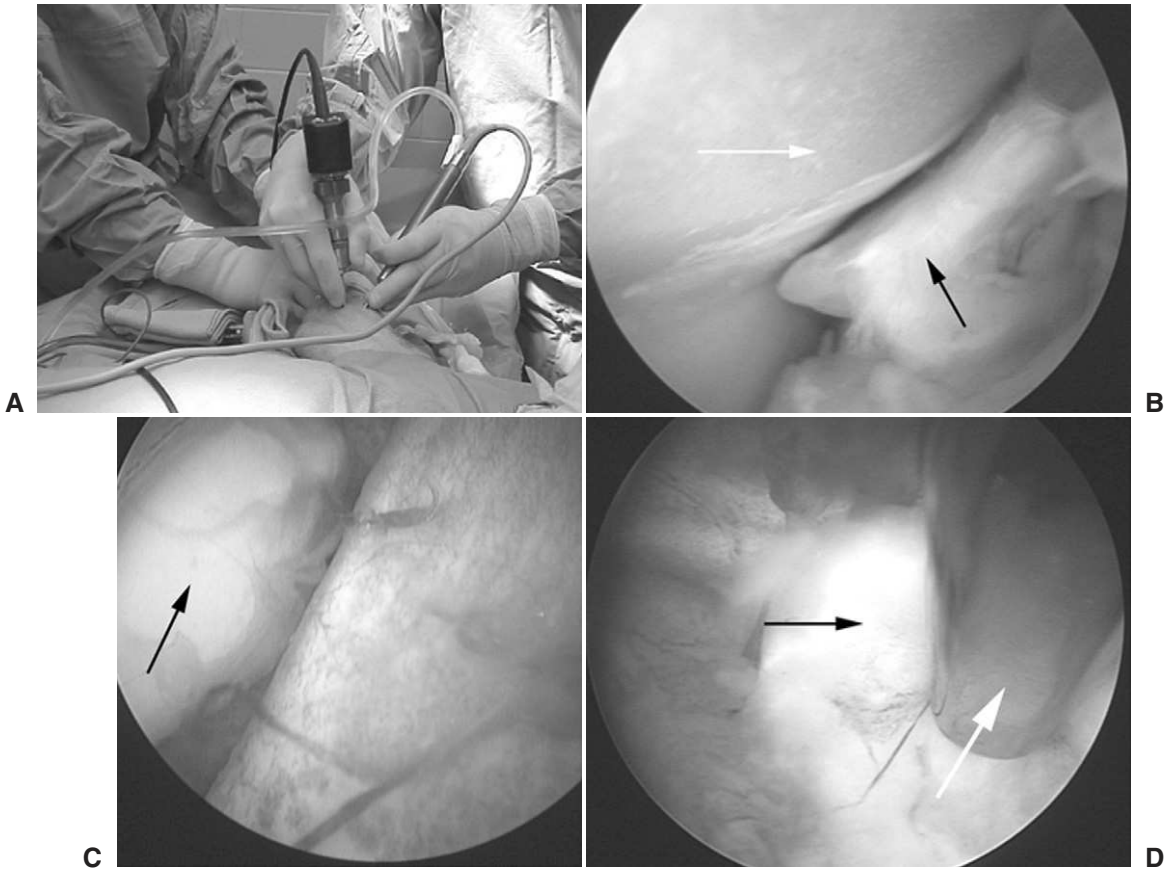


FIGURE 8-1. Arthroscopically assisted surgery. **A,** Minimally invasive joint surgery is accomplished with specialized endoscopes and surgical equipment to achieve surgical objectives. Arthroscope and motorized shaver used for elbow surgery in a dog are shown. **B,** The surgeon's diagnostic capability is improved by use of arthroscopy. In this case, a fragmented coronoid process is removed with minimally invasive technique *(black arrow)*, but severe cartilage loss to the medial portion of the humeral condyle has also been documented *(white arrow)*. **C** and **D,** Arthroscope has been used in a dog with osteochondritis dissecans of the humeral head to discover and remove a cartilage fragment *(black arrows)* located next to the biceps tendon using a grasper *(white arrow)*. This fragment may have gone undetected with conventional surgery.

power-driven shavers, and radiofrequency ablation equipment, is very expensive and difficult to justify outside of a high-volume orthopedic surgical practice. Maintenance and repair of delicate and frequently damaged equipment add additional expense. The disposable items alone, such as shaver blades and specialized ingress tubing, may cost hundreds of dollars per surgery.

Although excellent continuing education opportunities are available in canine arthroscopy, the learning curve for arthroscopic techniques is very steep because the surgeon must learn to work from a video image to manipulate instruments in three dimensions of a very small space. The purpose of this chapter, therefore, is not to provide information at the level of the expert, but to introduce the avid orthopedist to common, currently practical arthroscopic techniques and to encourage the serious student toward greater educational opportunities.

ARTHROSCOPIC PRINCIPLES AND INSTRUMENTATION

Arthroscopic surgery is accomplished by viewing the intraarticular space through a precisely placed video camera–assisted arthroscope that has been inserted through a small incision or portal into the joint (Figure 8-2, *A*). Specialized surgical instruments are introduced through one or more separate, precisely placed incisions to complete specific surgical objectives (Figure 8-2, *B*). A fluid management system is used to distend the joint capsule for better visualization with the arthroscope and to flush synovial fluid, blood, and other debris from the joint that may interfere with the surgeon's clarity of view. Ingress of fluid is generally through the arthroscope. Egress of fluid is either through a separate needle or cannula, or it may be achieved through the portal developed for surgical instrumentation. Surgical instrumentation includes various manual instruments for the functions of grasping, curettage, elevation, and cutting. Motorized shaving instruments with specialized cutting blades provide efficient debridement of soft tissue, cartilage, and bone. Continuous suction through



A



B

FIGURE 8-2. **A,** Surgeon views the intraarticular space on a video screen by using a video camera–assisted arthroscope that has been inserted through a small incision into the joint. **B,** Another small incision (portal) into the joint is maintained with a cannula and used for introduction of specialized hand instruments, such as the small probe shown here used by the surgeon to judge quality of tissue.

the shaver removes debris as it develops. Radiofrequency instruments can provide intraarticular electrocautery with capability for tissue shrinkage and ablation.

Arthroscope, Camera, and Light Source

A state-of-the-art arthroscope is a rigid endoscope, designed with fiberoptics and lenses to provide illumination within a joint and to transmit intraarticular images to a camera for display on a video monitor for real-time use by the surgeon. Arthroscopes are designed with varied diameters and lengths. Surgeons generally select scopes with 2.7-, 2.4-, or 1.9-mm diameter for canine arthroscopic surgery, with short or long lengths (Figure 8-3, *A*). Most surgeons select a 30-degree lens angle at the tip of the arthroscope (Figure 8-3, *B*).

Older systems allowed the surgeon to look directly through the eyepiece of the arthroscope; however, maintenance of sterility was a concern, and manual dexterity

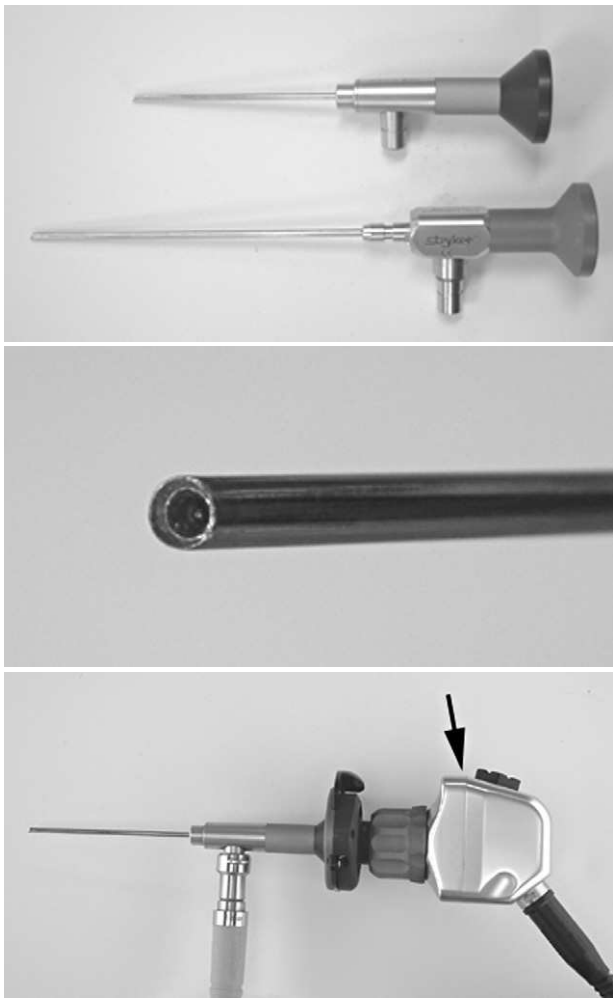


FIGURE 8-3. **A,** Arthroscopes 2.4 and 2.7 mm in diameter with short and long lengths are usually selected for arthroscopy in dogs. **B,** A 30-degree lens angle at the tip of the arthroscope is selected for improved visibility in the small spaces of a canine joint. **C,** Video camera *(arrow)* and light source are connected to the arthroscope for use in real-time visualization and image documentation by the surgeon.

using instruments was compromised while viewing through the scope. Current arthroscopes connect directly to a camera that transmits the image for real-time display on a video monitor and allows for image documentation and storage (Figure 8-3, *C*). Cameras of variable sizes and quality may be selected, with the most expensive cameras providing the greatest clarity and quality of image. A light source conveys light through a fiberoptic cable to the optics of the arthroscope. The best-quality light source uses an expensive xenon light bulb; however, tungsten-halogen lamps are also available.[2]

The arthroscope, camera, and light source system are fragile, and breakage is common with the inexperienced or cavalier clinician. Handling of the equipment at surgery, during cleaning and sterilization, and during storage must be carefully monitored to prevent unnecessary damage and expense.

Cannulas

The functions of cannulas in arthroscopic surgery are protection of the arthroscope, fluid ingress and egress, and maintenance of portals into the joint.[2] An arthroscope cannula is a metal sheathing that protects the scope from bending damage to the fiberoptics. The tube that makes up the cannula is slightly larger and shorter than the scope, which allows for fluid ingress into the joint (Figure 8-4, *A* and *B*). The cannula may have one or more ports for attachment to fluid lines. A trocar may be locked into the cannula for initial placement of the cannula into the joint (Figure 8-4, *C* and *D*). Once inside the joint the trocar is removed, and the arthroscope is locked into the cannula to begin viewing the joint. If the arthroscope slips out of the joint, the trocar is replaced into the cannula before reintroduction into the joint to prevent damaging the scope. A separate cannula may be used to maintain an instrument portal into the joint, although the use of a cannula may not always be required for this portal (see Figure 8-2). Specific cannulas may also be attached to motorized-shaver blades for portal maintenance and fluid ingress or egress.

Fluid Systems for Ingress and Egress

Endoscopic viewing requires a viewing medium, and arthroscopy generally uses a flowing fluid medium. Pressure of the fluid is important to expand the joint for viewing and to help to limit bleeding from small vessels. Fluid flow and egress are important to extract synovial fluid, blood, and tissue debris that obstruct the surgeon's view.

Fluid ingress is achieved by either a gravity flow system or a specialized fluid pump, connected with fluid lines directly to the cannula for the arthroscope (Figure 8-5, *A*). Both systems use isotonic intravenous fluids, such as lactated Ringer's solution, with fluid lines connected to the arthroscopic cannula. A *gravity flow system* uses 1-, 3-, or 5-L bags of fluid that are raised as needed to a height constrained by the ceiling of the surgical suite to improve flow. Pressure bags using inflatable cuffs further improve pressure and flow. Gravity flow systems are appropriate for smaller arthroscopes, such as the 1.9-mm scope, or in circumstances in which less egress suction is applied. Pressure and flow may be difficult to regulate with a gravity system and may require considerable attention from operating room personnel. *Motorized fluid pumps* are more appropriate when larger scopes are used or when a greater rate of flow is expected, as when a motorized shaver is used. Motorized pumps are expensive, and many require disposable fluid lines with a pump cartridge, which adds additional expense (Figure 8-5, *B*). A fluid pump,

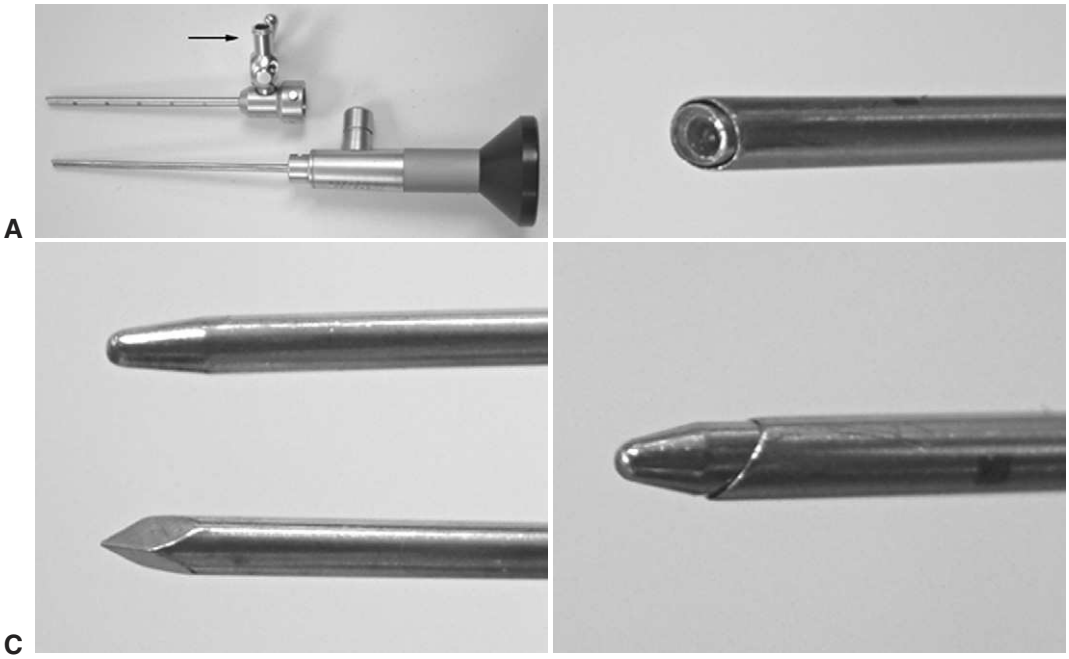


FIGURE 8-4. Cannulas for arthroscopic surgery. **A,** The cannula is a metal sheathing designed to protect the arthroscope from damage. One or more ports *(arrow)* are used for attachment of fluid lines. **B,** The cannula is slightly larger and shorter than the scope, which allows for ingress of fluids through the cannula and protection of the scope from bending damage. Note that the arthroscope extends from the cannula, which makes it susceptible to damage at its tip. **C** and **D,** A blunt or sharp trocar may be selected by the surgeon and locks into the cannula for initial placement into the joint. Once inside the joint the trocar is removed, and the arthroscope is locked into the cannula for viewing, or the cannula may be used for other instrumentation.

however, facilitates control of intraarticular pressure and fluid flow through the joint and allows the surgeons and technicians to concentrate on other matters. Automated fluid pressures in canine arthroscopy are often set between 20 and 60 mm Hg, depending on circumstances of a specific surgery.

Fluid egress from the joint is essential to maintain clarity of view within the joint and is achieved by several different methods. Large, fenestrated cannulas are available but are not useful in the small canine joints, except perhaps for the stifle joint (Figure 8-5, *C* and *D*). Small, nonfenestrated cannulas or standard intravenous-type needles can be used for the shoulder and elbow joints. Some joints, such as the elbow, are amenable to allow fluids to egress through the instrument portal without cannula or needle placement. Care must always be taken to prevent fluid extravasation into tissues surrounding the joint, which may collapse the joint and obscure the surgeon's view. Adequately sized incisions for portals into the joint allow for good drainage without trapping fluids within the tissues and collapsing the joint.

Manual Instrumentation

The magnification and visual acuity afforded the surgeon by the arthroscope are coupled with tactile sensory information by touching tissues of the joint with various instruments (see Figure 8-2, *B*). *Probes* are helpful in determining the

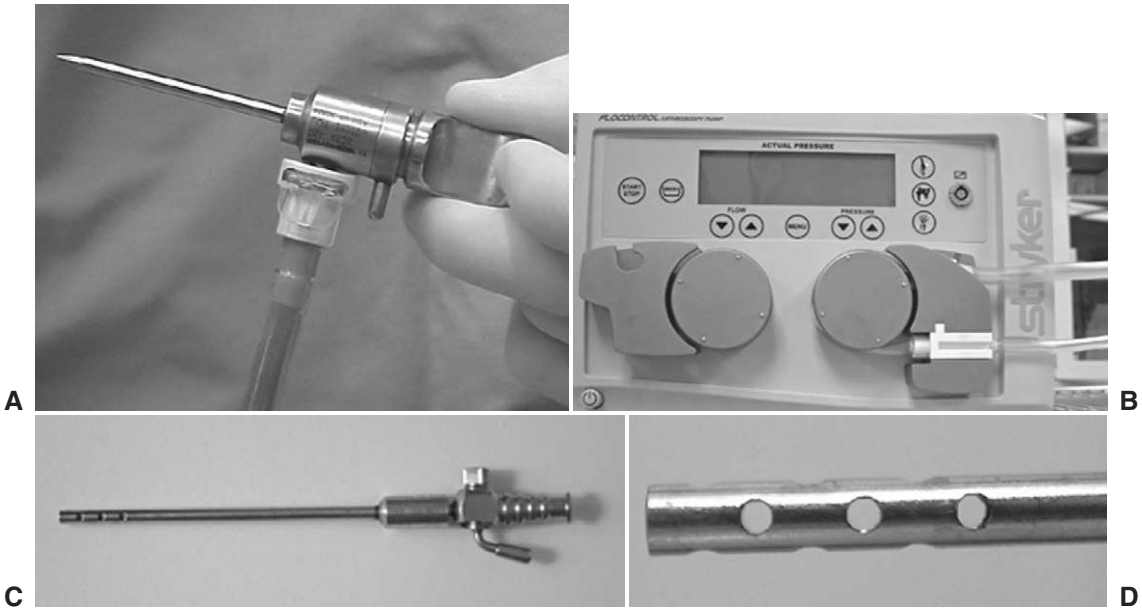


FIGURE 8-5. **A,** Fluid ingress into the joint is usually through the cannula, which will serve the dual purpose of also protecting the arthroscope. The cannula and fluid line are shown with a blunt trocar for initial placement into the joint. **B,** Motorized fluid ingress pump facilitates monitoring of fluid pressure and flow rates into the joint. **C** and **D,** Fenestrated cannulas can be used for fluid egress from large joint spaces, such as the stifle joint. Alternately, nonfenestrated cannulas, intravenous needles, or the instrument portal may be used for fluid egress.

quality of tissue, such as articular cartilage. Probes may be needed to palpate and find bony fragments among synovial attachments and proliferation. Right-angle probes of different sizes are available, and some have visible scaled markings to aid the surgeon in establishing size of lesions (Figure 8-6, *A*). Smaller, sensitive probes may be used to palpate consistency of articular cartilage or other tissues (Figure 8-6, *B*). Larger probes may be used to manipulate cartilage flaps or bone fragments for grasping with another instrument (Figure 8-6, *C*).

Grasping forceps are essential to manipulate and excise pathological tissues in arthroscopy. There is limited space in the small joints of dogs, and forceps manipulation in a small space can be very challenging. Various forceps are available for use as grasping instruments. Simple fine-tipped mosquito or alligator forceps may be preferred by some surgeons, although these instruments are nonspecific to arthroscopy. Except for instruments designed for the smallest joints, most arthroscopic graspers designed for human surgery are too large for arthroscopic surgery in dogs. Grasping forceps with a diameter of 2 to 3 mm are adequate for canine arthroscopy, if not somewhat large for the smaller joints (Figure 8-7, *A* and *B*). Forceps tips are designed with varied shapes and styles of teeth (Figure 8-7, *C*). Aggressive teeth may be needed for removing bone fragments with firm capsular attachments. Forceps with subtler teeth may be more appropriate for picking up small, loose cartilage fragments (Figure 8-7, *D*).

Excising tissue may require forceps with a grasping and cutting function. *Punch forceps* are available in configurations that provide these functions. A punch forceps has a hollow cutting scoop that articulates with the grasper to excise tissue (Figure 8-7, *E*). Different shapes, sizes, and angles are available according to the

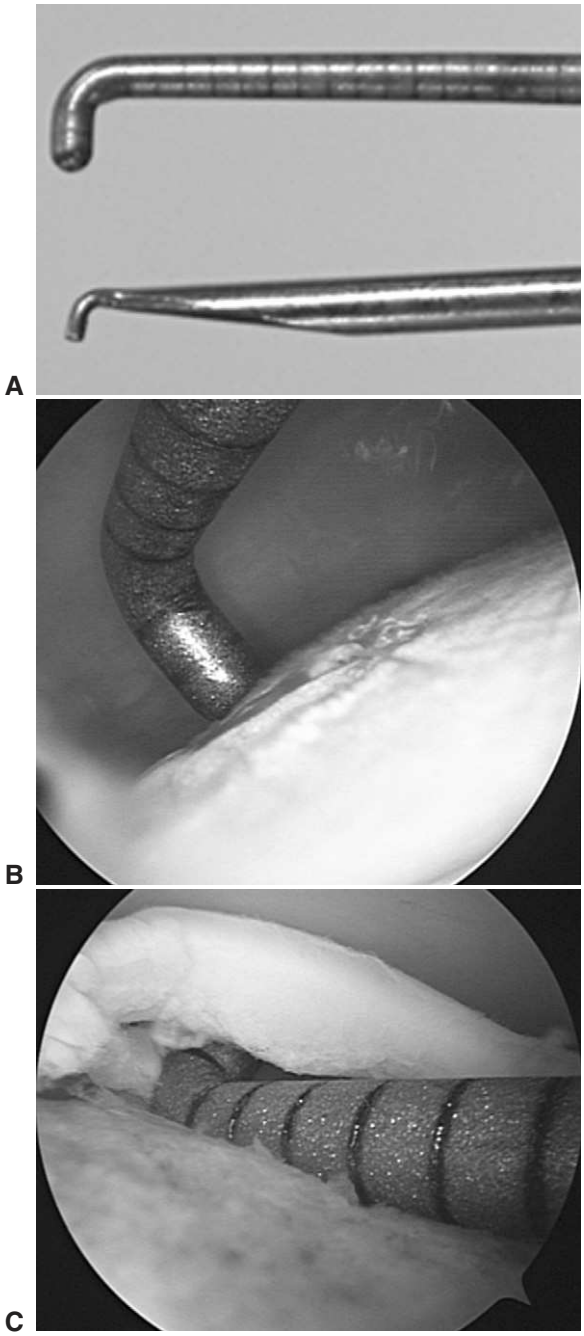


FIGURE 8-6. Probes used for athroscopic surgery. **A,** Right-angle probes of different sizes are available; some have scaled markings to aid the surgeon with perspective and sizing lesions. **B,** Probes are used to add tactile sense to arthroscopic surgery and may be used to sense texture and firmness of tissue. This probe is being used to palpate the quality of articular cartilage of the humeral head. **C,** Probes may be used to manipulate tissues physically. This probe is used to elevate an osteochondritis dissecans flap in preparation for grasping it.

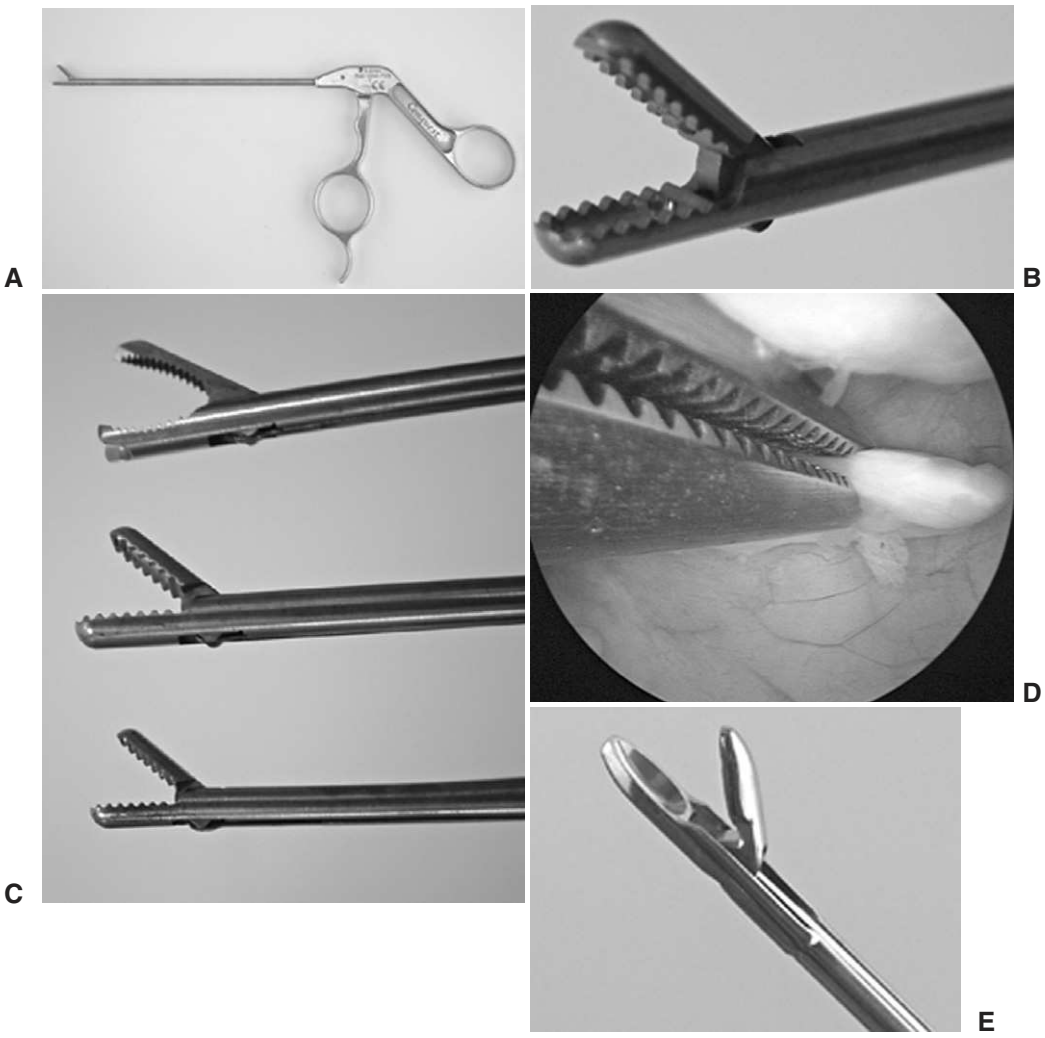


FIGURE 8-7. Grasping forceps. **A** and **B,** Grasping forceps for arthroscopic surgery in the small spaces of joints in dogs require a small diameter of 2 to –3 mm. The tip has teeth designed for grasping and removing tissues from the joint. **C,** Forceps tips have various styles of teeth for different grasping functions. **D,** Small, straight mosquito forceps may be used as a grasping instrument for arthroscopic surgery, shown here grasping a small cartilage fragment. **E,** Punch forceps have a hollow cutting scoop designed to grasp and remove soft tissue.

surgeon's preference. A specialized suction punch forceps is designed with a port for applying vacuum. As the tissue is excised by punch forceps, it is suctioned away into the vacuum collecting system. *Spoon forceps* are less aggressive at cutting firm tissue but are well suited to scoop or biopsy soft, friable tissue.

Arthroscopic *knives* are designed to be forward cutting as the instrument is pushed into a structure, reverse cutting as it is pulled toward the surgeon, or side cutting (Figure 8-8, *A*). Meniscal blades are forward-cutting blades with either rounded or V-shaped tips and are useful for meniscectomy and tendon-release procedures (Figure 8-8, *B*). A hooked knife provides cutting as the instrument

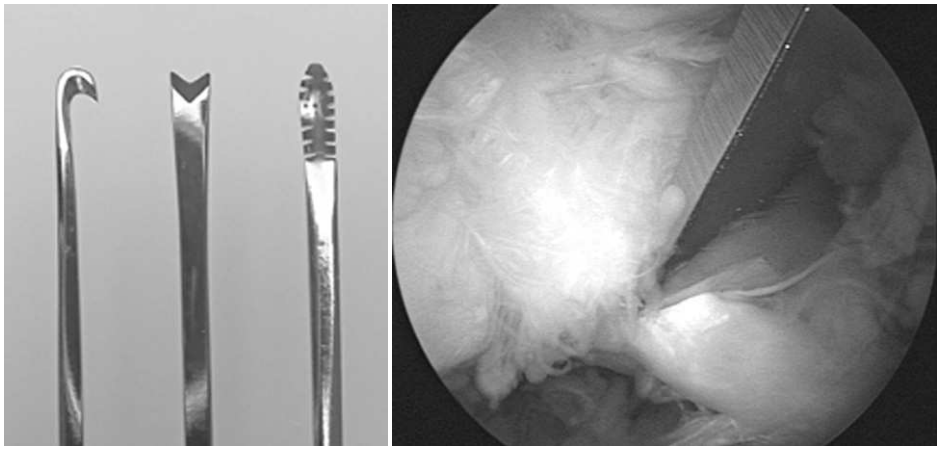


FIGURE 8-8. Arthroscopic knives. **A,** Hooked knife cuts as the instrument is pulled back against tissue. V-shaped knife is forward cutting as it is pushed into tissue. Side-cutting knife (serrated here) cuts as it is pushed against tissue. **B,** Forward-cutting V-shaped knife is used for a biceps tendon release in the shoulder of a dog. Note the frayed state of the tendon.

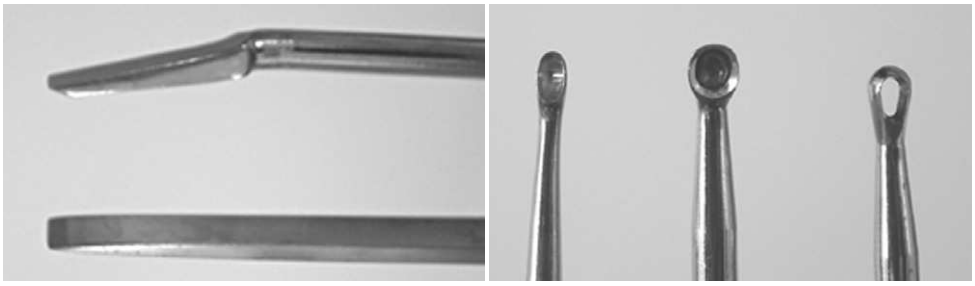


FIGURE 8-9. Osteotomes and curettes for arthroscopic surgery. **A,** Small osteotomes are useful in mobilizing bone fragments or contouring bone. An angled osteotome is helpful in working in the tight spaces of a small canine joint. **B,** Small curettes, of either the closed or the open ring style, are useful for mobilizing cartilage or bone fragments before using a grasper to remove them.

engages the tissue while pulling back toward the surgeon. Side-cutting knives and knives with serrated edges are available and may also be used for tendon-release procedures (see Figure 8-13, *G*).

Arthroscopic *curettes* and *osteotomes* are useful for contouring a bony surface, debriding a lesion, or mobilizing a tenacious cartilage or bone fragment. Osteotomes are straight or angled, and bone curettes are either closed or of the open ring style (Figure 8-9).

Motorized Shaver

A motorized shaver consists of a small, partially covered, rotating cutting tip inserted into a joint, powered by a variable-speed electric motor and equipped with suction to remove tissue debris as it develops (Figure 8-10, *A;* see also Figure 8-1, *A*). Small joint shavers are most applicable to small animal arthroscopy. Cutting tips for the shaver are interchangeable and vary with the requirements of the surgery

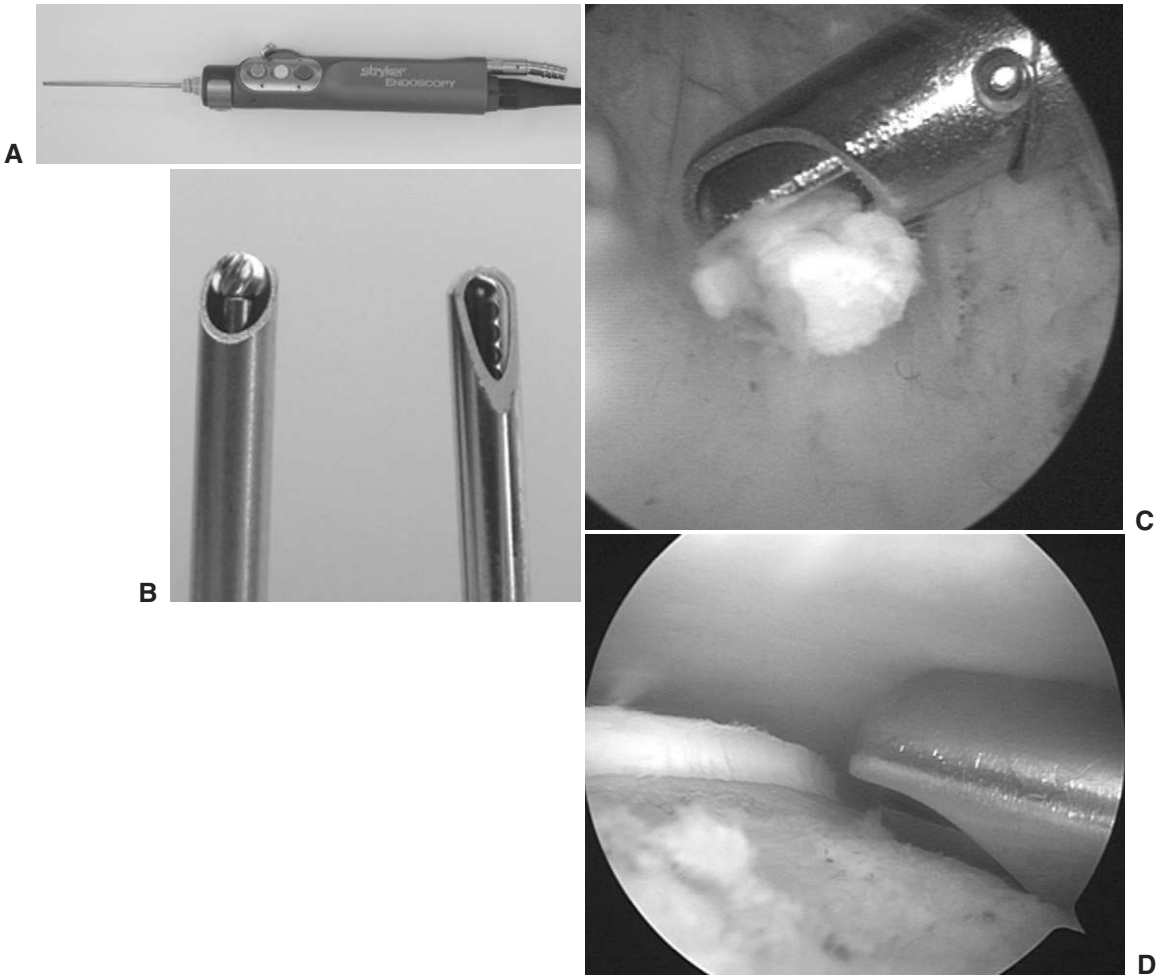


FIGURE 8-10. Motorized shaver. **A,** Electric motor drives a rotating cutting tip equipped with suction to remove tissue debris as it develops. **B,** Cutting tips for the shaver are disposable and interchangeable. Burr tips are designed to remove bone efficiently. Radial shaver blades have an open cup and blades with or without teeth for excision of softer tissues. **C,** Full radial shaver tip being used to remove a cartilage and bone fragment that was too "slippery" for a grasper. **D,** Radial shaver tip being used to trim loose edges of cartilage of an osteochondritis dissecans lesion in the shoulder of a dog.

(Figure 8-10, *B*). Burr-type shaver blades are designed to remove bone. Radial shaver blades have an open cup designed to debride soft tissues. Radial shaver blades with teeth provide the most rapid removal of soft tissues. Cutting speed is variable from 100 to 3000 rpm, with slower speeds and oscillating mode used for more efficient debridement of soft tissues (Figure 8-10, *C* and *D*).

Electrocautery and Radiofrequency

Electrocautery and radiofrequency units transfer electrical energy in the fluid environment of arthroscopic surgery to tissue for cauterization of bleeding vessels, tissue ablation, cutting, and shrinkage (Figure 8-11). *Monopolar* units dispense the energy through local tissue, through the body, to a grounding plate. *Bipolar* units

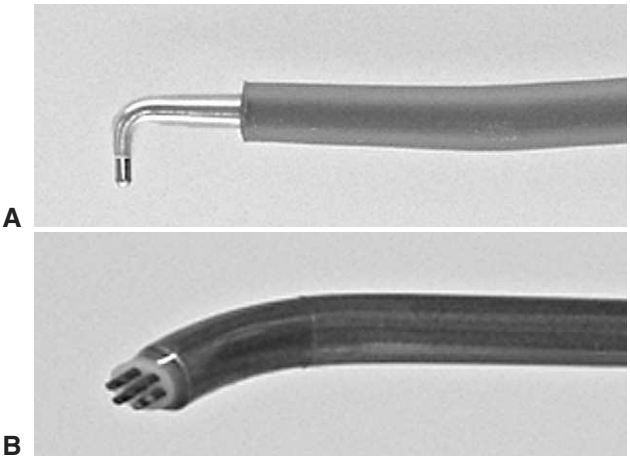


FIGURE 8-11. Electrocautery and radiofrequency instruments. **A,** Electrocautery tip used for arthroscopic applications. **B,** Radiofrequency tip used for tissue ablation in arthroscopic surgery.

limit energy dispersion only to the local tissues. Cauterization of bleeding vessels is a common arthroscopic application. Tissue shrinkage is another application that develops when the electrical energy is carefully applied to tissue to cause partial denaturation of collagen. Shrinkage techniques are typically used in the joint capsule for shoulder instability in humans. The role of tissue shrinkage in small animal orthopedics is currently evolving, and care must be exercised to avoid iatrogenic tissue injury. Tissue ablation is the most extreme use of radiofrequency that essentially vaporizes local tissue. Application of this function is applied for local partial synovectomy, partial meniscectomy, and various cutting applications.

IMAGE DOCUMENTATION

Video recording may be used to document an entire arthroscopic procedure. Digital capture of still images or digital video provides high-quality documentation of surgical diagnosis and treatment. Digital images are easily transferred for use in medical records, documentation for the client, and educational purposes. One disadvantage to digital recording is the sheer volume of information available and the labor inherent to data management.

ARTHROSCOPIC SURGERY OF SPECIFIC JOINTS

Elbow Joint

Van Ryssen and van Bree[3,4] first described arthroscopy of the canine elbow in 1993 (with Simsoens) and then again in 1997 with a series of 100 cases. The surgical access to the canine elbow is relatively superficial compared with other canine joints, which facilitates arthroscopy. Arthroscopic surgical objectives for diseases of the elbow are often simple, involving removal of small fragments or cartilage flaps. Elbow disease is very common in canine orthopedics, providing ample surgical opportunities. The combination of these factors has promoted the rapid development of expertise in arthroscopy of the elbow joint.

The two elbow diseases most frequently treated with arthroscopic surgery are fragmented coronoid process and OCD of the medial portion of the humeral condyle. Medial portals are used to access the elbow joint for these diseases. Craniolateral and caudal portals are also described but are used less often.[5,6] The arthroscope portal is located distal and slightly cranial to the medial epicondyle of the humerus at the approximate midpoint of the ulnar trochlear notch. The instrument portal is developed distal and cranial to the scope portal at the location superficial to the tip of the medial coronoid process.[7] A 2.7-mm arthroscope can be used for arthroscopy of the elbow joint; however, this scope is marginally large for this canine joint and may result in more iatrogenic cartilage injury. A 2.4-mm or 1.9-mm arthroscope is more suitable for the average large canine patient.

Because bilateral elbow arthroscopy is often completed, the dog is positioned in dorsal recumbency to allow each elbow to be dropped in turn to a small table with the medial side up. The elbow is levered over a fulcrum of padding to open the medial side of the joint. A needle and syringe are used to distend the joint with lactated Ringer's solution. A small incision is made for the arthroscope portal, and mosquito forceps may be used to dissect bluntly a small channel between muscle fascial planes to the level of the joint capsule. A cannula with blunt trocar is introduced into the joint, followed by the arthroscope.

Egress can be quickly established with an 18-gauge needle to flush synovial fluid from the joint to improve visibility and may be located caudally at the anconeus or at the site of the instrument portal. Egress at the instrument portal avoids flushing particulate matter to the caudal aspect of the joint. To establish the instrument portal, the arthroscope is aimed cranially in the joint and used to direct the 18-gauge needle into the joint directly over the coronoid process. A #11 scalpel blade is used to incise tissue along the needle to open the instrument portal to an appropriate width while the arthroscope is used to verify location. Fluid egress is maintained by using a cannula at the instrument portal site or fluid may be allowed to flow adjacent to manual instruments introduced at this site.

The joint is now completely explored. The medial coronoid process, trochlear notch of the ulna, anconeal process, humeral condyle, and medial portion of the radial head can be easily viewed (Figure 8-12, *A*). The lateral coronoid process of the ulna can be seen by placing the arthroscope across the trochlear notch, taking care to avoid iatrogenic cartilage damage. Most coronoid fragments and OCD flaps may be mobilized and removed with curettage and grasping forceps (Figure 8-12, *B* and *C*). A motorized shaver is useful for cleaning up small fragments attached to soft tissue. Especially large fragments are difficult to remove arthroscopically and may be broken up with an osteotome before removal.

Other uses for elbow arthroscopy include potential applications in diagnosis of arthritis, biopsy of intraarticular tumors, and visualization of fragment reduction in articular fractures.

Shoulder Joint

Goring and Price[8] described arthroscopic examination of the canine shoulder joint in 1987, and Person[9] described arthroscopic treatment of OCD of the shoulder in 1989. Arthroscopy of the canine shoulder contributes to diagnostic accuracy of shoulder conditions (see Figure 8-1, *C*) and to surgical therapy of selected conditions, such as OCD and biceps tenosynovitis.

Arthroscopic surgery of the shoulder joint is more difficult because of thicker overlying muscle mass and corresponding difficulty in manipulation of instrumentation through the instrument portal. The most common placement for the arthroscope

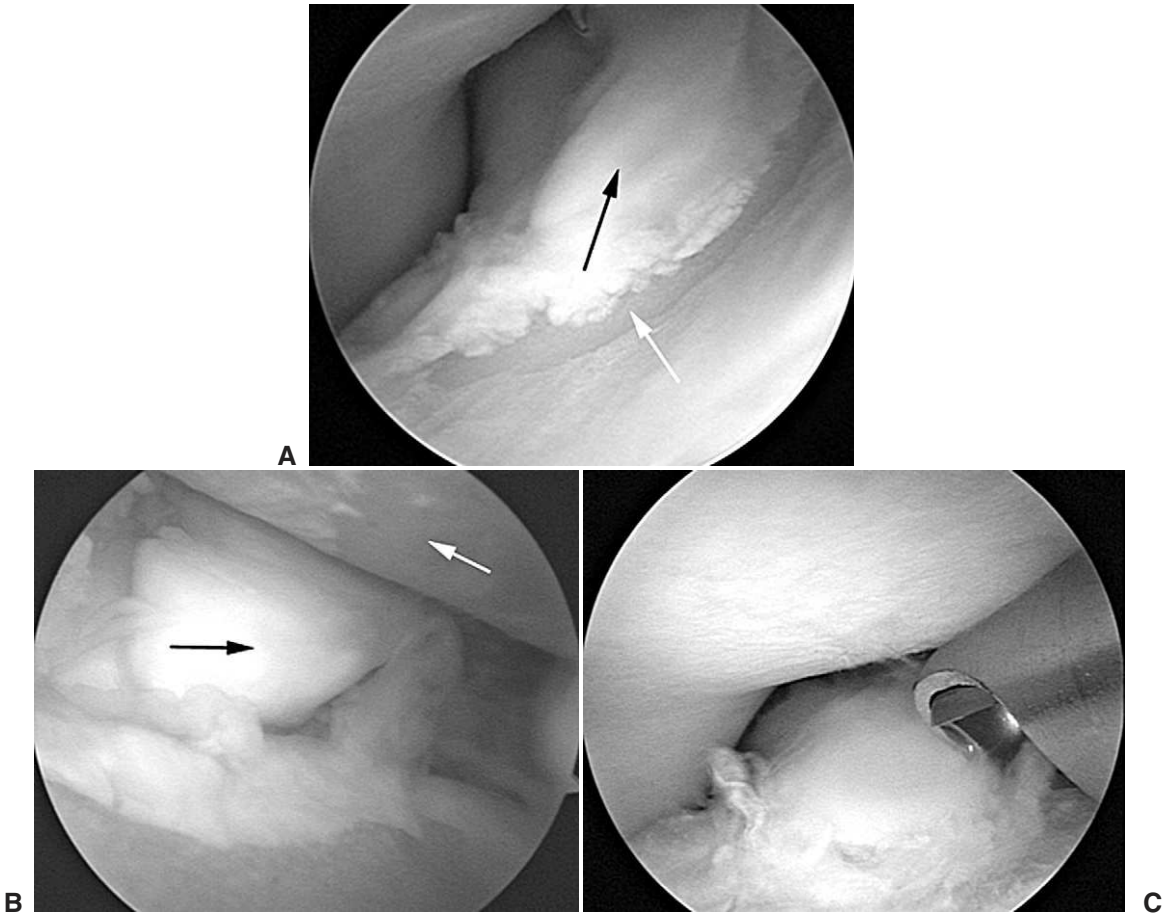


FIGURE 8-12. Arthroscopy of canine elbow joint. **A,** Fragmented coronoid process *(black arrow)* is seen through a medial portal. Full-thickness cartilage loss is seen *(white arrow)* at the base of the coronoid fragment. **B,** Fragmented coronoid process *(black arrow)* is shown in close association with full-thickness cartilage loss *(white arrow)* to the humeral condyle. **C,** Radial shaver is used to excise a fragmented coronoid process.

portal is a lateral site, just distal to the acromium.[2] Instrument portals may be positioned cranial or caudal to this site, depending on the specific needs of the patient. A 2.7- or 2.4-mm arthroscope is most often used for the canine shoulder.

The dog is positioned in lateral recumbency with the affected side up. A long needle and syringe are used to distend the shoulder joint with lactated Ringer's solution and identify the joint space at the intended arthroscope portal site. A small incision is made at the arthroscope portal site, and mosquito forceps may be used to dissect bluntly a tunnel between muscle fascial planes to the joint capsule. A cannula with a blunt trocar is introduced into the joint, followed by the arthroscope. An egress needle is placed cranial to the arthroscope portal or medial to the greater tubercle at the cranial aspect of the joint. Fluid flow is established to improve clarity of sight, and the joint can then be thoroughly explored by rotating the arthroscope at the light post and gently manipulating the arthroscope. Proximal biceps tendon, glenohumeral ligaments, subscapularis tendon, joint capsule, and most of the articular surface of the glenoid and humeral head can be visualized and

inspected for pathology. If an OCD flap is present, an instrument portal is established caudal to the arthroscope portal by 1.5 to 2.0 cm by introducing an 18-gauge needle into the joint, followed by a #11 scalpel blade to open the instrument portal along the needle. Grasping forceps are introduced into the joint. Combined with careful manipulation of joint position by an assistant, the forceps are used to mobilize the cartilage flap and twist it out through the soft tissues of the shoulder (Figure 8-13, *A* to *D*). An instrument portal may be established for treatment of biceps tenosynovitis cranial to the arthroscope portal. A forward-cutting or side-cutting arthroscope knife is used to cut the biceps tendon to provide tendon release (Figure 8-13, *E, F,* and *G*).

Other uses for shoulder arthroscopy include potential applications in diagnosis of arthritis and shoulder instability (Figure 8-13, *H* to *K*) with injuries to the glenohumeral ligaments, subscapularis tendon, and joint capsule, as well as biopsy of intraarticular tumors.

Stifle Joint

Siemering[1] described diagnostic arthroscopy for the canine stifle in 1978. Arthroscopic replacement of the cranial cruciate ligament was described by Person[10] in 1987, and arthroscopic management of OCD was described by McLaughlin and colleagues[11] in 1989. Diagnostic accuracy for partial and complete tears of the cranial cruciate ligament and meniscal injury is well established.[12,13] Most veterinary surgeons continue to prefer open surgery for stabilization of cranial cruciate rupture rather than arthroscopically assisted procedures. However, an arthroscopic procedure for meniscectomy is described and causes less morbidity than open techniques.[13]

The patient is positioned in dorsal recumbency with the operative table slanted at an angle that will present the stifle joint to the surgeon. Lateral and medial distal parapatellar portals are developed at the level of the meniscus. The distal lateral parapatellar portal is most often used for the arthroscope and the medial portal for instruments, but the portals may be interchanged. Fluid egress is established through a portal into the joint space proximal to the patella and medial or lateral to the quadriceps tendon. The large joint space at this area allows use of a fenestrated cannula for efficient fluid egress. A motorized shaver with a full radial blade is used through the distal medial parapatellar portal to remove a portion of the fat pad for visibility. Full exploratory surgery of the stifle joint may now be completed, with visualization of the medial and lateral condyles, femoral trochlea, patella, tibial plateau, cruciate ligaments, and menisci (Figure 8-14, *A* to *E*). Torn portions of the cranial cruciate can be debrided with a motorized shaver. Partial arthroscopic meniscectomy (Figure 8-14, *F*) is performed by grasping the bucket-handle tear with locking graspers and using an arthroscopic knife or a small tissue ablation tip to incise the axial and abaxial attachments.[12] The same arthroscopic and instrument portals described can be used to remove an OCD cartilage flap.

Other uses for stifle arthroscopy include potential applications in diagnosis of arthritis, treatment of avulsion injuries of the cranial cruciate ligament and long digital extension tendon, biopsy of intraarticular tumors, and visualization of fracture reduction in intraarticular fractures.

Coxofemoral, Carpal, and Tarsal Joints

Arthroscopic procedures have been described in other joints of the canine. Arthroscopic viewing of the coxofemoral joint has been advocated for assessment

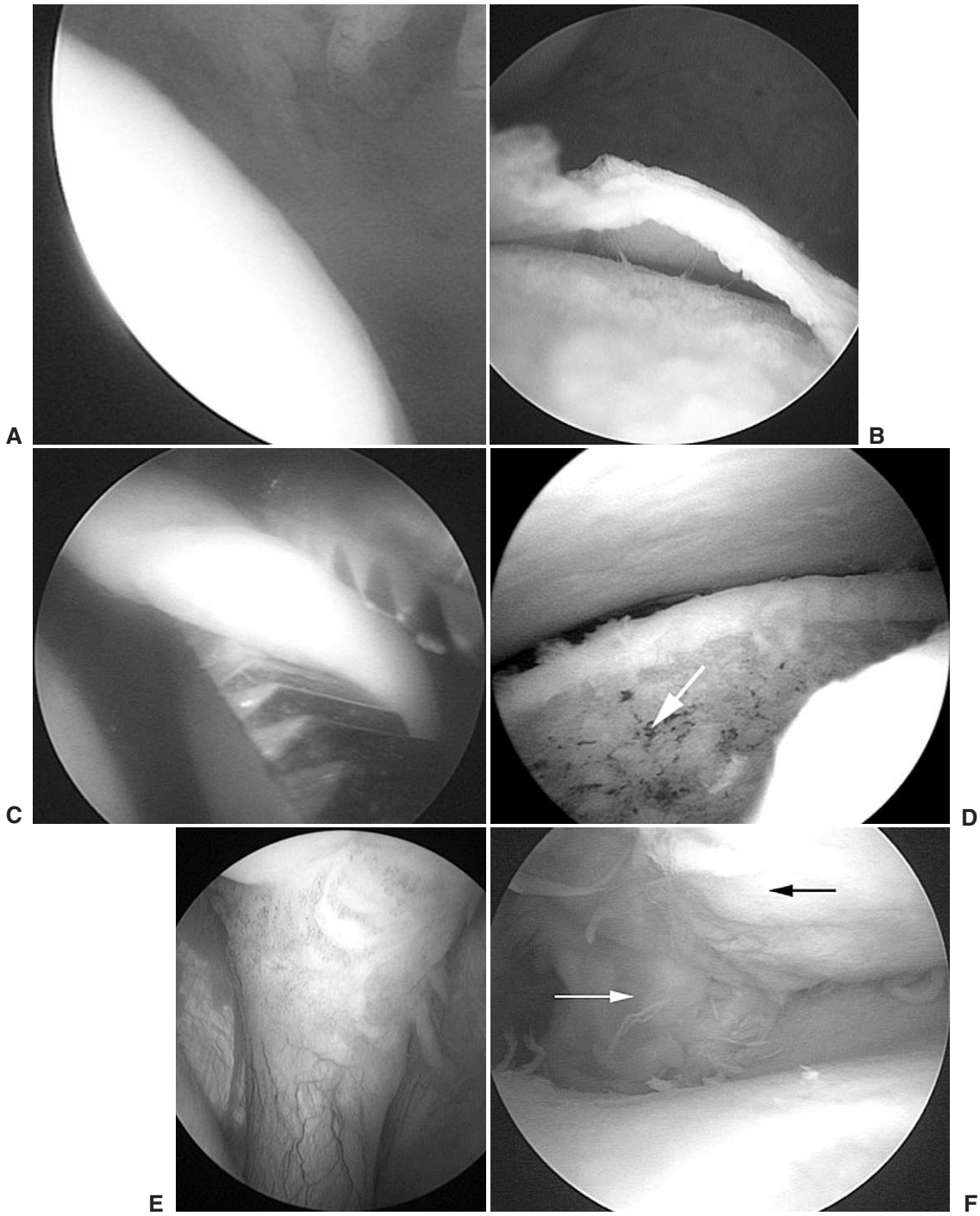


FIGURE 8-13. Arthroscopy of canine shoulder joint. **A,** View of the humeral head as seen through a lateral portal. **B,** Osteochondritis dissecans (OCD) lesion of the caudal and medial surface of the humeral head. **C,** Grasping instrument is used to mobilize and extract an OCD flap from the joint. **D,** OCD lesion site after the flap has been removed and the bed lightly curetted. Note the small, bleeding vessels from the subchondral bone *(arrow)*. **E,** Normal origin of the biceps tendon as seen through a lateral portal with the arthroscope directed cranially.

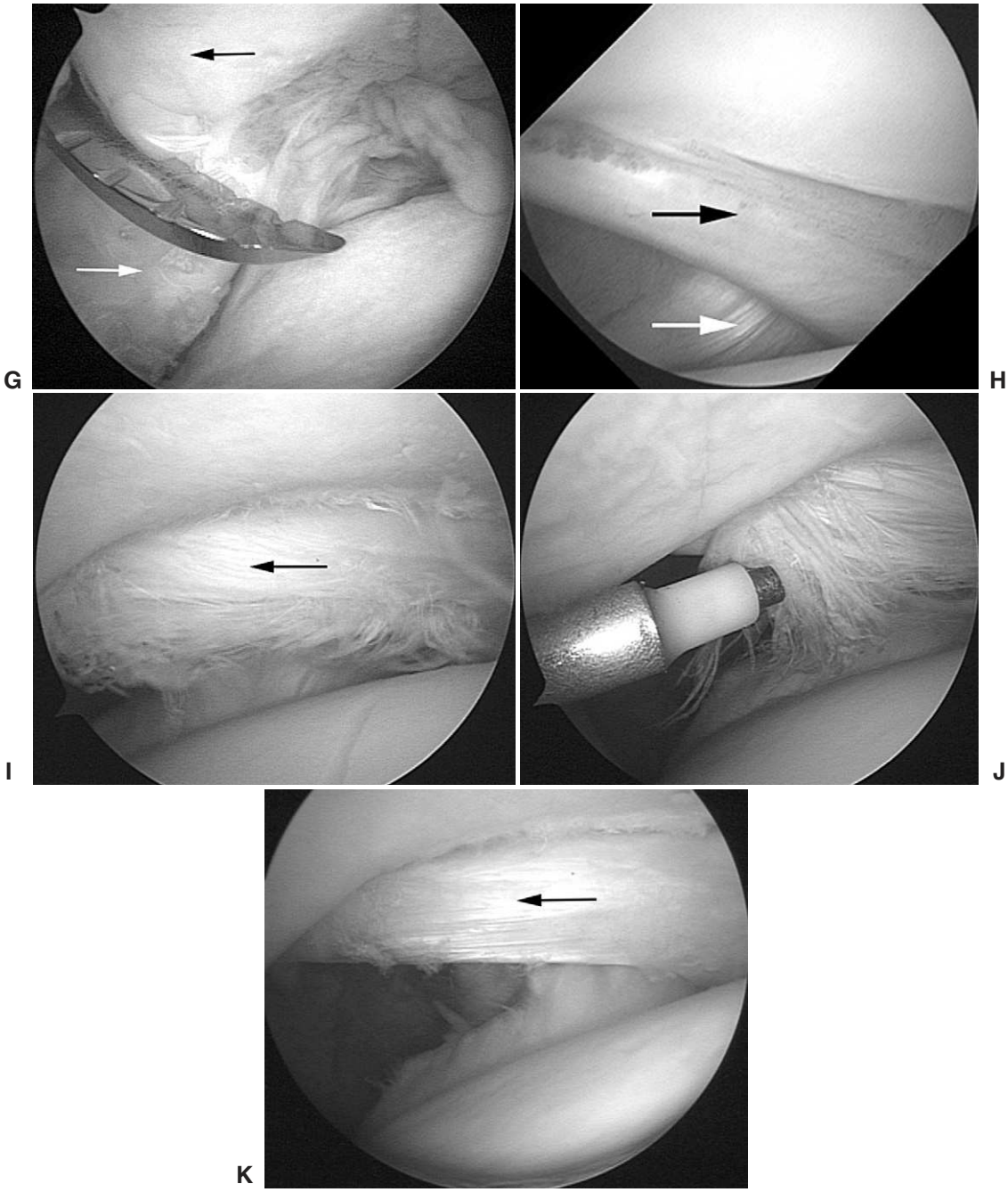


FIGURE 8-13. *Continued* **F** and **G,** Partial rupture of the origin of the biceps tendon *(white arrow)* is seen with severe fraying distal to the supraglenoid tubercle *(black arrow)*. A serrated side-cutting arthroscopic knife is used to perform tendon release at the origin of the biceps tendon. **H,** Normal medial glenohumeral ligament *(black arrow)* and subscapular tendon *(white arrow)* as seen through a lateral portal in the canine shoulder. **I,** Severely frayed and degenerative medial glenohumeral ligament *(black arrow)* is seen with canine shoulder instability. **J,** Radiofrequency instrument is used to ablate frayed portions of the medial glenohumeral ligament and provide "shrinkage" to remaining tissue to aid in stabilizing the joint. Care must be taken to avoid iatrogenic injury to the ligament. **K,** Improved appearance of degenerative medial glenohumeral ligament *(arrow)* after shrinkage procedure with radiofrequency instrument. (Images courtesy Dr. Loic Dejardin.)

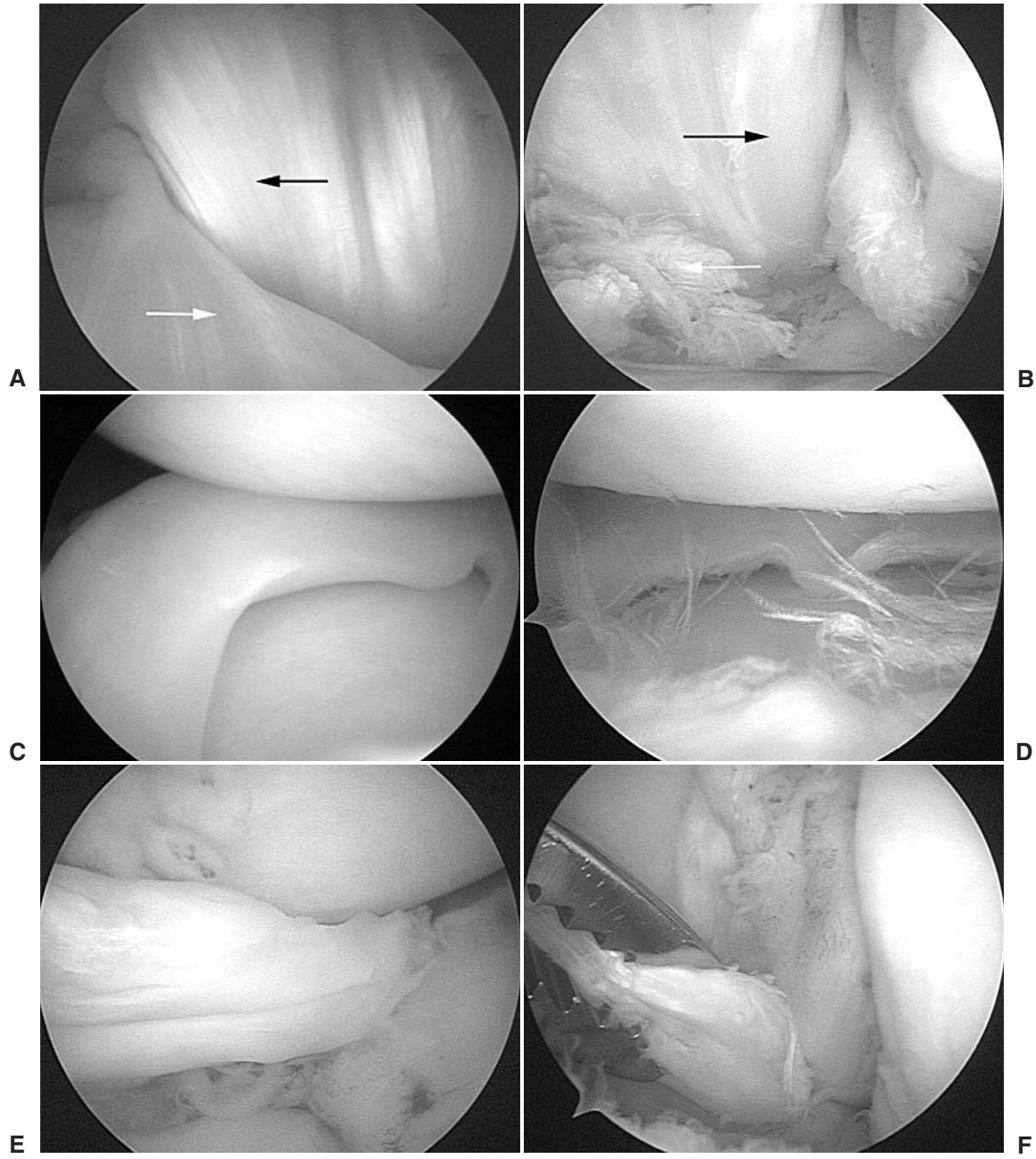


FIGURE 8-14. Arthroscopy of canine stifle joint. **A,** Normal cranial *(white arrow)* and caudal *(black arrow)* cruciate ligaments as seen through a lateral parapatellar portal. **B,** Ruptured cranial *(white arrow)* and intact caudal *(black arrow)* cruciate ligaments. **C,** Normal medial meniscus as seen through a lateral parapatellar portal. **D,** Frayed and torn medial meniscus is seen associated with the instability of cranial cruciate ligament rupture. **E,** Caudal horn of the medial meniscus has ruptured and displaced forward into view at the cranial aspect of the joint. **F,** Grasping instrument is used to hold the ruptured meniscal flap in preparation for partial medial meniscectomy. (Images courtesy Dr. Loic Dejardin.)

of hip dysplasia and the state of articular cartilage before completing triple pelvic osteotomy for pelvic reconstruction.[14] If sufficient damage to the articular cartilage is present, surgery is not recommended. Arthroscopic assessment and removal of small chip fractures are described in the carpal joint. The canine carpus and tarsus have little space for working, but a 1.9-mm arthroscope is small enough to accomplish some tasks. Arthroscopic removal of OCD cartilage flaps has been described for the medial trochlear ridge of the talus.[15]

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9

Fractures of the Scapula

CLASSIFICATION

Fractures of the scapula are relatively uncommon and may be classified according to the following anatomical locations[1,2]:

1. The body and spine
2. The acromion process
3. The neck
4. The glenoid and supraglenoid tuberosity

The most frequently encountered immediate complications of scapular fracture are pulmonary contusions, rib fractures, pneumothorax, pleural effusions, foreleg paralysis, and injury to the suprascapular nerve.[3] The most common cause of scapular fracture is automobile trauma (68%), and 56% of cases have concurrent injury to other organ systems, including pulmonary trauma in 42% of vehicular trauma cases.[4] Long-standing complications include suprascapular neuropathy caused by entrapment, as well as limitation in range of movement and osteoarthrosis in unreduced fractures of the neck or articular surface, particularly in large, athletic animals.

TREATMENT

Conservative Treatment

Most scapular body fractures are not grossly displaced because of the protection of the surrounding muscle mass and rib cage and can be treated closed unless there is loss of congruity of the articular surface or a distinct change in the angulation of the shoulder joint articulation, as in most fractures of the neck. Healing is generally rapid because of the high proportion of well-vascularized cancellous bone, and stability of fixation is not critical except for articular fractures. Many fractures respond well to simple limitation of the animal's activity. In many cases a modified Velpeau bandage adds greatly to the animal's comfort. The leg is flexed along the chest wall, padded, and bound to the body (see Figure 2-29). The spica splint is also useful for stabilizing these fractures and reducing pain (see Figure 2-23).

Internal Fixation

Open approach and internal fixation are indicated in fractures of the articular surface, the neck of the scapula, and most fractures of the acromion process.

Less frequently, some displaced body fractures are internally fixed, especially when athletic performance or cosmetic appearance is a major concern for the owner. The open approach varies considerably, depending on the area of involvement. Exposing the body simply requires elevating the spinati muscles from the spine and body, whereas exposure of the neck and glenoid cavity usually requires osteotomy of the acromion process and, in some cases, osteotomy of the greater tubercle (Figure 9-1).

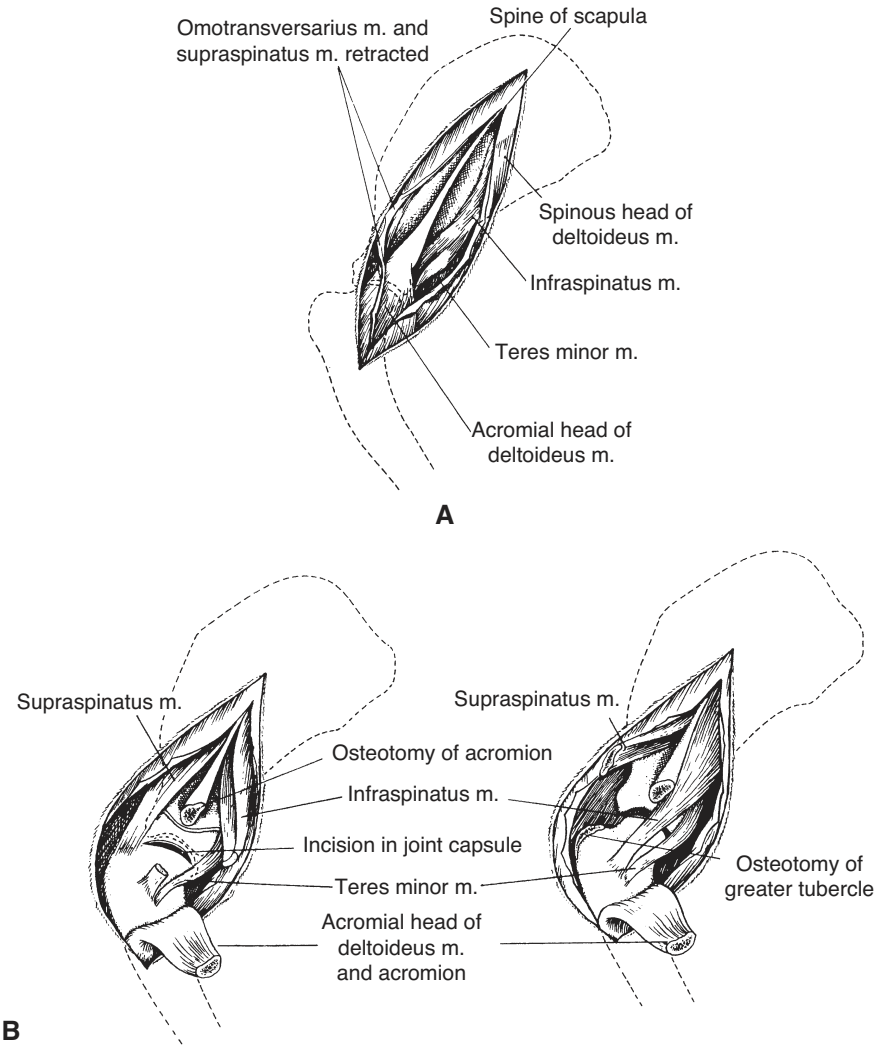


FIGURE 9-1. Open approaches to the scapula and shoulder joint. **A,** Fractures of the scapular body and spine; the infraspinatus and supraspinatus muscles are reflected caudally and cranially, respectively, from the spine. **B,** Fractures of the scapular neck; the acromion process is osteotomized so that the acromial head of the deltoid muscle can be reflected distally. The infraspinatus and supraspinatus muscles are reflected caudally and cranially, respectively. Their tendons of insertion may be severed for more exposure. The suprascapular nerve is located as it crosses the lateral surface of the neck just distal to the acromion process. In fractures involving the articular surface, the joint capsule is incised between the scapula and humerus for exposure. **C,** In avulsion fractures of the supraglenoid tuberosity or in multiple neck fractures, the belly of the brachiocephalicus muscle is reflected cranially. The greater tuberosity of the humerus is osteotomized, and insertion of the supraspinatus muscle is reflected proximally for exposure and working room. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

Acromion Process

This scapular fracture includes the origin of the acromial part of the deltoid muscle, which pulls the fragment away from the spine if the fracture is complete and results in a fibrous nonunion. Chronic soreness and lameness result. If the bone is large enough, pin and tension band wire is the most efficient fixation method (Figure 9-2, *A*). When the process and spine are too small to accommodate the Kirschner wires (one K-wire is sufficient), a variety of interfragmentary wire patterns can be used (Figure 9-2, *B* and *C*). It is more important to ensure good stability of the fracture than perfect reduction.

Body and Spine

As previously stated, most fractures in the scapular body and spine area can be conservatively treated, but if they are severely displaced, recovery will be more rapid and certain with open reduction. The body usually folds outward in a tentlike configuration. In young dogs the body may fracture and the spine may remain intact along the crest of the spine. Interfragmentary wire usually provides sufficient fixation once reduction is complete. Because the bone of the body is very thin, it is best to place the wire in the thickened areas of the cranial and caudal border and in the crest or base of the spine (Figure 9-3, *A*). The wire diameter must not be too large,

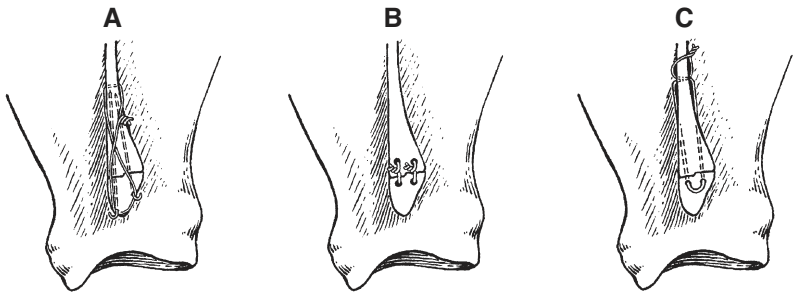
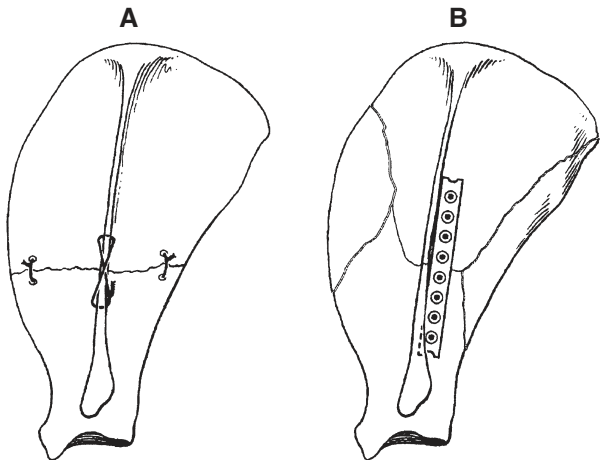


FIGURE 9-2. Fixation of fractured or osteotomized acromion process. **A,** Tension band wire and Kirschner wires. **B,** Simple interfragmentary wiring. **C,** Interfragmentary wiring, applicable to animals too small for the technique in *A*.

FIGURE 9-3. Fracture of the scapular body. **A,** Simple fractures of the body and spine are amenable to interfragmentary wiring of the body and a tension band wire in the spine. Wires are placed to take advantage of the thicker bone of the cranial and caudal borders of the body and the crest of the spine. **B,** Multiple fragment fractures are best fixed by a veterinary cuttable plate (VCP) (Synthes, Ltd., Paoli, Pa) with screws anchored at the junction of the spine and blade. The VCP shown here, or a semitubular plate, can be inverted to provide better contact with the bone.



or the wire will be so stiff that it will cut through the bone when tightened; 20 to 22 gauge is sufficient.

When body fractures are multiple, it is easier than multiple wiring simply to apply a plate along the base of the spine (Figure 9-3, *B*). This restores the basic alignment of the body and reduces the fragments to near normal position, where they do not require fixation. The use of the veterinary cuttable plate (VCP) discussed in Chapter 2 is extremely helpful here, and stacking these plates can make them sufficiently strong for most dogs.

Neck

The scapular body typically displaces distolateral to the neck fragment and restricts outward rotation of the humerus. The scapular nerve can be damaged by direct impingement between the fragments or can become trapped in callus in unreduced fractures. Although partial function of the shoulder remains in this situation, considerable cosmetic deformity results from atrophy of the spinati muscles.

A craniolateral approach with osteotomy of the acromion process is required for exposure (see Figure 9-1, *C*). Pin fixation is sufficient in simple transverse fractures (Figure 9-4, *A* and *B*). The pin from the supraglenoid tubercle into the scapular neck can also be inserted from the other direction, although with slightly less resultant stability. Occasionally, the neck fracture is sufficiently oblique to allow fixation with lag screws. More often, the obliquity is too short for screws only, and a plate is required (Figure 9-4, *C*). Right-angle or oblique-angle finger plates work well in this location, taking care to elevate the suprascapular nerve during placement. Two VCP plates are another option (see Figure 9-7, *C*).

An off-weight-bearing foreleg sling or Velpeau sling (see Figures 2-30 and 2-29, respectively) is indicated for 2 weeks postoperatively, with exercise severely restricted the first month and a gradual return to normal activity at 8 to 10 weeks. Use of the sling is especially indicated when pin fixation is used or when the dog is very active and poorly controlled by the owner.

Articular Fractures

Treatment of articular fractures of the glenoid is difficult because of the small size of most bone fragments and the relative difficulty of surgical exposure. Fractures of the cranial portion of the glenoid are most common, followed by the T-Y type.[4]

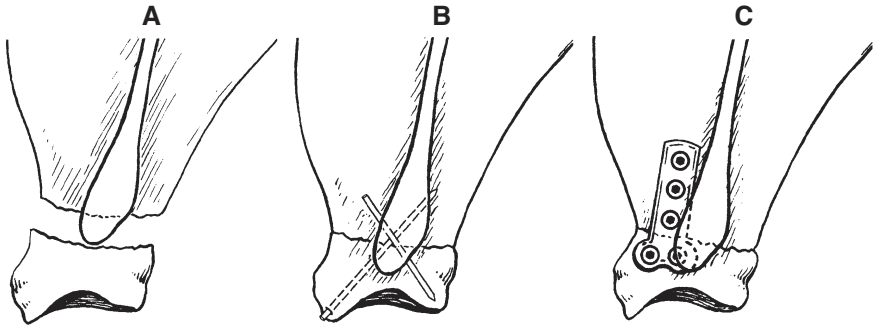


FIGURE 9-4. **A,** Transverse fracture of the scapular neck. **B,** Immobilization by insertion of two transfixing Kirschner wires. One wire was inserted at the acromion process and one in the scapular neck. **C,** Immobilization by a small bone plate; the suprascapular nerve is elevated to insert the bone plate. The use of two VCPs for a similar fracture is illustrated in Figure 9-7, *C*.

Supraglenoid Tubercle

Forming a separate center of ossification and the origin of the biceps brachii muscle, the tubercle (scapular tuberosity) is subject to avulsion from the tension of the biceps muscle in skeletally immature, large-breed dogs (Figure 9-5, *A*). Although the initial lameness is dramatic, this quickly disappears, and many of these animals are not presented until the lameness is chronic, with secondary degenerative joint disease (DJD) caused by malunion or nonunion of this intraarticular fracture. Attempts to reduce the fracture are probably not worthwhile at this point, and biceps tenodesis is indicated and quite successful if DJD is not advanced (see Chapter 10).

Recent fractures are best stabilized with either a lag screw or a pin and tension band wire. As with all articular fractures, accurate reduction and stable fixation are necessary. Screw fixation is preferred because less exposure is required and it can be applied from a cranial approach, whereas the pin and tension band wire usually require a craniolateral approach with osteotomy of the greater tubercle (see Figure 9-1, *D*). It is important that the screw be inserted into the scapular neck as parallel as possible to the biceps tendon in order to minimize bending loads on the screw (Figure 9-5, *B*). A cancellous thread screw provides the best security. Pin and tension band wire fixation requires that the wire span the suprascapular nerve, so care must be taken to protect the nerve during wire placement (Figure 9-5, *C*). An off-weight-bearing foreleg sling or Velpeau sling (see Figures 2-30 and 2-29, respectively) is indicated for 2 weeks postoperatively, with exercise severely restricted the first month and a gradual return to normal activity at 6 to 8 weeks.

Glenoid Rim

The most common fracture in this area is of the caudoventral angle of the glenoid (Figure 9-6, *A*); similar fractures of the craniodorsal angle are less common. Fracture of the medial rim is also seen, as in Figure 9-6, *B* and *C*. These fractures require lag screw fixation. Initial fixation with a K-wire is useful to remove the reduction forceps from the field for screw application. The K-wire is bent over at the protruding end to prevent pin migration and is left in situ. The concavity of the glenoid cavity must be kept in mind when placing the screws to prevent them from entering the joint.

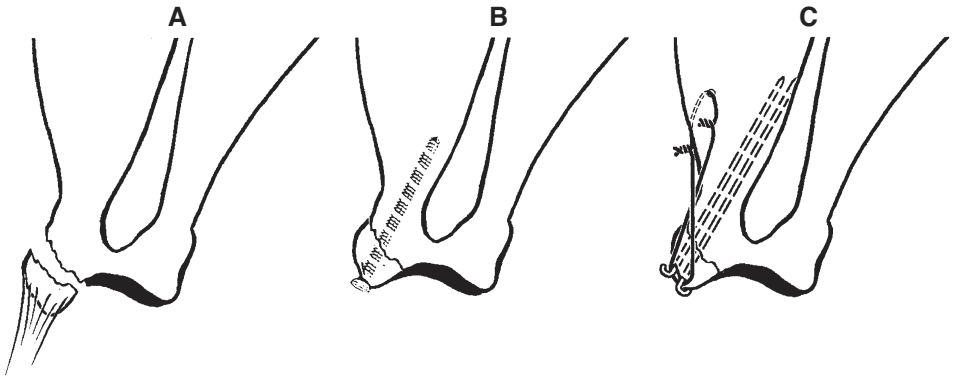


FIGURE 9-5. **A,** Avulsion fracture of the supraglenoid (scapular) tuberosity. **B,** Fixation with a lag screw, inserted as parallel to the tendon of the biceps brachii as possible. **C,** Fixation with Kirschner wires and a tension band wire. The suprascapular nerve must be protected during placement of the tension wire.

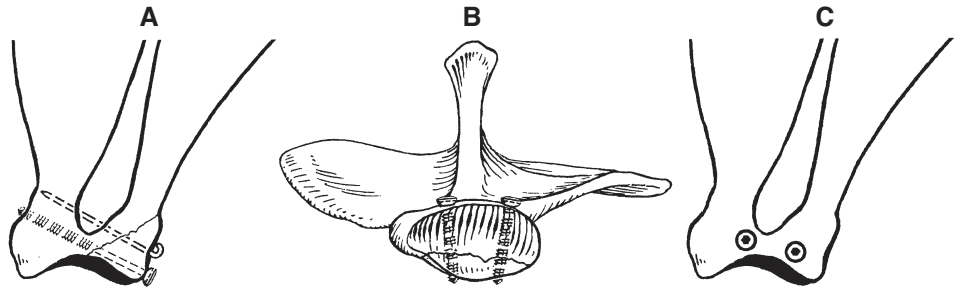


FIGURE 9-6. **A,** Fracture of the caudoventral angle of the glenoid fixed with Kirschner wire and lag screw. The K-wire is placed first. **B** and **C,** Fracture of the medial rim of the glenoid fixed with two lag screws placed from the lateral side.

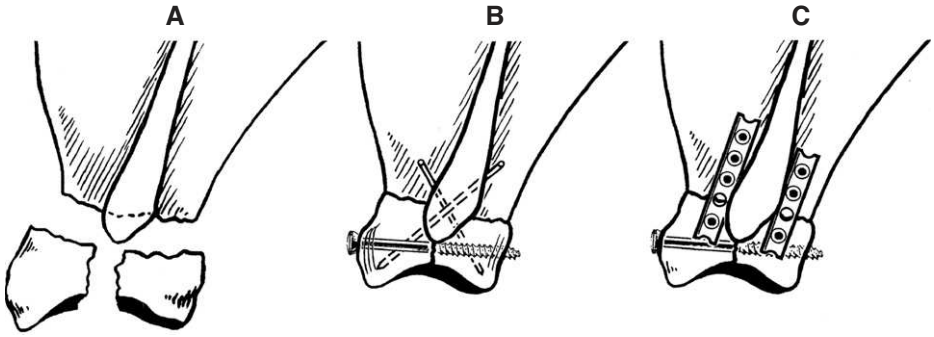


FIGURE 9-7. **A,** Fracture of the scapular neck and glenoid; T-Y fracture. **B,** Immobilization by a cancellous screw and two transfixing Kirschner wires. **C,** Fixation by a lag screw and two VCPs (Synthes). Although there is only one screw on the glenoid fragment for each plate, this is sufficient stabilization for this fracture.

An off-weight-bearing foreleg sling or Velpeau sling (see Figures 2-30 and 2-29, respectively) is indicated for 2 to 3 weeks postoperatively, with exercise severely restricted the first 6 weeks and a gradual return to normal activity at 10 to 12 weeks.

Glenoid and Neck; T-Y Fracture

As is typical in any fracture of this type, reconstruction of the joint is the first priority, followed by fixation of the neck. Methods of fixation are as previously described for glenoid and neck fractures (Figure 9-7).

An off-weight-bearing foreleg sling or Velpeau sling (see Figures 2-30 and 2-29, respectively) is indicated for 2 to 3 weeks postoperatively, with exercise severely restricted the first 6 weeks and a gradual return to normal activity at 10 to 12 weeks. Use of the sling is especially indicated when pin fixation is used or when the dog is very active and poorly controlled by the owner.

Prognosis for Intraarticular Fracture

Long-term follow-up of 20 animals with articular fractures indicated that only 15% were free of clinical signs related to the fracture, with the remainder showing variable degrees of lameness. Thus, although prognosis for limb function is good, some degree of continued lameness is probable.[4]

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3. Tomes PM, Paddleford RR, Krahwinkel DJ: Thoracic trauma in dogs and cats presented for limb fractures, *J Am Vet Med Assoc* 21:161-166, 1985.
4. Johnston SA: Articular fractures of the scapula in the dog: a clinical retrospective study of 26 cases, *J Am Anim Hosp Assoc* 29:157-164, 1993.

10
The Shoulder Joint

FORELIMB LAMENESS

Following a history and lameness examination of the animal, as described in Chapter 1, it is usually possible to localize the source of lameness with some degree of accuracy. After this, the veterinarian constructs a list of possible diagnoses and works through them until the correct cause is found. The following listing is not exhaustive but includes the problems that are seen regularly.

Forelimb Lameness in Large-Breed, Skeletally Immature Dogs

General/Multiple

- Trauma—fracture, luxation
- Panosteitis
- Hypertrophic osteodystrophy (HO)
- Cervical cord lesion—vertebral instability

Shoulder Region

- Osteochondritis dissecans (OCD) of humeral head

Elbow Region

- OCD of medial trochlear ridge
- Ununited anconeal process (UAP)
- Fragmentation of medial coronoid process (FCP)
- Avulsion and calcification of the flexor tendons of the medial epicondyle or ununited medial epicondyle (UME)
- Subluxation caused by premature physeal closure
- Synovial chondrometaplasia (SCM)

Carpal Region

- Subluxation/valgus or varus deformity caused by premature physeal closure
- Valgus deformity caused by retained cartilage cores in the ulna, or elbow conditions

Paw Region

- Fragmentation of the sesamoids

Forelimb Lameness in Large-Breed, Skeletally Mature Dogs

General/Multiple

- Trauma—fracture, luxation, muscle and nerve injuries
- Panosteitis
- Cervical cord lesion—disk, tumor, vertebral instability
- Brachial plexus tumor
- Bone cartilage or synovial tumor
- HO
- Synovial chondrometaplasia (SCM)

Shoulder Region

- OCD of humeral head
- Degenerative joint disease (DJD), primary or secondary
- Contracture of infraspinatus muscle
- Tenosynovitis of biceps brachii tendon
- Calcification of the supraspinatus muscle
- Luxation/Instability

Elbow Region

- DJD
- FCP
- Calcification of the flexor tendons or UME
- Subluxation caused by prior physeal injury or breed (chondrodystrophic) predisposition
- Subluxation caused by premature physeal closure
- Luxation

Carpal Region

- Ligamentous instability/hyperextension
- Subluxation caused by premature physeal closure
- DJD
- Inflammatory joint disease, with or without instability

Forelimb Lameness in Small-Breed, Skeletally Immature Dogs

General/Multiple

- Trauma—fracture, luxation
- Atlantoaxial luxation

Shoulder Region

- Congenital luxation

Elbow Region

- Congenital luxation
- Subluxation caused by premature physeal closure

Carpal Region

- Subluxation caused by premature physeal closure

Forelimb Lameness in Small-Breed, Skeletally Mature Dogs

General/Multiple

- Trauma—fracture, luxation, muscle and nerve injuries
- Cervical cord lesion—disk, tumor
- Brachial plexus tumor
- HO
- SCM

Shoulder Region

- DJD
- Recurrent medial luxation, nontraumatic

Elbow Region

- DJD
- Subluxation caused by physeal injury

Carpal Region

- DJD
- Inflammatory joint disease
- Subluxation caused by prior physeal injury

THE SHOULDER

Dorsal Luxation of Scapula

Multiple ruptures of the serratus ventralis, trapezius, and rhomboideus muscle insertions on the cranial angle and dorsal border of the scapula allow the scapula to move dorsally on weight bearing. Onset of clinical lameness is usually acute and is often directly associated with jumps, falls, or bite wounds.

Considerable soft tissue swelling is evident several days after injury. Mobility of the scapula is easily demonstrated and is diagnostic. This uncommon problem is seen in both dogs and cats.

Surgical Technique

The objective of surgical repair is to attach the scapula to a suitable rib with heavy stainless steel wire and to reattach as many ruptured muscles as possible. An inverted L-shaped incision is made along the cranial and dorsal borders of the scapula. If any portions of the trapezius, serratus, or rhomboideus muscle insertions are intact, they are cut sufficiently to allow lateral retraction of the scapula so that its caudal angle and caudal borders can be visualized. Two holes are drilled from a medial-to-lateral direction through the caudal border of the scapula, close to the caudal angle (Figure 10-1). Stainless steel wire of 20 to 22 gauge is carefully placed around an adjacent rib with the ends placed through the scapular holes, then pushed laterally through the muscles. The wire is twisted until dorsal movement of the scapula is minimized but still possible. All muscular insertions are sutured to the extent possible, and all tissues are closed in layers.

It is sometimes possible to eliminate the rib wire suture and simply attach muscle to the scapula through holes drilled near the cranial angle.

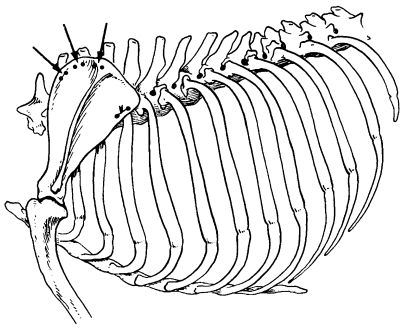


FIGURE 10-1. Dorsal luxation of the scapula. Heavy stainless steel wire is used to secure the caudal border of the scapula to an adjacent rib. Alternatively, holes are drilled through the cranial angle and vertebral border *(arrows)* to allow suturing to the serratus ventralis muscle.

Aftercare

The scapula is immobilized in either a Velpeau sling (see Figure 2-29), a spica splint (see Figure 2-23), or a carpal flexion bandage (see Figure 2-30) for 2 weeks. Exercise is gradually increased to normal in the 2 weeks after sling or splint removal.

Luxations of Shoulder

Luxations of the shoulder are relatively uncommon in the dog. Traumatic luxations can occur in all breeds, but the toy poodle and sheltie show a particular propensity to develop medial luxations without any history of significant trauma (Figure 10-2). At presentation, many of these animals have a history of lameness of several months' duration. Most luxations—perhaps 75%—are medial, and a large proportion of the remainder are lateral (see Figure 10-4). Cranial and caudal luxations are rarely seen (see Figures 10-6 and 10-8). Although the tendons of the parascapular muscles have long been thought of as the primary stabilizers of the shoulder joint, it was found experimentally that cutting the tendons that cross the shoulder joint resulted in minimal changes in joint motion, whereas cutting the joint capsule and glenohumeral ligaments caused marked alteration of joint motion.[1] This suggests that careful imbrication suturing of the capsule and associated ligaments should be an important part of any surgical repair.

With medial luxation the leg is usually carried with the elbow flexed and adducted and the lower limb abducted and supinated. With lateral luxation the position is similar except that the lower limb is adducted. On palpation, the relative positions of the acromial process and the greater tubercle are the keys to determining the position of the humeral head relative to the glenoid. These points should be palpated on the normal limb and then compared with the affected limb. Clinical signs and physical examination are usually diagnostic; as with any skeletal injury, however, diagnosis should always be confirmed radiographically to eliminate the possibility of bone injuries such as fractures. Stress radiography has been suggested as an objective method of measuring instability in this joint.[2] The presence of a severely eroded glenoid resulting from chronic luxation or the presence of a dysplastic glenoid or humeral head greatly reduces the probability of a successful reduction. Congenital luxations discovered later are usually irreducible because of severe malformations of both the glenoid and the humeral head.

If an injury is seen within a few days after dislocation, and particularly if there is a known traumatic event, it is probably worthwhile to attempt closed reduction and immobilization of the limb for approximately 2 weeks. If the joint is relatively stable after reduction, there is a good chance that this type of treatment

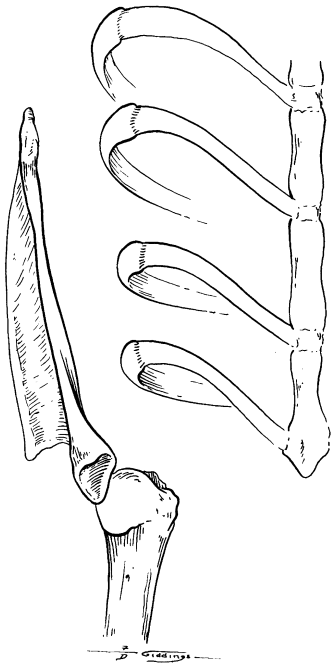


FIGURE 10-2. Medial luxation of the left shoulder (ventrodorsal view).

will be successful. If the joint remains unstable after reduction, or if the luxation recurs while the leg is in the sling, surgical treatment is indicated.

Medial Luxation

Prosthetic ligaments and imbrication techniques have not been as successful as methods for transposing the biceps tendon as in other areas. Medial transposition and tenodesis[3] of the biceps tendon create a stabilizing lateral force on the humeral head (see Figure 10-5). If the glenoid is deformed, surgical stabilization will usually fail. Treatment in this situation is excision arthroplasty (see Figure 10-11) or arthrodesis (see Figure 10-12).

Surgical Technique

The shoulder joint is exposed by a craniomedial approach.[4] Typically, the subscapularis tendon of insertion is torn at its insertion on the lesser tubercle and has retracted a considerable distance, making identification difficult. The tendon should be tagged with a suture when identified to assist in later suturing. If the joint capsule is not torn, it is opened carefully to inspect the joint. It is important to save as much capsule as possible for suturing. Careful assessment of the medial labrum of the glenoid and the lateral side of the humeral head is necessary. If the labrum is worn, successful stabilization is less likely. If there is significant chondromalacia or erosion of the humeral head articular cartilage because of rubbing on the medial labrum, degenerative joint disease (DJD) changes could limit long-term success even if the joint is stabilized. Arthrodesis or excision arthroplasty is probably indicated in these circumstances (see later discussion).

If the articular surfaces are in good condition and the luxation is recent, it may be possible to stabilize the joint by suture of the joint capsule and the subscapularis tendon (Figure 10-3, *B* and *D*). If these tissues are friable, tenodesis of the biceps tendon is carried out.

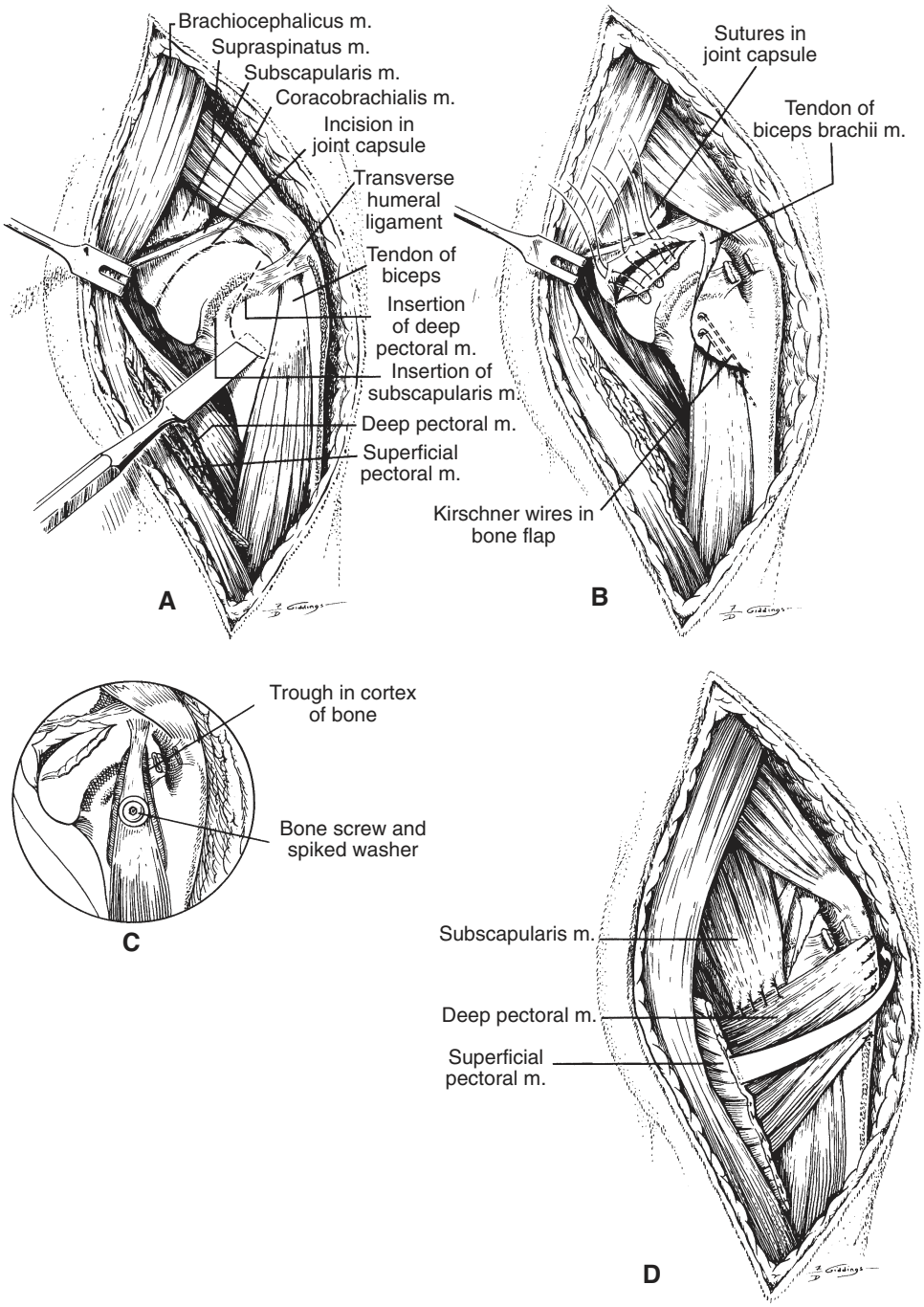


FIGURE 10-3. Surgical repair of medial luxation of the shoulder. **A,** The left shoulder joint has been exposed by a craniomedial approach, and the dislocation has been reduced.[4] The position for incision in the joint capsule is indicated. Elevation of the bone flap by means of an osteotome is being started. **B,** Transposition of the tendon of the biceps muscle has been completed. It is trapped under the osteoperiosteal flap, which is then secured to the humerus with two Kirschner wires or a bone staple. The joint capsule is imbricated with mattress sutures of heavy absorbable material. **C,** Another method of attachment is the use of a plastic spiked washer and bone screw (Synthes, Ltd., Paoli, Pa). The bone beneath the tendon is cut to form a shallow trough to encourage early attachment of the tendon. **D,** The deep pectoral muscle has been advanced and sutured to the origin of the superficial pectoral muscle. The superficial pectoral muscle is advanced craniolaterad until it can be sutured to the fascia of the acromial head of the deltoideus muscle. The subscapularis muscle is attached to the proximal border of the deep pectoral muscle and to any humeral periosteum or fascia available.

Tenodesis of the biceps tendon to a medial position begins by transecting the transverse humeral ligament overlying the biceps tendon (Figure 10-3, *A*). The tendon is mobilized from the intertubercular groove after incising the joint capsule as needed. A crescent-shaped flap of bone is elevated from the lesser tubercle with an osteotome. This flap should hinge on the periosteum along its cranial edge. Bone (and sometimes articular cartilage) is curetted from underneath the flap to accommodate the tendon. The tendon is transposed caudally under the flap and held in place by Kirschner wires driven through the flap into the humerus (Figure 10-3, *B*). An alternative method of tenodesis is illustrated in Figure 10-3, *C*. The tendon is bluntly split and a bone screw and spiked washer (Synthes, Ltd., Paoli, Pa) are used to fix the tendon to the bone in a shallow trough in the cortex. Removal of some cortical bone allows the tendon to heal to the bone more readily than if it were simply attached to the periosteal surface.

Joint capsule and medial glenohumeral ligament imbrication is accomplished by mattress or cruciate sutures of synthetic absorbable material. If the joint seems unstable when the humerus is externally rotated (thus turning the humeral head medially), a derotational suture to temporarily tether the humerus is helpful. Large-gauge nonabsorbable monofilament or braided polyester is anchored to the medial labrum of the glenoid by a bone tunnel or bone screw. A bone tunnel is then drilled through the greater tubercle in the region of the transverse humeral ligament. After passing the suture through the tunnel, it is tied moderately taut with the humerus *internally* rotated. Joint capsule and medial glenohumeral ligament imbrication is accomplished by mattress or Lembert suture patterns of absorbable material.

The deep pectoral muscle is sutured to the superficial pectoral muscle, and the subscapularis muscle is advanced as far cranially as possible and sutured to the deep pectoral muscle (Figure 10-3, *D*). The superficial pectoral muscle is pulled across the cranial border of the humerus and sutured to the acromial head of the deltoideus muscle. The effect of these transpositions is to tighten the muscles and to reinforce medial support of the joint. The remaining tissues are closed in layers.

Aftercare

The limb is supported in a foreleg (Velpeau) sling for 14 days (see Figure 2-29). Exercise is restricted for 4 weeks. Passive flexion-extension exercise may be needed after removal of the sling, supplemented with swimming when possible.

Prognosis

Hohn and colleagues[3] reported an overall 93% success rate (15 cases) for the tenodesis procedure applied to both medial and lateral luxations. Vasseur and colleagues[5] reported that 40% (two cases) of their medial luxation cases had normal gaits, 20% (one case) had occasional limping, and 40% (two cases) had persistent limping after the tenodesis procedure. If cases are carefully selected, and if those with wearing of the glenoid or humeral head are eliminated, it is likely that these results could be improved.

Lateral Luxation

Lateral luxations are more often seen in larger breeds of dogs and are usually traumatic in origin (Figure 10-4). They are more amenable to closed reduction when seen within a few days of injury. Fixation after closed reduction is by means of a spica splint (see Figure 2-23) rather than a Velpeau sling, which tends to turn the humeral head laterally. For surgical treatment of irreducible or chronic luxations,

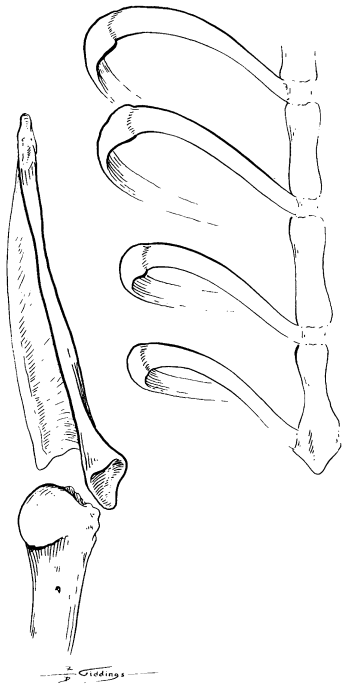


FIGURE 10-4. Lateral luxation of the left shoulder (ventrodorsal view).

biceps tenodesis can again be used to stabilize the joint.[3] By moving the tendon laterally, a "bowstring" effect creates a medial force on the humeral head.

Surgical Technique

A cranial approach to the shoulder is used with osteotomy of greater tubercle.[4] If the joint capsule is not torn, it is opened carefully to inspect the joint. All capsular material is saved for suturing. Careful assessment of the lateral labrum of the glenoid and the medial side of the humeral head is necessary. If the labrum is worn, successful stabilization is less likely. These changes are seen less with lateral luxations because of the more acute nature of most lateral luxations. If there is sufficient chondromalacia or erosion of the articular cartilage of the humeral head because of rubbing on the lateral labrum, DJD changes could limit long-term success even if the joint is stabilized. Arthrodesis or excision arthroplasty is probably indicated in these circumstances (see later discussion).

If the articular surfaces are in good condition and the luxation is recent, it may be possible to stabilize the joint by sutures through the lateral joint capsule (see Figure 10-9). If this does not appear to be a viable option, tenodesis of the biceps tendon is carried out.

Tenodesis of the biceps tendon to a lateral position begins by transection of the transverse humeral ligament over the biceps tendon. The joint capsule is incised as needed to allow lateral transposition of the tendon (Figure 10-5, *A*). To transpose the tendon lateral to the remaining crest of the greater tubercle, it may be necessary to rongeur or curette a trough at the proximal end of the tubercular osteotomy site (Figure 10-5, *B*). The tendon is then held lateral to the tubercle by reattaching it to the humerus with Kirschner wires, pins and a tension band wire, or bone screws, depending on tubercle size (Figure 10-5, *C*). Several sutures are placed between the biceps tendon and the deltoideus fascia. The joint capsule is imbricated with mattress or Lembert sutures. The superficial pectoral muscle is moved

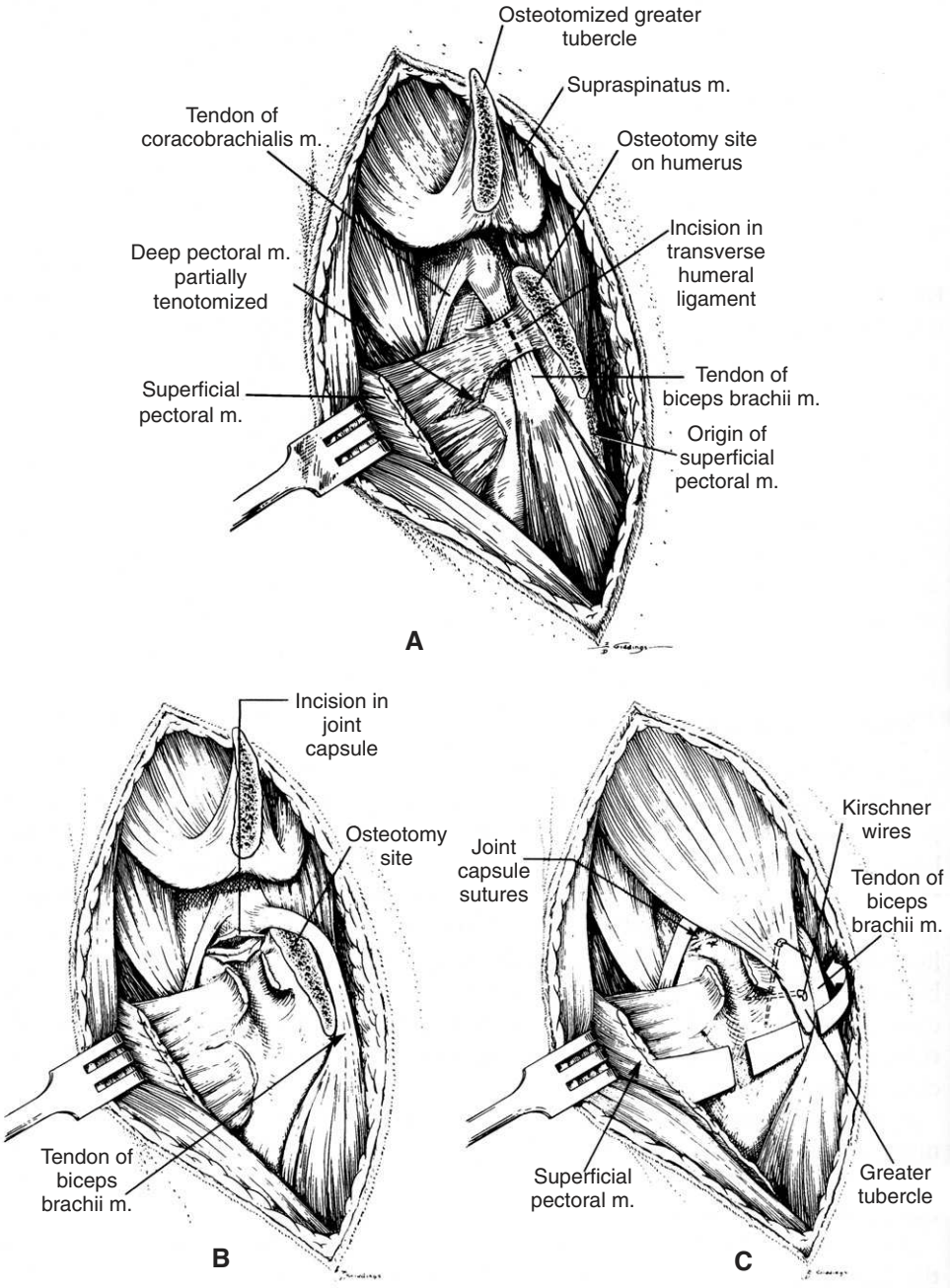


FIGURE 10-5. Surgical repair of lateral luxation of the shoulder. **A,** The left shoulder has been exposed by a cranial approach.[4] The greater tubercle of the humerus has been osteotomized, and the incision is marked in the transverse humeral ligament. **B,** The joint capsule has been incised to aid in moving the biceps tendon lateral to the greater tubercle osteotomy site. A small area of the proximal osteotomy site has been removed to ease positioning of the biceps tendon. **C,** The greater tubercle is pinned back to its original site by two Kirschner wires or bone screws, thus trapping the biceps tendon laterally. The joint capsule is imbricated with mattress sutures, and the superficial pectoral muscle is attached to the fascia of the acromial head of the deltoideus and the biceps muscles.

craniolaterally and sutured to allow attachment to the fascia of the deltoideus and biceps muscles.

Aftercare

A foreleg spica splint is maintained for 14 days (see Figure 2-23). Exercise is restricted for 4 weeks. Passive flexion-extension exercise may be needed after removal of the splint, supplemented with swimming when possible.

Prognosis

In one series of six cases treated by lateral transposition of the biceps, five dogs had normal function and one limped occasionally at follow-up.[5]

Cranial Luxation

In our experience, cranial luxation, a relatively rare injury, is always the result of trauma. The biceps tendon can again be used for the stabilization of this infrequent luxation (Figure 10-6). It is transposed cranially and thus is under increased tension and tends to hold the humeral head more tightly within the glenoid.

Surgical Technique

The shoulder is exposed by the cranial approach to the shoulder joint.[4] An incision is made in the transverse humeral ligament over the biceps tendon, and a trough is cut on the osteotomy surface on the crest and in the tubercle to accommodate the biceps tendon. If, as a result of tension, the tendon cannot be positioned within the osteotomy site on the humerus, sufficient bone is removed from the proximal osteotomy site to form a slight trough there (Figure 10-7, *A*). The tubercle is replaced and attached with Kirschner wires or pins and a tension band wire (Figure 10-7, *B*). Screw fixation should probably be avoided to prevent tendon injury. The joint capsule is imbricated with mattress or Lembert sutures.

Aftercare

The limb is supported in either a foreleg spica splint or Velpeau sling for 10 to 14 days (see Figures 2-23 and 2-29). Exercise is restricted for 4 weeks. Passive flexion-extension exercise may be necessary after removal of the external fixation, and swimming is encouraged.

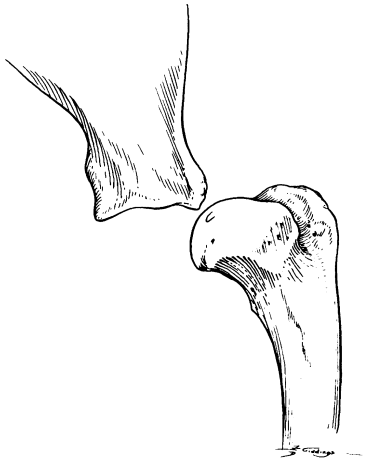


FIGURE 10-6. Cranial luxation of the left shoulder (mediolateral view).

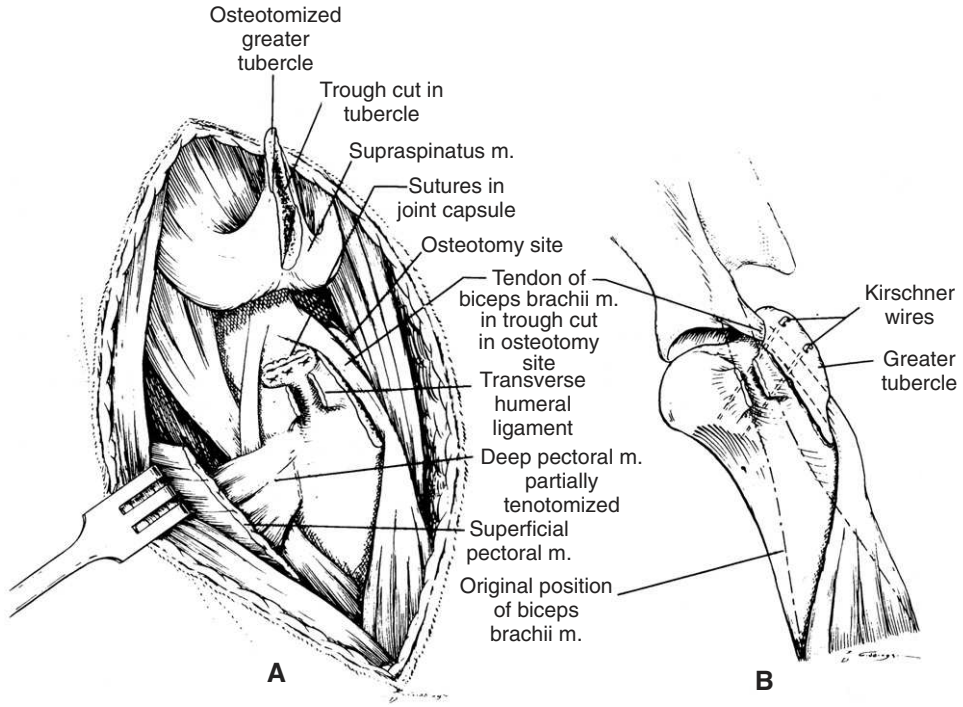


FIGURE 10-7. Surgical repair of cranial luxation of the shoulder. **A,** The left shoulder has been exposed by a cranial approach.[4] The transverse humeral ligament has been cut, and the biceps tendon has been transposed cranially to lie in a trough created in the tubercular osteotomy site and in the tubercle itself. The joint capsule is imbricated with mattress sutures. **B,** The tubercle is reattached to the osteotomy site with two Kirschner wires holding the biceps tendon in a position that pulls the humeral head into the glenoid.

Caudal Luxation and Subluxation

As with cranial luxation, caudal luxation/subluxation occurs infrequently and may be either a self-induced or traumatic injury. Hyperextension of the joint is the probable cause. The luxation may be total, as shown in Figure 10-8, *A*, or subluxated. In the latter case, the joint space between the humeral head and the caudoventral rim of the glenoid is increased on extension-stress radiographs (Figure 10-8, *B*). Imbrication of the lateral and caudolateral joint capsule has worked well in these cases.

Surgical Technique

Caudal Luxation. The shoulder joint is exposed by a craniolateral approach with osteotomy of the acromial process.[4] The joint capsule will be at least partially torn but may need to be opened farther to allow access to the joint. After inspection for intraarticular damage, the humeral head is reduced, and the craniolateral and caudolateral joint capsule is imbricated with mattress or Lembert sutures of synthetic absorbable material (Figure 10-9).

Caudal Subluxation. The shoulder is exposed by a caudolateral approach.[4] The caudolateral joint capsule is imbricated with mattress or Lembert sutures of synthetic absorbable material (Figure 10-10).

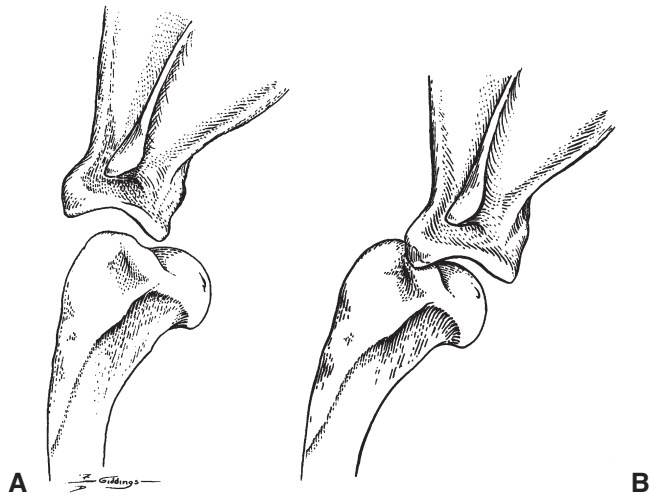


FIGURE 10-8. Caudal luxation and subluxation of the shoulder. **A,** Caudal luxation of the left shoulder (lateromedial view). **B,** Caudal subluxation of the left shoulder (lateromedial view). The joint space is increased caudally as extension stress is applied to the joint.

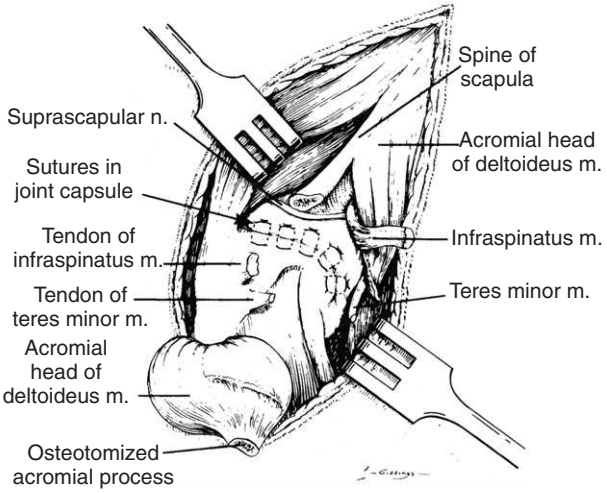


FIGURE 10-9. Caudal luxation of the shoulder. The left shoulder has been exposed by a craniolateral approach with an osteotomy of the acromial process.[4] The infraspinatus and teres muscles have been freed by tenotomy. Mattress sutures of heavy-gauge absorbable suture have been used to imbricate the joint capsule as far cranially and caudally as possible, following the line of the rim of the glenoid.

Aftercare. The limb is supported in a foreleg (Velpeau) sling for 14 days (see Figure 2-29). Exercise is restricted for 4 weeks. Passive flexion-extension exercise may be needed after removal of the sling.

Excision Arthroplasty

In some cases the glenohumeral joint cannot be reconstructed adequately. This situation is most often caused by excessive wear of the medial labrum of the glenoid as a result of chronic medial luxation. Gunshot wounds occasionally damage the articular surfaces in such a way that nothing resembling normal joint function can result. The traditional method of treatment in these animals has been arthrodesis, which is technically demanding and requires bone-plating equipment in most cases.

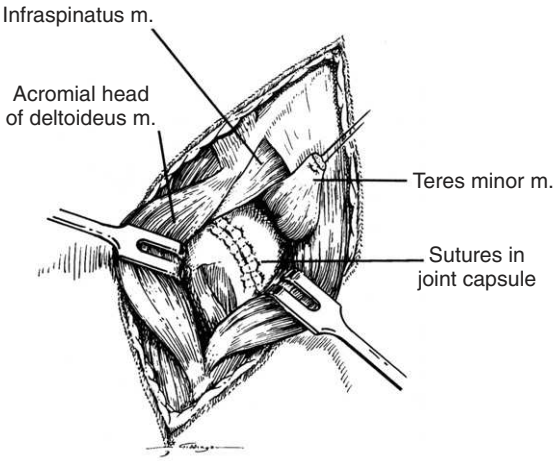


FIGURE 10-10. Caudal subluxation of the shoulder. The left shoulder has been exposed by a caudolateral approach.[4] The caudolateral joint capsule has been imbricated with mattress sutures of heavy-gauge absorbable suture. The suture line follows the rim of the glenoid as far caudad as possible, taking care to avoid the caudal circumflex humeral artery.

An alternative salvage procedure is resection of the glenoid based on the method of Parkes.[6] We have modified this procedure to include partial excision of the humeral head in an attempt to provide a larger vascular surface. We postulate that this will result in a more rapid and proliferative fibroplasia and thus earlier stability of the pseudoarthrosis.

Surgical Technique

The joint is exposed by the approach to the craniolateral region of the shoulder by osteotomy of the acromial process.[4] The joint capsule is opened widely, and the tendon of the biceps muscle is detached from the supraglenoid tubercle (Figure 10-11, *A*). With care taken to protect the suprascapular nerve and caudal circumflex humeral artery, ostectomies are made in the glenoid and humeral head with an osteotome or high-speed pneumatic surgical bur (Figure 10-11, *B*). The glenoid ostectomy is made obliquely to bevel the edge. The deep (medial) edge is longer than the superficial edge.

A notch is cut in the base of the spine of the scapula to allow proximal displacement of the suprascapular nerve. The teres minor muscle is pulled medially between the ostectomy surfaces and sutured to the biceps tendon and medial joint capsule (Figure 10-11, *C*). Soft tissue interposition may hasten formation of a fibrous false joint. Any available joint capsule is pulled into the "joint space" and sutured to the teres minor and biceps tendon. The infraspinatus is reattached. It may be necessary to wire the acromial process more proximally than normal to remove the resulting laxity in the deltoideus muscle created by the ostectomies.

Aftercare

The limb is not immobilized postoperatively. Early, gentle use of the limb is encouraged by leash walking. More vigorous activity is forced starting 10 days postoperatively, and swimming is encouraged. Early activity stimulates the fibrosis necessary to create a false joint without any bony contact.

Prognosis

It must be appreciated that this is a salvage procedure and that normal function of the limb is not to be expected. Moderate, pain-free exercise capability is the objective, and it usually is achieved. A slight limp and some atrophy of the shoulder girdle muscles are expected.

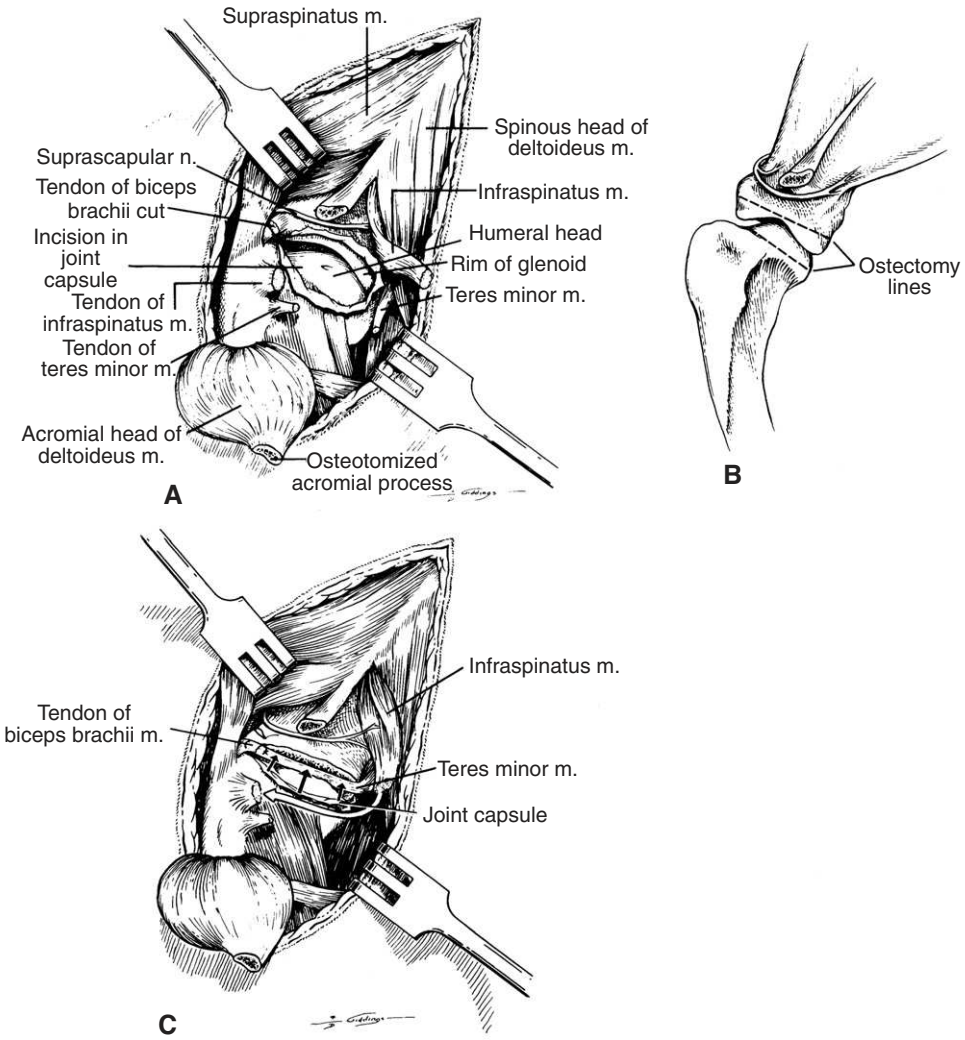


FIGURE 10-11. Resection of the glenoid and humeral head. **A,** The left shoulder has been exposed by a craniolateral approach.[4] Tenotomies have been performed on the biceps, infraspinatus, and teres minor muscles. The joint capsule is cut close to the glenoid rim. The joint capsule that is left attached to the humeral head is preserved. **B,** Positions of both ostectomy lines. **C,** Both ostectomies have been completed. The teres minor muscle has been pulled medially, where it has been sutured to the biceps tendon, which has previously been sutured to the fascia of the supraspinatus muscle. Accessible joint capsule from the humeral head is sutured to the teres minor. A small notch may be cut in the base of the spine of the scapula to allow the suprascapular nerve to be positioned more proximally if it is too near the ostectomy. The infraspinatus is reattached to its insertion, and the acromial process is wired to the spine more proximally than normal.

Thirteen cases have been reported in two series.[7,8] Good to excellent pain-free function was noted in each case. One case had bilateral surgery for chronic medial luxations of the shoulders, and at 6 months postoperatively, the animal was using both limbs at all times and bearing about 80% of normal weight on the limbs.

Arthrodesis of Shoulder Joint

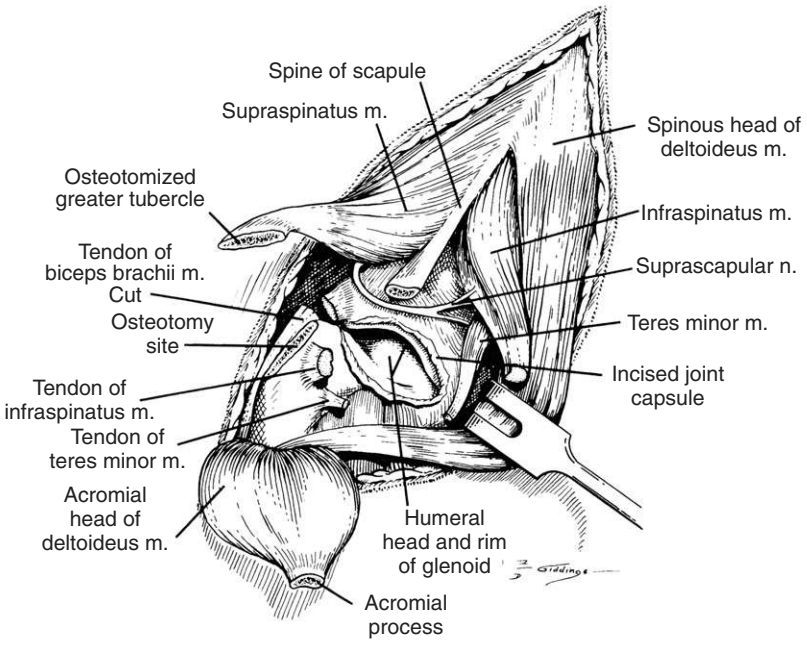
Surgical fusion of the shoulder joint results in remarkably little functional disability because of the extreme mobility of the scapula. This scapular motion compensates for loss of motion in the shoulder joint. This does not indicate that use of the limb is normal, but rather that enough function remains for active use of the limb. In one study the only gait abnormalities noted were limited circumduction and inability to advance the limb quickly when running.[2]

Common indications for arthrodesis of the shoulder are comminuted fractures of the glenoid, neck of the scapula, or head of the humerus. Additionally, chronic shoulder luxations often result in severe erosion of the glenoid and humeral head, making surgical repair impossible. Severe DJD is a legitimate but uncommon indication. As with all arthrodeses, this is a mutilating operation and should be considered only as a last-resort salvage procedure. It is important that other joints of the limb be normal if this procedure is performed.

Surgical Technique

A combined craniolateral and cranial approach to the shoulder joint is performed with osteotomy of both the acromial process and the greater tubercle[4] (Figure 10-12, *A*). This widely exposes the joint and allows the joint capsule to be opened for debridement of cartilage on both articular surfaces.

The biceps tendon is detached at the supraglenoid tubercle, and the suprascapular nerve is protected during 20 osteotomies, which parallel the lines shown in Figure 10-12, *B*. Flat osteotomy surfaces eliminate shear stress at the bone surfaces, especially when compression is exerted. The greater tubercle of the humerus is



A

FIGURE 10-12. Arthrodesis of the shoulder joint. **A,** The left shoulder has been exposed by a combined cranial and craniolateral approach.[4] The biceps tendon has been detached from the supraglenoid tubercle, and the joint capsule is opened.

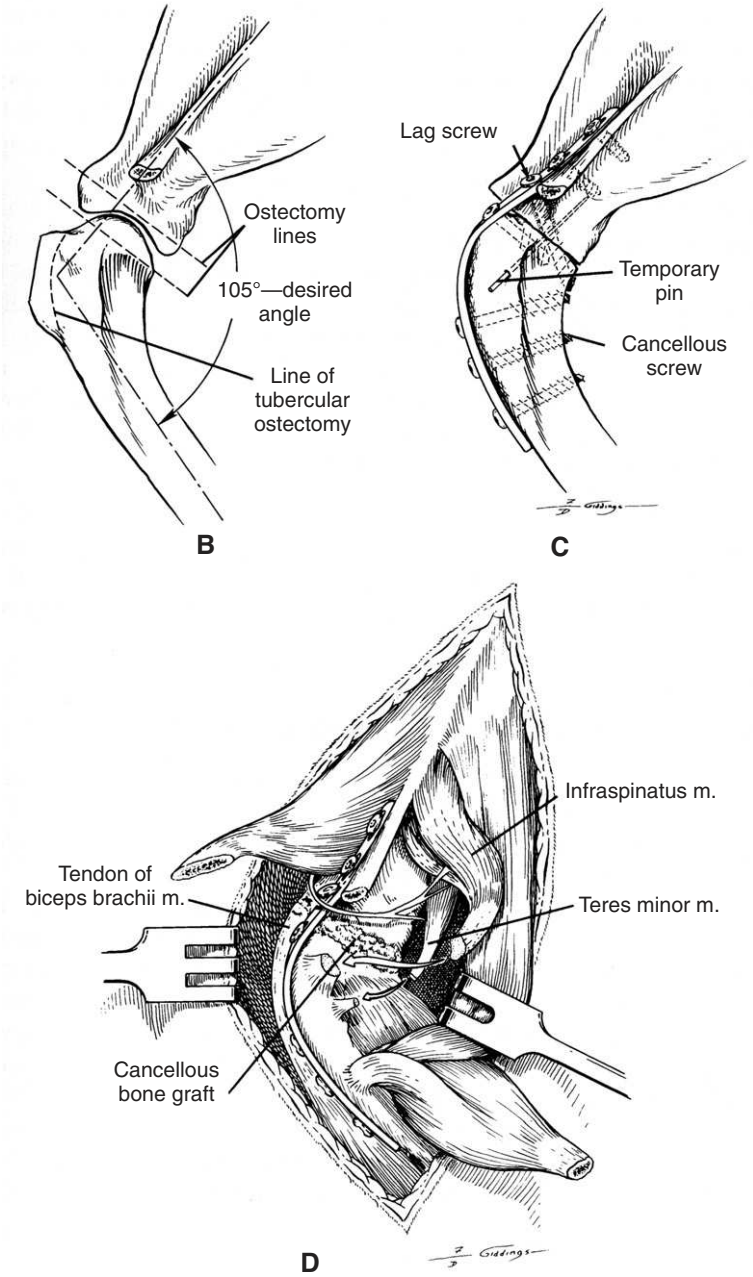


FIGURE 10-12. *Continued* **B,** With the joint positioned at a functional angle of 105 to 110 degrees, osteotomies of the glenoid and humeral head are performed to remove articular cartilage and produce flat opposing surfaces. The greater tubercle is further osteotomized to provide a gentle curve from the humeral neck to the cranial cortex. **C,** A small pin is driven across the joint to hold the bones at the correct angle while the plate is contoured and applied, after which the pin is removed. At least one screw must be a lag screw between the scapula and the humerus. **D,** Bone graft obtained from the greater tubercle is placed around the opposed bones. The biceps tendon is sutured to the supraspinatus muscle fascia. The osteotomized portion of the tubercle attached to the supraspinatus muscle is pinned or screwed lateral to the plate, and the rest of the tissues are closed routinely.

osteotomized with double-action bone cutters, Gigli wire, or saw to provide a gentle curve on a line from the spine of the scapula to the cranial aspect of the humerus. To immobilize the joint temporarily during plate application, a small intramedullary pin or Kirschner wire is driven from the cranial humeral cortex into the glenoid with the shoulder at a functional angle of about 105 degrees (Figure 10-12, *C*). An 8- to 10-hole plate is contoured to fit the cranial surface of the humerus and the dorsocranial junction of the spine with the body of the scapula. Some torsion of the plate will be necessary to make it fit the junction of the spine and the body of the scapula. The reconstruction plate (Synthes) is especially suitable for this procedure because it is more easily contoured than conventional plates. However, this fixation is not strong, and coaptation is needed for additional protection. The plate must either pass over the suprascapular nerve with sufficient room for the nerve or be placed underneath the nerve. In applying the plate, the surgeon must consider placing at least one screw in lag fashion across the debrided bone surfaces to create compression. As shown in Figure 10-12, *C*, the third screw hole was chosen.

One or two cancellous screws can be used to advantage in the humeral head. (Some types of plates do not accept cancellous screws except at the end holes.) The pin can be removed after the plate is applied. Cancellous bone removed from the greater tubercle osteotomy site can be used as a bone graft (Figure 10-12, *D*). The biceps tendon is reattached to the fascia of the supraspinatus muscle or to the cortex of the humerus medial to the plate using a bone screw and spiked washer (see Figure 10-15, *B* and *C*). After scarifying the proximal lateral aspect of the humerus, the osteotomized greater tubercle is attached to the humerus lateral to the plate with a screw or pins. The soft tissues are closed routinely in layers.

Aftercare

The shoulder is immobilized in a spica splint for 4 weeks (see Figure 2-23). Radiographic signs of fusion should be noted between 6 and 12 weeks postoperatively, at which time the splint is removed and the dog allowed to return to normal activity over a 4-week period. Barring complications, the plate is not removed.

Osteochondritis Dissecans of Humeral Head

A general discussion of osteochondrosis dissecans (OCD) is provided in Chapter 6. In the shoulder joint, OCD is manifested as a fragment of cartilage that becomes partially or fully detached from the caudocentral aspect of the humeral head, usually opposite the caudoventral rim of the glenoid. The cartilage flap usually remains attached to normal cartilage along the cranial edge of the flap; however, it may become free within the joint, in which case it usually becomes lodged in the caudoventral pouch or cul-de-sac of the joint capsule or rarely in the bicipital tendon sheath.

Free cartilage fragments within the joint can be resorbed, but some may remain viable and even grow in size because they are nourished by synovial fluid. Others become attached to synovial membrane, where they can become vascularized and undergo partial ossification; they are then called *ossicles*. Those cartilage fragments that lodge in the caudal joint often do not create clinical signs unless they grow in size sufficient to irritate the synovial membrane (see Figures 6-4 and 6-5). Fragments that migrate to the bicipital tendon sheath may produce clinical lameness.[9]

Clinical Signs and History

Large-breed dogs are most often affected by OCD, in a 2:1 to 3:1 male/female ratio. Various studies have reported bilateral radiographic involvement in 27% to 68%

of cases. Many dogs with bilateral radiographic signs will be clinically lame in only one limb. However, it is worth noting that when an animal is extremely lame in one leg, it is difficult to assess lameness in the contralateral leg. It is likely that animals diagnosed radiographically as bilateral in reality are showing only the signs of osteochondrosis in one shoulder and never develop a loose cartilage flap in the other shoulder. Our experience, as well as that of others,[10] is that only a few cases require bilateral surgical intervention for shoulder OCD.

Although most animals first show clinical signs of OCD between 4 and 8 months of age, some will present much later, at 2 to 3 years of age. In these cases the owners have simply ignored, or did not notice, the early lameness. Lameness is often first noted after severe exercise, but it may be insidious in onset. Rarely does the dog have three-legged lameness. A shortening of the swing phase of gait leads to atrophy of the spinatus and deltoid muscles, resulting in a more prominent acromial process. This is a consistent finding if lameness has been present more than 2 to 3 weeks. The change of gait is most noticeable at a walk. Pain on palpation is variable and is more often noted on severe extension than on flexion or rotation. Crepitus is also variable. Clinical signs are most notable after rest preceded by heavy exercise.

Radiology

OCD of the shoulder is usually detected by lateral radiographs of the shoulder. A flattening of the humeral head is usually seen if properly positioned (Figure 10-13). The presence of osteophytes on the caudal glenoid is indicative of significant cartilage damage (i.e., flap formation). Sedation is often necessary. Rarely, arthrograms may be needed if the flattening is inapparent (see Chapter 1). Usually, 4 to 5 ml of diluted contrast is injected. The dye seeps under the flap (Figure 10-13, *B*), and it also travels to the bicipital tendon sheath, where it may outline joint mice.

Diagnosis

The diagnosis of OCD causing the lameness must be based on clinical assessment of the history, radiographs, and physical examination. The lameness is usually of a mild to moderate severity. Often, pain may be elicited by palpation (flexion and extension).

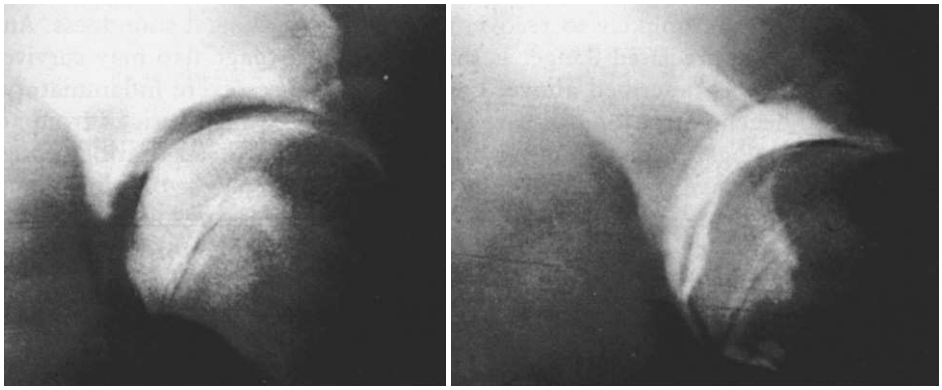


FIGURE 10-13. Osteochondritis dissecans of the humeral head. **A,** Flattening of subchondral bone of caudal aspect of the humeral head can be appreciated here, but there is no visible indication of the presence or absence of a cartilage flap. However, the presence of the osteophyte on the caudal glenoid signifies the probability of flap formation. **B,** This contrast arthrogram shows dye filling of the joint space and a filling defect that represents the cartilage flap.

The radiographic lesion should be at least 4 mm long. Other common "rule-outs," such as elbow conditions and panosteitis, must be eliminated.

Treatment

Opinions vary regarding surgical versus nonsurgical treatment of OCD. As experience has been gained, a more aggressive surgical approach has become evident. Although some animals do recover spontaneously, this can occur only if the flap breaks loose and is absorbed in the joint cavity. Furthermore, this process may take 9 to 12 months, and bilaterally affected animals are unlikely to recover to the point of clinical soundness. An additional, little-appreciated danger is that the loose cartilage flap may survive within the joint, as previously described. Large ossicles may cause severe inflammatory changes and DJD (see Figure 6-7). We have retrieved such ossicles from 3- and 4-year-old dogs. If the flap never breaks free, a similar deterioration of the joint occurs. We have removed partially attached flaps in 3-year-old dogs.

Surgical treatment has yielded much more uniformly good results than nonsurgical treatment in our experience as well as that of others.[11,12] Not only is the final outcome more predictable, but soundness is achieved within 1 to 2 months, and late degenerative changes are less likely. We recommend surgery in the following situations:

1. Pain is elicited on shoulder extension or flexion.
2. No other radiographic lesions of the forelimb are found.
3. The shoulder lameness has persisted after 6½ months of age.
4. A cartilage flap or "joint mouse" is confirmed radiographically.

Osteochondroplasty of Humeral Head

The aim of surgery is to remove cartilage flaps still attached and to remove all fragments of free cartilage from within the joint. Removal of the cartilage allows a fibrocartilage scar to fill the defect and seal the edges of the articular cartilage bordering the defect.

The choice of surgical approach varies. The caudolateral approach[4] or variations of it have generally worked well for us if an assistant is present. A humeral head retractor (Scanlan Surgical Instruments, Inc., Englewood, Colo) is useful for exposure of the lesion. If we work alone, the more generous exposure of the craniolateral approach with osteotomy of the acromial process[4] is preferable, lessening the need for retraction. However, this is a longer procedure and is associated with more postoperative morbidity (seroma, lameness).

The caudolateral approach provides adequate visualization of the lesion if the joint capsule is adequately retracted and if the leg is severely internally rotated (Figure 10-14, *A*). A scalpel blade or small, curved osteotome is used to cut the cartilage flap free (Figure 10–14, *B* and *C*). Irregular and undermined loosened areas of cartilage at the periphery of the lesion should be trimmed and smoothed with a curette to create vertical walls. Curettage may or may not be done at this point, depending on the surgeon's preference. Curettage of the lesion floor should be cautiously done to minimize removal of subchondral bone. There is often a layer of unorganized material covering the bed of the lesion that could have chrondrogenic potential. This can be gently scraped to expose the bone. There may be merit in *forage,* which is a technique of drilling multiple holes in the bed of the lesion with a Kirschner wire. This creates vascular channels to the subchondral bone and hastens ingrowth of "repair" tissue in the defect. The caudal cul-de-sac of the joint cavity must always be explored for free fragments of cartilage. Exposure of this area

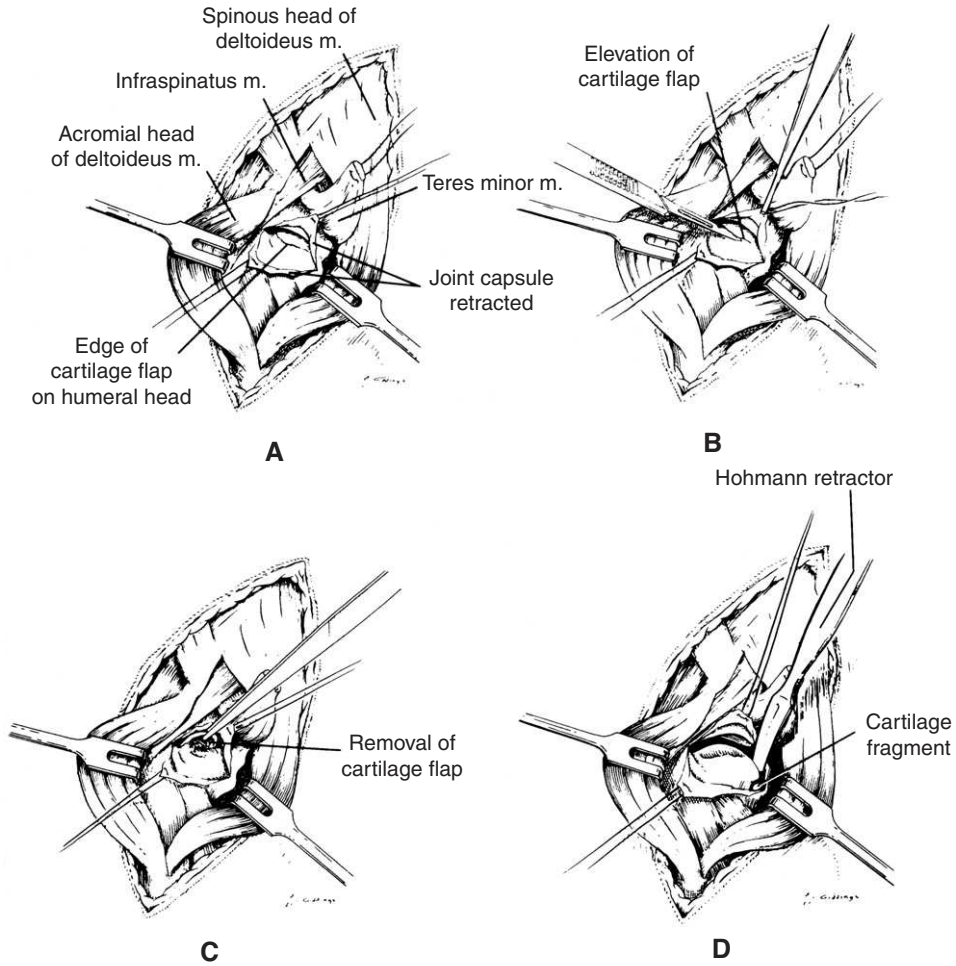


FIGURE 10-14. Osteochondroplasty of the humeral head for osteochondritis dissecans. **A,** The left shoulder has been exposed by a caudolateral approach.[4] The lateral edge of the cartilage flap is visible after retraction of the joint capsule by stay sutures. **B,** The cartilage flap is elevated from the humeral head by sharp dissection. **C,** When the flap has been sufficiently elevated, it can be cut free along its cranial border. **D,** The caudal cul-de-sac of the joint capsule is retracted with a small Hohmann retractor to allow removal of any free cartilage fragments.

is enhanced by a small Hohmann retractor and by flexing the shoulder and elbow (Figure 10-14, *D*). In chronic lesions, debridement of large caudal glenoid osteophytes may assist in removal of the flap and inspection of the lesion bed. The final step is forceful lavage of the joint to flush out small cartilage fragments. If cartilage fragments have been identified in the bicipital tendon sheath, they will need to be removed by a cranial approach because they cannot be exposed from a caudolateral approach.[4]

Another surgical technique, the lateral approach, involves partially incising the caudal half of the acromial head of the deltoideus tendon to facilitate the cranial incision into the joint capsule (Figure 10-15). The junction of the infraspinatus and teres minor muscles is bluntly separated, followed by incision into the joint capsule. A Gelpi retractor is helpful to keep the infraspinatus and teres minor muscles retracted.

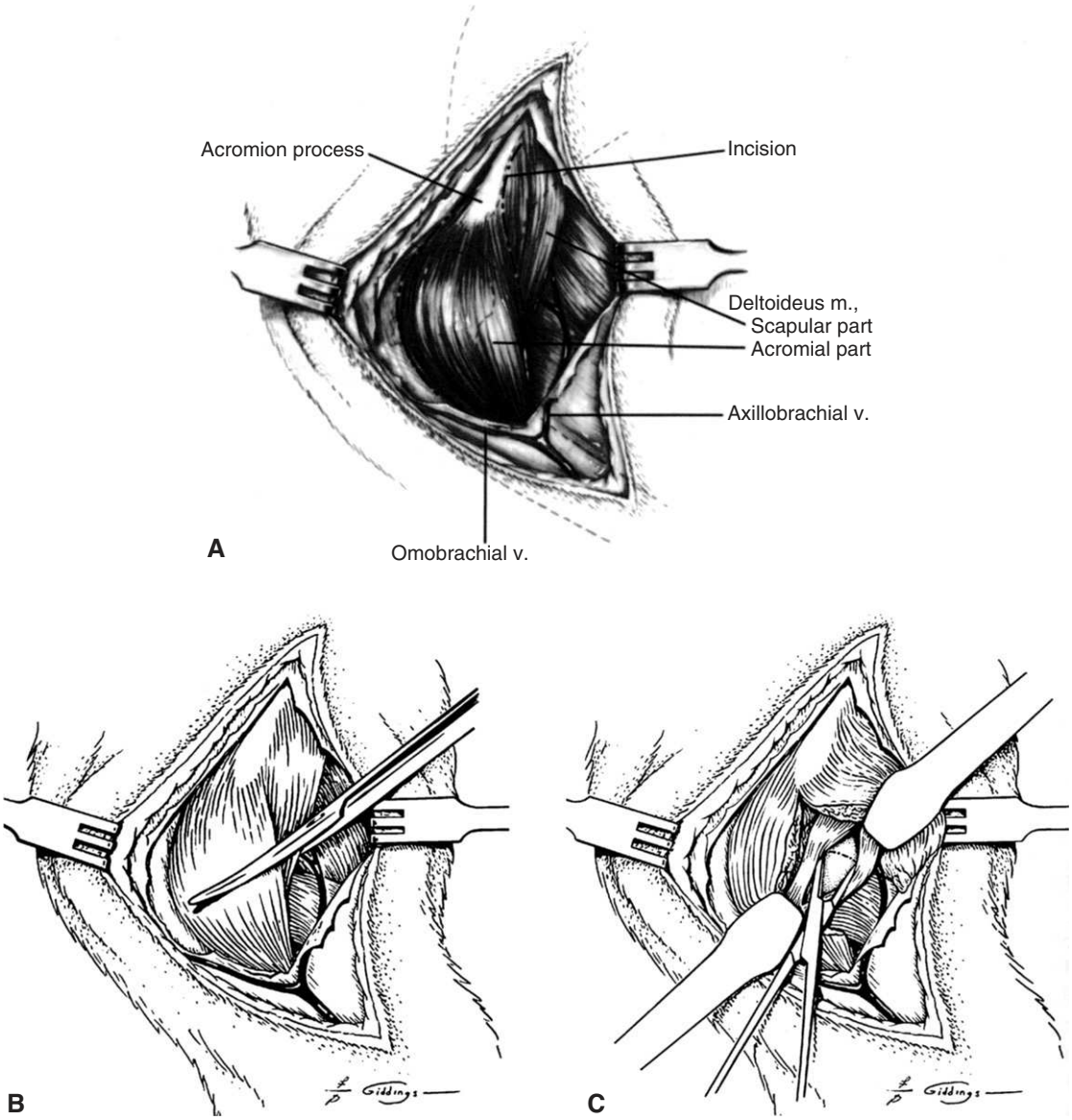


FIGURE 10-15. Lateral approach of the scapulohumeral joint. **A,** Slightly curved skin incision is made from above the acromial process to the proximal fourth of the humerus. The deep fascia has been incised from the caudal edge of the acromial process to the junction of the omobrachial and axillobrachial veins distally. The junction between the acromial and spinous heads of the deltoideus muscle is developed. **B,** The caudal half of the acromial deltoideus is incised 5 mm from its origin to gain increased exposure to the cranial joint. **C,** After retraction of the deltoideus cranially, the junction between the infraspinatus and teres minor muscles is separated. The teres minor is undermined off the joint capsule. The infraspinatus insertion and the deltoideus are retracted craniodorsally, whereas the teres minor is retracted caudoventrally. The joint capsule is incised as in Figure 10-14. (**A** from Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

Aftercare

Seroma formation is more common with shoulder surgery than with virtually any other canine surgery, perhaps because of the extreme amount of sliding motion of the skin and subcutis in this region over the muscle fascia. The only prevention is enforced rest for the first 10 to 14 postoperative days. A Velpeau sling may be indicated for some hyperactive animals (see Figure 2-29). Small seromas clear spontaneously in 2 to 5 weeks; large ones are treated with hot packs. Needle aspiration is usually unnecessary, since the seroma disappears in 4 to 6 weeks regardless. Often, if drained, the fluid recurs.

From 3 through 6 weeks postoperatively, very minimal activity (house confinement or leash) is suggested, followed by graduated exercise 2 to 3 months postoperatively.

Arthroscopy

Person[13] reported successful treatment of OCD with arthroscopic surgery in 23 shoulder joints in 21 dogs. Force plate evaluation showed objective signs of improvement in gait in 9 of 10 dogs seen postoperatively for follow-up. Arthroscopic treatment may well see much more application in the future (see Chapter 8).

Prognosis

With shoulder OCD, the prognosis with surgery is excellent if treated before 12 months of age. The prognosis is still very good in older animals.

Calcification of Supraspinatus Tendon

Calcification of the supraspinatus tendon of insertion[14] is a degenerative condition causing mild to moderate forelimb lameness in medium to large adult dogs. The etiology is unknown but is probably an overuse syndrome. It is often bilateral radiographically but rarely causes bilateral lameness.

History and Clinical Features

Lameness is usually insidious in onset, producing chronic signs. Unlike osteoarthritic conditions, lameness worsens throughout the day with minimal or moderate activity. The presence of calcification radiographically is often asymptomatic, and the clinician *must* eliminate other conditions before making the definitive diagnosis.

Physical Examination

Unfortunately, manipulations often do not produce pain. With few exceptions, the calcium deposit is not large enough to palpate.

Radiographic Examination

Calcification is often seen on careful scrutiny of a lateral view of the shoulder (Figure 10-16). The condition is often bilateral radiographically but rarely produces bilateral lameness. Calcification of the supraspinatus tendon is often subtle because of superimposition on the greater tubercle of the humerus. A tangential or "skyline" view of the intertubercular region of the proximal humerus eliminates this superimposition and allows distinction between biceps tendon calcification. The craniproximal-craniodistal (CP-CD) view is taken with the dog in sternal recumbency, with the radiographic cassette placed on top of the forearm with the elbow bent. The radiographic tube is positioned directly over the scapulohumeral joint (Figure 10-17). Calcification occurs cranial and just medial to the greater tubercle of the humerus (see Figure 10-3). It may be smooth or irregular and may have

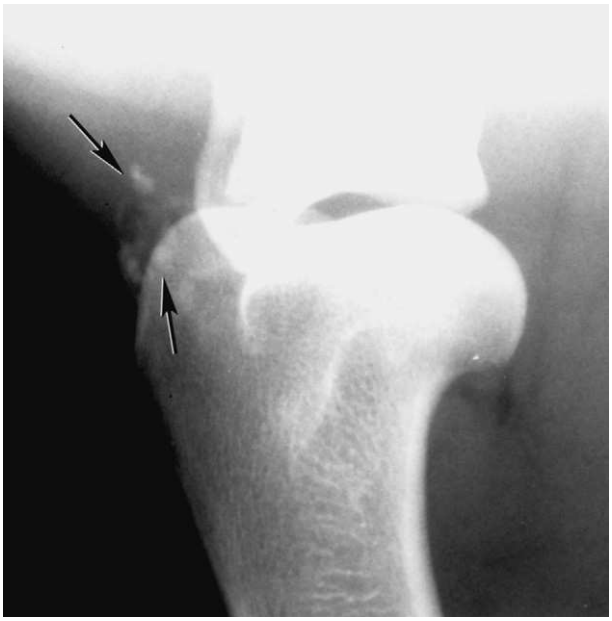


FIGURE 10-16. Calcification *(arrows)* of the supraspinatus tendon. This calcification was asymptomatic in the 2-year-old Rottweiler. Its symptomatic calcified supraspinatus tendon on the opposite side was not as apparent radiographically. Note the numerous pockets of mineralized material located on and superficial to the greater tubercle of the humerus.

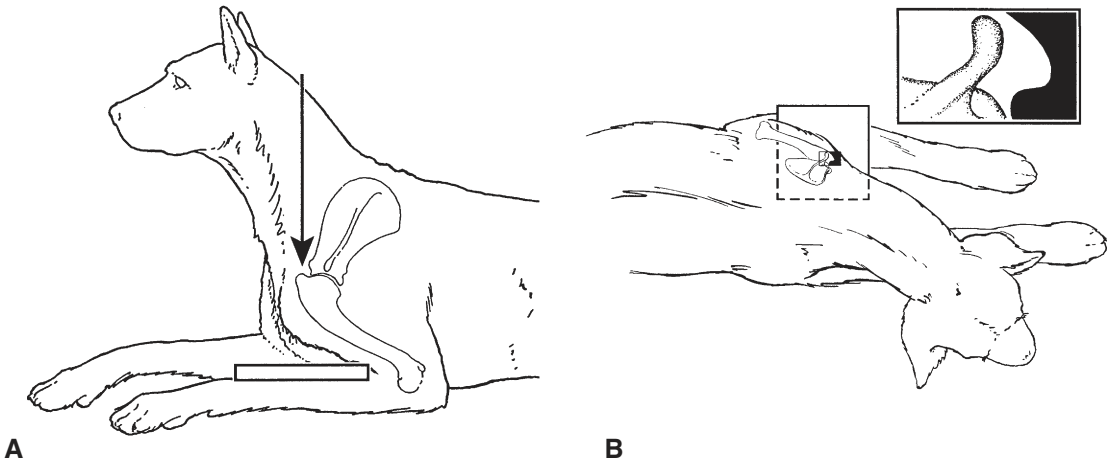


FIGURE 10-17. Positioning of dog for cranioproximal-craniodistal (CP-CD) view. **A,** With the dog in sternal recumbency, a radiographic cassette is placed on top of the flexed forearm. The radiographic tube is positioned directly over the point of the shoulder. **B,** Dorsal view of how the greater tubercle is projected on the radiographic cassette. The dog's head is pulled to the side.

multiple "pockets." Calcification of the biceps tendon occurs more medial and caudal into the groove closer to the humeral head.

Diagnosis

Because the presence of calcification can be asymptomatic and because there is no particular physical exam finding, the diagnosis of the calcification causing lameness is only presumptive. Other conditions, such as bicipital tendinitis and chronic congenital joint lesions, must be ruled out (Figures 10-18 and 10-19). When other

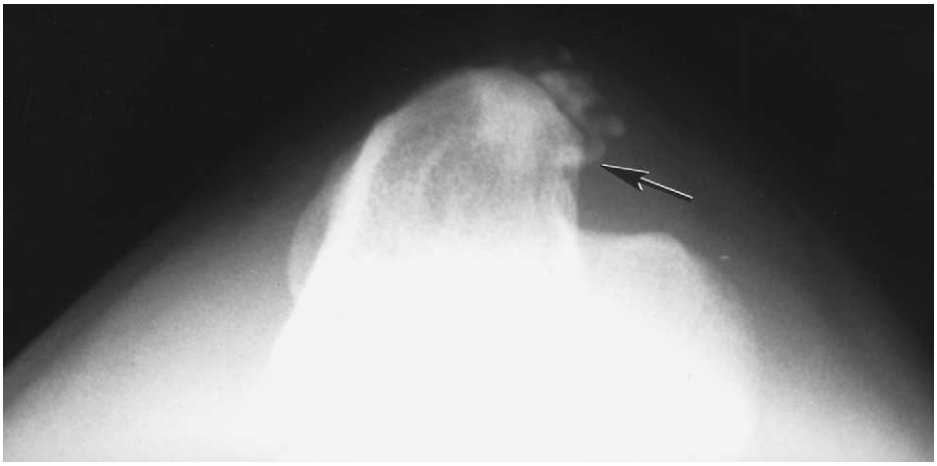


FIGURE 10-18. CP-CD view of the Rottweiler in Figure 10-16. The mineralization lies cranial and medial to the greater tubercle *(arrow)*. The biceps tendon lies in the intertubercular groove situated under the arrow. The convex white area represents the greater tubercle, and the concave area is the intertubercular groove.

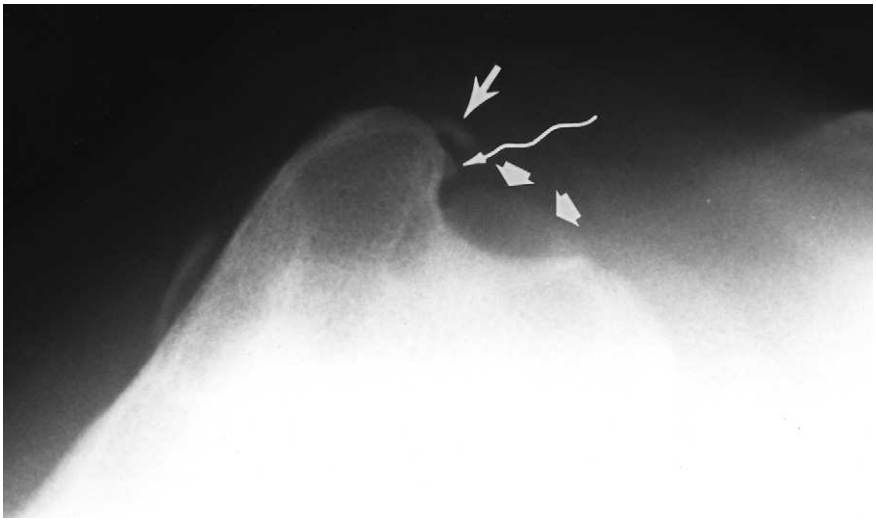


FIGURE 10-19. CP-CD view of a shoulder arthrogram of a dog with severe foreleg lameness from suspected bicipital tendinitis along with calcification of the supraspinatus tendon. Note the calcified material on top of the greater tubercle *(white arrow)*, osteophyte in the intertubercular groove *(curved arrow)*, and dye outlining the normal biceps tendon in the intertubercular groove *(white arrowheads)*.

conditions are found, a diagnostic quandary exists. Because the treatment is fairly simple, surgical treatment of both conditions at the same time may be undertaken. The amount of calcification is not relative to the amount of pain a dog may have.

Treatment

By longitudinally incising into the supraspinatus tendon, the calcium is evacuated. To accomplish this, the dog is placed in dorsal recumbency with both forearms secured alongside the body wall. The radiographs are placed on a viewer to mimic

the position of the dog to assist placement of the tendinous incision. A 6- to 7-cm cranial skin incision is followed by deeper dissection through the longitudinal fibers of the brachiocephalicus muscle (Figure 10-20, *A*). The tendon of the supraspinatus is identified along with the proximal end of the humerus. Longitudinal incisions are made in relation to the humerus (Figure 10-20, *B*). Normal tendon is a yellowish white, whereas the tendon surrounding the white calcium deposit is grayish white. The calcified material is very white and similar to what one sees when fenestrating a calcified disk. If multiple areas are seen radiographically, multiple small incisions may be needed to evacuate the material. Closure is made in layers using absorbable or nonabsorbable sutures.

Aftercare

A flexion carpal bandage (see Figure 2-30) is applied for 10 to 12 days to allow tendon healing, followed by limited activity for another 2 to 3 weeks. Although swimming is a good exercise for many orthopedic conditions, it may stress the supraspinatus and is not advised for several months.

Prognosis

Provided this calcification was the cause of the lameness, the prognosis is excellent. The dogs usually improve within 2 to 4 weeks and usually totally recover within 6 to 8 weeks. In a small retrospective study, four dogs undergoing calcium removal had a return of mineralization without a return of clinical lameness at a mean of 5 years postoperatively.[15]

Tenosynovitis of Biceps Tendon

This disease process is a common cause of forelimb lameness in medium-breed to large-breed adult dogs, especially the Labrador retriever, Rottweiler, and racing

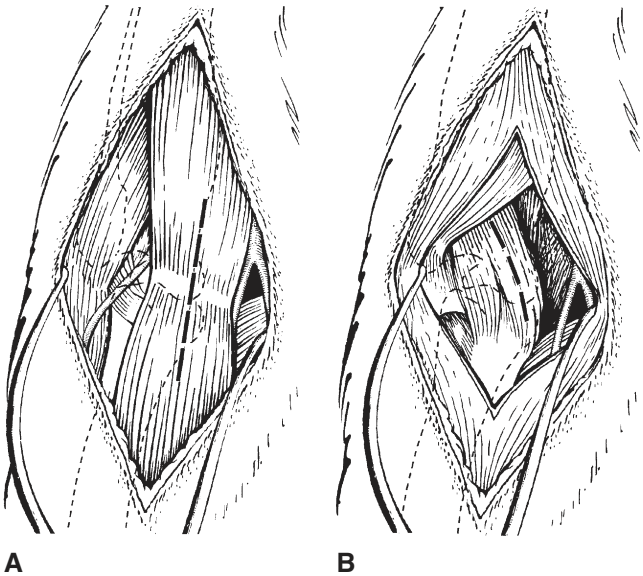


FIGURE 10-20. **A,** A 6- to 7-cm skin incision is made over the point of the shoulder. A similar incision is made between muscle fibers of the brachiocephalicus muscle. **B,** After retraction of the brachiocephalicus muscle, a blind longitudinal incision is made in the supraspinatus tendon, depending on the location of the mineral seen on the radiograph. Pockets of mineral have a whiter appearance than the surrounding tissue. Multiple incisions may be needed to find all the pockets. Closure consists of nonabsorbable sutures placed in the supraspinatus tendon, brachiocephalicus separation, and subcuticular and skin layers.

greyhound. Animals that are not physically well conditioned have some predilection for tenosynovitis of the biceps tendon.

Anatomy and Pathophysiology

After originating on the supraglenoid tubercle, the tendon of the biceps brachii muscle passes distally through the intertubercular groove of the humerus, where it is stabilized by the transverse humeral ligament. The muscle inserts distally on the radius and ulna, and its main function is flexion of the elbow. It has little involvement in stabilizing the normal shoulder joint.[1] The tendon is surrounded by a synovial sheath that is an extension of the glenohumeral joint capsule. This sheath extends distally just beyond the transverse humeral ligament. There is no bursa associated with this tendon.

This injury is a *strain* injury to the tendon of the biceps brachii (see Chapter 7). The mechanism of injury to the biceps tendon can be either direct or indirect trauma or simple overuse. Thus the pathological changes range from partial disruption of the tendon (grade 3 strain) to chronic inflammatory changes, including dystrophic calcification. Pathological changes also can be secondary to other diseases, such as OCD, in which joint mice migrate to the synovial sheath and create an acute synovitis.[9] Thus it can be seen that the initial irritating source usually first affects either the tendon or the synovial membrane individually, but that soon the inflammatory process involves the opposite member. Proliferation of fibrous connective tissue and adhesions between the tendon and sheath limits motion and causes pain.[16] In addition, osteophytes in the intertubercular groove may encroach on the tendon. Preoperative distinction between tenosynovitis and partial biceps tendon rupture or avulsion is difficult.

History and Clinical Signs

The owner may recall an inciting traumatic incident, but usually the onset of biceps tenosynovitis is insidious, and many cases will be of several months' duration when presented. The lameness is subtle and intermittent and worsens during exercise. Because the pain is present only during gliding motion of the tendon, there is no hesitation to bear weight on the limb; therefore, little change occurs in the stance phase of gait.[16] The swing phase of locomotion is limited because the shoulder joint is guarded by limiting the amount of extension and flexion.[17-19]

Atrophy of the spinati muscle group is soon evident, but more distal muscles appear normal in size. Shoulder pain on manipulation is not a consistent finding, especially in chronic cases. Pain is elicited by applying deep digital pressure over the tendon in the intertubercular groove region while simultaneously flexing the shoulder and extending the elbow (see Figure 1-5). Pain may also be produced in the standing dog by internally pressing the belly of the biceps, which stresses the proximal tendon. A few owners have reported a change in the dog's recumbent position in which the carpus is flexed. This relaxes the sore biceps and may represent the dog's own attempt to relieve pain.

Radiographic Findings

Tenosynovitis of the biceps tendon may stimulate a bony reaction on the supraglenoid tubercle (Figure 10-21), calcification of the bicipital tendon, and osteophytes in the intertubercular groove (Figure 10-22). The lateral and CP-CD or tangential radiographic views (Figure 10-23) are helpful in defining these changes. Arthrography is often very helpful in diagnosing the condition.

A normal arthrogram fills the tendon sheath, which is continuous with the scapulohumeral joint. The dye column should be continuous and has a lobulated



FIGURE 10-21. Reaction on the supraglenoid tuberosity in a 5-year-old mixed-breed dog with a small rupture of the biceps tendon *(arrows)*.

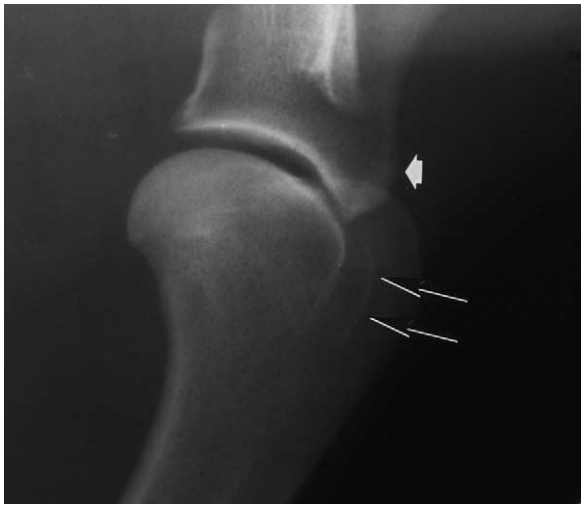


FIGURE 10-22. Osteophytes located in the intertubercular groove of a dog with chronic partial bicipital tendon rupture *(black arrows)*. Note also a minor reaction on the suprascapular tuberosity *(white arrowhead)*.

appearance distally (Figure 10-24). Abnormal findings include absence or decrease of dye filling the sheath (Figure 10-25), leakage of dye from the sheath, and narrowing of the bicipital tendon.[17-19] Recent experience suggests that ultrasonography has a place as a diagnostic tool.

Diagnosis

The diagnosis of bicipital tenosynovitis is based on history, pain with flexing the shoulder, and characteristic plain radiographs or arthrograms[17-19] and ultrasonography. Not all cases will have all the characteristic signs, and at times the diagnosis is presumptive, with definitive diagnosis made only after gross inspection or histopathology.

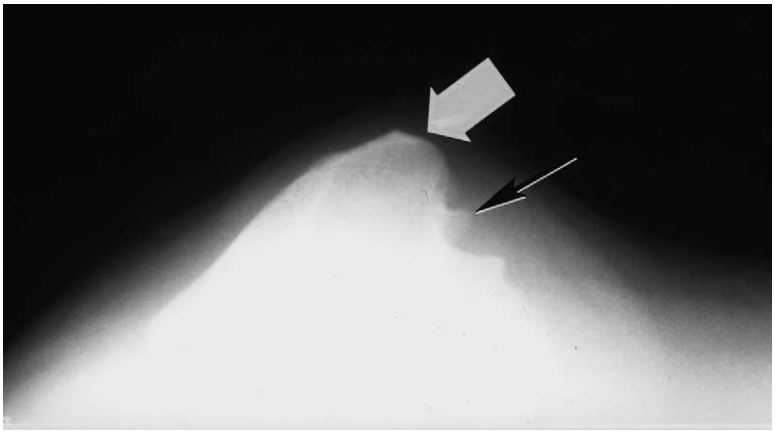


FIGURE 10-23. The cranioproximal-craniodistal (CP-CD) view is helpful in delineating the location of bony changes surrounding the proximal humerus. Note the greater tubercle *(white arrow)* and osteophyte *(black arrow)* in the medial aspect of the intertubercular groove. Compare with the calcification of the supraspinatus seen in Figures 10-18 and 10-19.



FIGURE 10-24. A normal shoulder arthrogram. Note the normal lobulations *(arrow)* surrounding the distal half of the bicipital tendon sheath, and compare with Figure 10-25.

Differential diagnoses include calcification of the supraspinatus, osteosarcomas and chondrosarcomas of the proximal humerus, neurofibromas of the brachial plexus and spinal cord, and chronic elbow conditions related to osteochondrosis and synovial chondrometaplasia. Occasionally, response to an intraarticular injection of a long-acting (days to weeks) corticosteroid (methylprednisolone acetate, 20-40 mg [Depo-Medrol, Upjohn Co., Kalamazoo, Mich]) in large dogs helps to locate the problem to the shoulder.

Treatment

In acute cases the treatment is aimed at reducing inflammation in the affected structures before the pathological changes become irreversible. Rest and nonsteroidal antiinflammatory drug (NSAID) therapy (see Chapter 6) are often sufficient. Strict confinement for 4 to 6 weeks is needed for resolution, and premature return to



FIGURE 10-25. Shoulder arthrogram of a 6-year-old mixed-breed dog with poor filling of the proximal *(black arrows)* and distal bicipital tendon sheath accompanying a bony reaction on the suprascapular tuberosity *(white arrow)* that was seen on plain radiographs. The biceps tendon was partially torn.

activity will almost ensure a chronic disease state. Systemic treatment with either nonsteroidal or corticosteroidal drugs has been unsuccessful in chronic cases in our hands. Intraarticular corticosteroid treatment can be successful in biceps tenosynovitis if there are no mechanical causes, such as joint mice, and when the pathological changes are not well established. There is no way of knowing if this is the case initially, so treatment is always given on a trial basis unless the injury is relatively acute and uncomplicated.

Arthrocentesis must be done aseptically (see Figure 1-19), and we prefer 1.5-inch, 22-gauge spinal needles, which cause less accidental damage to the articular cartilage. The joint is entered 1 cm from the acromial process, with the needle directed toward the glenoid and angled slightly cranially. Synovial fluid is aspirated and immediately observed for turbidity. If the fluid is off color or cloudy, or if the viscosity is greatly changed, a complete examination of the fluid is completed before injecting the joint with corticosteroid to prevent injection into a septic joint. If there are no contraindications, 20 to 40 mg of prednisolone acetate (Depo-Medrol) is injected, which will fill the joint and go down the tendon sheath. Direct injection of corticosteroid into the tendon itself is contraindicated because it is known to cause further tendon disruption. This is followed by strict confinement for 2 weeks and light activity the third week. A carpal flexion bandage may be used if strict confinement is not possible (see Figure 2-30). If lameness is greatly improved but not eliminated, a second injection is given 3 weeks later. If this is not curative, the dog should have surgical treatment. Return of the lameness several months or years later is possible, and many animals will respond again to corticosteroid injection.

Surgical treatment is recommended for dogs that do not respond to medical treatment or those in which a mechanical problem is found initially. The goal of surgical treatment is elimination of movement of the biceps tendon in the inflamed tendon sheath, and this is accomplished by tenodesis of the bicipital tendon. A newer technique advocated is releasing the biceps tendon without reattachment. This may be performed with open or arthroscopic techniques. Early anecdotal reports claim good success, but long-term clinical results and research concerning this procedure are currently unavailable.

Surgical Technique

The biceps tendon is exposed by a cranial approach to the shoulder joint.[4] The transverse humeral ligament and joint capsule are opened to expose the tendon and the intertubercular groove, which often has osteophytes along each edge (Figure 10-26, *A*). Partial rupture of the tendon near its origin is possible. Joint mice are sought and removed, and the tendon is transected near the supraglenoid tubercle. The tendon is reattached to the humerus distal to the groove by a bone screw and spiked washer (Synthes), as shown in Figure 10-26, *B*. More often, however, the tendon can be pulled through a bone tunnel in the greater tubercle of the humerus and then sutured laterally to the supraspinatus muscle or the infraspinatus tendon (Figure 10-26, *C*). No loss of stability or mobility to the shoulder joint is apparent from this procedure.[1] A section of the tendon should be saved for histopathological examination.

A simple procedure to reattach the biceps muscle after excision of the traumatized proximal tendon involves placement of a double Bunnell-Meyer suture pattern in the proximal biceps muscle. With the limb moderately extended, two parallel holes are made in the greater tubercle adjacent to the proximal end of the biceps. The ends of the suture material (No. 1 nonabsorbable suture material) are passed through these holes and tied laterally with the biceps relaxed (shoulder extended) (Figure 10-26, *D*).

Aftercare

The limb is supported in a Velpeau sling (see Figure 2-29) or carpal flexion bandage (see Figure 2-30) and the animal closely confined 3 weeks. Exercise is allowed to increase slowly to normal at 6 weeks postoperatively.

Prognosis

About two thirds of the cases we have seen are treated medically, and approximately two thirds of these are cured by the treatment. The remainder of this group is divided between those that are treated again medically and those that do not respond and require surgical treatment. Those treated early with surgery respond better than those surgically treated later. Normal gait and use of the leg return in 50% to 60% of the dogs, and the remainder stay variably lame, undoubtedly because of chronic DJD. Surgery is therefore recommended after one course (or less) of corticosteroids. Medical management of this problem is discussed in Chapter 6. Surgical treatment of tenosynovitis of the biceps tendon in humans is variably reported to be 50% to 94% successful.[20,21]

Rupture of Tendon of Biceps Brachii Muscle

The same forces that cause avulsion of the supraglenoid tubercle in young dogs cause rupture of the tendon of the biceps near its origin on the tubercle in the mature dog. Initially, there is pain and effusion in the cranial shoulder joint region.

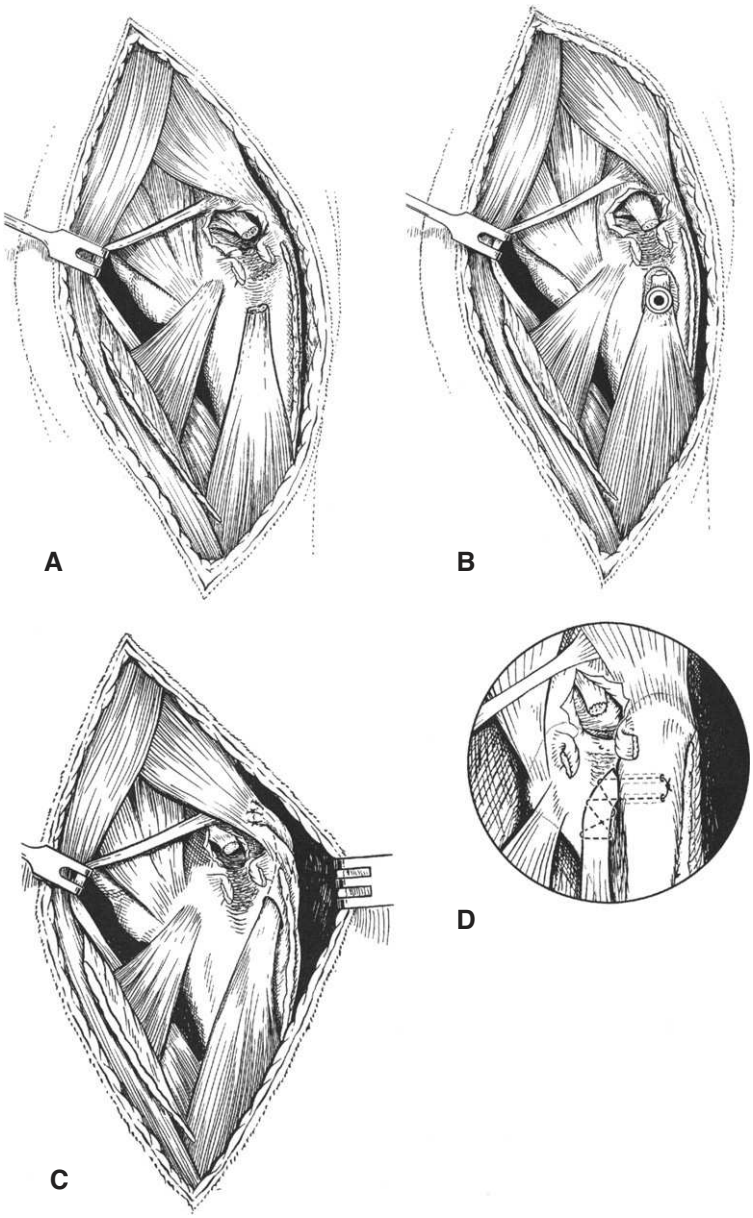


FIGURE 10-26. Tenodesis of the biceps brachii tendon. **A,** The tendon is exposed by a craniolateral approach to the shoulder.[4] The tendon is cut near the supraglenoid tubercle and again distal to the intertubercular groove. **B,** With the elbow flexed, the tendon is fixed to the humerus in a position that creates some tension on the muscle. After curettage of the periosteum, the tendon is bluntly split and attached to the humerus with a bone screw and an AO/ASIF plastic spiked washer (Synthes). **C,** A second method of attaching the tendon. The tendon is cut free from the tubercle but is not cut again distally as above. A hole is drilled laterally through the greater tubercle, and the tendon is brought through the bone tunnel and sutured to the insertion of the supraspinatus muscle. **D,** Alternatively, a double Bunnell-Meyer suture pattern utilizing No. 1 nonabsorbable suture material has been placed in the proximal biceps muscle. Two parallel holes are made with an 0.045 Kirschner wire in the greater tubercle of the humerus adjacent to the proximal biceps muscle. The ends of the suture material are passed through the holes and tied laterally with the limb in extension.

Although the animal will exhibit an obvious lameness on the affected limb, flexion of the elbow joint is not obviously impaired. It usually is not possible to palpate the area of rupture in the tendon digitally because of swelling of tissues. Partial rupture may be a cause of bicipital tenosynovitis.

Arthrography in acute cases is essential for diagnosis.[18,19] The contrast media may not allow actual visualization of the ruptured tendon, but a filling defect tends to support the clinical diagnosis. Plain films may demonstrate a slight laxity in the joint, but this is not consistent. Chronic cases frequently show bony reaction on the supraglenoid tubercle.

Because repair of the biceps tendon is difficult, and because there are no adverse effects from detaching the biceps tendon,[1] the treatment of choice is tenodesis (see Figure 10-26), as described in the previous section, or by detachment of the tendon without tenodesis.

Avulsion of Greater Scapular Tuberosity

Avulsion of the greater scapular tuberosity is an unusual injury in which the epiphysis along with the biceps brachii tendon separates from the distal scapula. It may become separated with mild or insignificant trauma. In the dog the separate ossification center of the greater scapular tuberosity unites with the scapula at 3 to 5 months of age.[22] Care must be taken in interpreting radiographs in younger puppies, because there is a normal "step" between the epiphysis and the rest of the glenoid that should not be interpreted as a fracture separation. A radiograph of the noninvolved shoulder may be helpful. We have seen a few cases in 6- to 8-month-old dogs in which minimal trauma (rough play with another dog) created the separation, and radiographs of the opposite limb showed a partially opened physis. We believe that this delay in closure may represent a form of osteochondrosis.

Diagnosis

The diagnosis of avulsion of the glenoid tuberosity is made from lateral radiographs of both shoulders. The triangular bone fragment is pulled distally.

Treatment

If the dog is diagnosed less than a week from the onset of lameness, fixation with screws or pins is indicated using a cranial approach, with osteotomy of the humeral tubercle[4] (see Figure 9-5). However, surgical repair is technically difficult because of rapidly forming callus and the resulting poor visualization for accurate reduction and proper implant angle. The joint must not be penetrated with implants. In chronic cases the tubercle is friable, and reduction is even more difficult to appreciate. Tenodesis of the biceps tendon may be the only salvage repair possible. If instability is present, it may lead to a poor result. An arthrodesis can be attempted after bone growth has ceased. An alternative is scapulohumeral excision arthroplasty (see Figure 10-11).

Aftercare

The limb is supported for 8 to 14 days in a carpal flexion bandage (see Figure 2-30) after fracture fixation or tenodesis.

Prognosis

If the fracture is reduced and stabilized appropriately, the prognosis is very good. Implant failure, poor reduction, and late surgery are reasons for a guarded prognosis.

Fibrotic Contracture of Infraspinatus Muscle

Fibrotic contracture of the infraspinatus muscle is an uncommon cause of shoulder lameness in hunting or working dogs. Electrophysiological and histological studies have indicated infraspinatus contracture to be a *primary muscle disorder* rather than a neuropathy. Affected muscle shows degeneration and atrophy with fibrous tissue replacement. The cause of this syndrome is hypothesized as an acute traumatic event that results in incomplete rupture of the infraspinatus muscle, leading to fibrotic contracture.[23] Although the trauma is usually self-induced and probably caused by indirect trauma, outside sources may also cause the injury. We have seen two cases of contracted infraspinatus in nonhunting breeds sustaining known direct trauma and another in a Doberman pinscher with known von Willebrand's disease.

Usually, there is a history of a sudden onset of lameness during a period of field exercise. Lameness and tenderness in the shoulder region gradually disappear within 10 to 14 days. Gait abnormality develops 3 to 4 weeks later. At this time, the animal elicits no pain but is completely unable to rotate (pronate) the shoulder joint internally. This results in a stance with the elbow adducted and the foot abducted (Figure 10-27, *A*). The lower limb swings in a lateral arc (circumduction) as the foot advances during the stride. There is atrophy of the infraspinatus muscle on palpation; when the forelimb is forcibly pronated or adducted, the proximal border of the scapula becomes more prominent as it abducts from the thorax. Radiographs are usually normal. Although rare, the condition can be bilateral.

Treatment consists of tenotomy and excision of 1 cm of the infraspinatus tendon insertion on the greater tubercle of the humerus. The tendon is exposed by the approach to the craniolateral region of the shoulder joint.[4] The belly of the infraspinatus is inspected to confirm its fibrosis and contracture, and then the scarred

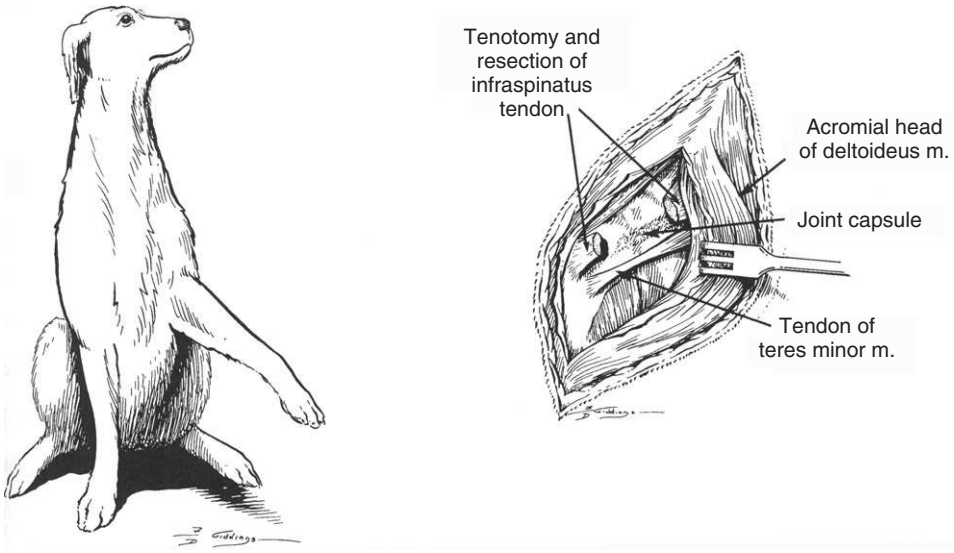


FIGURE 10-27. Fibrotic contracture of the infraspinatus muscle. **A,** Typical sitting posture of a dog with infraspinatus contracture. The lower limb is permanently externally rotated and therefore shortened. **B,** The left shoulder has been exposed by the craniolateral approach by tenotomy of the infraspinatus muscle.[4] The tendon is dissected free of the joint capsule until the shoulder moves freely; then about 1 cm of the tendon is excised.

tendon is undermined from the joint capsule and severed. If complete range of motion is not achieved, the joint capsule is also contracted and needs to be released (Figure 10-27, *B*). A distinct "pop" is often felt when the last of the adhesions is released. Full range of motion is immediately restored.

Aftercare and Prognosis

Dogs are leash-walked immediately, with no constraint of the limb. Normal activity is resumed in 10 to 14 days. These animals uniformly return to normal limb function.[24]

Fibrotic Contracture of Supraspinatus Muscle

Although only a single case of fibrotic contracture of the supraspinatus muscle appears to have been reported,[25] we have seen this condition in conjunction with external trauma and in Doberman pinschers suspected of a spontaneous hemorrhage from von Willebrand's disease (platelet dysfunction). Clinical signs were identical to those described for infraspinatus contracture. Dogs respond well to sectioning of the tendon of insertion of the supraspinatus muscle. It would thus seem prudent to inspect both spinatus muscles for evidence of fibrosis and contracture before either tendon is sectioned.

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11

Fractures of the Humerus

Most fractures involving the humerus are in the middle and distal thirds.[1,2] In a study of 130 humeral fractures, 4% involved the proximal physis, 47% the shaft, 13% the supracondylar region, and 37% the distal articular surfaces.[3] Rarely, fractures of this bone may be accompanied by foreleg paresis or paralysis resulting from radial nerve injury. Nerve injury may occur at the fracture site or in the brachial plexus (axillary nerve), or it may be caused by avulsion of spinal nerves from the cord. Nerve impairment may be temporary or permanent; fortunately it is temporary in most cases. Establishing the presence of withdrawal response by toe pinch and sensorium by skin pricks may be helpful in differentiation. Nerve conduction studies can be used to establish whether nerves are intact, but results are not reliable until about 7 days after injury. Most patients with a humeral fracture carry the affected leg with the elbow dropped and with the paw resting on its dorsal surface because of pain and weakening of the extensor musculature. This mimics the appearance of loss of proprioception resulting from nerve injury, and response to the toe-pinch reflex may be obtunded because of pain, making early differentiation of nerve injury difficult.

FIXATION TECHNIQUES

Coaptation

Few fractures of the humerus lend themselves to external fixation because of the difficulty of immobilizing the shoulder joint. The spica splint is the only device that will stabilize the proximal fragment of a humeral fracture (see Figure 2-23). Most diaphyseal fractures have considerable angular displacement of the distal segment because of muscular forces, and these forces cannot be adequately neutralized by the spica splint. Greenstick or nondisplaced fractures in skeletally immature dogs are the major indications for this type of fixation.

Intramedullary Pins and Wires

Steinmann pins have wide application in the humerus in the more stable fractures. These pins can be inserted either retrograde or normograde. The pins are most often driven distally into the medial condyle, which gives firm anchorage in the distal fragment (Figure 11-1, *D*). The pin must be small enough in diameter to pass through the epicondylar crest into the epicondyle. This method is applicable to fractures at any level of the bone. A larger-diameter pin, or multiple pins, can be

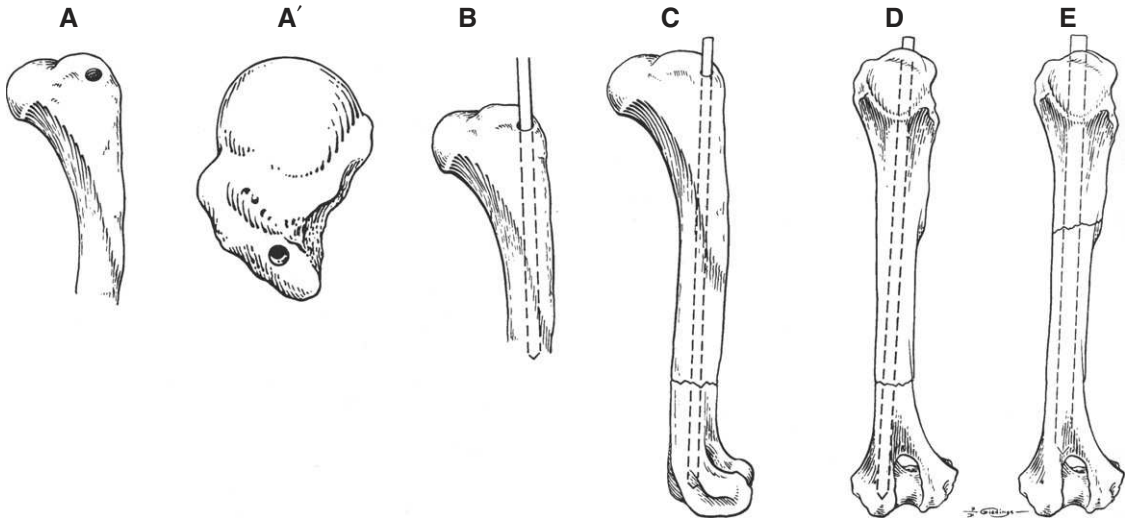


FIGURE 11-1. Internal fixation with an intramedullary (IM) pin. **A,** The Steinmann pin is inserted from the proximal end by entering the skin and bone obliquely just lateral to the ridge of the greater tuberosity of the humerus. **B,** After the bony anchorage is secured in the outer cortex, the IM pin is directed distally in the marrow cavity. **C** and **D,** *Method 1:* The IM pin is directed to pass along the medial cortex of the shaft and anchors well down in the medial condyle. Care must be taken that the pin is not too large to pass through the medial epicondylar area. If too large, The IM pin will break through into the elbow joint. **E,** *Method 2:* A large-diameter IM pin is directed centrodistal in the medullary canal and is seated just proximal to the supratrochlear foramen.

anchored distally just proximal to the supratrochlear foramen (Figure 11-1, *E*). The use of this type of pin should be restricted to fractures proximal to the midshaft, because anchorage of the pin is not firm in the distal fragment.

For *normograde* insertion, the Steinmann pin is driven from the proximal end by entering the bone on the lateral slope of the ridge of the greater tubercle near its base (Figure 11-1, *A* and *B*). Note that the pin enters near the base of the curve connecting the tubercle to the shaft. Initial drilling is done with the pin held perpendicular to the bone surface. After bony anchorage is secured in the outer cortex, the pin is redirected distally into the marrow cavity canal to pass along the caudomedial cortex of the shaft and anchors well down in the medial condyle, at least to the level of the epicondyle. The medial condyle forms a square corner with the caudomedial shaft that can be easily palpated to judge the depth of the pin (Figure 11-1, *C* and *D*). During insertion of the pin into the distal segment, the two segments are held firmly in the reduced position with one or two self-locking bone forceps. Allowing one segment to rotate on the other during insertion results in a loose-fitting pin. To ensure passage of the pin down into the medial condyle, the bone fragments are bowed slightly medially at the fracture site. For anchorage of the pin proximal to the supratrochlear foramen, it is allowed to follow the center of the medullary canal until resistance is felt, then driven slightly farther to secure bone anchorage without entering the foramen. These pins are all usually cut as close to the bone as possible, leaving just enough pin protruding to allow removal after fracture healing.

Retrograde insertion from the fracture site can be done by initially driving the pin either proximally or distally through the medial condyle. The pin is directed proximally toward the craniolateral cortex until it exits through the greater tubercle, after which it is withdrawn proximally until the distal pin tip is flush with the fracture.

The fracture is reduced and the pin seated distally with either method just described. If medial condylar seating of the pin is chosen, the pin also can be first driven distally until it exits from the condyle, after which the pin is retracted and the fracture reduced. The pin can now be seated by the following two methods:

1. Drive the pin proximally through the greater tubercle, then pull it proximally until the distal pin is within the medial condyle. The pin is cut proximally as described. If the pin is small enough, it should be bent at the greater tubercle of the humerus to prevent migration distally. Figure 11-26 shows this method used in a supracondylar fracture.
2. Drive the pin proximally until it has just penetrated the greater tubercle, then cut the pin distally close to the bone of the condyle.

The chief indication for using a Steinmann intramedullary (IM) pin as the sole method of fixation is for transverse or short oblique type A fractures in small dogs and cats. The IM pin may be used in combination with other methods of fixation in unstable fractures. After an open approach, the fracture is first reduced, and the IM pin is inserted in the proximal segment. The auxiliary fixation is applied next. The methods of auxiliary fixation are as follows:

1. Cerclage wires, type A2 fracture (Figure 11-2, *A*).
2. Hemicerclage wires, type A2 fracture (Figure 11-2, *B*).
3. Interfragmentary wire inserted to secure the cortical fragments to each other and the IM pin at the fracture site, type A3 fracture (Figure 11-2, *C*). This method does not establish complete rotational stability because the cortex opposite the wire is still free to move unless the fragments interlock.
4. Skewer pin and wire, type A fractures (see Figure 2-63, *G*).
5. Lag screw fixation, type A2 fracture (Figure 11-2, *D*). This is only possible in very large breeds.
6. Two or more IM pins, type A3 fracture (Figure 11-2, *E*).
7. External fixator, type I, 1/1 pins for stable type A fractures (Figure 11-2, *F*). The 2/2 pin configuration is used on unstable type B fractures.

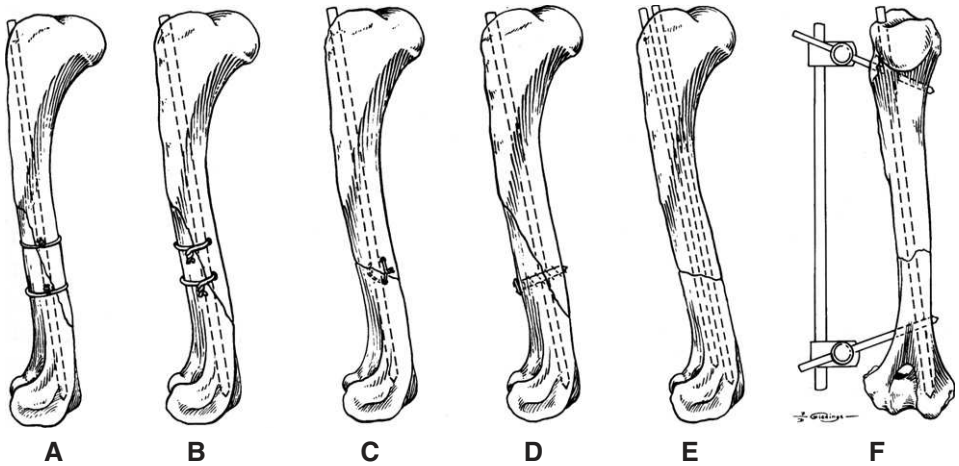


FIGURE 11-2. Intramedullary (IM) pin and auxiliary fixation. **A,** Cerclage wires. **B,** Hemicerclage wires. **C,** Orthopedic wire secures cortical fragments to each other and the IM pin at the fracture site. **D,** Lag screw fixation. **E,** Use of two pins. **F,** Unilateral external fixator, 1/1 pins.

Rush pin intramedullary fixation is useful in both proximal extraarticular type A and distal segment extraarticular type A1 fractures of the humerus because the ability to use double pins is effective in eliminating rotary motion. Pin entry sites are shown in Figure 11-3. Typically, a distal pin through the lateral epicondylar crest will need to be smaller in diameter than that in the medial side because of the small diameter of the bone of the lateral crest.

Interlocking Nails

Interlocking nails are indicated for closed diaphyseal fractures, type A, B, and C, in medium to large dogs with sufficient medullary size to accept the 6- or 8-mm nails. Smaller nails of 4 and 4.7 mm are now available for treatment of smaller dogs and cats. Sufficient bone should be intact in the proximal distal humeral fragment to allow seating of the nail and placement of at least one interlocking screw in each main fragment (Figure 11-4). Because most diaphyseal humeral fractures are in the

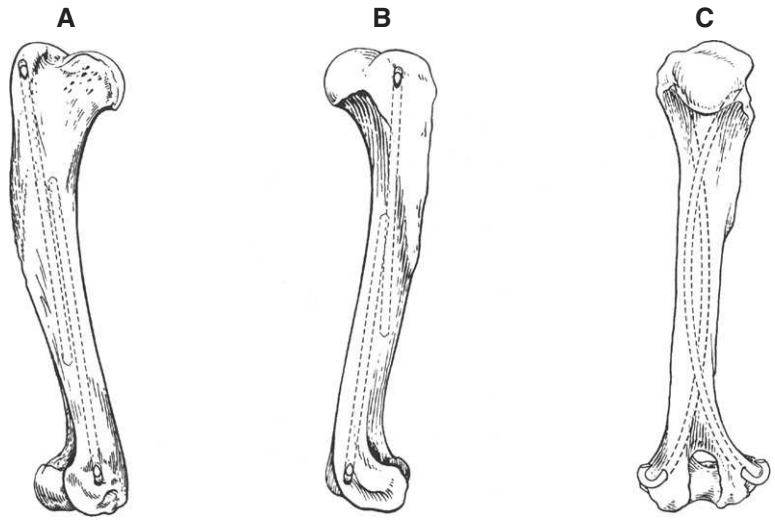


FIGURE 11-3. Rush pin sites in the humerus. **A,** Proximal and distal sites on the lateral aspect. **B,** Proximal and distal sites on the medial aspect. **C,** Distal sites as seen from the caudal aspect.

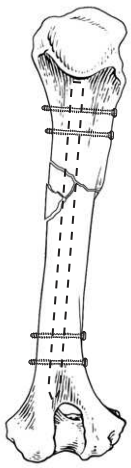


FIGURE 11-4. Interlocking nail in the humerus. Two screws in each the proximal and distal fragments are preferred, with a minimum distance of 1 cm from the fracture to the nearest screw.

distal one third of the shaft, careful evaluation of the distal fragment is indicated. The relatively larger size of the interlocking nails inhibits placement of the nail through the medial epicondyle. The nail is usually directed centrodistal and is seated proximal to the supratrochlear foramen (Figure 11-1, *E*). Type B and C fractures heal with abundant callus because reduction of all fragments is not attempted with this fixation system. The major goal is to achieve rapid healing with the concept of "bridging osteosynthesis" with minimal disruption of fragment blood supply.

External Fixators

External skeletal fixation is applicable to all diaphyseal fractures as well as distal extraarticular type A fractures. Unilateral type I single-bar or double-bar fixators are used in shaft fractures (see Figure 11-21), and a hybrid type I-II is very helpful for very proximal type B (see Figure 11-15) or distal extraarticular type A2 and 3 fractures (see Figure 11-29, *B*).

Although the fixator may be used on most types of fractures, it is most often used on diaphyseal types B and C and open fractures. The splint is placed on the craniolateral surface of the bone to minimize muscle impingement. If the distal segment is short, the distal pin may be inserted in a transcondylar position (see Figure 11-21). The distal (positive-thread-profile) pin is usually inserted first in the transcondylar position, in the same position as a transcondylar screw (see Figure 11-30). The proximal pin is inserted next, followed by application of the connecting bar and clamps, then by insertion of the center pins through the clamps. For the strongest buttress effect, particularly in dogs over 50 pounds (25 kg) with a diaphyseal type C3 fracture, a double connecting rod is advisable when using the Kirschner-Ehmer system. Another option, when increased stress on the fixator is expected because of dog size, temperament, fracture configuration, or polytrauma, is to use an external fixator system with larger-diameter carbon fiber, aluminum or titanium connecting rods for increased fixator stiffness (IMEX SK, IMEX Veterinary, Inc., Longview, Texas).

If the distal segment is fragmented and strong buttressing is needed (type C3 fracture), the hybrid splint shown in Figure 11-29 can be used. This placement of pins allows full range of movement of the elbow joint during the healing period.

Fixators are also useful in combination with IM pins to control rotational and compressive shear forces (see Figures 11-2, *F,* and 11-27, *D*). The fixator can be removed as soon as callus formation is observed, usually 4 to 6 weeks, and the IM pin is left in place until clinical union is ascertained by radiography.

Bone Plates

The choice between plates and external fixators is often arbitrary, following the surgeon's preference. Plates are indicated for all unstable type B and C diaphyseal fractures, as well as the more stable type A fractures in large-breed dogs. Bone plates can be applied to every side of the humerus, depending on the fracture location (Figure 11-5). In most cases where the fracture is proximal to the midshaft, the plate may be applied on the cranial surface to advantage (see Figures 11-19, *C,* and 11-20). The lateral surface has two disadvantages: marked curvature of the bone and proximity of the radial nerve and brachialis muscle. The plate must be placed under these structures (see Figure 11-19, *D*). Fractures of the distal third and fractures requiring a long plate (type C) are best handled with a medial plate.[4] Supracondylar fractures can be treated with a caudomedial plate (see Figure 11-29, *A*)

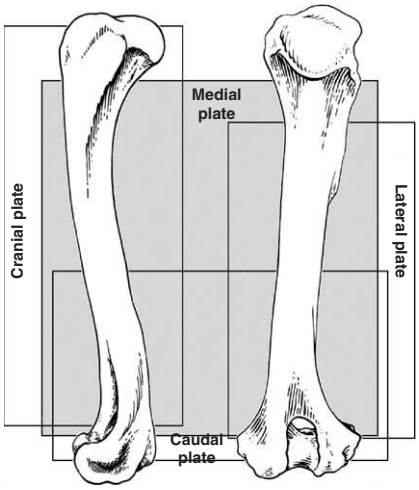


FIGURE 11-5. Various fracture zones on the humerus are indicated by the overlapping boxes. Suggested bone plate position is labeled within the boxes. There is considerable overlap of potential plate position for a specific fracture, so the choice may be related to other factors, such as patient size, bone shape, soft tissue injuries, or simply personal preference.

or a caudal plate on the medial epicondylar crest (see Figure 11-34, *G*), sometimes supplemented with a plate on the lateral crest (see Figure 11-34, *H*). (See Figure 2-75 for suggested plate sizes.) Bone plates can be used with neutralization or compression functions, with lag screws or cerclage wire providing interfragmentary compression for primary reconstruction of the bone. The surgeon may also employ the concept of bridging osteosynthesis and use a buttress function plate with minimal fragment manipulation. When increased stress on the plate construct is expected because of dog size or temperament, fracture configuration, or polytrauma, additional stiffness and strength may be achieved by use of a plate and pin combination fixation (Figure 11-6).

Lag Screws

The interfragmentary compression afforded by lag screw fixation is essential for most type B and C intraarticular fractures (see Figures 11-30, 11-31, 11-33, and 11-34) in adult animals. Because of the shear loads imposed on these screws with weight bearing, the use of a fully threaded cortical screw as a lag screw (see Chapter 2) is preferred over partially threaded cancellous screws. The junction of the threaded and smooth shank in partially threaded screws is a stress-raiser area and is prone to fatigue failure if this junction is near the fracture line. The dog's bone is dense enough in the condylar region that the cancellous thread is not important. (See Figure 2-75 for suggested screw sizes.)

PROXIMAL FRACTURES

Fracture Type 1-1-A; Proximal, Extraarticular Simple
(Figure 11-7, A)

Physeal fractures are uncommon injuries, comprising about 5% of humeral fractures, that occur in young animals before physeal closure.[3] They may be a result of direct or indirect force (avulsion). The proximal humerus has two epiphyses: the greater tubercle and the humeral head. These epiphyses may be confluent, with a bridge of cartilage between, or entirely independent from one another.

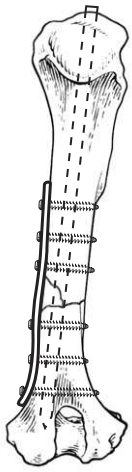


FIGURE 11-6. Multiple fractures of the distal third of the humerus repaired with a plate and IM pin combination. When increased stress on the plate construct is expected because fragments are not reduced, additional stiffness and strength may be achieved with a plate and IM pin combination.

Therefore, some fractures will involve both portions, as in Figures 11-8 and 11-9, whereas others involve either just the tubercle (Figure 11-7, *A*) or just the head (Figure 11-7, *C*). Impacted metaphyseal fractures (Figure 11-7, *A*) are quite rare.

Closed Reduction and Fixation

Closed reduction can usually be accomplished when the fracture leaves both epiphyses intact, particularly in cases of recent origin (see Figures 11-8 and 11-9). If the displacement of the fracture is 5 mm or less, immobilization may be accomplished by use of a modified Velpeau bandage encircling the chest and the affected leg with the joints flexed[3] (see Figure 2-29). This area heals readily with minimal fixation, and vigorous remodeling quickly restores normal alignment.

Open Reduction and Fixation

An open craniolateral approach to the shoulder joint and proximal humerus[5] and reduction can be performed if closed reduction cannot be accomplished. The fracture is reduced by levering. Internal fixation, which is necessary in most cases, is accomplished by inserting one or more Steinmann pins or Kirschner wires (K-wires) in young animals with open growth plates. There is minimal chance of creating iatrogenic growth arrest with small, smooth pins. Figures 11-8, *B;* 11-9, *B;* 11-10; 11-11, *A;* and 11-12, *A,* show this technique. Because of the vigorous healing response of the physeal area, only minimal stability is needed. In animals at or near skeletal maturity, a wider variety of fixation, including lag screws and tension band wires, provide additional stability when needed (Figures 11-11, *B* and *C*, and 11-12, *B*).

Fracture Type 1-1-B; Proximal, Extraarticular Multifragmentary (Figure 11-7, *B*)

Open reduction and internal fixation is always indicated in these fractures because the bone segment or callus may encroach on the joint or brachial plexus or change the functional angle of the shoulder joint and thus limit range of movement or alter function. As is typical of metaphyseal fractures, they are quick to heal, but if they cannot be anatomically reconstructed (type B2) by interfragmentary compression, they present a challenge for fixation because of the shortness of the proximal fragment.

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FIGURE 11-7. Proximal fractures of the humerus. **A:** *A1,* Involving tuberosity; *A2,* impacted metaphyseal; *A3,* nonimpacted metaphyseal. **B:** *B1,* Metaphyseal wedge; *B2,* metaphyseal complex. **C:** *C1,* Simple; *C2,* simple and metaphyseal; *C3,* multifragmentary. (From Unger M, Montavon PM, Heim UFA: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

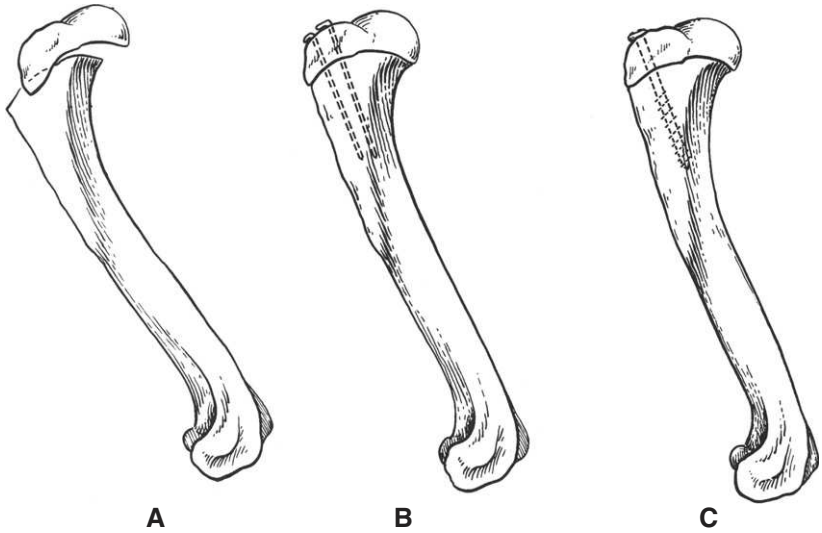


FIGURE 11-8. **A,** Type A3 (Salter-Harris I) fracture of the proximal humeral physis and the apophysis of the greater tuberosity. **B,** Fixation using transfixing Kirschner wires. **C,** Fixation with a cancellous bone screw is reserved for animals that are close to maturity.

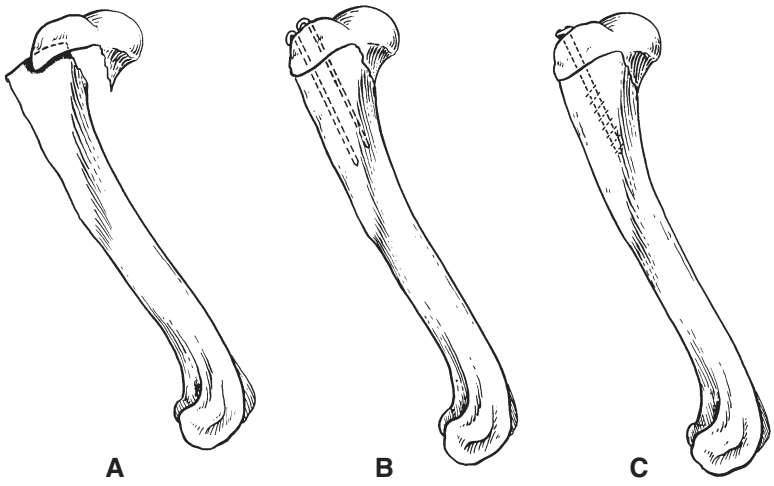


FIGURE 11-9. **A,** Type A3 (Salter-Harris II) fracture of the proximal humeral physis and metaphysis. **B,** Fixation using transfixing Kirschner wires. **C,** Fixation with a cancellous bone screw is reserved for animals that are close to maturity.

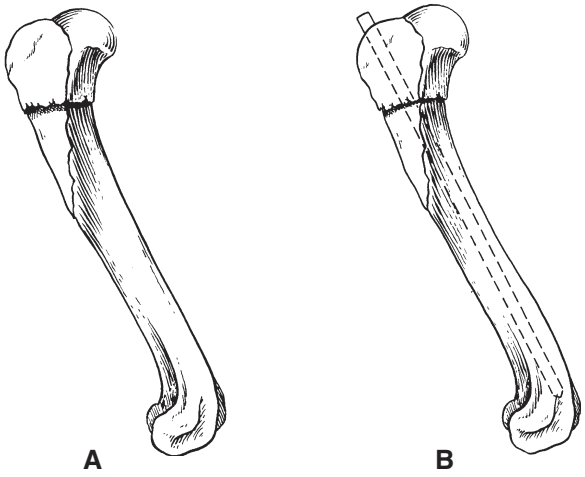


FIGURE 11-10. **A,** Type A2 impacted fracture of the proximal humeral metaphysis. **B,** The IM pin is inserted closed, starting on the ridge of the greater tuberosity and proceeding distally into the medial aspect of the condyle.

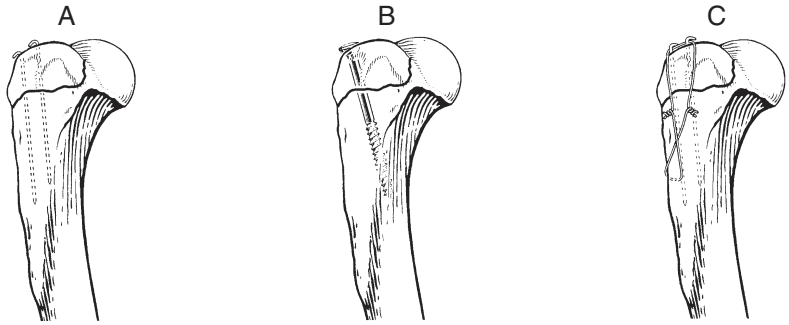


FIGURE 11-11. Type A1 fracture involving the apophyseal growth plate of the greater tuberosity of the humerus. **A,** Fixation using transfixing Kirschner wires (K-wires). **B,** Fixation with a cancellous bone screw is reserved for animals that are close to maturity. **C,** Fixation with K-wires and tension band wire is also reserved for animals that are close to maturity.

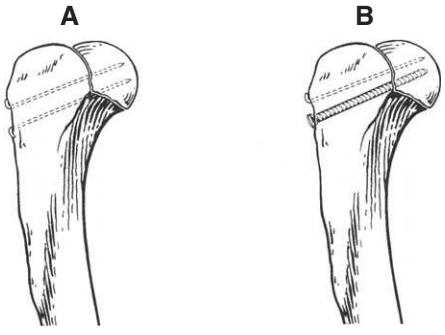


FIGURE 11-12. **A,** Type C1 (Salter I) fracture of the proximal humeral physis fixed by double transfixing K-wires. **B,** Fixation by lag screw. The K-wire is inserted first and maintains reduction while the screw is placed. Screw fixation is used only for animals that are close to maturity.

Open Approach

These fractures are exposed through the approach to the proximal shaft of the humerus (Figure 11-13).[5]

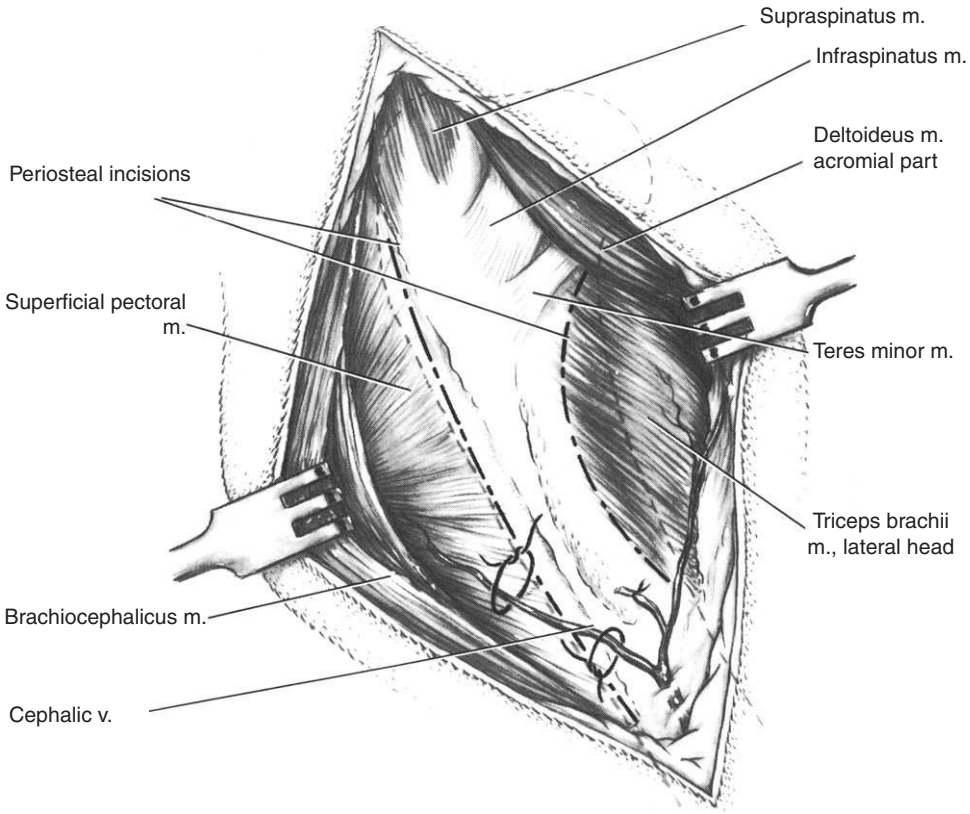


FIGURE 11-13. Approach to the proximal shaft of the humerus. Because it is relatively superficial, this region is easily exposed. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

Internal Fixation

Type B1 wedge fractures can usually be reduced and the fragment stabilized by lag screw or cerclage wire, which should be placed through a drill hole or notch in the bone to prevent migration. Fixation of the resulting two-piece fracture is then done with a cranial plate or by pins and tension band wire, as in Figure 11-11, *C*, except that long IM pins are used instead of the pictured K-wires.

Type B2 complex fractures require buttress or bridging fixation. This can be accomplished by a cranial straight plate or T-plate (Figure 11-14) or by a hybrid external fixator (Figure 11-15). Autogenous cancellous bone graft is packed into the unreduced fragment area if this can be done without disturbing the fragments. A carpal flexion bandage is useful for the first 2 to 3 weeks postoperatively to protect the fixation (see Figure 2-30).

DIAPHYSEAL FRACTURES

Fracture Type 1-2-A; Diaphyseal Simple or Incomplete

(Figure 11-16, *A*)

Considerable overriding resulting from spastic contraction of the brachial muscles can be seen with these fractures.[1,6] The distal segment is usually tilted cranially.

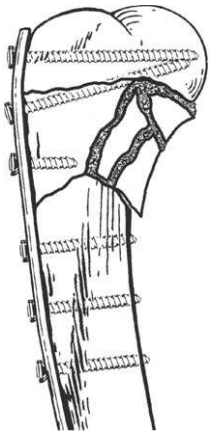


FIGURE 11-14. Type B2 fracture of the proximal humeral metaphysis stabilized by a buttress plate. The fragments are left as undisturbed as possible during the open reduction.

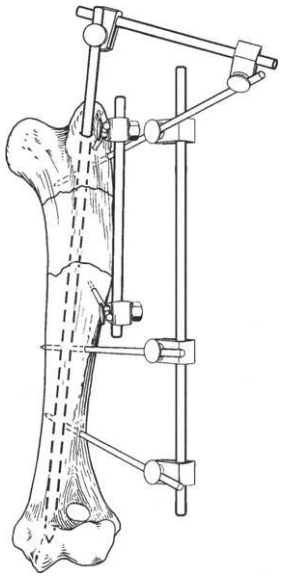


FIGURE 11-15. Type B2 fracture of the proximal humeral metaphysis shown in Figure 11-14, stabilized by two type IA external fixators, one of which is tied into a Steinmann IM pin. The proximal fixation pin of the smaller fixator is driven deeply into the humeral head, in a manner similar to the proximal screws in Figure 11-14.

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FIGURE 11-16. Diaphyseal fractures of the humerus. **A:** *A1,* Incomplete; *A2,* oblique; *A3,* transverse. **B:** *B1,* One reducible wedge; *B2,* reducible wedges; *B3,* nonreducible wedges. **C:** *C1,* Reducible wedges; *C2,* segmental; *C3,* nonreducible wedges. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

Shaft fractures constitute approximately half of all humeral fractures.[3] Treatment recommendations are keyed to the fracture patient scoring system detailed in Table 2-6.[7,8]

Open Approaches[5]

Figure 11-17 shows the craniolateral open approach to the distal shaft of the humerus. This approach may be used to expose the proximal three fourths of the humerus when combined with the approach to the proximal shaft of the humerus. Figure 11-18 shows a medial open approach to the shaft of the humerus, which is useful for application of a long bone plate.

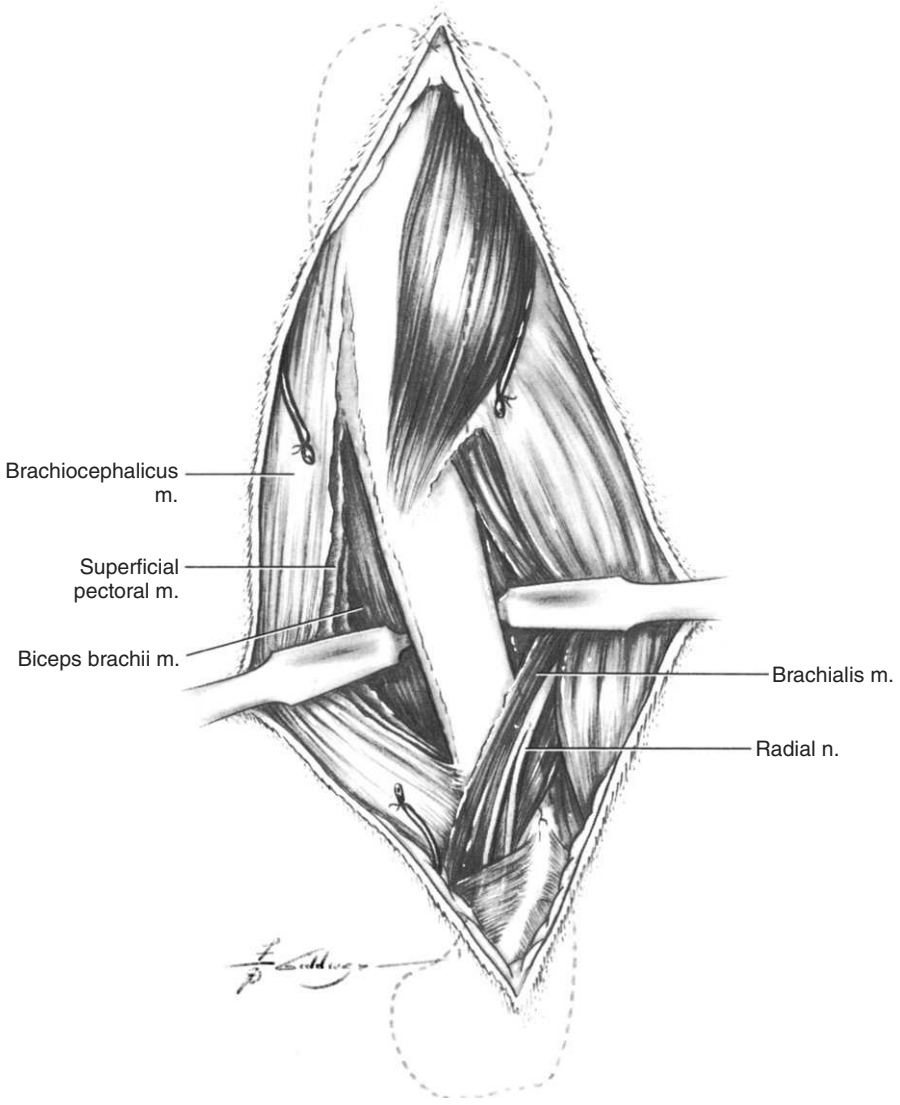


FIGURE 11-17. Approach to the shaft of the humerus through a craniolateral incision. The triceps and brachialis muscles are retracted caudally, and the biceps, superficial pectoral, and brachiocephalicus muscles are retracted cranially. The radial nerve is protected by the brachialis muscle, which can also be retracted cranially to better expose the distal shaft. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

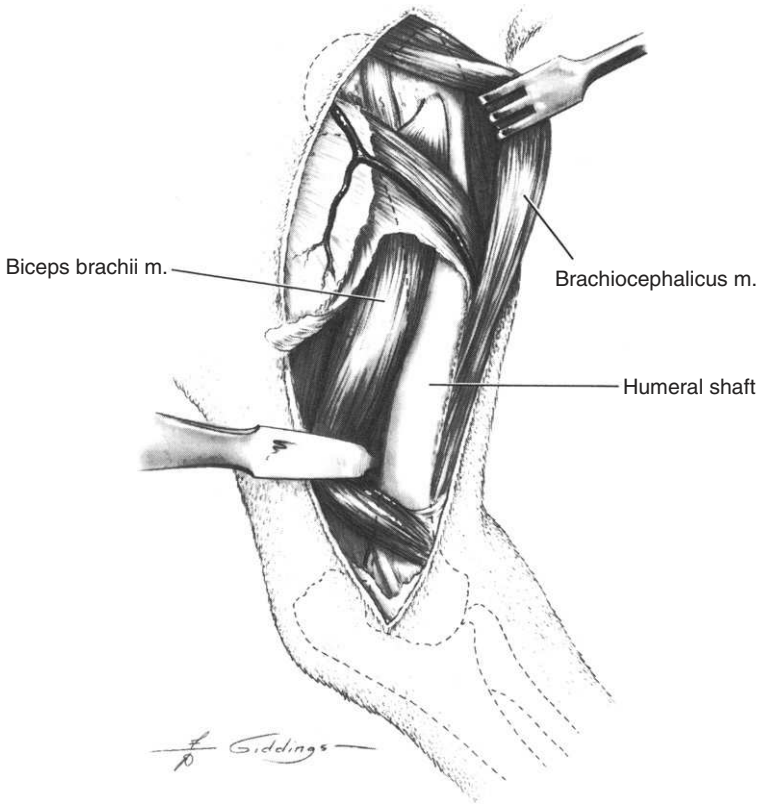


FIGURE 11-18. Approach to the shaft of the humerus through a medial incision. The entire shaft of the bone can be exposed, and the relatively flat surface is advantageous for plate application. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 3, Philadelphia, 2004, Saunders.)

Closed Reduction and Fixation

Closed reduction is occasionally possible, particularly in cats and small dogs, when the fracture is of the transverse or short oblique type and can be readily palpated. Immobilization is most often done by intramedullary pinning, with a type I half-pin external fixator added for supplemental fixation when needed for rotational stability (see Figures 11-1 and 11-2). An external fixator can also be employed as primary fixation.

Internal Fixation

Potential methods of internal fixation are as follows:

1. Intramedullary pin alone when the fracture patient score is 9 to 10 or more (see Table 2-6 for interpretation), usually with supplemental fixation (see Figure 11-2) when the fracture patient score is 8 to 9.
2. Type I external fixator alone or with supplemental fixation for fracture patient score of 7 to 8 or less. Four to six fixation pins and one connecting bar are used. There is the possibility of closed reduction and splint application or of a limited open approach.
3. Bone plate, especially in large-breed dogs, for any fracture score. The plate is applied as a neutralization plate in oblique fractures and as a tension band compression plate in transverse fractures.

4. Interlocking nail, in medium to large dogs, for any fracture score. There must be sufficient intact bone to allow placement of at least one interlocking screw in each main proximal and distal fragment.

Fracture Type 1-2-B; Diaphyseal Wedge (Figure 11-16, *B*)

These fractures all require open approach and internal fixation because they are all unstable in rotation and may be minimally stable relative to compression (weight-bearing) loads.

Type B1, One Reducible Wedge

If the wedge can be reduced and fixed by cerclage or lag screw, the fracture is then treatable as a simple type A fracture with any of the fixation methods previously detailed, as long as the fracture patient score is 8 or above. Figure 11-19 shows neutralization plate fixation of such a fracture.

Type B2, Several Reducible Wedges

Fracture patient score is typically in the 4 to 7 range, and there is a choice of reconstruction or bridging osteosynthesis. Figure 11-20 depicts a reconstructive approach to a proximal shaft fracture using a neutralization plate. An external fixator and supplemental fixation of the fragments could also be used. Bridging osteosynthesis can be accomplished with either a bridging plate or a plate and IM pin combination. Another good choice would be an external fixator, since a much more limited open approach can be used. The fixator would be applied as shown in Figure 11-21, *B*, or could be used in combination with an IM pin. An interlocking nail could also be used (see Figure 11-4).

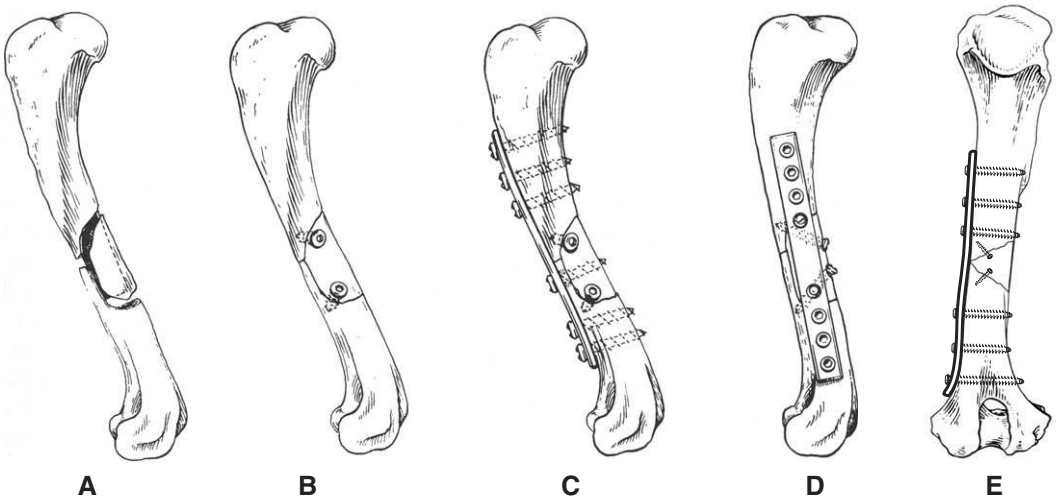


FIGURE 11-19. **A,** Midshaft, type B1, one reducible wedge humeral fracture. **B,** The wedge was first reduced with the proximal segment and fixed with a lag screw. The distal segment was next reduced and attached with a second lag screw. **C,** Neutralization plate applied to cranial surface. **D,** A neutralization plate may be applied to the lateral surface, although surgical exposure and contouring the plate may be more difficult. **E,** The medial side of the humerus provides an excellent surface for plate fixation for most midshaft humeral fractures.

Type B3, Nonreducible Wedges

With a fracture patient score in the 3 to 6 range, these fractures are treated by bridging osteosynthesis, as detailed for B2 fractures. The interlocking nail is also applicable.[9]

Fracture Type 1-2-C; Diaphyseal Complex (Figure 11-16, *C*)

These fractures all require open approach and internal fixation because they are all unstable both in rotation and compression (weight-bearing) loads. Fracture patient scores range from 1 to 3 (see Table 2-6).

Type C1 Reducible Wedge and C2 Segmental

Intramedullary pin fixation is rarely applicable to these fractures. The exception would be in a small-breed patient when the fracture lines are long enough to allow cerclage wire fixation. The more common options are as follows:

1. Reconstructive; interfragmentary compression by lag screws or cerclage wires and application of a neutralization plate or a type I external fixator.

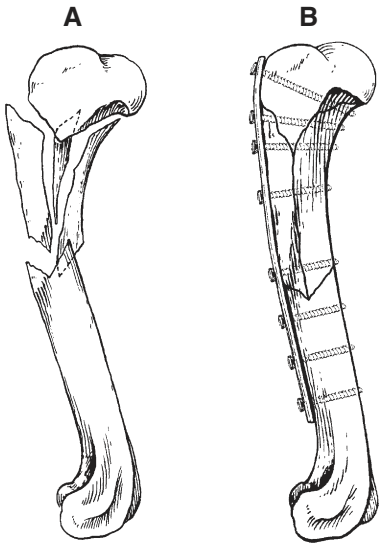


FIGURE 11-20. **A,** Type C1 reducible wedges of the proximal humeral shaft. **B,** Fixation by application of bone plate to cranial surface. Screws crossing the fracture line are inserted with a lag effect through the plate.

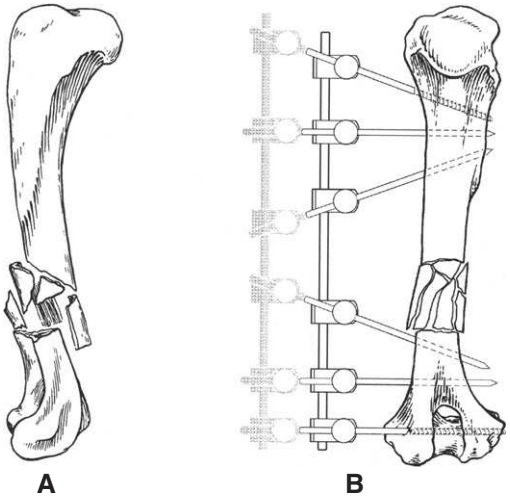


FIGURE 11-21. **A,** Multiple fractures of the distal third of the humeral shaft. The reduction is done closed or by minimal open approach, and the fragments are not reduced. **B,** Type IA external fixator with single or double *(shaded)* connecting bar. The distal pin is usually inserted first in the transcondylar position. The proximal pin is inserted next, followed by application of connecting bar and clamps, then the center pins. The double connecting bar is indicated in animals more than about 40 pounds (18 kg) when there is no load sharing by the bone.

2. Bridging osteosynthesis; most often by a type I external fixator (Figure 11-21), but a long bridging plate could be used. A combination of plate and pin fixation may also be considered to reduce the stress on the bridging plate (see Figure 11-6).
3. Bridging osteosynthesis by interlocking nail (see Figure 11-4).

Type C3 Nonreducible Wedges

Bridging osteosynthesis is the only option available. This is usually accomplished by a type I external fixator (see Figure 11-21), but a long bridging plate, plate and pin combination, or interlocking nail could be used.

DISTAL FRACTURES

Fracture Type 1-3-A; Distal, Extraarticular (Figure 11-22, *A*)

Distal humeral shaft and supracondylar fractures appear to be more common in cats than in dogs, in which condylar fractures, type 1-3-B, are more common.[10] In supracondylar humeral fractures the fracture line may vary somewhat, but it usually passes through the supratrochlear foramen.[1,3] In young animals the injury may be a combination fracture and physeal separation (Salter-Harris type II injury). Even though the fracture may be reduced closed, an open approach is usually indicated for the application of internal fixation. Best results are obtained by using stable internal fixation, which allows movement of the joint during the convalescent period.

Open Approaches[5]

The skin incision may be medial (Figure 11-23), lateral (Figure 11-24), or both. In most cases, both medial and lateral incisions are used. In some multiple, type C2 or C3 fractures in this area, the transolecranon (caudal) approach may give the best visualization and working area (Figure 11-25).

Internal Fixation

Type A1, Simple

The exact method of fixation may be dictated by the individual fracture. Possibilities include the following:

1. Insert a double-pointed Steinmann pin retrograde through the shaft of the humerus along the medial cortex, reduce the fracture, and run the pin

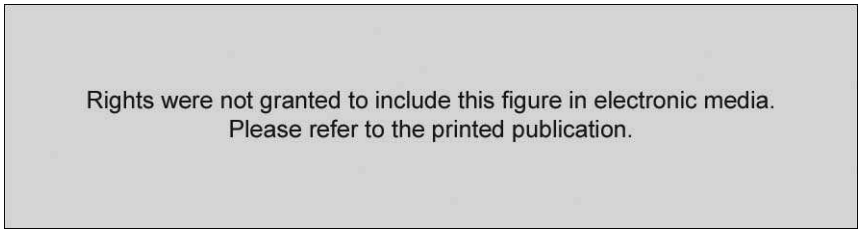


FIGURE 11-22. Distal fractures of the humerus. **A:** *A1,* Simple; *A2,* wedge; *A3,* complex. **B:** *B1,* Lateral; *B2,* medial. **C:** *C1,* Simple, metaphyseal simple; *C2,* simple, metaphyseal wedge; *C3,* simple, metaphyseal complex. (From Unger M, Montavon PM, Heim UFA: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

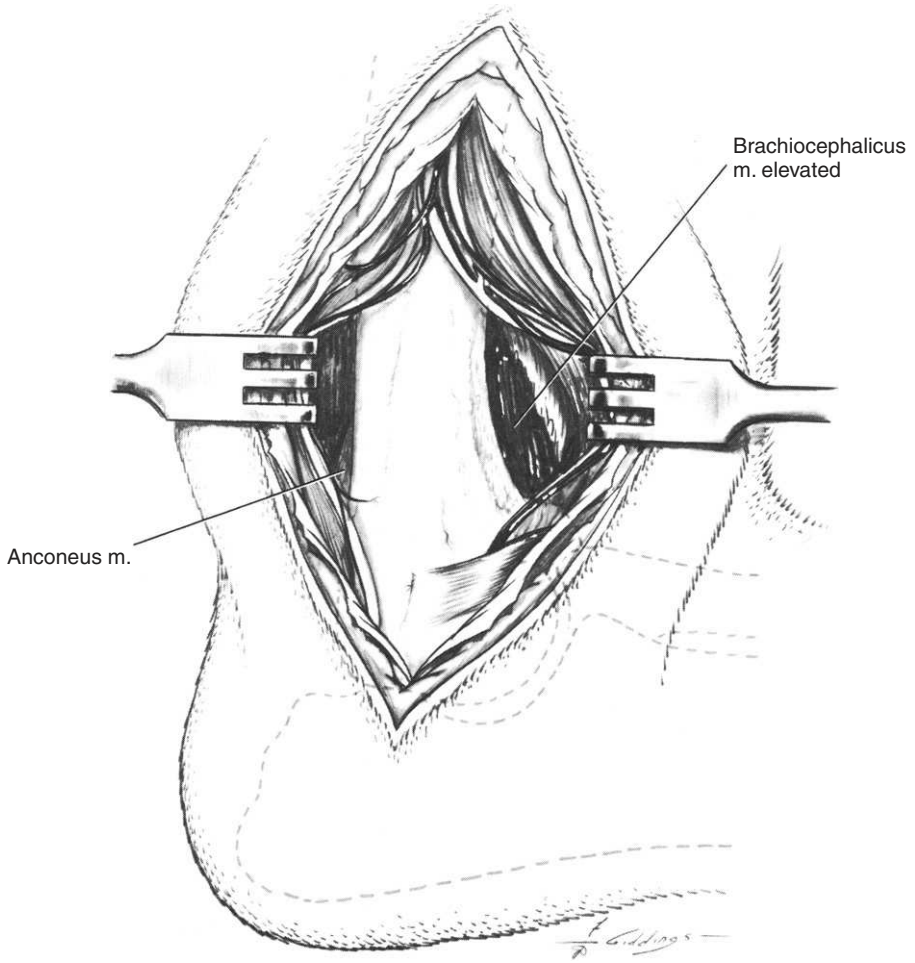


FIGURE 11-23. Approach to the supracondylar region of the humerus from a medial incision. Cranial retraction of the median nerve and accompanying vessels and caudal retraction of the ulnar nerve and triceps muscle provides exposure of the medial aspect of the condyle and supracondylar region. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

well into the medial aspect of the condyle (Figure 11-26). This type of fixation will allow rotation at the fracture site unless the fracture is serrated and interlocking on reduction, and it is best reserved for skeletally immature dogs in which early callus formation is expected.

2. Insert a double-pointed Steinmann pin as just described. In addition, insert another pin (usually of a smaller diameter) or K-wire from the lateral epicondyle across the fracture to anchor in the medial cortex of the humeral shaft proximal to the fracture line (Figure 11-27, *A*).
3. When the lateral fragment is slightly longer, insert a double-pointed Steinmann pin as described in 1. In addition, insert a lag screw through the lateral epicondylar crest, and anchor it in the medial cortex of the humeral shaft (Figure 11-27, *B*). This will bring about compression at the fracture site and ensure rotational stability. When applicable, this is the preferred method.
4. Insert a double-pointed Steinmann pin down into the medial condyle as described. In addition, insert one or more cerclage wires if the fracture is of the oblique type (Figure 11-27, *C*).

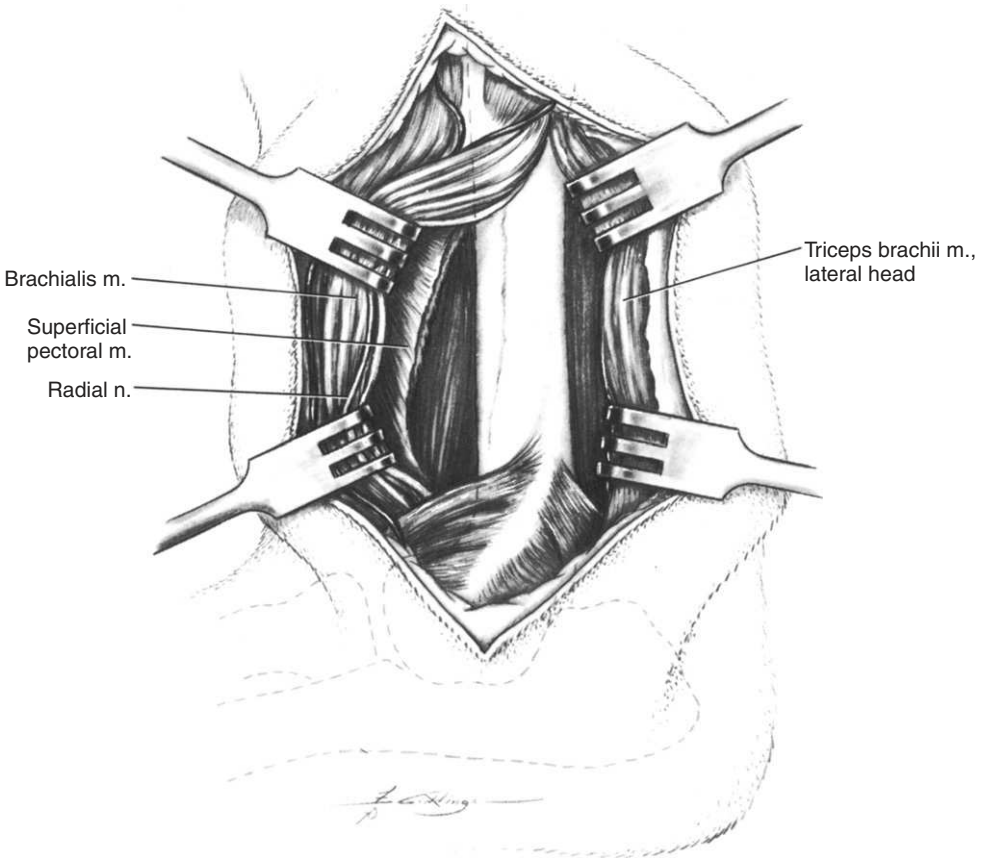


FIGURE 11-24. Approach to the supracondylar region of the humerus through a craniolateral incision. Caudal retraction of the triceps muscle combined with cranial retraction of the brachialis muscle and radial nerve are used to expose this region. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

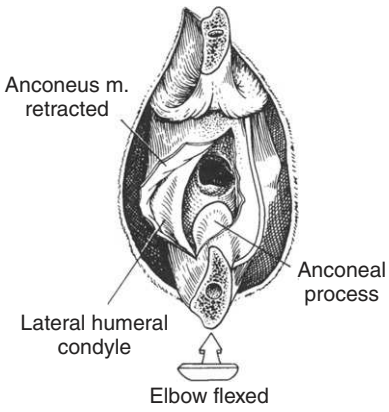


FIGURE 11-25. Approach to the humeroulnar part of the elbow joint by osteotomy of the tuber olecrani. This approach allows reduction of both parts of the humeral condyle, and further elevation of the triceps muscle exposes the supracondylar region of the humerus.

5. A Steinmann pin is inserted as described, and a two-pin type I external skeletal fixator is added for rotational stability (Figure 11-27, *D*). The distal fixation pin is inserted across the condyles in the same manner as a transcondylar screw. (See the description of screw placement in the following section on distal partial articular fractures.)

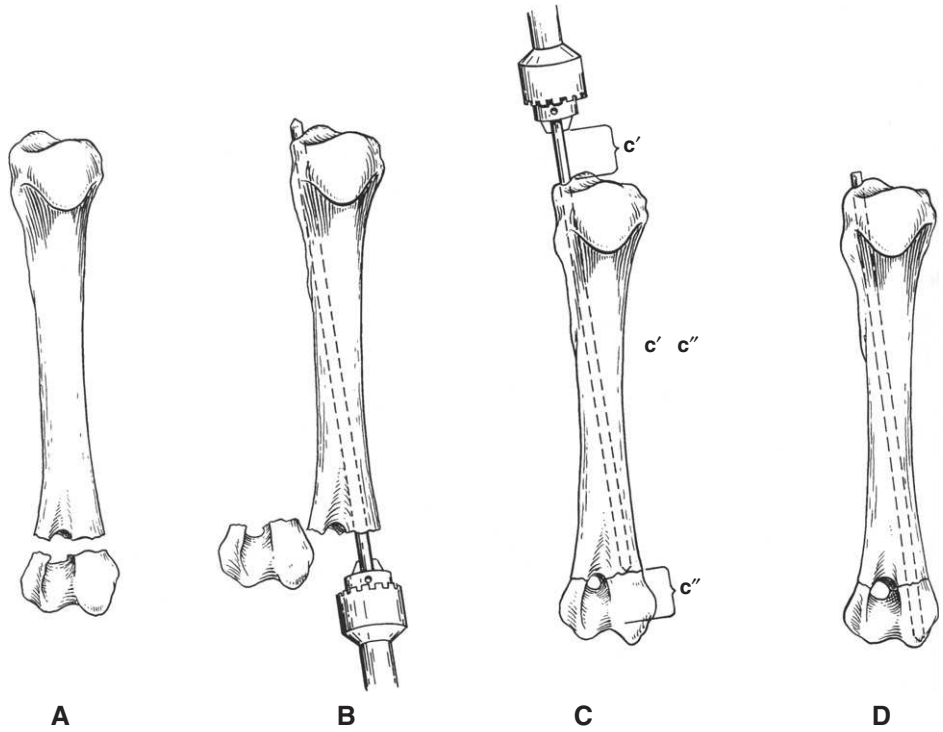


FIGURE 11-26. Placement of the IM pin for a type A1 distal extraarticular fracture. **A,** Fracture of the supracondylar type. **B,** The fracture site is exposed from the medial side, and a double-pointed pin, started near the medial cortex, is inserted retrograde. **C,** A pin chuck is attached at the proximal end at a distance (*c′*) that corresponds to the length of the condyle (*c″*). The fracture is reduced, and the elbow joint is extended before insertion. **D,** Final position; if fracture segments do not interlock, rotation is possible at fracture site, and supplemental fixation is indicated.

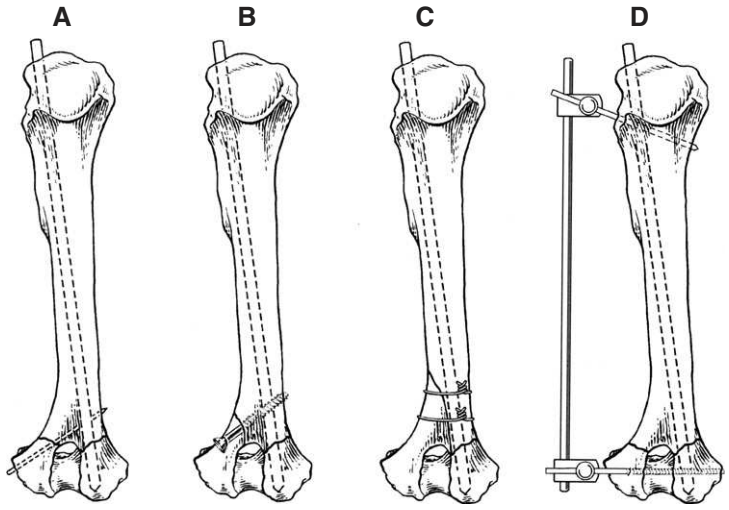


FIGURE 11-27. Intramedullary pin and auxiliary fixation for a supracondylar fraction. **A,** An additional pin is inserted up the lateral epicondyle and penetrates the medial cortex. **B,** A lag screw is inserted in addition to the pin. **C,** Two cerclage wires are added for supplemental fixation. **D,** Type I external fixator applied for rotational stability for this type A1 fracture.

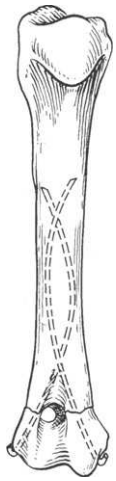


FIGURE 11-28. Two Rush pins give good stabilization.

6. Insert Rush pins at the medial and lateral epicondyles and drive them simultaneously into the shaft of the humerus (Figure 11-28).

Type A2, Wedge

The wedge is usually lateral, and if the fragment is large enough, these fractures can be fixed with the methods shown in Figure 11-27, using an IM pin into the medial condyle and K-wires and/or lag screws to secure the wedge. A caudomedial bone plate is more stable because it will better prevent rotation (Figure 11-29, *A*). The distal screws must be angled cranially into the condyle to prevent penetration into the supratrochlear foramen. If the wedge fragment cannot be captured by lag screw, double caudal plating can be applied (see Figure 11-34, *H*).

IM pins are not an option when the medial condyle is fragmented, and either a neutralization or a buttress plate caudomedially (see Figure 11-29, *A*) or a hybrid external fixator (Figure 11-29, *B*) can be used.

Type A3, Complex

A strong buttress effect is needed for these fractures. This can be supplied best with double caudal plating (see Figure 11-34, *H*) or the external fixator shown in Figure 11-29, *B*.

Note that all methods of fixation allow movement of the joint during the convalescent period. IM pins are usually removed after the fracture reaches the stage of clinical union.

Fracture Type 1-3-B; Distal, Partial Articular (Figure 11-22, *B*)

Fractures of the lateral portion of the humeral condyle occur much more frequently than fractures of the medial portion.[3,10] The lateral portion is the major weight-bearing part, and its smaller lateral epicondylar crest makes it biomechanically weaker. Also, a problem of incomplete ossification of the humeral condyle in cocker and Brittany spaniels in North America appears to predispose them to humeral condylar fractures from minor trauma or normal activity.[11] Others have noted the tendency for condylar fractures caused by minor trauma,[10] but the cocker spaniel in Europe does not appear to be predisposed to these fractures.[12]

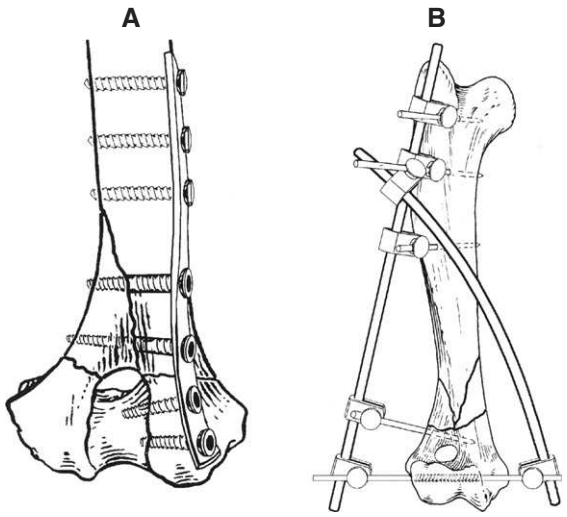


FIGURE 11-29. Distal extraarticular fractures of the humerus. **A,** Type A2 wedge fracture stabilized by a caudomedially applied plate. Minimal contouring of the plate is required. The wedge is lag-screwed to the supracondylar region of the humerus, and the condyle fracture line is compressed by using the load drill guide in the two distal plate holes. **B,** Type A3 complex fracture stabilized by a hybrid type I-II external fixator. A minimal exposure, open approach is used to partially reduce the fragments, and the transcondylar center-threaded fixation pin is placed first, followed by the most proximal half pin. The remaining fixation pins are then inserted, and a curved connecting bar is attached to one of the proximal half pins and to the medial end of the transcondylar pin for rotational stability.

Two distinct age groups are noted in this fracture type: those less than 4 months old (often toy or miniature breeds) and those older than 2 years.[10,12]

The procedure for reduction and fixation will vary depending on the length of time since injury, the amount of swelling and edema, and the ease with which the fragments can be palpated. As a result of muscular pull, the prereduction radiograph will usually show the fractured lateral portion to be dislocated proximally and rotated laterally and cranially. The fractured medial epicondyle is usually rotated medially and caudally. Subluxation is present in the elbow joint. Recent fractures of the lateral and medial aspects of the humeral condyle are shown in Figures 11-30, *A,* and 11-31, *A*. Within the first 36 to 48 hours after injury, there is usually minimal swelling, and the fragment can be palpated.

Reduction and Internal Fixation

Accurate reduction of articular elbow fractures is imperative because degenerative joint disease and elbow stiffness are common sequelae of poorly reduced fractures, leading to severe functional impairment.

The fractured leg may be placed in the Gordon extender for 10 to 15 minutes to fatigue the muscles and overcome spastic contraction (see Figure 2-13). The leg can be prepared and draped for surgery while still in the Gordon extender. Using a lateral or medial approach (Figure 11-32, *A* and *B*), the fracture area is exposed.[5] The fracture is reduced, and a pointed reduction forceps or vulsellum forceps is applied across the epicondyles (Figures 11-30, *D,* and 11-33, *A*). On the side opposite the open approach, this clamp will penetrate the skin, so a sharp, pointed forceps is needed. If additional rotational stability is desired, a transcondylar K-wire can be placed from epicondyle to epicondyle, as in Figure 11-33. Care must be taken to prevent this pin from entering the supratrochlear foramen.

The points of entry and exit of the transcondylar hole to be drilled are referenced to the epicondyles and are halfway between the epicondyle and the articular surface

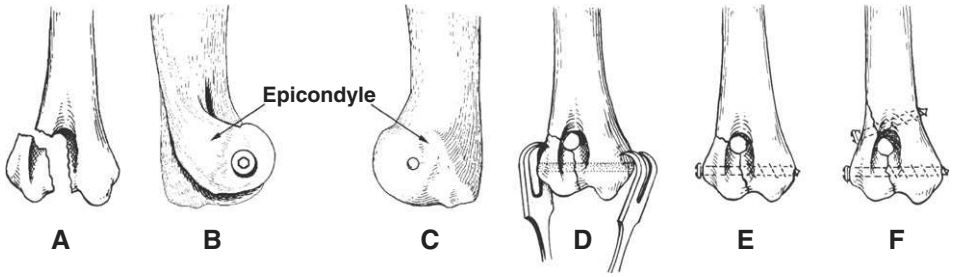


FIGURE 11-30. **A,** Distal partial articular fracture of the lateral aspect of the humeral condyle. **B,** Lateral view to show screw placement centered on the condyle. Note the proximocaudal position of the epicondyle relative to the screw. **C,** Medial view to show the tip of the screw protruding distocranial to the epicondyle. **D,** Reduction may be maintained during drilling of the screw hole by use of a vulsellum or pointed reduction forceps placed on the epicondyles. This leaves the area to accommodate transcondylar bone screw free for drilling. (See also Figure 11-33.) **E,** Bone screw insertion with lag effect. **F,** Insertion of additional bone screw proximal to the supratrochlear foramen adds to stability and is important when the proximal fracture line does not provide any buttress effect to support the transcondylar screw.

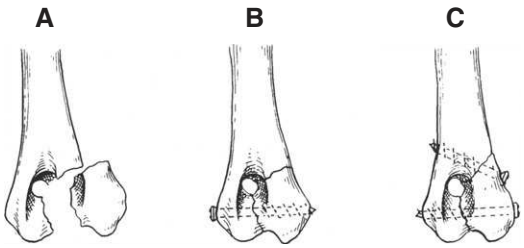


FIGURE 11-31. **A,** Recent type B2 fracture of the medial aspect of the humeral condyle. **B,** Bone screw insertion with lag effect. **C,** Insertion of additional bone screw proximal to the supratrochlear foramen adds to stability.

of the condyle (Figure 11-30, *B* and *C*). It is necessary to separate bluntly the extensor or flexor tendons to anchor the drill sleeve in these areas. The screw hole can also be started by a trocar-pointed pin, then enlarged with a drill of the appropriate size to accommodate the bone screw. To avoid cartilage penetration, retrograde drilling of the fractured condyle can be accomplished by drilling from the fracture surface, then reducing the condyle and completing the drill hole, as illustrated in Figure 11-33, *B*. This technique is preferred by less experienced surgeons but needs more soft tissue dissection, and screw insertion parallel to the elbow joint surface is more difficult to achieve.

Compression of the fracture site may be obtained by using a cancellous bone screw or a cortical bone screw inserted with a lag effect (see Figure 2-67, *E* and *F*); the latter is preferred because there is less chance of screw failure. In the very immature dog, minimal or no compression is advisable because of crushing of soft bone. In very small breeds, drilling a glide hole for a full-threaded screw can remove a significant portion of the condyle, and in these cases a tap hole–diameter drill is used through both cortices, and the only compression is that supplied by the bone clamp. Two or more small pins or K-wires placed in a diverging pattern may be substituted for the transcondylar screw in toy breeds that are less than 4 kg in weight.[13] Small vulsellum or pointed reduction forceps are used to obtain compression during the insertion procedure. This method is definitely not recommended in larger breeds, and the availability of 1.5- and 2-mm screws lessens the need to use it even in small breeds. In some cases it is useful to use a K-wire through the lateral or medial epicondylar crest to supply additional rotational stability to the condyle, as shown in Figure 11-34, *A* and *B*.

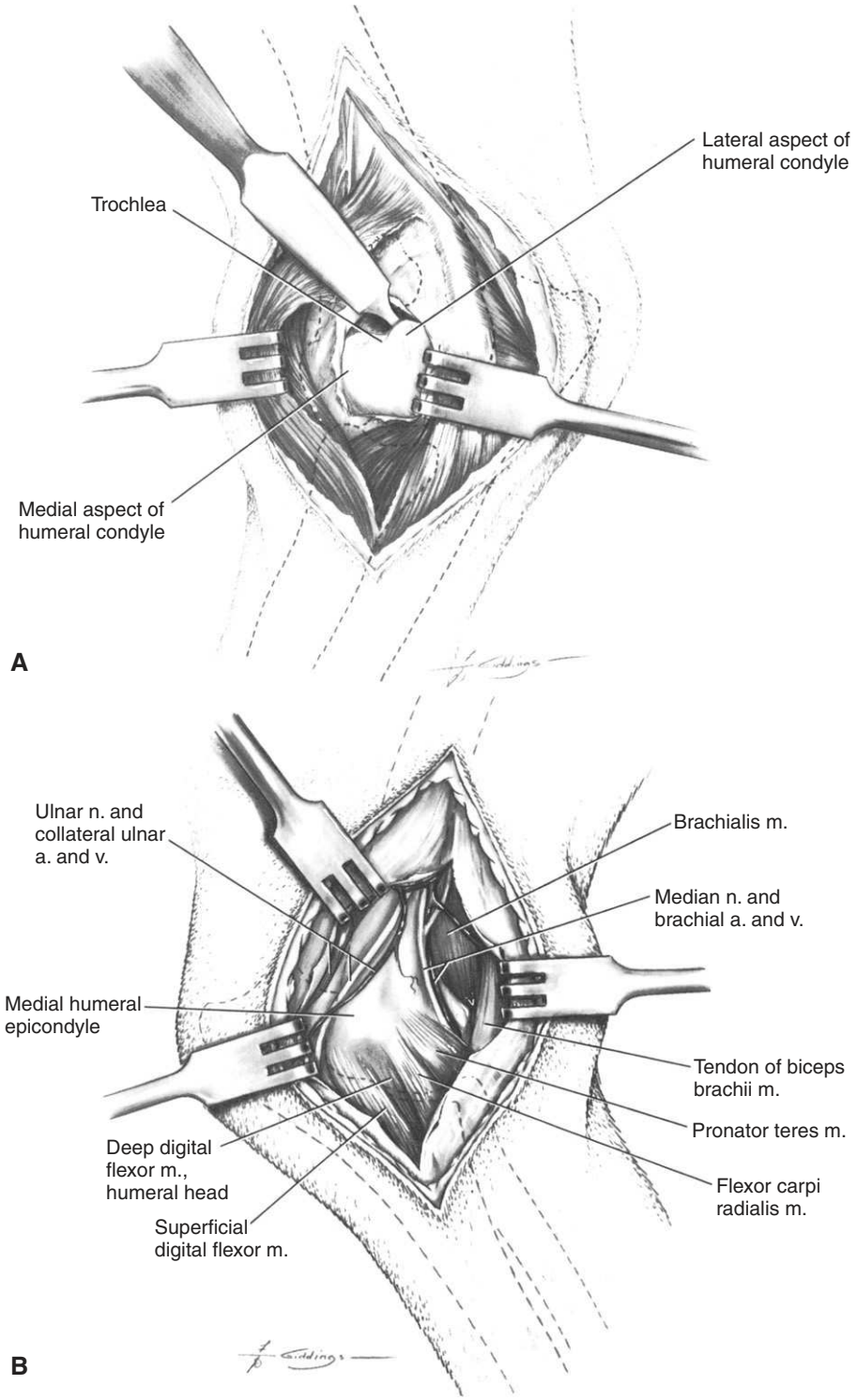


FIGURE 11-32. **A,** Approach to the lateral aspect of the humeral condyle and epicondyle. The extensor carpi radialis muscle has been elevated and the joint capsule opened. **B,** Approach to the medial humeral epicondyle. The medial and ulnar nerves must be protected during this approach. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

Additional fixation, preferably a second screw, is necessary in some cases, especially with lateral condylar fractures. Note that when the metaphyseal fracture line is relatively transverse (see Figures 11-30, *A*, *D*, and *E,* and 11-31, *A* and *B*), the bone can load-share weight-bearing forces with the fixation screw, and the screw is unlikely to fail. However, if the metaphyseal fracture line is less than 45 degrees to the long axis of the bone, no load sharing can occur, and the screw is at jeopardy to fail in a few weeks (Figures 11-30, *F,* and 11-31, *C*). Because there is no callus formation in the intercondylar fracture area, it is slow to regain normal strength through the haversian remodeling process. Under these circumstances, fixation of the metaphyseal fracture is important to prevent screw failure. A pin large enough in diameter to resist bending can be substituted for the screw if necessary.

For longer-standing fractures of the lateral or medial region of the condyle, if the fragments cannot be accurately reduced or if the fracture is more than 3 to 4 days old, this procedure can be modified by performing a caudal approach with osteotomy of the tuber olecrani (see Figure 11-25) to expose the fracture site. When the patient is very young, a triceps tenotomy is preferred to an osteotomy of the olecranon process. The additional exposure gained by these approaches simplifies reduction. Prognosis for good to excellent function after repair is reported to be 89% for lateral condylar fractures and 87% for medial condylar fractures.[14]

An additional method of fluoroscopically guided closed reduction and fixation has been described for fractures of the lateral portion of the condyle.[15] Manual reduction of the fragment is achieved and confirmed with a fluoroscope. The reduction is maintained with a condylar clamp or reduction forceps, and a temporary transcondylar K-wire is applied. A positional or lag screw is then placed across the condyle, using previously described landmarks, through a small stab incision. Position is confirmed with the fluoroscope. Malreduction of less than 1 mm was achieved in 91% of the cases reported.[15]

Aftercare

It is important to maintain motion in the elbow joint postoperatively, so no external splintage is employed. Passive range of motion (ROM) exercise is started as soon as tolerated. If the animal seems likely to damage the fixation, a carpal flexion bandage will protect the fixation while still allowing motion of the elbow joint (see Figure 2-30). The bone screw may be removed in the young, growing animal, up to approximately 4 months of age, but it is usually left in place in those over this age unless otherwise indicated.

Fracture Type 1-3-C; Distal, Complete Articular

(Figure 11-22, *C*)

Bicondylar, or T-Y, fractures occur most frequently in mature animals and usually result from trauma exerting torsional stress.[1,3] The spaniel breeds are particularly prone to this fracture. Spastic contractions of the muscles of the foreleg pull the ulna and radius proximally between the fractured medial and lateral portions of the condyle.

Open Approaches[5]

The caudal approach to the humeroulnar part of the elbow joint by osteotomy of the tuber olecrani usually gives the best visualization of the fracture area (see Figure 11-25). This approach provides good exposure of the caudal surface of the distal end of the humerus, including the condyle, trochlea, and anconeal process. The surgeon also may use two other approaches: (1) to the elbow joint by osteotomy of the proximal ulnar

diaphysis and (2) to the supracondylar region of the humerus and caudal humeroulnar part of the elbow joint. In cats, two anatomical differences should be noted when making surgical approaches in this area, as follows:

1. The median nerve passes through the supratrochlear foramen.
2. The ulnar nerve lies under the short portion of the medial head of the triceps muscle.

Reduction and Fixation

Perfect anatomical reduction of the fractured articular surfaces with uninterrupted rigid fixation (preferably with screws, with or without plates) and early postoperative movement of the elbow are mandatory for the best functional results. This type of fracture is one of the most challenging to repair in veterinary medicine; any errors in reduction and fixation lead to decreased range of movement, abnormal wear, and degenerative joint changes.

After exposure of the fracture and removal of the organizing clot and fibrin, the condyles are reduced and temporarily held by one or two vulsellum or pointed reduction forceps (Figure 11-33). After being rigidly immobilized with the two forceps, the elbow can be further flexed to evaluate fracture reduction. The addition of one or two transverse K-wires proximally or cranially to the screw site increases rotational stability for drilling the condyle. The hole is drilled for insertion of the transcondylar bone screw. This hole may be drilled directly from the lateral or medial surface, as described earlier for type B fractures, or retrograde from the fracture surface (Figure 11-33, *B*). Before the transcondylar hole is drilled, there should be perfect anatomical reduction of the articular cartilages of the humeral condyle along the fracture lines. The humeral condyles should be checked for good approximation at the intercondylar and supracondylar fracture sites. Less than anatomical reduction may impinge the anconeal process, limit range of movement, and result in abnormal wear.

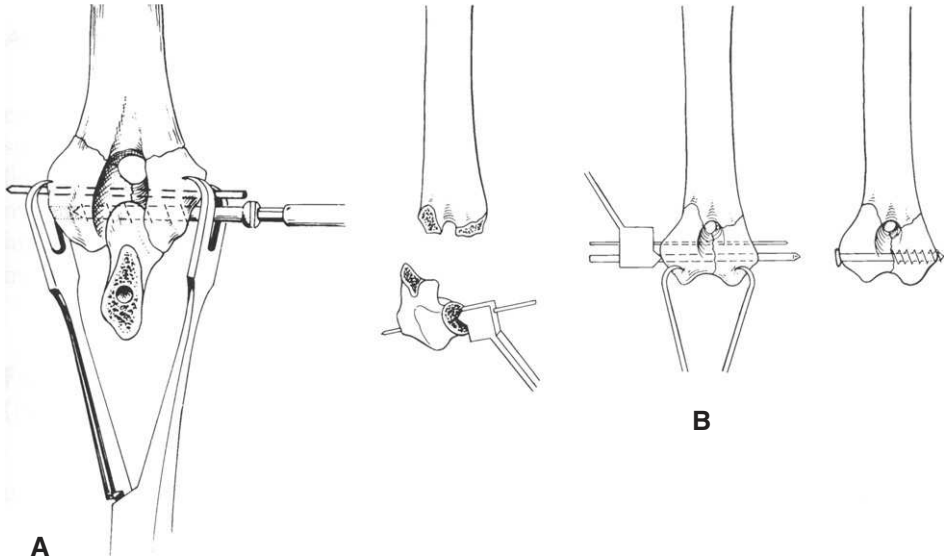


FIGURE 11-33. Methods of fixation for type C distal, complete articular fractures of the humerus. Reduction is usually maintained during the fixation procedure by use of a vulsellum forceps and transcondylar Kirschner wire. **A,** The hole may be drilled and the screw inserted directly from the medial or lateral surface or, **B,** from the fracture surface. The K-wire is usually removed after lag screw insertion.

The transcondylar bone screw is then inserted with a lag effect. It now remains to fix the supracondylar fracture, which is done in the same manner as described for type 1-3-A distal extraarticular fractures. The method is dictated by the fracture pattern, size of the animal, and the equipment available. The objective is rigid uninterrupted fixation that is capable of withstanding considerable abuse during the healing period. Documentation studies on T-Y fractures of the humerus indicate that less-than-adequate fixation in this area is the most frequent cause of failure.[14] Bone plate fixation has the highest percentage of successful results, especially in type C2 and C3 fractures. In most cases it is advantageous to carry out the reduction and fixation of the condyle first. In some cases, however, it may be advantageous first to reduce and fix one of the condyles to the humeral shaft and then reduce the remaining condyle and insert the transcondylar bone screw. Figure 11-34 presents some suggested methods of fixation of the supracondylar fracture.

Type C1 Fracture

An IM pin is inserted in retrograde fashion at the fracture site (Figure 11-34, *A* and *B*) and then driven back into the medial epicondyle (see Figure 11-26). An additional pin is inserted just distal to the lateral epicondylar ridge and directed diagonally through the epicondylar crest, across the fracture, and through the medial cortex of the shaft. This provides good two-point fixation if the fracture is of the stable type. Alternatively, fixation can also be accomplished using two Rush pins (Figure 11-34, *C* and *D*) or by a caudomedial bone plate (Figure 11-34, *G*).

An IM pin can also be used in combination with one or more lag screws when the wedge fragment is long enough to accept a lag screw proximally (Figure 11-34, *E*). This provides interfragmentary compression and is preferable to the use of a diagonal pin, when applicable. If the arms of the Y fracture are relatively long, they may be attached using several lag screws (Figure 11-34, *F*).

Type C2 Fracture

A bone plate inserted caudally along the medial epicondylar crest and shaft (Figure 11-34, *G*) is applicable for most type C2 wedge fractures. This plate must be carefully positioned on the crest to avoid interference with the olecranon process within the supratrochlear foramen. Because the bone is almost perfectly straight in this region, minimal contouring of the plate is necessary. The distal screws are quite long and well anchored in the medial condyle, but care should be taken not to penetrate the articular surface cranially. It is necessary to add lag screw or pin fixation to the wedge fragment. In some cases, these fractures may be fixed by combining the methods shown in Figure 11-34, *A* and *E*, with both a lag screw proximally and a pin distally in the wedge fragment, combined with an IM pin.

Type C3 Fracture

Double-plate fixation is the safest method of fixation in this situation[16] (Figure 11-34, *H*). The medial plate can be applied either to the caudal surface of the epicondylar crest, as shown here, or to the medial surface of the distal shaft and epicondylar crest. The difficulty with this position for the plate is that unless the most distal screws can be angled cranially into the condyle, they can only penetrate one cortex, or they will enter the supratrochlear foramen.

Aftercare

It is important to maintain motion in the elbow joint postoperatively, so no external splintage is employed. Passive ROM exercise is started as soon as tolerated. If the animal seems likely to damage the fixation, a carpal flexion bandage will

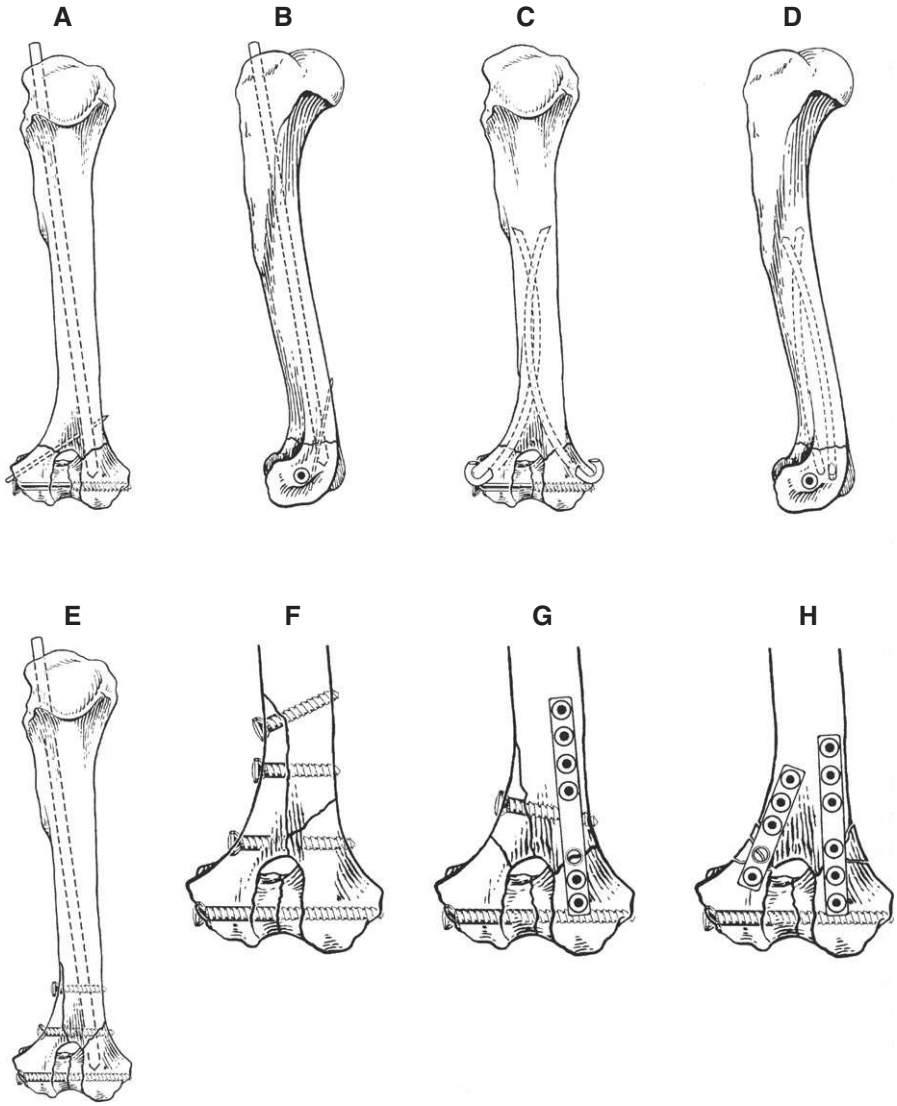


FIGURE 11-34. Fixation techniques for type C distal, complete articular fractures of the humerus. In all cases the transcondylar screw is placed first, followed by reduction of the supracondylar fracture line. **A** and **B,** Type C1 fracture stabilized with a Steinmann IM pin inserted retrograde at the fracture site and seated in the medial aspect of the condyle. An additional pin, inserted just distal to the lateral epicondylar ridge and directed obliquely across the fracture through medial cortex of the shaft, gives good two-point fixation in these stable fractures. **C** and **D,** Fixation of type C1 fracture using two Rush pins. **E,** An IM pin in combination with lag screws gives interfragmentary compression to all fragments when the fracture lines permit. **F,** If the fracture lines are relatively long, they can all be stabilized using lag screws in a type C1 fracture. **G,** Type C2 and C3 fractures are best fixed using two small bone plates placed caudally on both epicondylar crests. **H,** Fixation of a type C1 fracture using one bone plate inserted caudally along the medial epicondylar crest, with a K-wire in the lateral epicondylar crest for additional rotational stability.

protect the fixation while still allowing motion of the elbow joint (see Figure 2-30). Exercise is limited during the healing period, and IM pins are removed after healing. Other implants are left in place unless migration or soft tissue irritation is encountered. Prognosis is less than optimistic for type C fractures, with only 52% attaining good to excellent results in one study.[14]

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12
The Elbow Joint

TRAUMATIC LUXATION OF THE ELBOW

Because of the bony anatomy of the region, virtually all elbow luxations are lateral (Figure 12-1). The large, square caudodistal corner of the medial epicondyle of the humerus prevents the ulna from moving medially, whereas the rounded shape of the lateral epicondyle permits the anconeal process to clear the lateral epicondylar crest when the elbow is flexed more than 90 degrees. When medial luxations are seen, they are usually accompanied by severe ligamentous damage.

Clinical Signs

The general appearance of an animal with a lateral luxation is distinct, but similar to infraspinatus contracture (see Figure 10-28). Palpation easily differentiates the condition, with the laterally displaced radius and ulna being quite prominent. The antebrachium and foot are abducted, and the elbow is flexed. There is usually marked pain and increased elbow width, with resistance to flexion and extension. Because of elbow flexion, the foot does not touch the ground when the animal is standing or sitting.

Diagnosis

Although the basic diagnosis can be made by physical examination, radiographs in two planes are necessary to look for associated fractures and avulsion of ligaments.

Treatment

Closed Reduction

Many lateral luxations can be reduced closed during the first few days after injury. Muscle contracture makes later reduction more difficult. The rarity of this condition and the lack of experience opportunities by clinicians contribute to reduction difficulties.

With the animal under general anesthesia, firm palpation is used to establish the position of the humeral condyles relative to the radius and ulna. In some cases the anconeal process will still be inside (medial to) the lateral epicondylar crest. In such a patient, medial pressure is maintained on the olecranon while the elbow is flexed

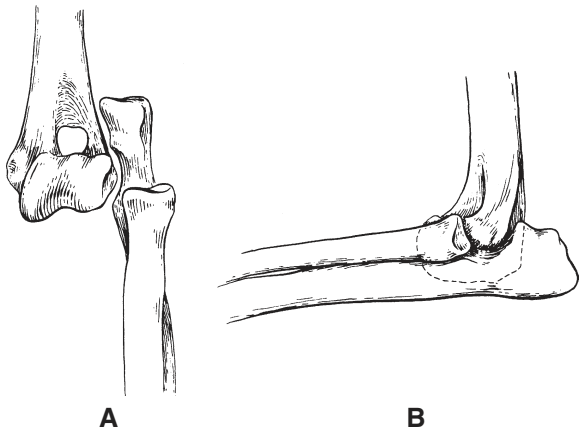


FIGURE 12-1. Lateral luxation of the elbow. **A,** Craniocaudal view. **B,** Lateromedial view. Note that in this case the anconeus is completely luxated.

to 100 to 110 degrees. Medial pressure is then placed on the radial head to force it under the humeral capitulum to the reduced position. The elbow is also abducted. If medial pressure on the radial head does not bring about reduction, additional pressure can be exerted by slightly extending the joint to lock the anconeal process inside the lateral epicondylar crest. The antebrachium should then be twisted inward (pronated) and adducted while abducting the elbow, causing the radial head to slip medially relative to the fixed fulcrum of the anconeus.

If the anconeal process lies lateral to the lateral epicondyle, an additional step is required. With the elbow flexed to 100 to 110 degrees, the antebrachium is twisted inward (pronated) to force the anconeal process inside the lateral condyle (Figure 12-2, *A*). The joint is extended slightly, then flexed while medial pressure on the radial head is continued. With pronation the radial head can be forced under the capitulum (Figure 12-2, *B*), especially with *abduction* of the elbow.

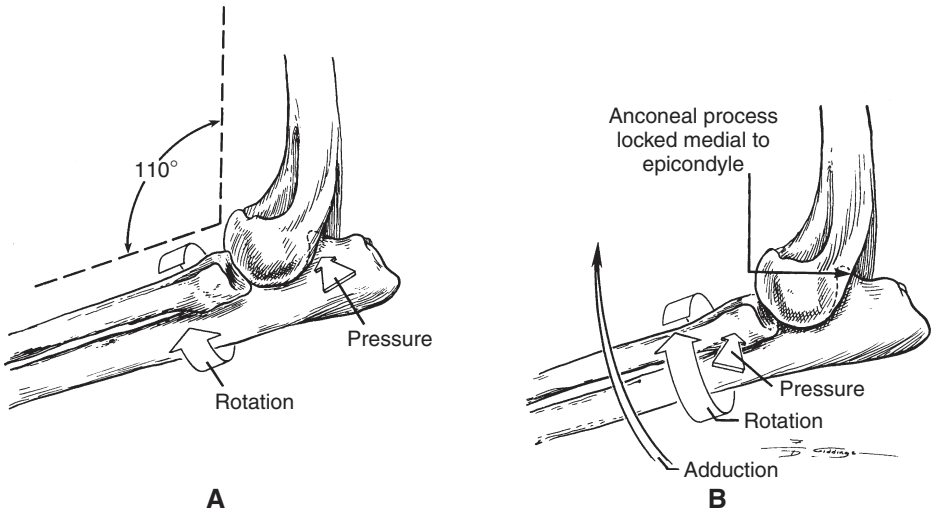


FIGURE 12-2. Closed reduction of lateral luxation of the elbow. **A,** With the elbow flexed to 100 to 110 degrees, the antebrachium is twisted internally, and the joint is slightly extended to lock the anconeal process inside the lateral epicondyle. **B,** Continuous inward pressure is maintained on the radial head while the antebrachium is internally twisted. Gradual flexion and adduction of the antebrachium and abduction of the elbow force the radial head medially, using the anconeal process as a fulcrum.

After reduction, evaluation of ligamentous damage is necessary. Although most luxations can be reduced closed, a few will require open reduction. A straight craniocaudal radiograph of both elbows is necessary to ascertain full reduction.

Examination of Collateral Ligaments

The collateral ligaments of the elbow (Figure 12-3) are intimately associated with the tendons of origin of the extensor (lateral) and flexor (medial) muscles and may be difficult to differentiate from these tendons at surgery.

The collateral ligaments are evaluated by the method of Campbell.[1] After reduction the elbow and carpus are both flexed to 90 degrees. Rotation of the paw laterally and medially causes similar rotation of the radius and ulna, which

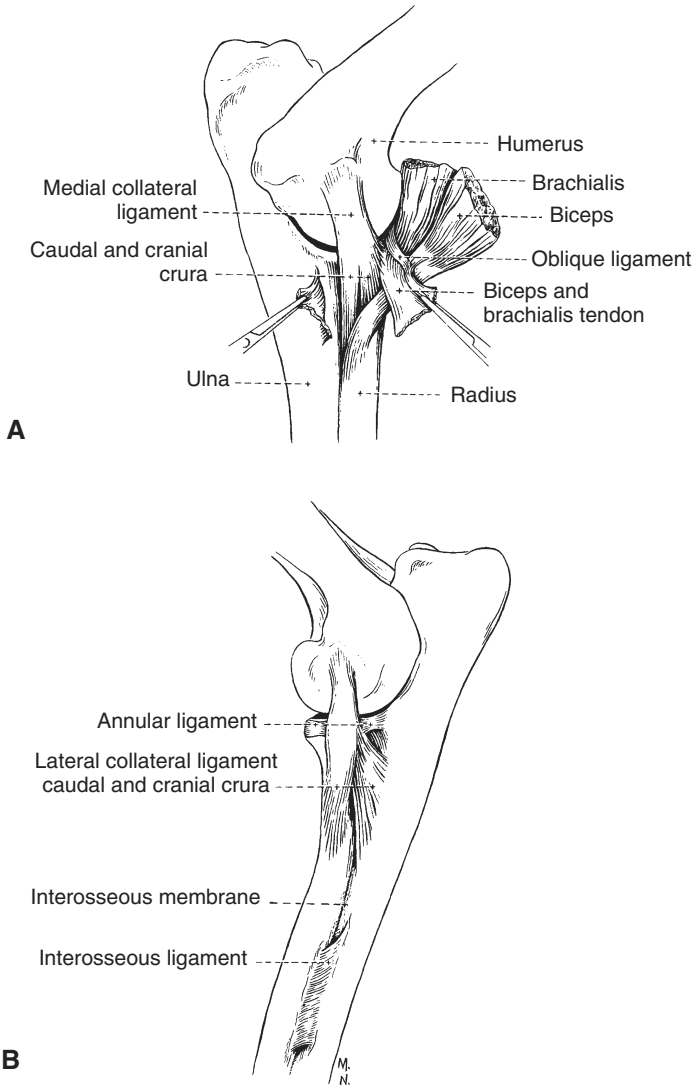


FIGURE 12-3. Collateral ligaments of the elbow. **A,** Medial ligaments of the left elbow. **B,** Lateral ligaments of the left elbow. (From Evans HE: *Miller's anatomy of the dog,* ed 3, Philadelphia, 1993, Saunders.)

are constrained at the elbow by the collateral ligaments. If these ligaments are intact, lateral rotation of the paw is possible to about 45 degrees and medial rotation to about 70 degrees. If the lateral collateral is severed or avulsed, the paw can be rotated *medially* to about 140 degrees. If the medial ligament is damaged, the paw can be rotated *laterally* to about 90 degrees. In both cases, the paw rotation is about double the normal and can be compared with the opposite limb.

Excessive movement indicates damage to the collateral ligaments, and the clinician must decide whether surgical treatment is indicated. If the joint is easily reluxated, the decision for surgical repair is simple to make. If the joint is reasonably stable despite the signs of ligament damage mentioned, the decision is more difficult. Immobilization will allow healing by fibrosis of periarticular soft tissues and may provide sufficient stability for smaller breeds, especially if they are not athletic or working animals. Conversely, surgical treatment is more often indicated in larger and more active animals.

Open Reduction

The elbow is exposed by a limited approach to the head of the radius and lateral compartments of the elbow joint.[2] This approach may be used up to 6 to 7 days after injury. Organized hematoma and shreds of ligament muscle and joint capsule are cleared from the joint. Occasionally an avulsed collateral ligament is folded into the joint, precluding total reduction, and can be retracted to its normal position and sutured. The procedure then continues as for a closed reduction. It may be necessary to use a smooth-surfaced instrument such as closed scissor blades or a bone lever to pry the radial head into the reduced position. Because of the inevitable damage to articular cartilage, this maneuver should be avoided if possible, but damage may be minimized by protection of the instrument with a piece of sterile catheter.

If reduction is still not possible, it may be necessary to extend the exposure by performing the caudal approach with osteotomy of the olecranon process.[2] This allows debridement of granulation and scar tissue in chronic cases. It also relieves the tension exerted by the triceps muscle and simplifies reduction. After reduction, necessary repairs are performed as explained in the following discussion.

Repair of Ligaments

The surgical principles governing repair of ligamentous injuries are discussed in Chapter 7. Stretched ligaments are plicated (shortened), torn ligaments are sutured, and avulsed ligaments are reattached. Occasionally, ligaments are totally replaced or supplemented with various synthetic materials, although this is rarely necessary in the elbow.

Figure 12-4 illustrates repair of the lateral collateral ligaments. The elbow is approached laterally, with transection of the tendinous origin of the ulnaris lateralis[2] (Figure 12-4, *A*). The ligament is sutured or reattached to the bone (Figure 12-4, *B*). The adjacent extensor muscles are plicated with mattress sutures in the tendinous areas (Figure 12-4, *C*). If ligaments are shredded, a "prosthetic ligament" can be constructed by passing nonabsorbable suture material from holes placed across the lateral epicondyle and head of the radius. Similar repairs are done medially if both ligaments are damaged. If the ligaments are torn near their distal insertions, they can be attached by suturing to the annular ligament. Damage in the midportion of the ligament is handled by suturing, using the locking loop suture described in Chapter 7.

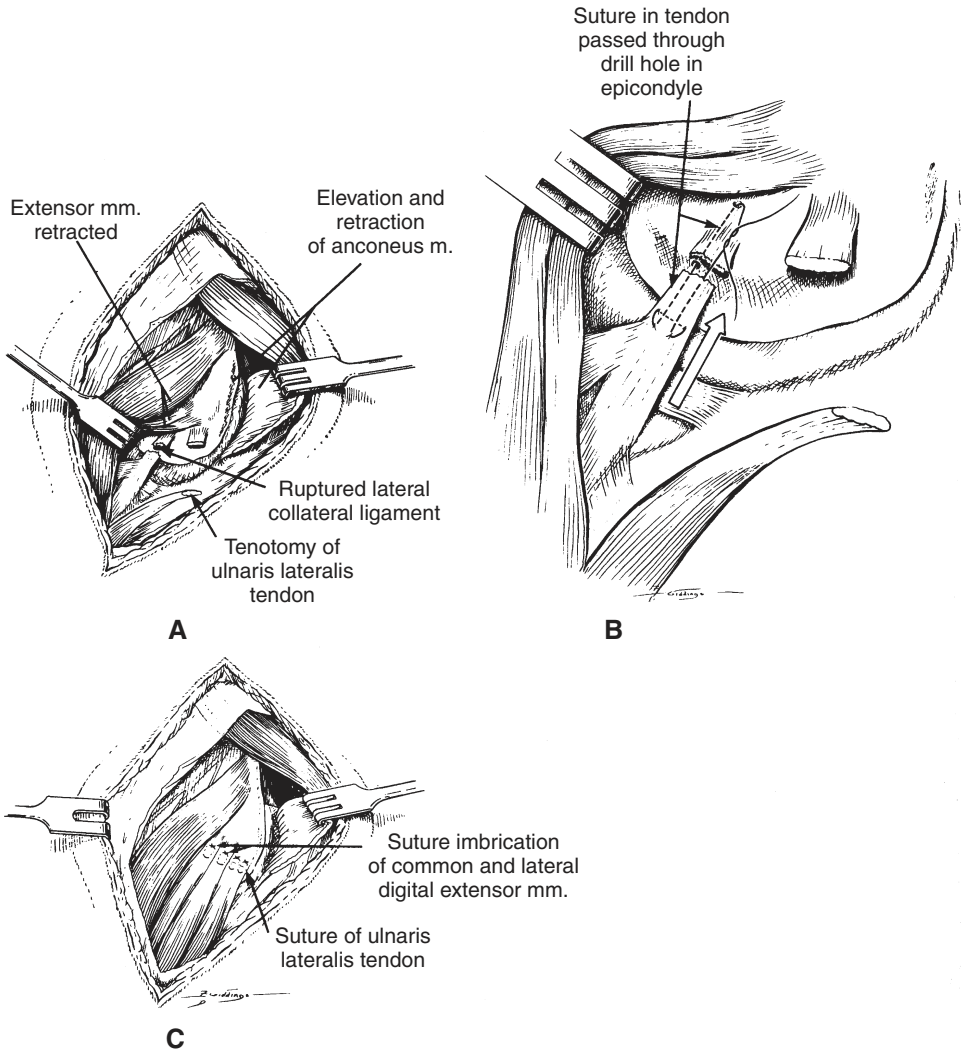


FIGURE 12-4. Surgical repair of lateral collateral ligaments of the elbow. **A,** The left elbow has been exposed by a lateral approach with tenotomy of the ulnaris lateralis. Retraction of the other extensor muscles exposes the torn ligament. **B,** The ligament has been torn close to the humerus. A locking loop suture has been placed in the ligament. One end of the suture is passed through a bone tunnel in the epicondyle to allow the ligament to be pulled to the bone. **C,** The common and lateral digital extensors are imbricated with mattress sutures, and the ulnaris lateralis is sutured.

Aftercare

Closed or Open Reduction with No Ligament Damage

The elbow is most stable when moderately extended to about the normal standing angle of 140 degrees. Because the elbow joint is prone to lose range of motion as a result of periarticular fibrosis when completely immobilized, a soft splint (e.g., modified Robert-Jones dressing; see Figure 2-33) is useful. Immobilization for 5 to 7 days is usually sufficient if exercise is restricted to the house or leash for 2 more weeks. Passive flexion-extension exercises are started immediately after removal of the dressing. This is facilitated by flexing the carpus while flexing the elbow.

Closed Reduction with Ligament Damage

More rigid postoperative immobilization is needed with ligament damage despite the risk of joint stiffness. A spica splint (see Figure 2-23) or Thomas splint (see Figure 2-25) is maintained for 2 weeks. Passive flexion-extension exercise is important after splint removal. Exercise is restricted to the house or leash for 3 to 4 more weeks.

Ligament Damage Surgically Repaired

Aftercare is similar to that for ligament damage, except that the splint is maintained for 3 weeks.

DEVELOPMENTAL ABNORMALITIES AFFECTING THE ELBOW JOINT

Disturbed growth resulting from traumatic physeal closure of either the radius or ulna can produce subluxation of the elbow and is covered in Chapter 23.

Congenital elbow problems include luxation, asynchronous growth of the radius and ulna resulting in elbow incongruity, luxation of the radial head, and the presence of unstable and irritating cartilaginous bodies with or without bone.

Congenital Luxation and Subluxation

Congenital luxation of the elbow is occasionally seen in small breeds of dogs (e.g., terrier, Lhasa apso, pug). It can occur at birth or anytime up to 3 to 4 months of age. A proposed mechanism is aplasia of the medial collateral ligament leading to hypoplasia of the coronoid and anconeal processes and a shallow trochlear notch.[3] The proximal ulna is typically twisted laterally 45 to 90 degrees (Figure 12-5). When diagnosed early (7-10 weeks of age) and if closed reduction can be achieved, one or two temporary Kirschner wires driven from the olecranon to the humerus, followed by a spica cast for 10 to 14 days, has been successful in our hands. In older pups (12-16 weeks old), reduction usually requires an ulnar osteotomy distal to the semilunar notch. After the ulna is placed in the humeral trochlea, small Kirschner wires are driven across the joint (Figure 12-6, *A*), followed by spica coaptation until pin removal 2 to 3 weeks later. These dogs, if reduction is maintained, do surprisingly well (Figure 12-6, *B*). If reduction cannot be maintained, amputation or later arthrodesis is the only alternative.

Elbow incongruity can be caused by physeal trauma or congenital factors. At times the inciting cause is difficult to determine. Chondrodystrophied breeds are prone to asynchronous growth between the radius and ulna, resulting in the ulna being too short relative to the radius (usual case) (Figure 12-7, *A*) or the radius being too short relative to the ulna (Figure 12-8, *A*). Traumatic physeal injuries resulting in elbow incongruity are covered elsewhere (see Chapter 23). In cases under consideration here, there is usually no known evidence of injury to the growth plate, and the cause is unknown. Hereditary factors must be considered in the breeding animal.[4] Radiographs of the semilunar notch should be carefully inspected for a loose coronoid fragment, which we have occasionally observed when the radius is too short relative to the ulna.

Radiographic Findings

Mediolateral projections with the joint in approximately 90 degrees of flexion are most useful (Figures 12-7, *A,* and 12-8, *A*), although the craniocaudal view should



FIGURE 12-5. **A,** Bilateral congenital luxation of the proximal ulna in a 9-week-old mixed-breed dog. Note the 90-degree or more internal rotation of the paw. Pressure sores of the cranial surface of the limb were present from abnormal weight bearing. **B,** Intraoperative view demonstrating the 90 degrees or more of rotation of the anconeal process *(a)* and olecranon. The humeral trochlea is located at *b*.

also be examined. Varying degrees of degenerative changes will be seen, depending on the age of the animal. Ununited anconeal process may be seen concurrently in breeds such as the basset hound that are prone to this problem.

1. Normally the bottom of the semilunar notch lies on the same level as the radial head (Figure 12-9, *A* and *B*). With ulnar shortening, the coronoid process region lies below the radial head (see Figure 12-7, *A*). In addition, the joint space surrounding the rounded humeral condyles may be pinched at the proximal anconeal process region and widened distally at the coronoid region (see Figure 12-7, *A*). With unusual



FIGURE 12-6. **A,** Lateral radiograph 2½ weeks after surgery on the elbow of the dog in Figure 12-5, *A*. **B,** Lateral radiograph of the dog in Figure 12-5, *A*, taken 2½ months after bilateral elbow surgery. Note the elbow congruity. The puppy's forelimb function at this time was described by the owner as "normal."

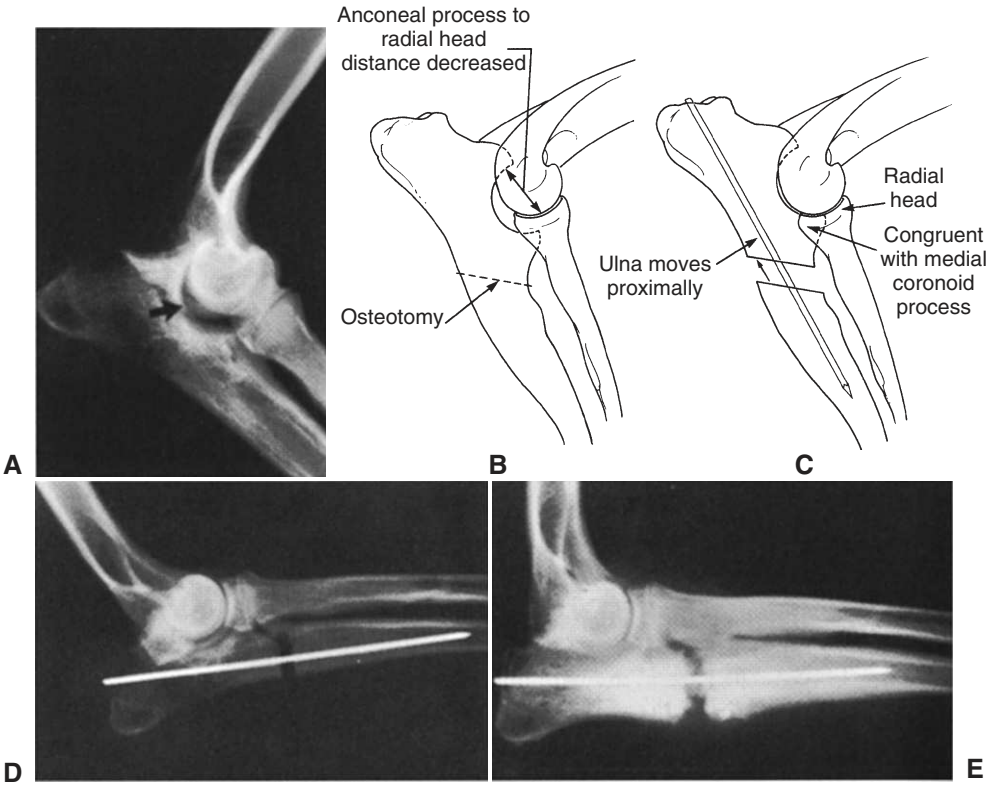


FIGURE 12-7. Incongruity of the elbow in the growing dog; the ulna is too short relative to the radius. **A,** This mediolateral radiograph of elbow region illustrates that the trochlear notch *(arrow)* is not congruent with the radial head, resulting in subluxation of the humeroulnar joint. **B,** Drawing illustrates the changes seen radiographically in *A*. Note the position and angle of the osteotomy. **C,** After osteotomy of the ulna, the proximal ulna is free to move proximally because of muscular forces. **D,** Postoperative radiograph of the case shown in *A*. Note the congruity of the trochlear notch of the ulna and the humeral condyles. A transverse osteotomy was performed here. **E,** Three weeks postoperatively the ulnar gap is being bridged by callus, and the humeroulnar joint is congruent. Normal exercise can be resumed. (**B** and **C** from Gilson SD, Piermattei DL, Schwarz PD: *Vet Surg* 18:114, 1989.)

cases the radial head lies distal to the coronoid region because of radial shortening (Figure 12-8, *A*).

2. The usual surgical options for elbow incongruity involve lengthening the ulna (Figure 12-7, *D*), when the ulna is too short relative to the radius; shortening the ulna (Figure 12-8, *D*), when the radius is too short relative to the ulna; or lengthening the radius (see Figure 23-15), when the radius is too short. Lengthening the radius requires bone plate or external fixation, which is a more expensive procedure than altering the ulna, which is usually repaired with pins, or no internal fixation. (See Chapter 23 for further details.) As mentioned, with total ulnar luxation (see Figures 12-5 and 12-6), an ulnar derotational osteotomy is used.

Surgical Alternatives

The clinician must decide how much surgical limb shortening is acceptable in an already-shortened limb. A crude method for ascertaining limb length relative to the normal side during the physical examination is to align both olecranon regions

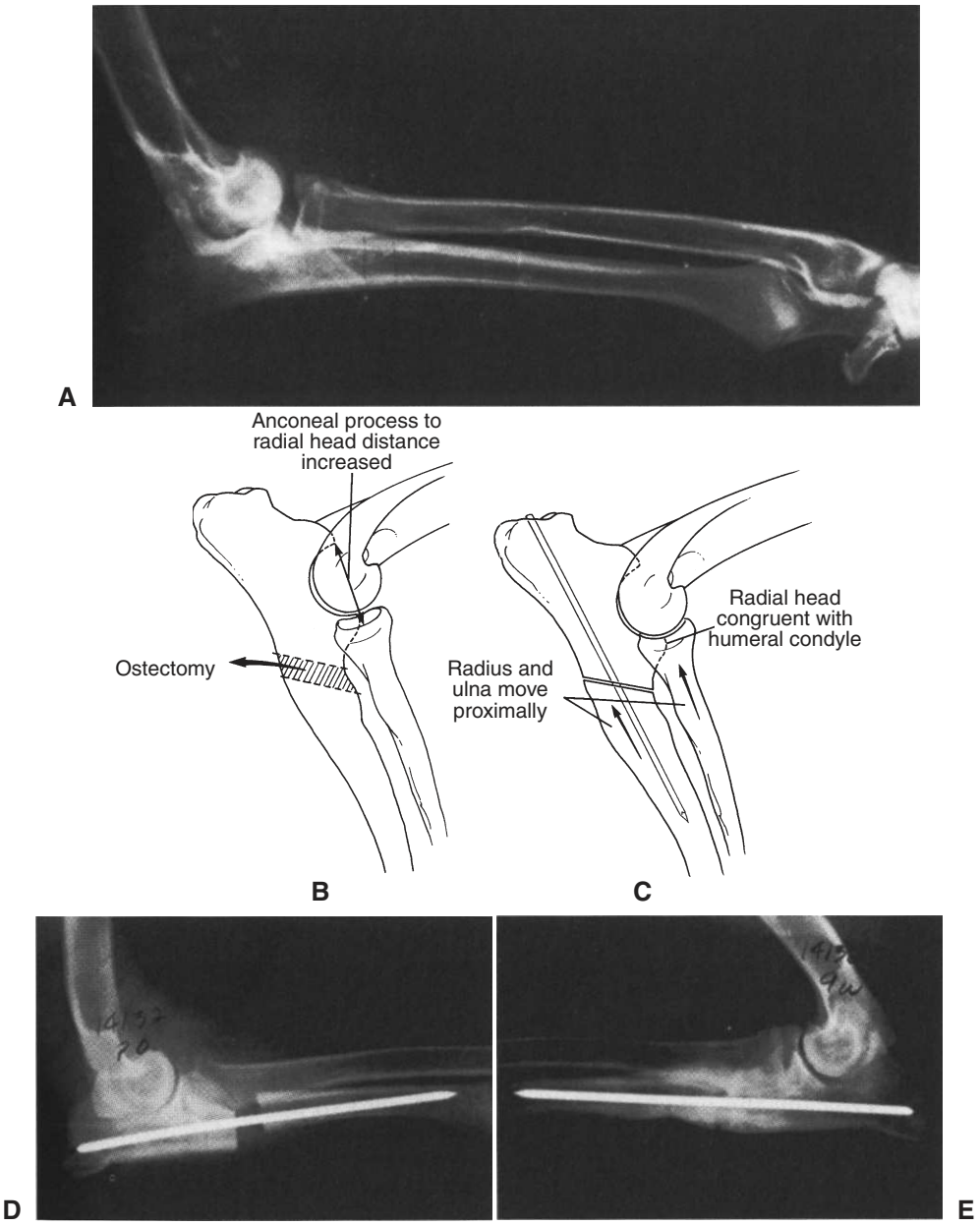
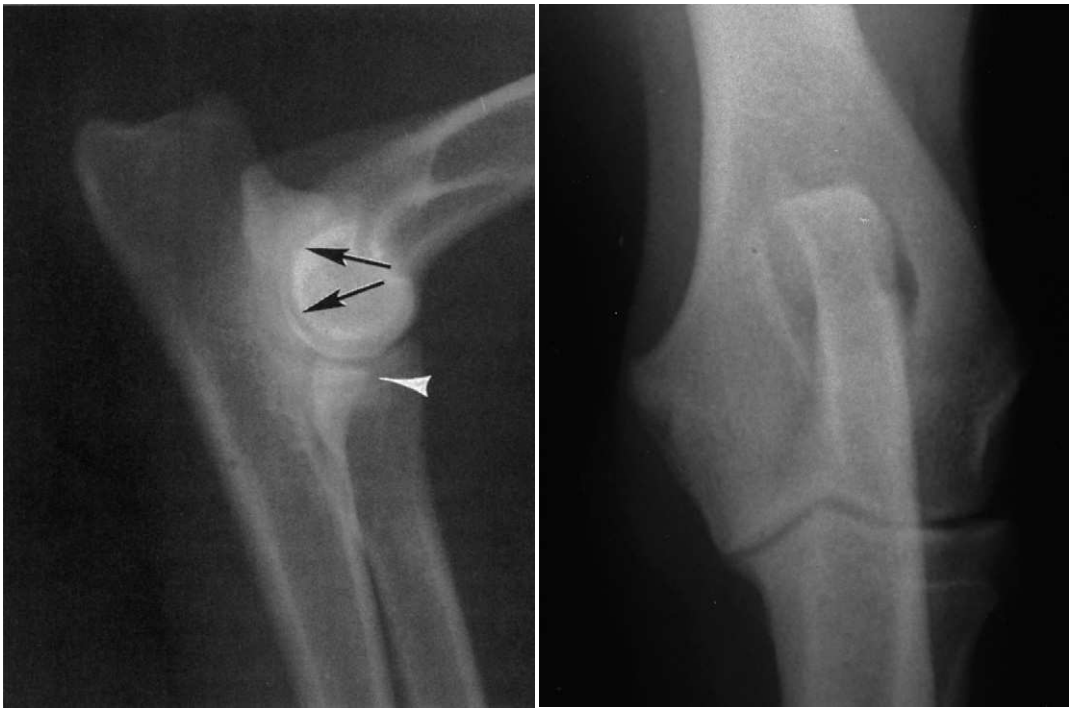


FIGURE 12-8. Incongruity of the elbow in the growing dog; the radius is too short relative to the ulna. **A,** This mediolateral radiograph of elbow region illustrates a gap between the humeral condyle and the radial head, resulting in subluxation of the humeroradial joint. **B,** Drawing illustrates the changes seen in *A* and the site for the ulnar ostectomy. **C,** After ostectomy the radius and distal ulna are pulled into reduction by muscular forces. **D,** In the postoperative radiograph the gap between the humeral condyle and the radial head has been partially reduced. An overly generous section was removed from the ulna. **E,** At 9 weeks postoperatively the ulna has healed and the humeroradial joint is congruent. (**B** and **C** from Gilson SD, Piermattei DL, Schwarz PD: *Vet Surg* 18:114, 1989.)



A B

FIGURE 12-9. **A,** Lateral radiograph of a normal elbow. Note the contour of the semilunar notch and its even joint space *(black arrows)*. The rounded coronoid process *(white arrowhead)* lies on the same level as the radial head. **B,** Craniocaudal radiograph of a normal elbow.

parallel to each other and evaluate the relative position of the toe length. If the toes lie within 1/2 inch of each other, perhaps another 1/2-inch shortening of the radius would be acceptable. If the toe discrepancy is worse, however, and the radius is more than 1/4 inch short at the elbow, radial lengthening should be considered.

When the ulna is too short, an ulna-lengthening osteotomy is performed, and the osteotomy site is wedged apart. The insertion of a small, nonthreaded intramedullary pin and Kirschner wires provides some fixation (Figure 12-7, *B* and *C*) but still allows muscular forces to reduce the proximal ulna on weight bearing. This situation has a better chance of being truly anatomical than the surgeon's estimation of reduction. The intramedullary pin prevents the osteotomy site from "jackknifing," which could result in persistent lameness. Limb length is unaffected, and the surgical procedure is simple and effective.[5]

Alternatively, some surgeons prefer to perform the osteotomy in the distal third of the ulna, obviating pin insertion and removal. However, elbow joint exposure with visualization of the reduction is usually not performed. With either technique, active controlled limb use is encouraged postoperatively to allow muscular forces to provide final fine-tuning of the reduction.

Ulna Too Short

The ulna is exposed by a caudal approach to the proximal shaft of the ulna.[2] The joint capsule is incised on both sides of the ulna in the distal trochlear notch area

to allow joint visualization. An oblique osteotomy of the ulna is performed distal to the trochlear notch (Figure 12-7, *B*). This cut should be made with a Gigli wire saw or power saw, because an osteotome may split this hard bone. Typically the osteotomy will spontaneously gap apart as the osteotomy is completed, illustrating the dynamic muscular forces working on the proximal ulna. If this is not the case, a periosteal elevator is used to break down the interosseous membrane until the proximal ulna can be moved by forcing the osteotomy gap apart. A small, nonthreaded intramedullary pin or Kirschner wire, 1/8 to 3/32 inch in diameter (1.6-2.4 mm), is driven from the tuber olecrani across the osteotomy and seated into the midshaft region of the bone (Figure 12-7, *C* and *D*). The oblique osteotomy and the pin protect against angular displacement of the tuber olecrani from triceps muscle forces.

Radius Too Short

If the radius is too short in relation to the ulna, a similar approach is made to the proximal ulna. An ostectomy of the ulna distal to the trochlear notch is performed instead of a simple osteotomy (Figure 12-8, *B* and *C*). The width of the removed bone must be sufficient to allow the radius and distal ulna to move proximally until the radial head articulates normally with the lateral aspect of the humeral condyle. Some narrowing of the gap will be seen postoperatively (Figure 12-8, *D*). A pin is driven as in the previous case of ulnar shortening. If a radial lengthening is performed, stability must be rigid and is accomplished by plate fixation or an external fixator (see Chapter 23).

Aftercare and Prognosis

With either type of surgery previously described, it is important that early, active weight bearing of the limb be achieved. A padded bandage is applied and nonsteroidal antiinflammatory drugs (NSAIDs; see Chapter 6) are administered to help reduce pain and inflammation. Leash walking and limited free exercise are encouraged. Full activity is resumed after healing is confirmed by radiography (Figure 12-8, *E*). If a lengthening procedure of the radius is performed (see Figure 23-15), excessive activity could cause premature implant loosening in overly soft bone. Therefore, coaptation and very limited activity are recommended for several weeks.

The prognosis in these incongruent elbows depends on the severity of the incongruency, growth potential remaining after repair, and age at time of repair. If surgery is performed successfully at 6 to 7 months of age, the prognosis is very good. If surgery must be performed at a younger age due to severity, multiple surgeries may have to be done to achieve lasting congruency. If the incongruency is severe and surgery occurs later than 8 to 9 months of age, remodeling of the joint surfaces may be impossible, and significant degenerative joint disease may ensue.

If surgery is done before degenerative joint disease is established, good results can be expected.[5]

Congenital Luxation of Radial Head

This uncommon condition is seen in young chondrodystrophic breeds and sporadically in other breeds, including the Akita.[6] The radial head migrates lateral relative to the humeral epicondyle, along with ulnar shortening. Luxation may be partial or total, in which case the medial side of the radial head lies lateral to the non–weight-bearing aspect of the humeral epicondyle and is nonfunctional. Subluxation is common in chondrodystrophied breeds and at times may be relatively asymptomatic,

whereas luxation can be very painful and result in severe elbow changes. This condition is often bilateral.

Clinical Signs

Beginning at 2 to 4 months of age, there is forelimb lameness, elbow swelling, valgus deformity of the carpus, and varus deformity at the elbow (Figure 12-10).

Physical Examination

The limb deformities are noted, and crepitus may be palpated. The radial head lies more lateral than the humeral epicondyle (Figure 12-11, *A* and *B*).

Radiographic Findings

On the craniocaudal radiographic view, a subluxated radial head lies more lateral than normal, but it still articulates somewhat with the weight-bearing surface of the humerus. A luxated radial head lies lateral, proximal, and caudal to the humeral weight-bearing surface (see Figure 12-11). The ulna may be bowed.

Pathogenesis

A proposed mechanism is ulnar physeal injury or improper intraarticular annular ligament formation, as well as hereditary factors.[4] The semilunar notch probably becomes a more important weight-bearing structure as the radius becomes nonfunctional.

Treatment

The radial articular surface becomes extremely deformed when luxated in very young puppies. Therefore, reduction should be achieved early. A corrective osteotomy with radial shortening, if done before 4½ months of age, will result in reluxation as asynchronous growth continues, thereby necessitating another surgical correction. Unfortunately, if performed after 5½ months of age, remodeling of the thinner articular cartilage is less likely. After osteotomy the radial head is reduced and stabilized with pins (Figure 12-12) or a plate. Postoperative care

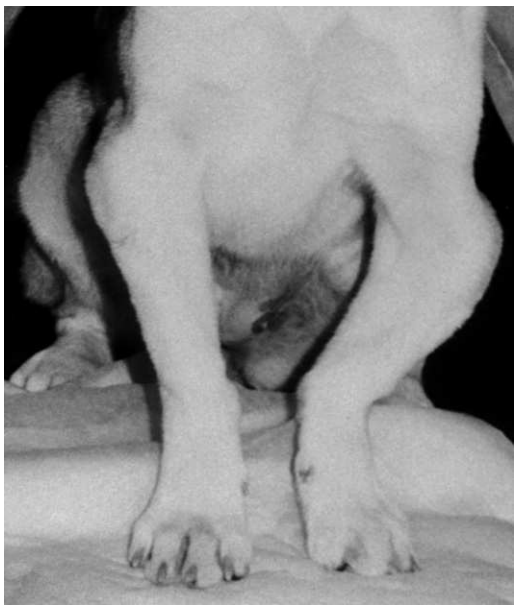


FIGURE 12-10. This 8-month-old Akita has severe radial head luxation and varus of the left elbow. The right radial head is also luxated.

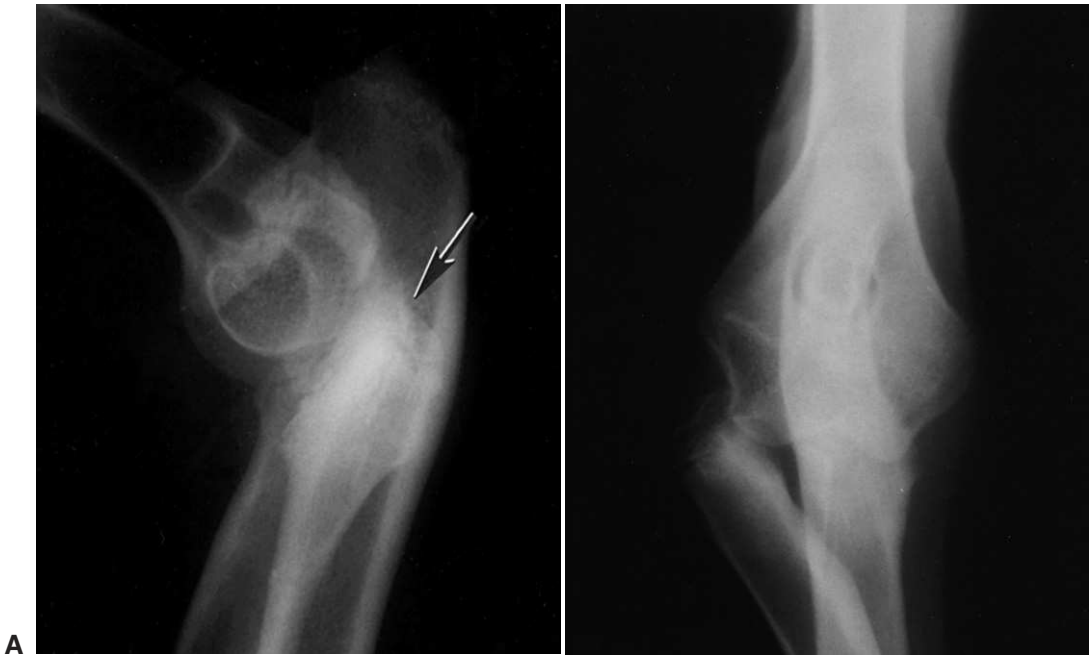




FIGURE 12-11. **A,** Lateral radiograph demonstrates caudal and proximal displacement of the radial head *(arrow)* of a 4 1/2-month-old German shepherd. **B,** Craniocaudal radiograph of the dog in *A* demonstrates lateral displacement of the radial head. **C,** Intraoperative photo of a deformed radial head *(a)* of a 3-month-old basset hound lying lateral and proximal to the articular weight-bearing surface of the humerus *(b)*.



FIGURE 12-12. Healed corrective osteotomy of the proximal radius with pin fixation that was performed in this basset hound at 4 months of age.

includes bandaging for 7 to 24 days and severe activity restriction until radiographic evidence of bone healing (4-8 weeks).

Another procedure that can be performed in the 6- to 7-month-old dog is a lengthening procedure of the ulna (see Figure 12-7, *B*). This allows reduction of the intact radius, which is then stabilized to the ulna utilizing screw fixation.[4]

A third option that we have used successfully in a few cases involves amputating the radial head and neck (Figure 12-13). This is a simple, less costly procedure. However, stability of the elbow is less than if the humeral radial joint can be saved. Activity is restricted for 3 to 4 weeks.

OSTEOCHONDROSIS OF THE ELBOW

Four conditions of the elbow are presumed to be a result of osteochondrosis: (1) ununited anconeal process (UAP), (2) osteochondritis dissecans (OCD) of the medial humeral condyle, (3) ununited or fragmented coronoid process (FCP), and (4) ununited medial epicondyle (UME), also known as calcification of the flexor tendons. Each is discussed in the following sections.

Ununited Anconeal Process

UAP is found primarily in large-breed dogs, especially German shepherds, basset hounds, and the Saint Bernard. It is characterized by failure of the ossification center of the anconeus to fuse with the olecranon by 5 months of age. Instability or detachment of the process leads to eventual osteoarthrosis of the elbow joint. This condition can be bilateral.

Hayes and associates[7] observed a positive association between risk and adult body weight; they suggested that in addition to familial genetics and hormonal factors, growth plate trauma associated with rapid or long periods of growth might be involved in the etiology. Olsson[8,9] has suggested that UAP is a manifestation of osteochondrosis, that is, a failure of endochondral ossification of the physeal cartilage.

The anconeal process has a separate ossification center in some of the larger breeds. It is not ossified and therefore not visible radiographically until 12 to 13 weeks of age. It does not unite to the proximal ulna until 16 to 20 weeks of age in the German shepherd and somewhat later in the Saint Bernard and basset hound. Therefore the diagnosis of UAP should not be made until 5 months of age in the German shepherd, which is the breed most affected in the United States. We have seen spontaneous reattachment between 7 and 8 months of age in the Saint Bernard and basset hound.

Wind[10] believes a growth disturbance of the proximal ulna results in an "elliptical" semilunar notch. It articulates poorly with the humerus, resulting in increased pressure against the anconeal process, thereby separating the thickened osteochondrotic physis. We have seen this obviously elliptical semilunar notch especially in the chondrodystrophied breeds.

Clinical Signs

Clinical signs of UAP are usually not apparent before 5 to 8 months of age. Occasionally, lameness is not evident until the dog is several years old. The signs consist initially of only a slight limp, with the lower limb and elbow slightly abducted. The swing phase of gait is limited by reduced motion at the elbow joint, which is virtually locked. The elbow circumducts laterally during the swing phase of gait. The dog stands and sits with the carpus in valgus and the paw externally rotated, and the toes often seem widespread (Figure 12-14). Crepitus on flexion-extension is more likely in older animals; joint effusion is also noticeable between

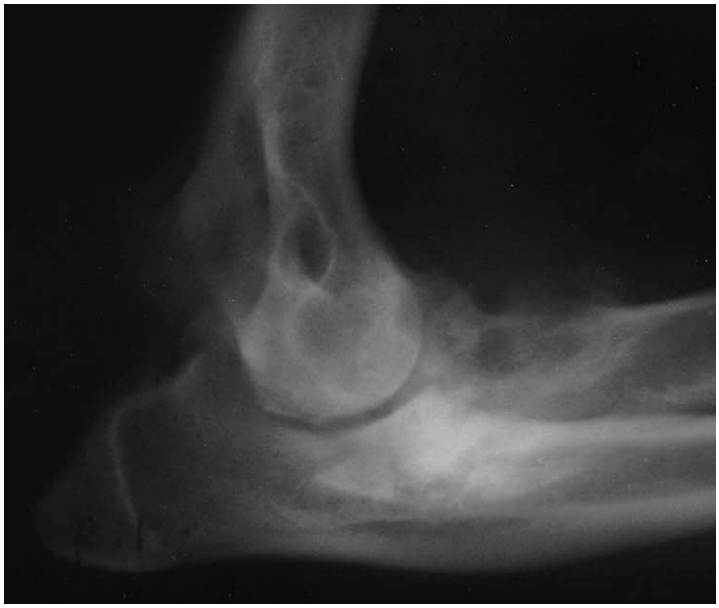


A

FIGURE 12-13. **A,** Lateral elbow radiograph of a 3-month-old basset hound after amputation of the radial head because of congenital luxation. Note the radial head and metaphysis cranial to the foreleg that were removed and placed on the radiographic cassette.



B



C

FIGURE 12-13. *Continued* **B,** Lateral elbow radiograph of the dog in *A*, 4 months postoperatively. This dog had good function, but the opposite radial head was now luxated. Note regrowth of a "new" radial head. **C,** Lateral elbow radiograph of a 9-year-old coonhound that underwent radial head amputation for radial head luxation 8 1/2 years previously. The dog was still able to hunt and only became slightly lame after a strenuous hunt.

the lateral epicondyle and the olecranon. This is best appreciated with the dog standing.

Diagnosis

Clinical signs, age, and breed form the basis for a provisional diagnosis of UAP; however, this must be radiographically confirmed. Both elbows should be examined. Acute flexion of the elbow moves the anconeal process distal to the medial epicondyle and facilitates visualization (Figures 12-15 and 12-16). In younger dogs there is a thin, linear black space between the anconeal process and the rest of the olecranon (Figure 12-15, *A*). In older dogs the anconeal process is often completely



FIGURE 12-14. Typical stance of a dog affected with bilateral elbow osteochondroses. Note varus of the elbows and valgus of the carpi.



A **B**

FIGURE 12-15. A, Extreme flexion of the elbow permits good visualization of this ununited anconeal process (UAP) in a 6-month-old dog. Note the wide lucent zone dividing the olecranon from the anconeal process (mediolateral view). **B,** In this 24-month-old dog the anconeal process has become completely detached and is seen at the proximal extent of the joint. Signs of joint incongruency and secondary degenerative joint disease are evident (mediolateral view).

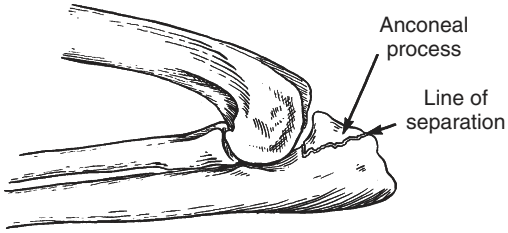


FIGURE 12-16. Ununited anconeal process (lateromedial view).

detached and lies in the supratrochlear foramen (Figure 12-15, *B*). Considerable arthritic changes in the form of osteophytes may be visible throughout the joint and are best visualized from the craniocaudal view.

Treatment

Surgical Excision

Removal of the anconeal process is the most widely practiced method of treatment for UAP. Although it is unquestionably true that the joint is mildly unstable with the process removed, it is much better to remove the source of inflammation and degenerative changes. In a series of 19 procedures on 16 dogs, with an average follow-up of 19½ months, good function was noted in most cases despite some loss of range of motion, crepitus, and arthritic changes.[11] Early removal—before marked arthrosis—produces the best results.

The elbow is exposed by a lateral approach to the caudal compartment of the elbow[2] (Figure 12-17, *A*). Considerable synovial hyperplasia may need to be resected to visualize the process adequately. Usually, the anconeal process is still attached to the ulna by a fibrous tissue and must be sharply dissected to free it. This is usually accomplished with a narrow osteotome, periosteal elevator (Figure 12-17, *B*), or scalpel blade. Grasping the process with a small, pointed bone clamp or towel clamp aids in removing it from the joint. The anconeal process may be completely

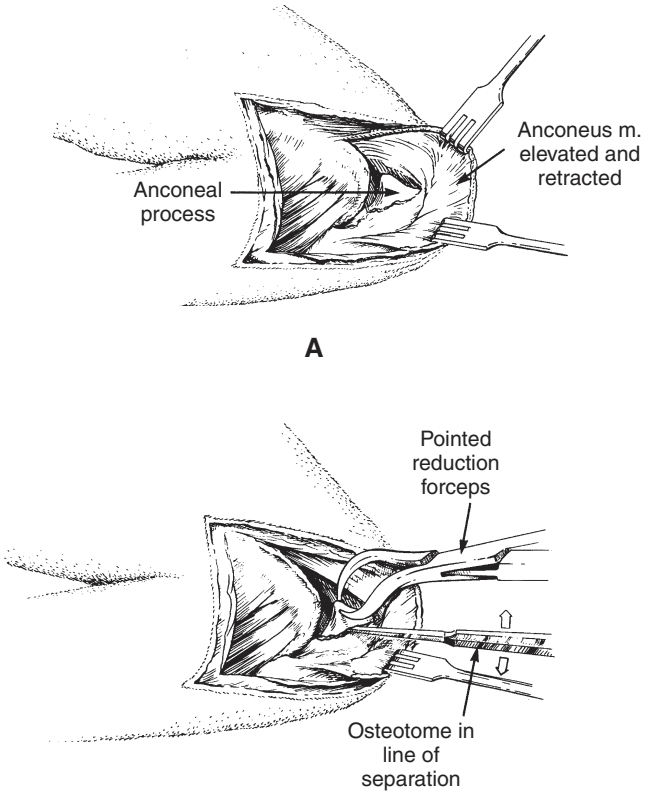


FIGURE 12-17. Surgical removal of ununited anconeal process. **A,** The left elbow has been exposed by an approach to the caudal compartment of the elbow joint.[2] With the anconeus muscle retracted, the anconeus is visualized. **B,** A narrow osteotome is being used to free the anconeal process from the ulna. Grasping the process with a small, pointed bone forceps aids in removing the process.

free within the joint, particularly in older dogs. In such cases, it may migrate to the proximal portion of the joint (Figure 12-15, *B*). The process usually is not well attached and can be removed quite easily.

Occasionally the separation area is not readily observable. Approximately one third the way down the semilunar notch, a small cartilage defect may be noted. Gentle probing may cause the nonunion area to "give way." The process removed is usually 25% to 30% larger than appreciated from the radiograph because of its cartilaginous surfaces.

Screw Fixation

Repair of the UAP by screw fixation has been advocated.[12,13] It is true that when a lag screw is properly placed, the anconeal process will heal. The difficulty in this approach lies in properly placing the screw. The primary consideration is that the process must be perfectly positioned, or it will interfere with one of the humeral condyles on extension of the elbow. The wobble induced by such interference results in fatigue fracture of the screw. Screw fixation has the best chance of success in the animal that is presented early, between 5½ and 6 months of age. In this circumstance the process is still firmly attached to the ulna and has not moved. This ensures that fixation of the process will be in an anatomically perfect position. The screw is placed from the caudal side of the ulna by first drilling a tap hole from the anconeal process caudally through the ulna, then drilling a glide hole from the caudal ulnar side. This eliminates having the screw head in the joint, as the original technique described.[12,13]

Lengthening osteotomy of the proximal ulna also has been used, which reduces pressure of the anconeal process on the humeral trochlea and allows the UAP to unite. Preliminary results by others appear encouraging in selected cases.[14] We have seen this work in a few cases of UAP in conjunction with severe ulnar shortening in which release osteotomy was used to lengthen the ulna and improve congruity of the elbow.

Aftercare

Animals with significant joint effusion tend to have slow healing of soft tissue. Immobilizing the joint in a modified Robert-Jones dressing (see Figure 2-23) for 7 to 10 days aids significantly in preventing seromas and dehiscence.

Osteochondritis Dissecans of Medial Humeral Condyle

Osteochondritis dissecans (OCD) affects the medial condyle of the humerus, sometimes bilaterally, in the same dog populations that are affected by OCD of the shoulder. Although retrievers, Bernese mountain dogs, and Rottweilers between the ages of 5 to 8 months are the breeds most frequently affected, many other large breeds are affected as well. (See Chapter 6 for a general discussion of osteochondrosis.)

Clinical Signs

Affected dogs show a foreleg lameness or stiffness and stilted gait starting between ages 5 and 8 months. Occasionally, lameness is not obvious to an owner until later in life. Lameness is intensified by exercise and is often most prominent immediately after resting. Frequently, joint swelling can be palpated laterally between the lateral epicondyle of the humerus and the olecranon with the dog standing. There may be valgus of the carpus. Pain may be elicited by deep palpation over the medial collateral ligament or by stressing the ligament by flexing the carpus 90 degrees and rotating the foot laterally. Pain may also be evident on

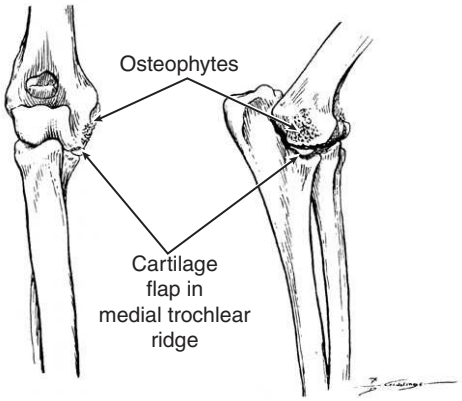
hyperflexion or extension of the joint. Crepitus is occasionally elicited in dogs over 1 year of age, when osteoarthrosis will be sufficiently advanced to produce palpable thickening.

Radiographic Signs

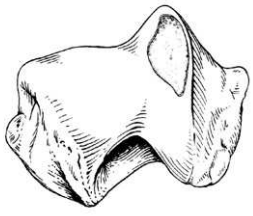
The radiographic diagnosis of OCD of the elbow joint has been well described by Olsson.[15] A triangular subchondral defect can be seen on the medial aspect of the humeral trochlea in the craniocaudal projection (Figure 12-18, *A* and *B*). Sclerosis of the medial condyle is often present near the lesion. Roughening of the medial epicondylar surface is an early sign. The lesion is radiographically visible by age 5 to 6 months. Later in the disease, osteophyte production is apparent in many areas of the joint. The lateral view also allows visualization of discontinuity of the medial trochlea (Figure 12-18, *C*). In dogs older than 9 to 10 months, osteophytes will be



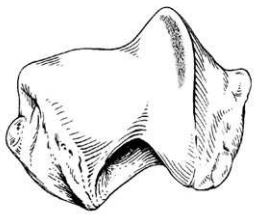
A



B



C



D E

FIGURE 12-18. Osteochondritis dissecans (OCD) of the medial humeral condyle. **A,** A subchondral defect *(arrow)* is seen on this craniocaudal view of the right limb. **B,** Similar changes are seen here in the trochlear ridge of the left limb, and, in addition, osteophytes are present on the medial epicondyle. **C,** Although the cartilage flap is seen in this drawing, it is rarely seen radiographically because of superimposition of the condyles and its cartilaginous composition. **D,** Typical bed of OCD lesion on medial humeral condyle. **E,** Typical "kiss" lesion on medial humeral condyle caused by fragmented coronoid process in young dogs.

seen on the anconeus and radial head. Both elbows should be examined. Fragmented coronoid process (FCP) may be seen concurrently with OCD.

In our experience with OCD of the elbow, the cartilage flap is traumatized and eroded away quicker than OCD of other joints. By 8 to 9 months of age, often only an oval area of "erosion" on the humerus is seen, with or without "joint mice" observable (Figure 12-18, *D*). With FCP, there is usually a "kiss" lesion on the same area of the humeral condyle, but it is often narrower and longer than the OCD bed (Figure 12-18, *E*). Therefore, in dogs older than 10 months, it is very difficult to determine whether the damage to the humerus is attributable to an eroded OCD flap or trauma from an FCP. Statistics as to OCD occurrence with or without FCP thus may be misleading. In a study using computerized data on elbows in 62 cases, only 2 of 64 elbows were believed to be OCD, whereas 34 of 64 were diagnosed as fissured or fragmented coronoid processes.[16] In our surgical experience, we see many more cases of FCP than OCD, and occasionally we see the two together. Often, however, we cannot tell if OCD had accompanied the FCP, as previously discussed. In the cited study, 27 elbows underwent surgery, with two cases of OCD found, 22 fragmented or fissured coronoid processes, two ununited medial epicondyles, and one undiagnosed arthritic joint.[16]

Diagnosis

The specific diagnosis of OCD must be made radiographically and while the dog is 5 to 9 months of age. On exploration, observation of a flap confirms the diagnosis. After 9 months of age the triangular defect may fill in radiographically, and the flap may be gone on exploration. The diagnosis is only presumptive at this point.

Treatment

Treatment consists of surgical excision of cartilage flaps and removal of loose cartilage from the joint. Good clinical results are obtained if surgery is done before degenerative joint disease is well established. This means that animals treated after about 9 months of age have a progressively poorer prognosis. Despite surgery, further arthrosis will develop. Grondalen[17] found that dogs with OCD had a better prognosis than those with FCP, which conflicts with Olsson's results.[15]

Surgical Technique

The elbow is approached from the medial aspect.[2,18] This simple muscle-separating approach gives adequate exposure (Figure 12-19, *A*), especially if a valgus stress using a sandbag is applied on the lateral aspect of the elbow. Occasionally, some prefer an osteotomy of the medial epicondyle (Figure 12-19, *B*). The epicondyle is fixed with a lag screw. Drilling for placement of the lag screw before osteotomy of the epicondyle ensures accurate replacement of the epicondyle and simplifies the drilling process. We have not found this technique necessary since adopting the muscle-separating approach.

Removal of the cartilage flap is easily accomplished with either approach because the usual location of the lesion is in the center of the surgical field (see Figure 12-19). Sharp excision frees partially attached flaps. Curettage should be just sufficient to clean the edges of the lesion. The joint should be thoroughly searched for free fragments of cartilage before the closure.

Aftercare

A light bandage is applied for 2 weeks, with restricted activity advised for 4 weeks. Often, dogs after a muscle separation technique are walking normally within a few days after surgery, even when done bilaterally.

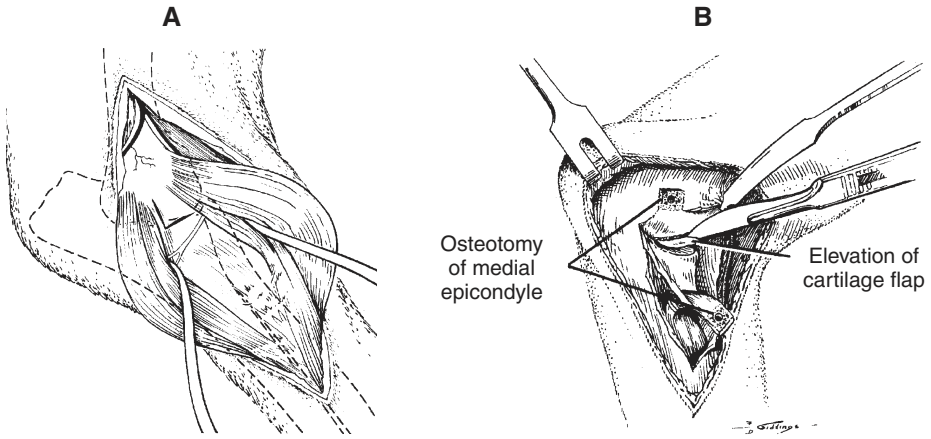


FIGURE 12-19. Surgical treatment of osteochondritis dissecans of the medial humeral condyle. **A,** The left elbow is exposed by a medial muscle-splitting procedure. After separating between the pronator teres and the flexor carpi radialis, the median nerve is undermined cranial and caudal to the pronator to facilitate retraction and avoidance while retracting with a Gelpi retractor. An L-shaped incision is made through the joint capsule and medial collateral ligament. Exposure is greatly assisted by applying a valgus stress to the elbow with the aid of a sandbag positioned laterally on the elbow. **B,** The left elbow has been exposed by a medial approach with osteotomy of the epicondyle.[2] The pronator teres, flexor carpi radialis muscles, and medial collateral ligament are attached to the osteotomized bone. A cartilage flap is elevated with a scalpel.

Fragmented Medial Coronoid Process

The breeds of animals affected, clinical manifestations, and etiopathology of the FCP are similar to those found for OCD of the humeral condyle. According to some,[15] OCD and FCP coexist 37% of the time. As explained previously for OCD of the elbow, the humeral lesion is often undefinable. It may represent the bed after the OCD flap has been eroded, or it may represent a "kiss" lesion from the FCP underneath it (Figure 12-18, *D* and *E*). As with OCD, this lesion is often considered to be part of the osteochondrosis complex,[19] but trauma[20] and growth discrepancies between the radius and ulna have been proposed as causes.

Wind[10] found a developmental incongruity of the trochlear notch of the ulna that was associated with the development of UAP, FCP, and OCD of the medial humeral condyle. In affected breeds a slightly elliptical trochlear notch with a decreased arc of curvature develops, which is too small for the humeral trochlea. This results in major points of contact in areas of the anconeal process and medial coronoid process and little or no contact in other areas of the trochlea. The incidence of FCP and OCD (which were not separated in this study) was 16%, and the incidence of FCP with UAP was 3%.[21]

In our experience, FCP is seen much more often at surgery than elbow OCD. The majority of FCP cases are bilateral radiographically, although clinically the dog may show either unilateral or bilateral lameness. In some instances, one elbow may have an OCD lesion while the other may have an FCP or an FCP and OCD. Grondalen[22] has shown that, especially in the Rottweiler, there can be a "fissured" coronoid process, meaning that the process is not grossly loose, but usually has an observable line in the articular surface. This has paralleled our experience. Computed tomography (CT) examination is especially helpful in assessing these cases for surgical decisions.

Surgical excision of loose cartilage or bony fragments or excision of a fissured coronoid before significant arthrosis develops affords a good prognosis, but later surgery in the presence of marked arthrosis is not as successful.[20] This is verified by our own experience. The fragmented coronoid process usually causes a "kissing" lesion on the medial aspect of the humeral condyle. This lesion is a cartilage abrasion and is difficult to distinguish from an old OCD lesion. The abrasion is usually 2 mm wide and extends almost the whole length of the articular surface of the medial condyle (Figure 12-18, *E*).

Clinical Signs

Little clinical evidence exists to differentiate FCP from OCD of the elbow. Pain on flexion-extension of the elbow and lateral rotation of the paw is slightly more consistent in FCP. In younger dogs, effusion is often present and is detected as a bulge between the lateral epicondyle of the humerus and the olecranon process of the ulna. In dogs older than 10 to 11 months, joint effusion, crepitus, and general thickening resulting from osteophyte production are also more evident. In older dogs a ridge of osteophytes may be palpable between the prominence of the humeral lateral epicondyle and the olecranon.

Radiographic Signs

Radiographic examination of the elbow is important despite radiographic signs of the FCP often being nonspecific. Excessive osteoarthrosis and superimposition of the radial head and coronoid process make identification of the FCP difficult. Usually the first radiographic sign seen is the appearance of an osteophyte on the anconeal process (Figure 12-20, *A* and *B*). This may be subtle at first and consists of a convex bony opacity on top of the normally dish-shaped concave anconeal process (see Figure 12-9, *A*). This view and finding are used for screening purposes for breeding dogs. On the craniocaudal view, osteophytes appear medially on the coronoid process (Figure 12-20, *C* and *D*) and on the medial humeral condyle (Figure 12-21, *A*). Occasionally, the osteophytes are present on the coronoid process but not obvious on the anconeal process (Figure 12-20, *C*). Therefore, three views are normally recommended for symptomatic dogs: lateral, flexed lateral, and craniocaudal.

The second subtle radiographic finding is sometimes seen on the straight lateral view. The normal coronoid process has a beaklike projection cranially (Figure 12-9, *A*). With FCP, however, there may be a squared or blunted cranial margin without the "beak" (Figure 12-20, *B*). With chronicity, sclerosis of the proximal ulna surrounding the semilunar notch may be seen (8-10 months of age).

A normal sesamoid bone is seen in some large dogs, located just lateral to the radial head, and should not be mistaken as a joint mouse (Figure 12-21, *A*).

Although radiographic signs may be suggestive, definitive diagnosis often depends on arthrotomy. This should be undertaken immediately on any young, large-breed animal that shows persistent lameness and radiographic signs of osteoarthritis or joint effusion, preferably between 6 and 8 months of age. We have seen some dogs, however, whose lameness did not begin until 2 to 3 years of age, with minimal degenerative joint disease present. Perhaps this represents a fissured coronoid process with a recent break. These dogs have functioned well after surgery. Often these cases are bilateral and may be operated bilaterally. In affected Labrador retrievers, Studdert and colleagues[23] reported a 90% occurrence of bilateral lesions.

Diagnosis

As mentioned earlier, FCP is usually not proved with conventional radiography. The diagnosis is presumptive based on the breed, age, joint swelling palpated laterally,



FIGURE 12-20. Fragmentation of the medial coronoid process. **A,** Mediolateral view. Typical osteophytes on the dish-shaped anconeal process *(white arrow)*. **B,** Mediolateral view. Subtle osteophytes causing the anconeal process to lose its dish-shaped profile *(black arrow)*. Note the vertical blunting of the coronoid process *(black arrowhead)*. Compare with Figure 12-9. **C,** Craniocaudal-lateromedial oblique view. Osteophytes are seen on the medial epicondyle *(open white arrow)*, and the nondisplaced coronoid process is uncharacteristically well visualized *(solid arrow)*. **D,** The craniocaudal view of the dog seen in *B*. Note the osteophytes on the medial epicondyle of the humerus and coronoid process *(black arrowheads)*.

and radiographs demonstrating osteophytes without an OCD defect. A CT scan may actually demonstrate the separate piece (Figures 12-22 and 12-23), but CT is costly, often unnecessary (i.e., not needed for the surgical exploration), and unavailable to many practitioners (see Chapter 1). However, loose pieces seen on the CT scan and at surgery may actually represent fractured osteophytes or joint mice from OCD, especially if not located in the typical area of the FCP (between radius and coronoid process). Therefore, making an absolute diagnosis based on surgical and CT findings may not be entirely accurate, especially in dogs over 1 year old. This must be kept in mind in breeding and genetic studies.

Surgical Technique

Exposure of the elbow joint is identical to that for OCD, as discussed previously (see Figure 12-19). Forceful abduction and rotation of the antebrachium are helpful

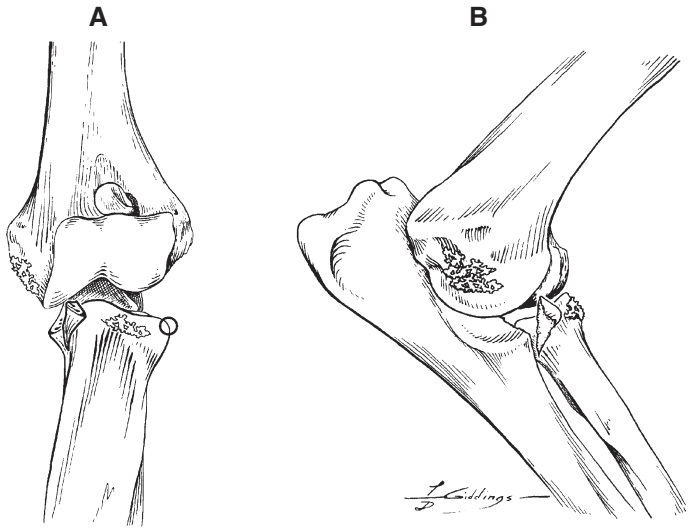


FIGURE 12-21. Fragmented coronoid process (FCP). **A,** Osteophyte production is evident on the medial epicondyle, and a displaced FCP is noted on this craniocaudal view. There is typically a faint erosion of the articular cartilage of the humeral condyle opposite the site of the FCP. The process may not be displaced in all cases. **B,** In this mediolateral view, osteophytes are present on the radial head, but anconeal osteophytes are obscured by the humerus. The FCP can be seen here, but radiographically it is superimposed on the radial head. Note the normal sesamoid lateral to the radial head seen in some individual large-breed dogs.

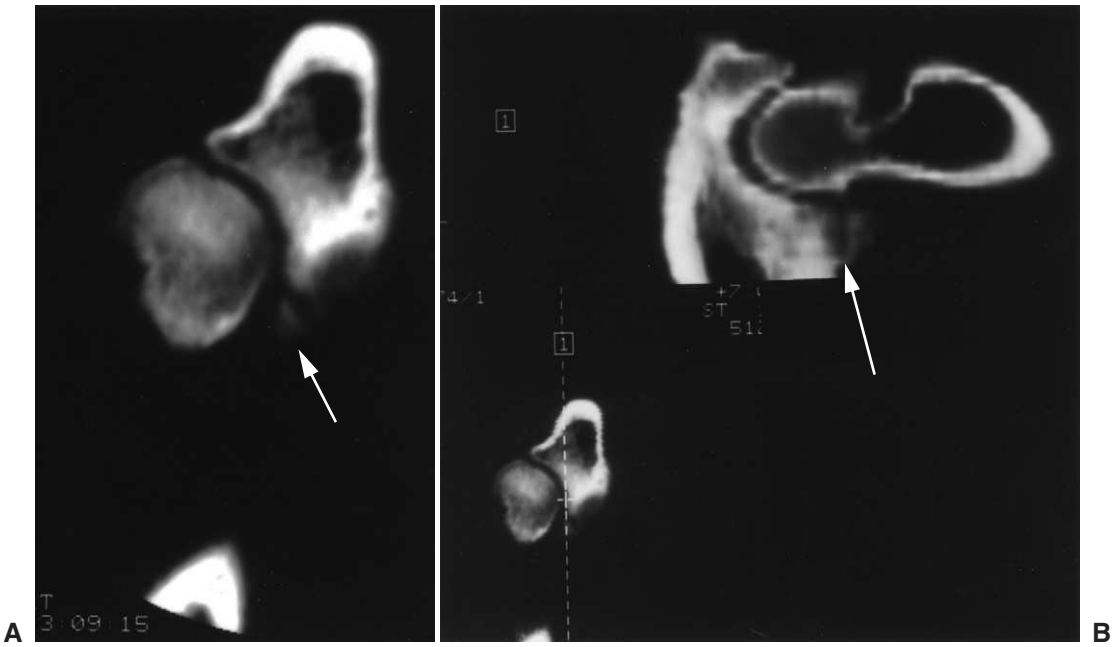
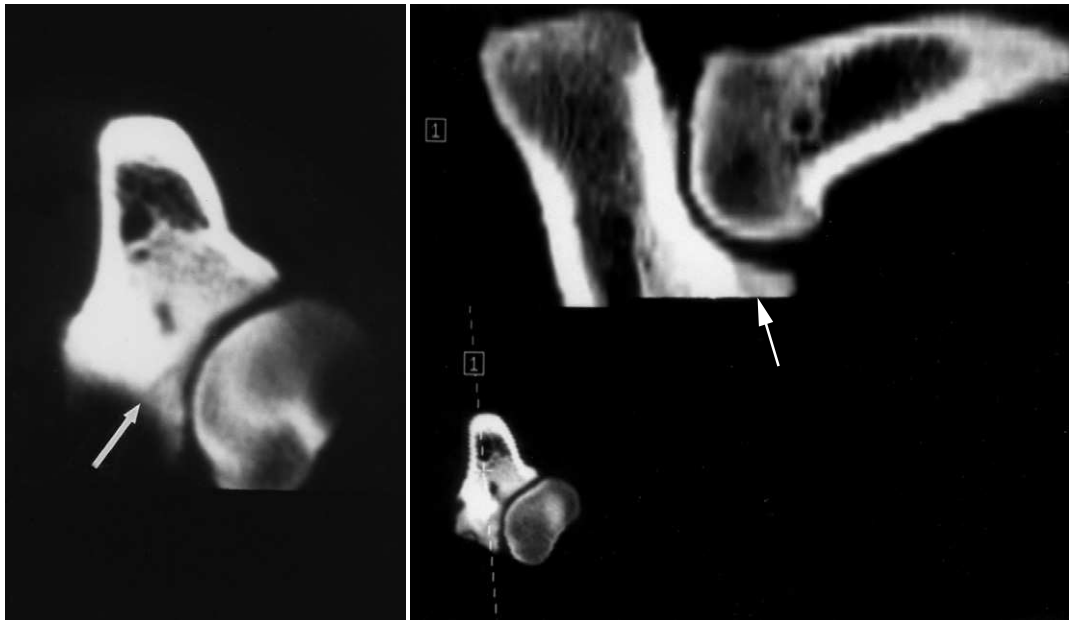


FIGURE 12-22. **A,** Computed tomography (CT) scan through the ulna and radius. Note the obvious black separation between the coronoid and its tip *(white arrow)*. **B,** Reformatted CT view in the plane of the dotted white lines in the lower left part of the picture. In the upper right, the black separation is seen *(white arrow)*.



A B

FIGURE 12-23. **A,** CT scan through the radius and ulna in a 9-month-old Rottweiler with a "fissured" or cracked coronoid *(white arrow)*, which may not be apparent on visual inspection. An osteotome is used to start the removal parallel to the cleavage plane denoted from the CT image. **B,** Reformatted CT view of the white dotted lines in the lower part of the picture. Note also a separate piece (fracture of an osteophyte) to the left of the dotted line. In the upper right, a dark, abnormal coronoid process *(white arrow)* is seen, but no obvious "fracture" line.

in increasing exposure of the coronoid process. In most cases the process is loose enough to be readily apparent, but in some patients it is necessary to exert force on the process to find the cleavage plane. Loose coronoid processes are usually attached cranially with soft tissue, requiring sharp dissection. In fissured processes, a small-width osteotome is used to break the top surface, which usually breaks cleanly. A CT scan is especially helpful in these cases.

Older dogs with secondary osteophytes present different problems. In these cases the medial aspect of the coronoid process may be overgrown with enough osteophytes to cover the cleavage plane and may give the process sufficient stability so that it is not easily moved. It is necessary to remove the osteophytes by rongeurs before the FCP can be appreciated. In addition, erosions in the osteophytic proliferation of the humerus may represent "kiss" lesions from the osteophytes on the coronoid region.

Because of the possibility of slight malarticulation resulting from discrepancies between the ulna and humeral condyle,[10,21] Olsson[24] advised removal of the base of the medial coronoid process so that there is no possibility of contact with the condyle. The joint is carefully inspected for OCD lesions and fractured osteophytes. After their removal, irrigation is used to remove any small cartilage fragments before closure.

Aftercare and Prognosis

A soft bandage is applied for 2 weeks, with restricted activity for 4 weeks, followed by gradual return to full activity. The outlook for function is good if the FCP

is removed before secondary degenerative joint disease is well established. These animals will have recognizable signs of degenerative joint disease later in life but usually function well because the changes are not as severe as in untreated cases. This means that animals treated at 7 to 9 months have the best outlook; the prognosis declines rapidly when surgery is delayed past 12 months and degenerative joint disease is extensive. Cases that suddenly worsen in later years have also improved with surgery. A CT examination is especially helpful in identifying all loose fragments and fractured osteophytes that should be removed,[25] in hopes of achieving limb function before the condition worsens.

Ununited Medial Epicondyle

UME is a poorly defined, uncommon elbow condition seen in several large breeds, especially the Labrador retriever. UME is characterized by detached ossified bodies located either at the medial joint line or caudally just distal to the squared-off medial epicondylar ridge. In many cases these bodies are located in both locations (Figures 12-24 and 12-25, *C* and *D*). Often they are seen in conjunction with other osteochondroses of the elbow. These pieces may actually grow to be 3 or 4 cm in length.

With no other conditions, the ossified bodies may cause lameness or may be asymptomatic. There may be no history of trauma, or the lameness may result from nonviolent trauma, such as hunting or playing with other dogs. Signs may begin at age 4 to 5 months or at 5 years, or again, signs may be an incidental finding. Others prefer to call this condition "calcification of the flexor tendons of the medial epicondyle."[26] We believe, as do Olsson[9] and Bennett and May,[27] that UME is a form of osteochondrosis in which fragments of the cartilage avulse with tendons. Over time, the cartilage changes to bone and enlarges, reaching a point where the bony pieces may rub against the humerus or ulna, causing lameness (Figure 12-25, *E* and *F*).

The rationale in believing there is an underlying problem (i.e., osteochondrosis) other than trauma is that UME (1) is often bilateral, (2) is often seen without trauma in the history, (3) has been seen in three littermates of English setters, and (4) is seen especially in the Labrador retriever, German shepherd, and English setter. We have seen a case in a 14-month-old Labrador retriever with FCP that was surgically treated and did well for 4 years. On reexamination for a 2-month-old lameness, the 2-mm UME that was seen 4 years earlier had grown six to eight times in size (see Figure 12-25, *E* and *F*). After excision the lameness resolved within 3 weeks. Histological analysis of these pieces in the older dog is not helpful in elucidating the pathogenesis of UME.

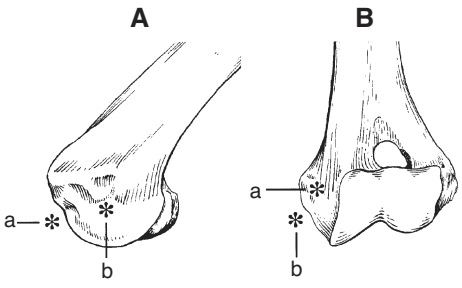


FIGURE 12-24. Schematic drawing of the two locations where loose pieces of bone (ununited medial epicondyle) are located. **A,** Lateral distal humerus. **B,** Craniocaudal view of the distal humerus. The asterisk at site *a* is the position of the fragment that detaches from the caudal distal medial epicondyle. The asterisk at site *b* is the position of the fragment that detaches from the medial aspect of the medial epicondyle.



FIGURE 12-25. Ununited medial epicondyle (UME), or calcification of the flexor tendons, arising from the caudal medial epicondyle. **A,** Lateral view of UME located at the open arrowhead. **B,** Lateral view of UME in another dog. **C,** Lateral view of a large UME seen caudal, as in site *a* (see Figure 12-24) *(black arrows)*. The mineralized densities at site *b* are not evident *(white arrowheads)*. (*D*) Craniocaudal view of dog in *C*. Note the densities in site *b* are obvious, but those in site *a* are obscured by the humerus.

Continued

Clinical Examination

On physical examination, thickness around the medial condyle may be detected along with pain, sometimes elicited by direct pressure.

Radiographic Findings

Two radiographic views (flexed lateral, craniocaudal) of the elbow must be studied carefully to determine the number and location of the fragments. These may be found only on the craniocaudal view spanning or just distal to the joint line. On the lateral view, they may be undetected because of superimposition of the humerus

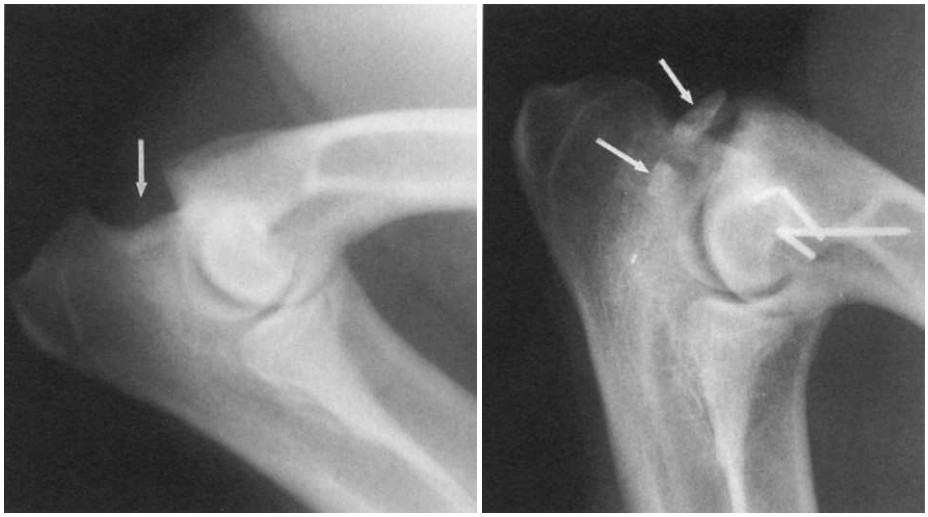


FIGURE 12-25. *Continued* **E,** A 2-mm mineralized density *(arrow)* in a 14-month-old Labrador treated successfully for a fragmented coronoid process. **F,** Four years later, the dog presented with 2-month-old lameness that resolved quickly after extirpation. Note the growth of the fragment seen in *E (arrows)*.

and radius. The fragments located on the distal caudal epicondyle may be seen on the flexed lateral view but not on the craniocaudal view, again because of superimposition (Figure 12-25).

Diagnosis

The diagnosis as to whether lameness is caused by UME is problematic, since it may be asymptomatic and may coexist with OCD or FCP. In the mature dog, however, these fragments are just outside the articular surface and cause minimal degenerative joint disease. If degenerative joint disease is present, other conditions (e.g., OCD, FCP) may be the real cause of lameness and should be explored.

Treatment

Surgical extirpation usually is rewarding if there is no coexisting elbow condition. In Figure 12-25, *C* and *D*, lesion at site *b* is located in the fibrotic tissue surrounding the flexor carpi radialis, whereas lesion at site *a* is more caudal in the scarred origin of the deep and superficial flexors. Often these fragments are not palpable, and knowledge of the regional anatomy and careful dissection are required. The bony fragments are sharply dissected, carefully avoiding horizontal transection of tendons. All fragments should be removed. If fragments are left, they may grow and result in return of lameness. If degenerative joint disease is present, the elbow should be explored further. (See OCD and FCP sections.)

Aftercare and Prognosis

The limb is bandaged for 10 to 14 days, followed by another 2 weeks of restricted activity. If all fragments have been removed, and if no other condition is present to cause the lameness, the prognosis is excellent.

ARTHRODESIS OF THE ELBOW

Arthrodesis of the elbow is an alternative to amputation for severely comminuted intraarticular fractures, chronic luxation or subluxation from a variety of causes, and severe osteoarthritis. High radial nerve palsy has also been suggested as an indication. Elbow arthrodesis, however, is a very disabling fusion and should be considered only when the owner refuses amputation. Amputation will provide better overall function than arthrodesis if other joints are relatively pain free.

Strict attention to detail to establish proper joint angles and rigid internal fixation are necessary for success. Although a variety of fixation methods have been described, multiple-screw or bone plate fixation has yielded the best results in our experience. (See Chapter 7 for discussion of indications for and principles of arthrodesis.)

Surgical Technique

Bone Plate Fixation

The joint is exposed by a combined caudal approach with osteotomy of the olecranon process and lateral approach to the elbow (Figure 12-26, *A*). A second ostectomy of the proximal ulna is performed to provide a smooth curve from the caudal humeral shaft to the caudal ulnar shaft, with the joint at the functioning angle, usually 110 degrees (Figure 12-26, *B*). The lateral joint capsule is opened widely to allow the radius and ulna to be rotated medially and thus expose the interior of the joint. Articular cartilage is removed from all contact surfaces of the radial head, humeral condyles, and trochlear notch of the ulna. The humeral capitulum is flattened to fit against the radial head.

A temporary pin is driven across the joint to hold it at the selected angle, and an 8- to 10-hole bone plate is contoured to the caudal surfaces of the ulna and humerus (Figure 12-26, *C*). The proximal ulna may have to be further flattened slightly to allow good seating of the plate. One screw is placed as a lag screw through the plate and lateral epicondyle into the radial head. Ideally, a second lag screw is lagged through the plate and ulna into the medial epicondyle. The rest of the screws are inserted, and the temporary pin is removed.

Autogenous cancellous bone graft from the proximal humerus and the ulnar ostectomy is packed into and around the joint. The olecranon process is attached medial to the plate by a lag screw (Figure 12-26, *D*). The anconeus muscle is detached from the humerus, and the ulnaris lateralis tendon is sutured. The remaining tissues are closed in layers.

Lag Screw Fixation

This technique to arthrodese the elbow requires less surgical exposure and operating time while eliminating the cost of a large bone plate. The joint is exposed by the lateral approach to the elbow.[2] Additional extensor muscles and the lateral collateral ligament are cut to expose the joint widely (Figure 12-27, *A*). Articular cartilage is debrided as detailed previously.

A temporary pin is placed across the joint to maintain the desired angle. The first screw is placed as a lag screw from the lateral epicondyle to the radial head (Figure 12-27, *B* and *C*). The second screw is lagged from the olecranon process into the humerus just proximal to the supratrochlear foramen. The third screw is lagged

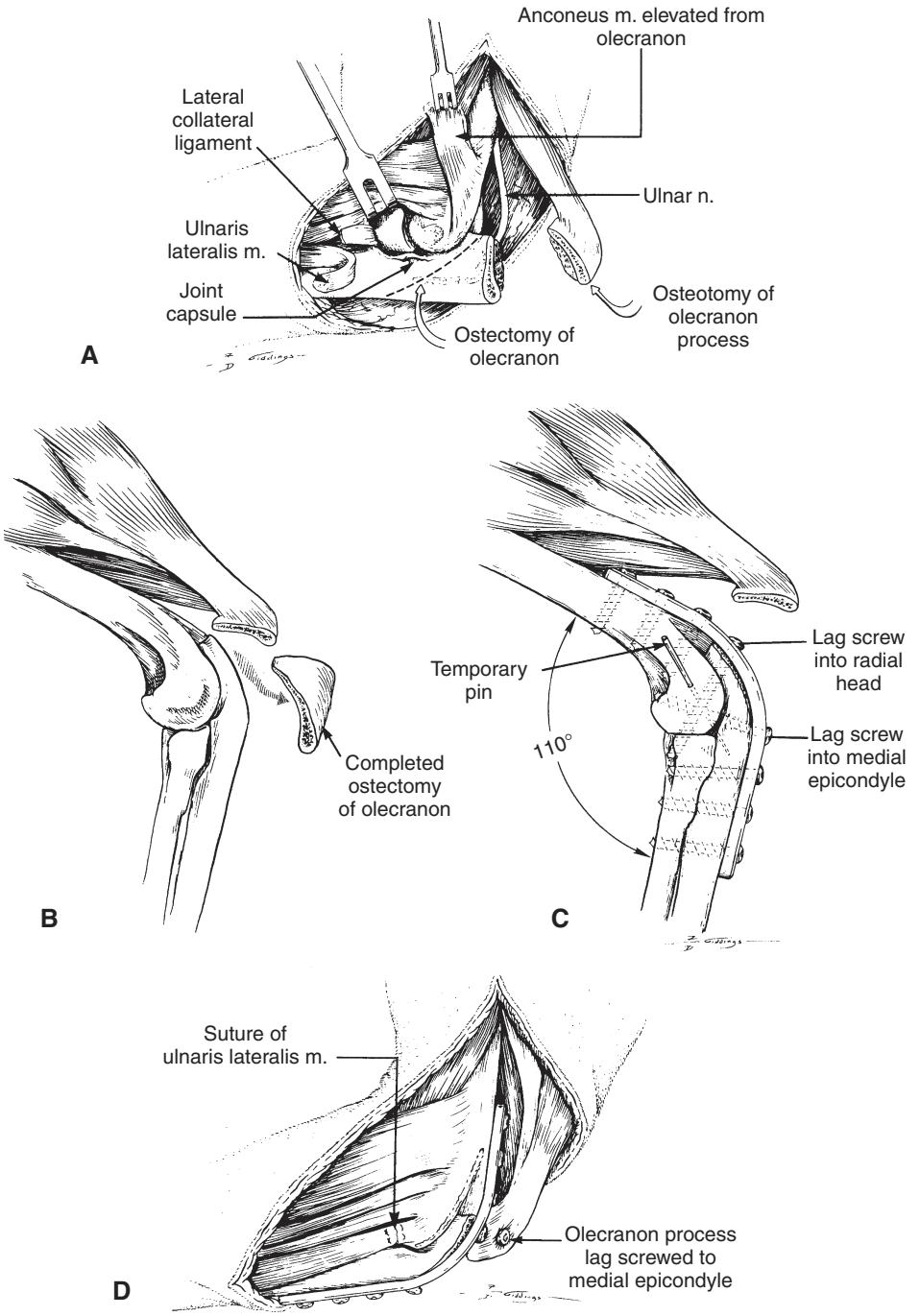


FIGURE 12-26. Arthrodesis of the elbow by bone plate fixation. **A,** The left elbow has been exposed by a combined caudal approach with osteotomy of the olecranon process and lateral approach.[2] The ulnaris lateralis and lateral collateral ligament have been sectioned, and the joint capsule has been opened widely to allow for removal of joint cartilage. Ostectomy of the ulna is outlined here. **B,** Ostectomy of the ulna is completed to form a smooth curve from the humerus to the ulna. **C,** Temporary pin holds the joint at the selected angle, and the plate is contoured. A minimum of four plate holes for each bone is required. One screw is lagged through the plate and lateral epicondyle into the radial head, and a second screw is lagged through the plate and ulna into the medial epicondyle. **D,** The olecranon process is lag-screwed to the humerus medial to the plate, and the ulnaris lateralis tendon is sutured. The anconeus muscle has been excised.

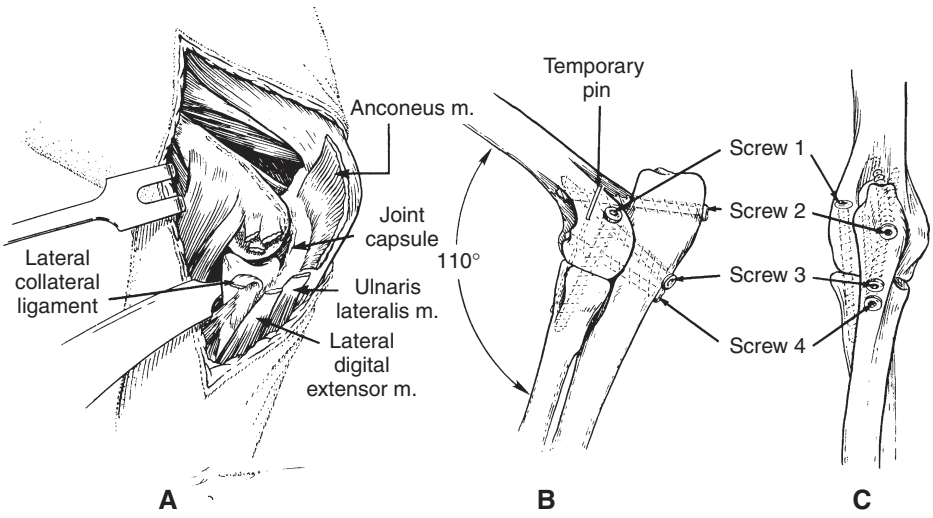


FIGURE 12-27. Elbow arthrodesis with lag screw fixation. **A,** The left elbow has been exposed by a lateral approach. The ulnaris lateralis, lateral digital extensor, and lateral collateral ligament have been sectioned, allowing the joint capsule to be opened widely. Removal of articular cartilage follows. **B,** Temporary pin fixes the joint at the desired angle, and the screws are placed in order. Screws 1, 2, and 3 are lag screws, and screw is 4 positional, threaded in both bones. **C,** Caudal view of the screw placement.

from the ulna into the medial epicondyle. The fourth screw is positional and threaded into the ulna and the center of the epicondyles. The temporary pin is removed. Autogenous cancellous bone graft from the proximal humerus is packed into and around the joint. Extensor and anconeus muscles are sutured, and the remaining tissues are closed in layers.

Aftercare

A spica splint is applied and maintained for 4 weeks (see Figure 2-23). Exercise is restricted for 4 more weeks, at which time radiographic signs of fusion should be noted before exercise is gradually returned to normal.

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13

Fractures of the Radius and Ulna

All the various types of radial and ulnar fractures can be seen involving either bone or both the radius and the ulna.[1-3] Distal to the proximal third of the radius, these bones usually fracture as a unit, but proximal to this region, independent fractures of both bones are typically seen. The development of angulation and rotation at the fracture site, delayed union, nonunion, and subsequent growth deformity may occur in fractures of the distal third, and the surgeon should always keep in mind measures to prevent these common sequelae.

FIXATION TECHNIQUES

Coaptation

Stable type A1 and A2 fractures of the diaphysis and distal radius/ulna respond to external coaptation in a narrow range of cases (see Table 2-1 and Figure 13-13, *A*). Fractures of only the radius or the ulna with its paired bone intact, however, are often satisfactorily managed with coaptation. Lappin and colleagues[4] reported a 75% serious complication rate in toy and miniature breeds, whereas medium-sized dogs (10-65 pounds) less than 1 year of age responded well, with no serious complications. Figure 13-1 illustrates the principle of location of fracture versus length of cast for applying coaptation fixation for these fractures. Reduction may be accomplished closed by a combination of traction, countertraction, and digital manipulation. In some cases, open reduction is preferable to closed manipulation, which may cause an undue amount of trauma to tissue in the fracture site. There is a tendency for the carpus to hyperextend, develop valgus deviation, and rotate outward postoperatively (because of loss of tone in the flexor muscle group). The position of the foot on standing and walking while favoring the leg is also a factor. To prevent this undesirable development when an external splint is used, the foot should be placed in a position of slight varus, flexion, and inward rotation. Ordinarily, this can be accomplished best with a molded cast.

Splinting

As the sole method of fixation, the use of a Mason metasplint or similar coaptation splint (see Figure 2-27) is limited to the more stable and more distal fractures (e.g., greenstick and certain intraperiosteal fractures) because it is impossible to

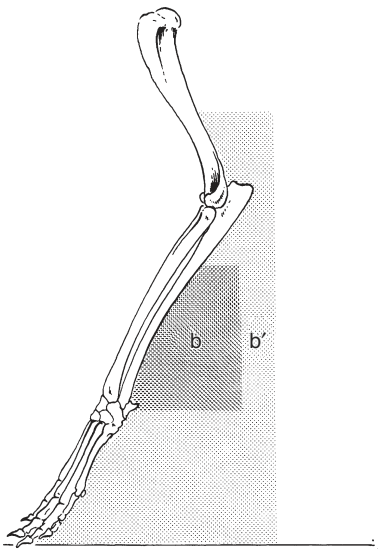


FIGURE 13-1. Stable fractures of the ulna and radius *(b)* may be immobilized with a cast extending to the midhumeral region *(b′)*.

immobilize the elbow joint adequately. Many splints tend to loosen and need constant rechecking to make sure they are accomplishing the intended objective. For complete fractures, the position of slight varus, flexion, and inward rotation is difficult or impossible to obtain and maintain when these splints are used. Thomas splints can be satisfactorily used for diaphyseal fractures for those familiar with their application (see Figure 2-25); however, the molded fiberglass cast is generally more satisfactory.

Casts

In stable fractures, a plaster of Paris or fiberglass molded long-leg cast may be used as the sole method of fixation (see Figure 2-21). If a cast is used on an unstable fracture, overriding frequently develops at the fracture site. Overpadding inside the cast allows for torsional movement at the fracture site and may result in delayed union, nonunion, or malunion. If the cast is applied when the leg is swollen, looseness and instability may result if the cast is not readjusted. Two sites that are predisposed to pressure ulceration under a forelimb cast are the accessory carpal pad and the point of the olecranon. The use of "doughnut" pads under the cast at these pressure points reduces the overall requirement for padding thickness and reduces pressure ulceration at these sites. An alternative to doughnut pads, if fiberglass is used, is to use a cast saw to cut a rectangular window in the fiberglass over the pressure point to reduce local pressure.

Intramedullary Pins and Wires

The radius is not as amenable to intramedullary (IM) pin fixation as are other long bones because the radius is relatively straight and covered at both ends by articular cartilage, and the medullary canal narrows in craniocaudal diameter.

If an IM pin is used, it must be inserted medial to the distal articular surface and must be of small diameter to bend and travel up the medullary canal in the manner of a Rush pin. If inserted cranially, the IM pin must be started above the joint to

avoid cartilage trauma and flexion contracture of the carpus. Likewise, it must bend to follow the medullary canal. Supplemental coaptation must be used after IM pinning.

In small dogs the IM pin may be used to assist in holding end-to-end alignment in stable fractures. In general, the pin that is inserted is too small to approximate the marrow cavity in size. This type of fixation must always be supplemented with coaptation. Attempts at IM fixation, especially in small and toy breeds, are a common cause of delayed union and nonunion.[4,5] IM pinning is only practical in large breeds, and even in these cases it has the disadvantage of requiring supplemental coaptation. Better methods of fixation are available.

Figure 13-2 shows the method of insertion of an IM pin in the radius in large-breed dogs, as follows:

1. The pin is started at the styloid process, then continues up through the marrow cavity, Rush pin style (Figure 13-2, *A*).
2. The pin is inserted obliquely through the cranial cortex and medullary cavity of the distal segment into the proximal segment, Rush pin style.

Intramedullary pinning of the ulna is easily accomplished from the tuber olecrani distally. The narrow diameter of the distal third of the bone limits the use of suitable-size pins to the proximal two thirds of the ulna. Steinmann pinning of the ulna is generally indicated for additional support for a radial fracture fixation. Type A1 proximal extraarticular fracture (see Figure 13-7) is the only diaphyseal fracture suitable to IM pinning as the primary fixation.

External Fixators

The fixator is adaptable to most shaft fractures of the radius and ulna. It is particularly indicated in open fractures, delayed unions, nonunions, and corrective osteotomies. The splint works particularly well with small dogs. In most cases the pins are inserted on the medial or craniomedial border of the radius because the bone is more superficial in this location, and the splint is in the position of least interference from cages, fences, and other objects.

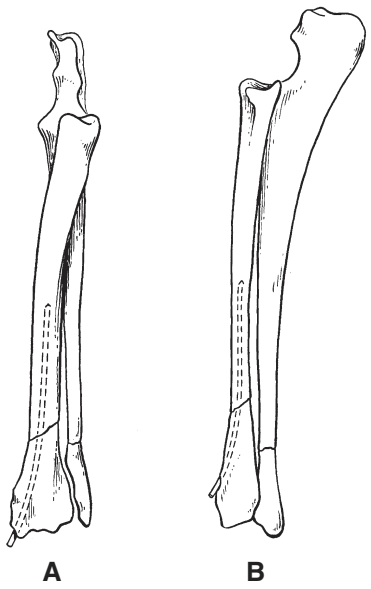


FIGURE 13-2. Insertion of intramedullary (IM) pins in radius. **A,** IM pin is started at the styloid process, continuing up through the marrow cavity in a Rush pin style. **B,** Alternatively, IM pin is inserted obliquely through the cranial cortex and marrow cavity of the distal segment into the marrow cavity of the proximal segment in a Rush pin style.

All the various configurations (unilateral and biplanar type I, bilateral type II, trilateral type III) may be used. In the authors' experience, however, the unilateral type I single bar is adequate in almost all cases, is the simplest to apply, and has the fewest complications. This method requires the placement of all pins in the same plane (Figure 13-3). Figure 13-17, *A* and *B*, shows a complex fracture of radius and ulna with single-bar type I fixator, 3/3 pins, and Figure 13-17, *C,* shows a type II fixator. Depending on the size of the animal and stability of the fracture, 2/2, 3/3, or 4/4 pins may be used. On some extremely fragmented fractures, a biplanar configuration type IB (one unilateral splint on medial surface and one on cranial surface) may be indicated. This configuration is also useful for distal A2 fractures because it allows placement of three fixation pins in the very short segment (see Figure 13-22). A hybrid type II-III splint also has application in extremely short distal segments (see Figure 13-23). If increased stress is expected at the fracture site because of large dog size, temperament, or fracture configuration, another option is to select a fixator system with larger-diameter connecting rods for increased fracture stiffness, such as the SK system (IMEX SK, IMEX Veterinary, Inc., Longview, Texas). The use of this system may allow the surgeon to select simpler frames for more complex and unstable fractures (see Figure 2-34, *G*).

An important advantage of the external fixator in radial fractures is the ability to employ the *biological osteosynthesis* concept by applying the splint with the fracture closed or with a very limited open approach and reduction. Because of the limited musculature of the antebrachium, closed reduction is more feasible than in the

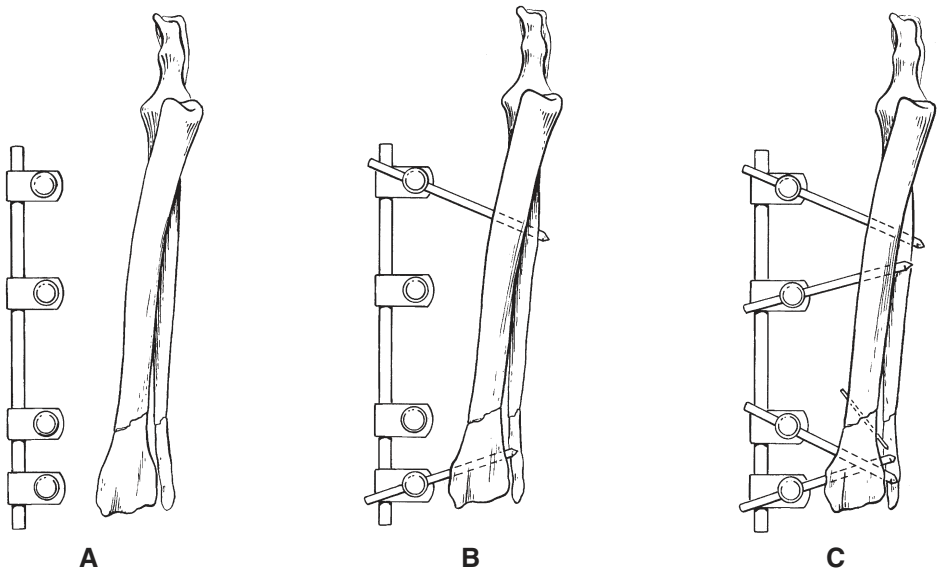
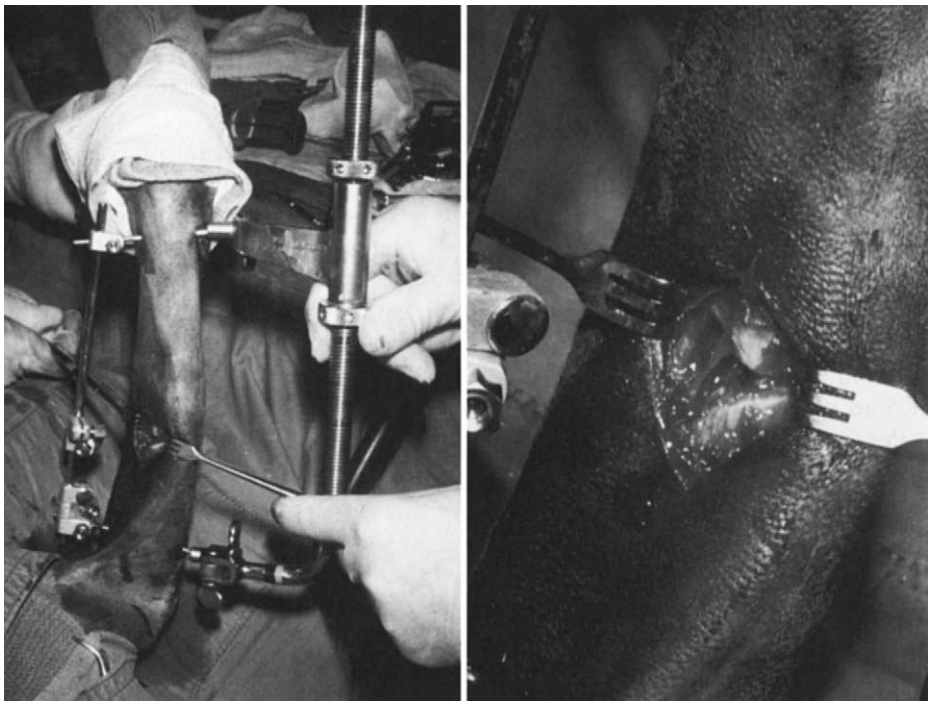


FIGURE 13-3. Applying a type IA unilateral external fixator with one connecting bar and all pins inserted in the same plane. **A,** The fracture is openly reduced and held with locking forceps; a connecting bar with four single clamps is prepared. **B,** The proximal and distal pins are inserted in the same plane; the connecting bar and outer clamps are attached. **C,** Middle clamps are positioned; the two inside pins are inserted through holes in the middle clamps. The nuts on the clamps are securely tightened. In some cases an additional, obliquely directed Kirschner wire is inserted to give more stability at the fracture site. If the fracture pattern is a longer oblique, insertion of a lag screw is indicated.

humerus or femur. The animal is prepared and draped for surgery with the limb suspended, as shown in Figure 2-12. Sterile towels or bandage materials are wrapped around the suspending material a sufficient distance to prevent the chance of accidental contamination of the surgeon during reduction.

Although any type of fixator can be used, type II has special application during closed reduction. If the most proximal and distal fixation pins are inserted first, at 90 degrees to the bone, they become a visual indicator of the adequacy of reduction in the frontal plane, since they will be parallel to each other when angular deformity in this plane is reduced. Additionally, they can be employed to anchor a fracture distractor to aid in the reduction (Figure 13-4, *A*), if desired. If difficulty is encountered in reducing the fracture closed, it is often possible to make a small approach over the shaft of the ulna, then to reduce the ulnar fracture under direct vision. If the ulnar fracture is simple, reducing it ensures that the radius is also adequately reduced. The other method is to employ a limited open approach to the radius to allow reduction under direct vision, but with minimal disruption of the fracture site, thus maintaining maximal vascularity of the fracture segments (Figure 13-4, *B*). The open approach also allows the use of auxiliary fixation, such as Kirschner wires (Figure 13-3, *C*) or lag screws (see Figure 13-14), both of which can be inserted with minimal disruption of soft tissues.



A B

FIGURE 13-4. Application of a type IIA external fixator with a limited open approach to the radial diaphysis. **A,** Fixation pins have been placed proximally and distally in the radius, and the fracture has been reduced by means of the fracture distractor applied laterally to the fixation pins. The medial connecting bar is loosely positioned at this point. Note the varus angulation induced by the distractor; this can be adjusted when the lateral connecting bar is attached. **B,** The adequacy of the reduction is verified by a small cutdown over the fracture site. If necessary, the ends can be levered into better contact, but the fracture hematoma is disturbed as little as possible.

Bone Plates

Plates are adaptable to most radial and ulnar shaft fractures.[1,3] For diaphyseal fractures, the usual procedure is to plate only the radius. If the radius is well stabilized, fixation of the ulna is usually unnecessary. In large dogs it is useful to use small plates on both the radius and the ulna (see Figure 13-16) rather than one large plate on the radius. A large, cranially placed plate may make it difficult to attain adequate soft tissue closure at implantation, or it may interfere with movement of the extensor tendons. Round hole plates, dynamic compression plates (DCPs), limited contact dynamic compression plates (LC-DCPs), or semitubular plates may be used. The plate most frequently used is the DCP because it has the built-in potential of compression at the fracture site. A semitubular plate must be of sufficient size, and bending must be minimal in contouring it to fit the bone surface. For distal fractures, the T-plate allows placing two or three screws in a short segment (see Figure 13-21, *A*), and the veterinary cuttable plate (VCP) is also helpful in small breeds. (See Figure 2-75 for suggested plate sizes.)

Cranial placement of the plate has been the most widely used method for all diaphyseal fractures, because it is easily accessible and provides a broad and only slightly curved surface (see Figure 13-14, *B*).[3] This surface serves well for fractures of the proximal and middle regions of the radius, but in the distal zone the plate is the source of some morbidity. Dissection and elevation of the extensor tendons from their synovial sheaths in the middle groove of the distal radius and the subsequent gliding of these tendons over the plate surface produce varying degrees of functional problems. Additionally, problems are sometimes encountered in closing the scant soft tissues over a distal plate. Most of these problems can be eliminated by medial plate placement for distal fractures (see Figure 13-21, *B*), and mechanical testing has shown this position to be equivalent in axial stiffness to cranially placed plates following distal osteotomy.[6] The medial aspect of the radius is narrower than the cranial surface, and a smaller plate must be used (2.7 vs. 3.5 mm). The smaller plate allows more screws to be placed per unit of plate length, and the medial position increases the possibility of incorporating a lag screw through the plate into an oblique fracture. The smaller plate for a medial position may also be slightly contoured with a slight bow to fit the natural cranial bow of the radius.[7]

Combination fixation on the radius and ulna is more often considered in complex fractures in larger or giant-breed dogs. Bone plates may be applied to both radius and ulna, providing a very rigid fixation for a two-bone system, or a plate may be applied to the radius fracture and an IM pin applied to the ulna component. The ulna pin provides excellent protection against bending forces that affect the radial plate.

Postoperative swelling and pain are eased by use of a Robert-Jones dressing for 3 to 5 days (see Figure 2-33).

Lag Screws

As primary fixation, lag screws are mainly used in distal articular fractures (see Figures 13-24 and 13-25). Long oblique or spiral simple fractures of the radius and ulna may be stabilized with lag screws for holding alignment and exerting interfragmentary compression at the fracture site (see Figure 13-14, *A*). This fixation must be supplemented with either external coaptation or internal fixation. Internal fixation may consist of a bone plate (see Figure 13-14, *B*); an IM pin in the ulna (see Figure 13-14, *C*), which may still need external splint support; or an external fixator (see Figure 13-14, *D*).

PROXIMAL FRACTURES

A major consideration in type B and C articular fractures is the pull of the triceps muscle on the tuber olecrani, with the tuber pivoting at the trochlear notch. Some form of tension band fixation is essential in these fractures to neutralize these muscle forces.

Open Approaches

Two open approaches can be used individually or combined to expose this region: the approach to the proximal shaft and trochlear notch of the ulna and the approach to the head and proximal metaphysis of the radius (Figure 13-5).[8]

Fracture Type 2-1-A; Proximal, Extraarticular (Figure 13-6, *A*)

Type A1, Ulnar Fracture

This fracture is relatively rare because this region of the ulna is non–weight bearing and is not subjected to any indirect forces; therefore, fractures can only be the result of direct trauma. Treatment is by external coaptation by long-leg cast (see Figure 2-21), Thomas splint (see Figure 2-25), or Velpeau sling (see Figure 2-29) in reduced fractures. An IM pin may also be used for unstable proximal ulnar fractures.

Monteggia Fracture[9]

The Monteggia lesion is a fracture of the ulna and dislocation of the radial head and is a special class of injury that does not conform completely to the AO Vet fracture classification system. In a type I lesion the luxated radial head is cranial in relation to the joint, and the bones are angulated cranially. This injury in dogs is usually a result of being struck by a car, whereas in cats it usually results from a fall. The proximal radioulnar joint can be intact (Figure 13-7, *A*), or the bones can become separated by rupture of the annular ligament of the radius and the caudal crus of the lateral collateral ligament (Figure 13-8, *A*). Type I is by far the most common type of Monteggia lesion. Type II lesions have a caudal dislocation of the radial head with caudal angulation, and in type III injuries the radial head is luxated in a lateral or craniolateral direction. Rarely seen are type IV lesions, with cranial luxation of the radial head and fracture of the proximal radial and ulnar diaphyses.

Reduction and Fixation. If the Monteggia fracture is relatively recent in origin, a closed reduction often can be accomplished by a combination of traction and countertraction, along with caudal pressure on the radius to manipulate the radial head back into the reduced position.

Types I, II, and III; proximal radioulnar joint intact. Internal fixation may be accomplished by inserting a pin from the proximal end of the olecranon process into the shaft of the ulna (Figure 13-7, *B*). In some cases it may be necessary to perform an open approach to the proximal ulna and trochlear notch to accomplish accurate reduction. The pin in the ulna may be inserted either from the proximal end or by use of the retrograde technique. If indicated, an interfragmentary wire may be inserted in the ulna for additional stabilization and compression (Figure 13-7, *C*). If temporary additional external support is indicated, it may be in

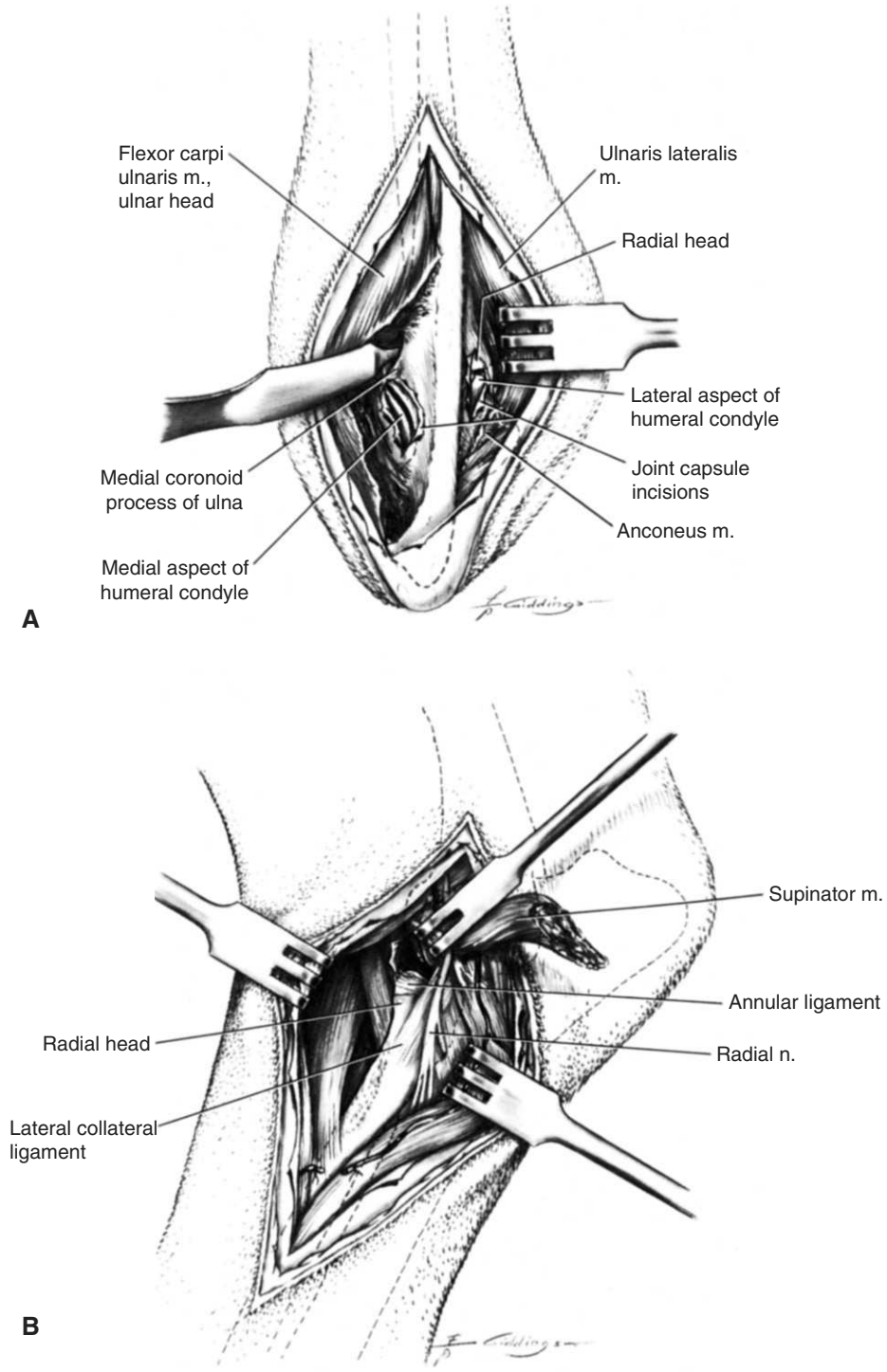


FIGURE 13-5. Approaches to the proximal radius and ulna. **A,** The approach to the proximal shaft and trochlear notch of the ulna gives good visualization of the articular surface of the trochlear notch. **B,** The radial nerve must be preserved during this lateral approach to the head and proximal metaphysis of the radius. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders, pp 237, 246.)

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FIGURE 13-6. Proximal fractures of the radius and ulna. **A:** *A1,* Ulnar; *A2,* radial; *A3,* radial and ulnar. **B:** *B1,* Ulnar; *B2,* radial; *B3,* of one bone, the other extraarticular. **C:** *C1,* One bone remains intact; *C2,* of one bone, the other extraarticular; *C3,* radius and ulna. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

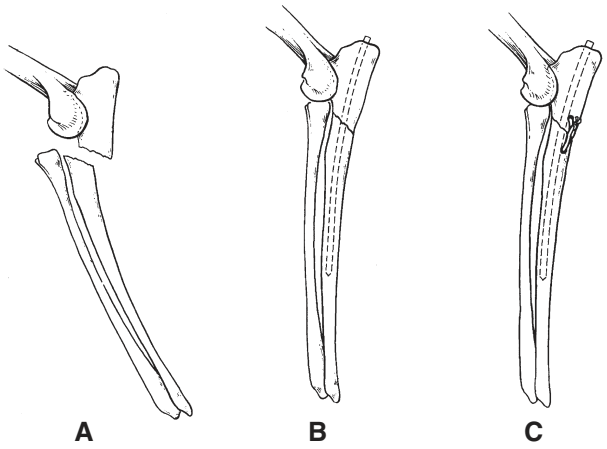


FIGURE 13-7. A, Type A1 fracture of ulna with dislocation of the radial head (Monteggia fracture). The annular ligament is intact. **B,** Immobilization by use of an intramedullary pin in the ulna and a coaptation splint. **C,** The addition of an interfragmentary wire improves stability at the fracture site; this need not be a tension band wire.

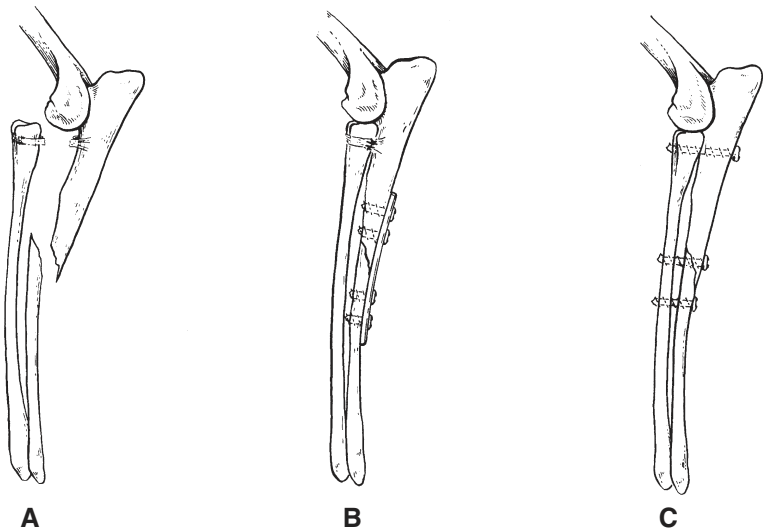


FIGURE 13-8. A, Monteggia fracture with the annular ligament disrupted. **B,** Repair by immobilizing the ulna with a bone plate and suturing the annular ligament. **C,** Fixation by use of bone screws. The ulna is fixed to the radius. The proximal screw should be removed in 3 to 4 weeks to allow the return of some pronation-supination motion.

the form of a modified Robert-Jones dressing. Exercise is restricted during the healing period.

Types I, II, and III; proximal radioulnar joint luxated. Frequently, there is soft tissue (usually one or more of the extensor muscles) interposed between the two bones. An open approach may be necessary to accomplish reduction. The usual procedure is to repair the ulnar fracture (with a bone plate or IM pin) and then suture the annular and collateral ligaments to restore and maintain apposition of the radius and ulna (Figure 13-8, *B*). If suturing the annular ligament is not possible, apposition between the radius and ulna can be accomplished by the use of several bone screws (Figure 13-8, *C*). Ordinarily, this procedure is not used in the young, growing animal because it interferes with normal shifting of the ulna on the radius in the growing process and may result in incongruency of the elbow joint and radius curvus. Also, it should be used with caution in cats because marked supination and pronation are a part of the normal function of the foreleg. If it is used out of necessity in either the dog or the cat, the screws should be removed 3 to 4 weeks postoperatively to allow return of normal motion between the radius and ulna.

Type IV. The radioulnar joint is typically intact in this Monteggia injury. Reduction of the radial head luxation is followed by fixation of the radial fracture, as described next. Additional fixation of the ulna can be supplied by an IM pin if desired.

Type A2, Radial Fracture

The radial head is rarely fractured. It may or may not be accompanied by dislocation of the elbow joint. There is usually a history of trauma. Separation at the physeal plate always threatens to disturb growth. Premature closure of the physis and shortening of the radius are possible sequelae (see Chapter 23). Anatomical reduction and fixation are indicated. Figure 13-9 shows an epiphyseal fracture and separation of the radial head. Open reduction and simple Kirschner wire (K-wire) fixation is used. Healing is rapid, and the wire may be removed in 2 to 3 weeks or left in place. A Robert-Jones dressing may be indicated for temporary additional support.

Type A3, Radial and Ulnar Fracture

Stabilization of the ulna by IM pin, IM pin and interfragmentary wire, or bone plating caudally (Figure 13-10, *F*) or laterally (Figure 13-10, *G*) may provide sufficient support for the radius. Additional radial fixation can be gained either by K-wire fixation or a small T-plate or VCP applied either cranially or laterally. A Robert-Jones dressing may be indicated for temporary additional support.

Fracture Type 2-1-B; Proximal, Simple Articular (Figure 13-6, *B*)

Following fracture, the triceps brachii muscles pull the tuber olecrani segment proximally, bending it toward the shaft of the humerus (Figure 13-10, *A*). For best results, this pull should be neutralized by use of the tension band principle. In general, the pin and tension band wire method is used on stable fractures, and a plate is used for unstable fractures (Figure 13-10, *B*, *C*, *E*, *F*, and *G*). Repair of intraarticular proximal ulnar fractures with pin and tension band wire has been associated with a greater prevalence of implant loosening, breakage, and delayed union than fixation with bone plates.[10] This is especially true for large and giant breeds of dogs. Although it seems reasonable to do, simple IM pin fixation of the ulna in these fractures never works well in animals of any size. The medullary canal of the ulna is simply not large enough to accept a sufficiently large pin to resist the bending forces of the triceps muscle (Figure 13-10, *D*).

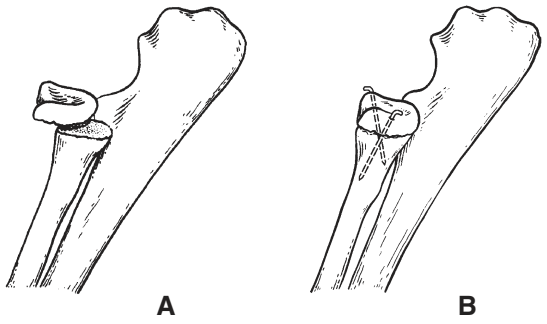
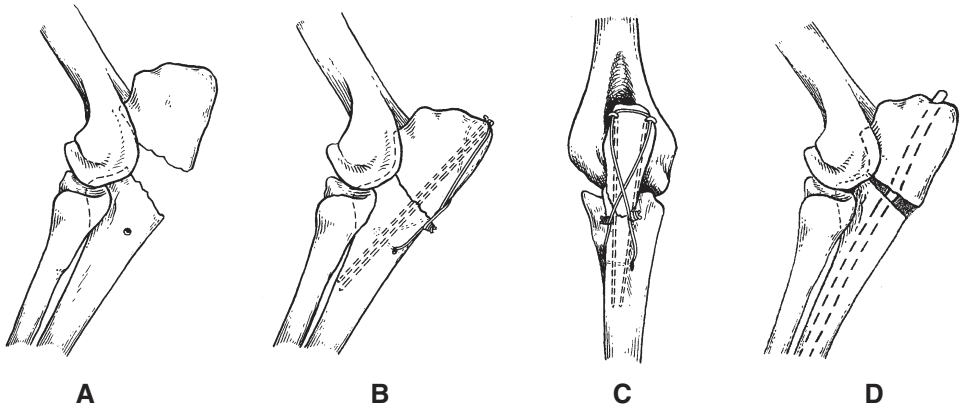


FIGURE 13-9. **A,** Type A2 physeal fracture of the radial head. **B,** Simple transfixation pinning with Kirschner wire. The wires enter the bone near the joint surface and proceed distally and diagonally into the opposite cortex.



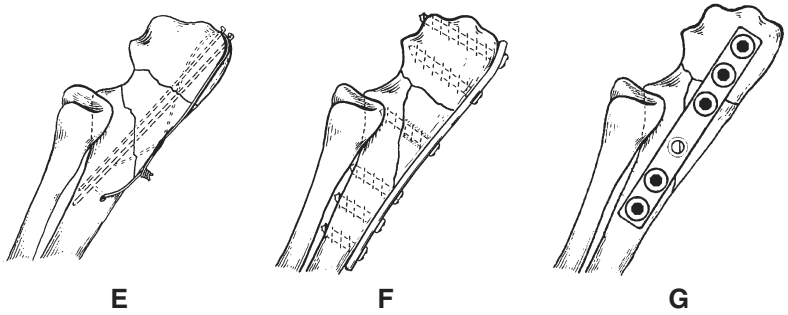


FIGURE 13-10. Fixation of olecranon fractures. **A,** Type B1 transverse fracture of the olecranon process. **B** and **C,** Fixation using two Kirschner wires and a figure-of-8 tension band wire works very well on simple fractures involving the articular surface. **D,** Fixation with a smooth intramedullary pin alone is inadequate to resist the bending forces; as the proximal segment slides proximally due to pull of the triceps brachii muscle, a gap develops at the fracture site, and delayed union or nonunion results. With a fracture in this location, pins or screws used alone as intramedullary fixation are subject to bending or fatigue fracture. **E,** Type C1 fractures involving the articular surface must be anatomically reduced and may be stabilized using the tension band wire if the articular surface can be completely reconstructed on reduction. **F,** In multifragmentary type C1 fractures (unstable fractures), the semitubular or dynamic compression plate (DCP) may be used as a tension band if the articular surface is intact after reduction. **G,** In some multifragmentary fractures, it may be advantageous to place the plate on the lateral surface of the ulna, especially if the articular surface is not well reconstructed. The plate must be bent perfectly to avoid malarticulation between the anconeal process and the humerus.

Type B1, Ulnar Fracture

Reduction and Fixation

The fracture site and the shaft of the ulna about 2 to 3 cm distal to it are exposed, and the fracture is reduced. When the articular surface is involved, anatomical reduction is mandatory for restoration of good joint function. Two Kirschner drill wires are started in the proximal end near the caudal edge of the olecranon process and are driven distally into the shaft of the ulna. In small-breed dogs it is advantageous to place the pins in the sagittal rather than the frontal plane. The pins are directed to engage the cranial cortex of the ulna distal to the trochlear notch rather than going directly down the marrow cavity, because this may not adequately prevent rotation (Figure 13-10, *B* and *C;* see also Figure 2-64). A transverse hole is drilled through the ulna distal to the fracture line. A figure-of-8 wire connects the protruding pins on the proximal end with the hole that was drilled transversely in the distal segment. If the K-wires were inserted in the sagittal plane, the wire engages only the more caudal K-wire. It is important to place the wire under the triceps tendon, directly on the bone rather than over the surface of the tendon. The wire is twisted in both arms of the figure-8 to ensure that the entire wire is tight enough to resist the bending muscle forces, but not so tight that the articular side of the fracture is opened. The protruding portions of the pins are bent over caudally in hook fashion, cut off, and rotated 180 degrees cranially into the triceps tendon and driven against the bone with a nail set. This will minimize soft tissue irritation over the pins.

With long oblique fractures, the tension band wire needs to be long. To shorten this figure-of-8 wire, a second drill hole can be made in the tuber olecrani, and wires are passed through two holes rather than one end being passed around the K-wires. With this type of fixation, the K-wires guard against rotation and shear forces at the fracture line, and the figure-of-8 wire transforms tension force into compression.

Aftercare

In most cases, no external support is required. Activity should be limited during the healing period. The pins and wire should be removed if there is any indication of irritation or loosening after the fracture is healed.

Type B2, Radial Fracture

Because these are articular fractures, simple K-wire fixation as described earlier for A2 fractures is not optimal. Lag screw or T-plate fixation is indicated. The plate is applied cranially or laterally, depending on the plane of the fracture line.

Type B3, One Bone Articular and One Bone Nonarticular

In the illustrated example for type B3 (Figure 13-6, *B*), the ulnar fracture is the articular fracture. The ulnar fracture is stabilized by the methods described for type B1 fractures. The radial fracture is best treated by a short cranial plate, with at least four cortices engaged by plate screws in the proximal fragment. If the fractures were reversed, the radial fracture would be treated as in B2 above, and the ulnar fracture as in A1.

Fracture Type 2-1-C; Multifragmentary Articular (Figure 13-6, *C*)

These fractures are fortunately rare, since they can present a real challenge to stabilize. Fixation is a combination of methods previously described. If the fragments can be anatomically reduced, fixation is straightforward (see Figure 13-10, *E*). If the trochlear notch portion of the fracture can be reconstructed, small plates can function as tension bands in larger breeds (see Figure 13-10, *F* and *G*). If the ulnar

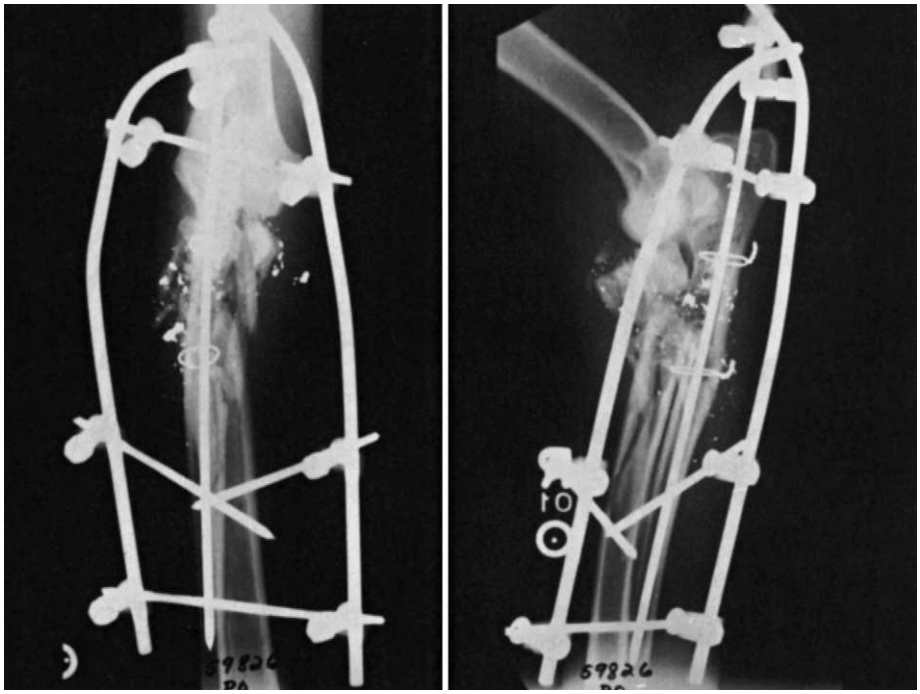
articular portion cannot be reconstructed, the plate will not function as a tension band and will be subject to bending forces. In this situation a laterally applied plate is stronger than a caudal plate.

If plate application is not feasible, a hybrid external fixator can be employed (Figure 13-11). Using an IM pin for one fixation pin provides some additional axial stability. This can be combined with plate fixation of the radius in type C2 and C3 fractures.

If fixation is less than totally stable, a carpal flexion bandage (see Figure 2-30) is applied postoperatively for 2 to 3 weeks to prevent weight bearing while allowing passive motion of the elbow joint.

DIAPHYSEAL FRACTURES

A high percentage of the fractures involving the shaft of the radius and ulna occur in the middle and distal thirds with both bones involved.[1-4] However, these fractures occur at all levels and include all types; in a few cases, they may involve only the radius or ulna. The development of angulation, rotation, delayed union, and nonunion at the fracture site are common sequelae when the bones are handled improperly. Two of the more typical mistakes are using fixation methods that allow rotation at the fracture site and removing the fixation device before the callus becomes sufficiently mature for weight bearing.



A B

FIGURE 13-11. An extremely fragmented type A3 gunshot fracture. **A,** Intramedullary pin in the ulna was used to restore angular alignment, and the proximal end of this pin was tied into a type IIA external fixator by means of contoured connecting bars. **B,** Note that the most proximal full-fixation pin is placed in the ulna. No attempt was made to reduce the radial head; it was allowed to "float" against the humeral condyle and healed in a functional position.

When applicable, treatment recommendations are keyed to the fracture patient scoring system detailed in Table 2-6.[11,12]

Open Approaches[8]

The main indications for open approach are as follows:

1. When reduction by closed methods is difficult or impossible.
2. When there is difficulty in maintaining reduction in the process of applying fixation. (Viewing the fracture site during this process is most helpful.)
3. When internal fixation is applied.

The choice of approach may vary, depending on the location of the fracture and the objective to be accomplished. The approach to the proximal radius is shown in Figure 13-5, *B*. The diaphysis can be approached either laterally or medially; in most cases the medial approach is preferred because the radius is subcutaneous in this area and can be exposed with minimal hemorrhage. Figure 13-12, *A,* illustrates this technique. The lateral approach might be chosen when there are medial skin wounds or where positioning the animal for access to other limbs makes it more convenient (Figure 13-12, *B*). The ulna is exposed by simple incision over the caudal border proximally (see Figure 13-5, *A*) or in the diaphysis laterally.

Fracture Type 2-2-A; Diaphyseal, Radial Simple or Incomplete (Figure 13-13, *A*)

Type A1, Incomplete or of One Bone Only

Fracture patient scores of 9 to 10 are typical for these fractures. If only the shaft of the *ulna* is fractured, it can be treated by compression bandaging to reduce pain and with rest. Rarely, a short caudal splint might be applied (see Figure 2-27).

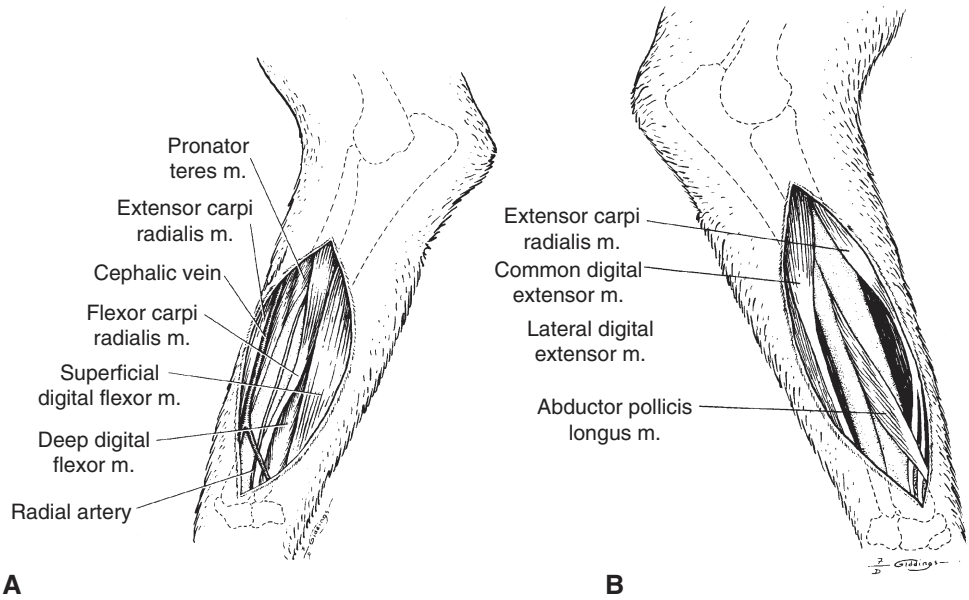


FIGURE 13-12. Approaches to the diaphysis of the radius and ulna. **A,** The craniomedial approach provides good exposure without much muscle elevation. **B,** The lateral approach is used when there is soft tissue injury to the medial side of the limb.

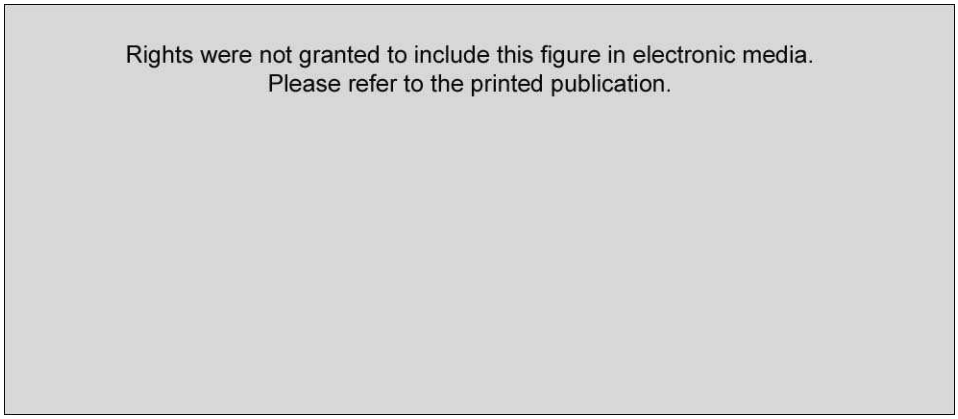


FIGURE 13-13. Diaphyseal fractures of the radius and ulna. **A:** *A1,* Incomplete or of one bone only; *A2*, simple, distal zone; *A3,* simple, proximal zone. **B:** *B1,* Simple, with ulnar fracture; *B2,* distal zone, multifragmentary ulnar; *B3,* proximal zone, multifragmentary ulnar. **C:** *C1,* With ulnar simple or wedge fracture; *C2,* segmental radial, complex ulnar; *C3,* complex ulnar. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3: 41-50, 1990.)

If the *radius* is fractured, more aggressive treatment is indicated. Incomplete (greenstick) fractures respond to caudal splinting. Complete fractures can be handled with a long-leg cylinder cast (see Figure 2-21), bivalved cylinder cast, or Thomas splint (see Figure 2-25). In a young animal, less than 6 months old, caudal splinting will usually suffice.

Type A2, Simple, Distal Zone; and Type A3, Simple, Proximal Zone

Slightly more complex than type A1, fracture patient scores for types A2 and A3 may range as low as 7, with 8 to 9 more common.

Closed Reduction and Fixation

Fixation by long-leg cylinder cast or bilvalved cylinder cast is appropriate for relatively transverse fractures of the distal zone (stable relative to shortening, fracture patient score 9 to 10) in medium to large breeds, especially if under 1 year of age.[4] (See previous discussion on cast fixation under Fixation Techniques.)

Open Reduction and Fixation

Fractures that are not stable relative to shortening (fracture patient score 7 to 8), those in dogs older than 1 year, those in small and toy breeds, and proximal-zone fractures are best treated by internal fixation. A variety of methods are applicable, with the choice being personal preference or availability of equipment.

1. Type I external skeletal fixators are easily applied here (see Figure 13-3), often by closed or minimal open reduction (see Fixation Techniques). Auxiliary fixation in the form of interfragmentary K-wires or lag screws can be used in oblique fractures (Figures 13-3, *C,* and 13-14, *D*). Proximal fractures with a very short proximal segment may require a type IB biplanar splint (see Figure 13-22) with three pins in the proximal fragment.
2. Cranially placed compression or neutralization plates (Figure 13-14, *B* and *E*).

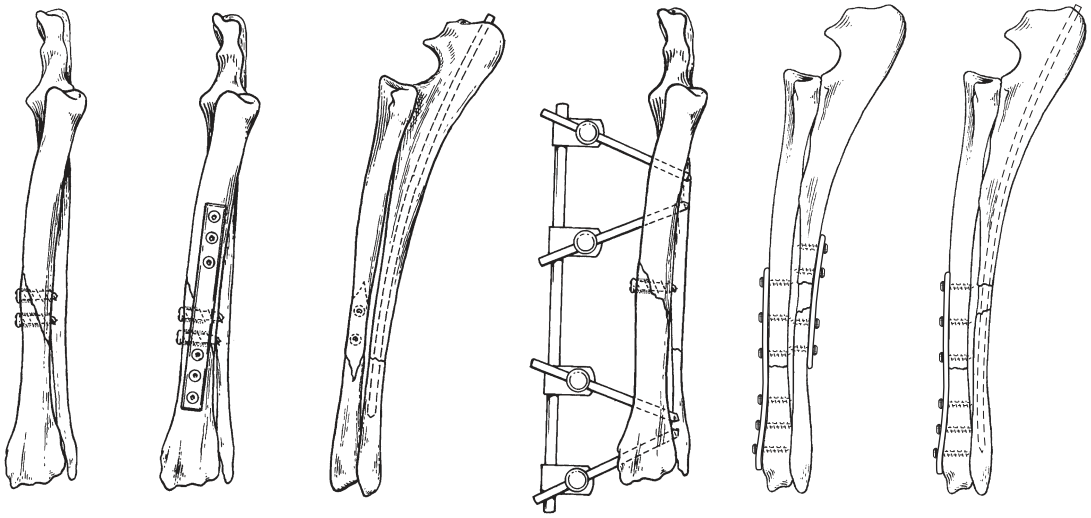


FIGURE 13-14. Fixation of type A simple fractures of the radius and ulna. **A,** Long oblique or spiral fractures of the radius and ulna may be stabilized by lag screws to restore alignment and to exert interfragmentary compression at the fracture site. Additional stabilization may consist of a coaptation splint; **B,** a neutralization plate; **C,** an intramedullary pin in the ulna; or **D,** a type I external fixator. **E,** Distal transverse fracture stabilized with a compression plate on the radius and a buttress plate on the ulna. **F,** Distal fracture stabilized with a compression plate on the radius and an intramedullary pin in the ulna.

3. Intramedullary Rush-type pins in large breeds for distal-zone fractures (see Figure 13-2).

Fracture Type 2-2-B; Diaphyseal, Radial Wedge (Figure 13-13, *B*)

Because of their instability, none of these fractures is amenable to coaptation fixation. Fracture patient scores will usually be in the 4 to 7 range and occasionally as low as 3. The choice of fixation is limited to either bone plating or external skeletal fixation. The degree of fragmentation has little effect on the choice of fixation, since the radius is the weight-bearing bone.

Internal Fixation by Bone Plate

If the radial wedge is reducible, a reconstructive approach can be taken, with lag screw and neutralization plate fixation (Figure 13-15). Cerclage wire fixation can be substituted for the lag screw(s) in some cases. Cranial application of the radial plate is indicated. If the radial wedges are not reducible, the plate is applied with buttress function, with autogenous cancellous bone graft added to the fragments. A long bridging plate on the ulna is useful for proximal-zone radial fractures where only two screws (four cortices) are possible in the proximal fragment. Another suitable fixation combination is to apply a plate to the radius fracture with buttress function and to apply an IM pin to the ulna fracture, to reduce bending stress on the radial plate (Figure 13-14, *F*).

Internal Fixation by External Skeletal Fixator

Type I fixators are sufficient for those with higher fracture patient scores, whereas type II fixators are more certain for lower scores. Closed reduction or limited open

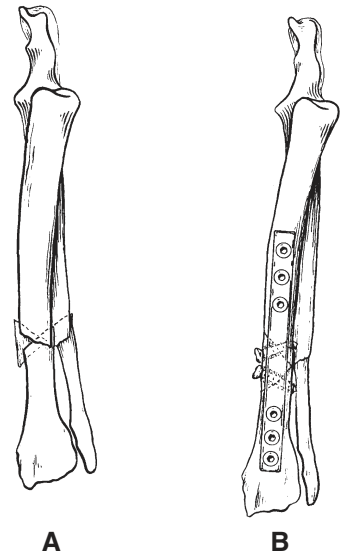


FIGURE 13-15. **A,** Single radial wedge-type B1 midshaft fracture. **B,** Fixation with two lag screws and a neutralization plate on the cranial surface of the radius.

reduction (biological osteosynthesis) is the best choice for application, because this will result in the least disruption of the vascular supply to the fragments. Proximal fractures with a very short proximal segment may require a type IB biplanar splint (see Figure 13-22) with three pins in the proximal fragment.

Fracture Type 2-2-C; Diaphyseal, Radial Complex

(Figure 13-13, *C*)

As stated earlier for wedge fractures, none of these injuries is amenable to coaptation. Fracture patient scores will be 1 to 3 or 4.

Type C1, C3

Plate fixation in the bridging or buttress mode is applicable to these fractures (Figure 13-16). This is supplemented with autogenous cancellous bone graft in the fragmented area, and in some cases involving large breeds, the ulna is also plated, or an ulnar IM pin is used.

Although bone plate fixation is feasible, these fractures heal with more certainty and heal faster when a more biological approach is taken, using closed or limited open reduction and external skeletal fixation. Type IA external fixators (Figure 13-17, *B*) are sufficient for those patients with the highest fracture patient scores for this type of fracture. A lower score is an indication for the type II fixator (Figure 13-17, *C*) or perhaps a type IB biplanar splint (see Figure 13-22).

Type C2

Segmental fractures are also treatable by either plates or external fixators. With DCPs, both fracture lines can be compressed, as shown in Figure 2-72. The disadvantage with plate fixation is the need for a very long plate if the middle bone fragment is long. External fixators of type IB or II are both applicable to this type of fracture. A minimum of two fixation pins is required in each fragment.

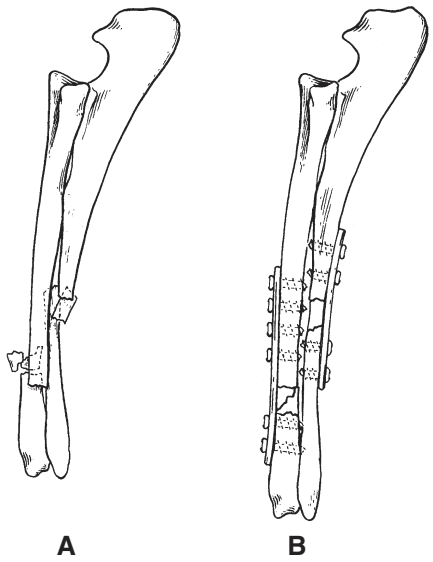


FIGURE 13-16. **A,** Type B2 distal-zone fracture of the radius and midshaft fracture of the ulna in a large Saint Bernard dog. **B,** Fixation using two bridging plates.

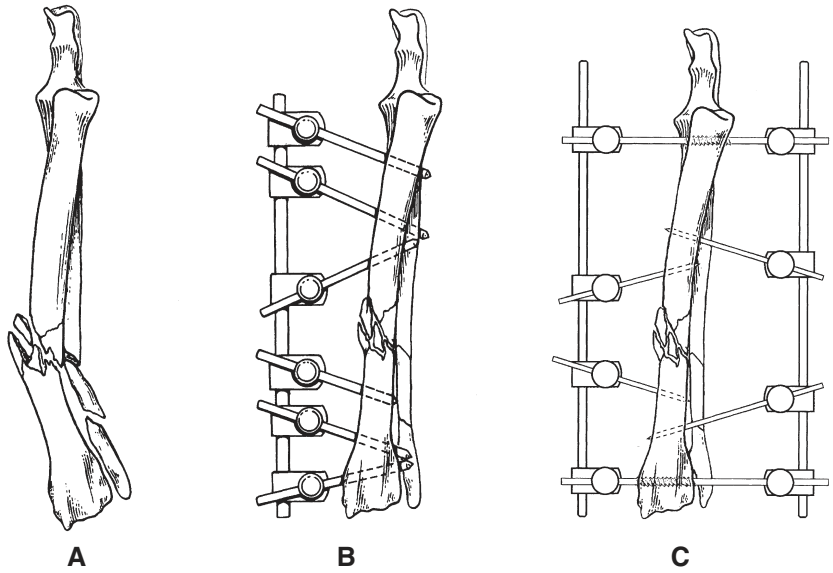


FIGURE 13-17. **A,** Type C3 midshaft fracture of radius and ulna. **B,** Fixation with a type IA external fixator, after closed reduction. **C,** Somewhat more stability can be provided in large, active breeds by this type IIB external fixator. Because of the cranial bow of the radius, it is much easier to place half pins rather than full pins in the midportion of the splint.

DISTAL FRACTURES

Radial fractures of this region can be exposed by a cranial midline incision between the extensor tendons.[8] Ulnar fractures are virtually subcutaneous and are exposed by simple skin incision.

Fracture Type 2-3-A; Distal, Extraarticular (Figure 13-18, *A*)

Type A1, Ulnar Fracture

These fractures may occur in association with luxation or subluxation of the antebrachiocarpal joint (Figure 13-19) or in isolation (Figure 13-20). Because the ulnar collateral ligaments originate on the styloid process, it is essential to fix these fractures to help stabilize the joint, especially in large, active animals. Supplemental external fixation in the form of a short caudal splint is necessary (see Figure 2-27).

Type A2, Simple Radial Fracture, and Type A3, Multifragmentary Radial Fracture

These injuries are common in small and toy breeds, usually the result of a jump or fall. Coaptation and IM pinning are common causes of nonunion in these breeds.[4,5,13]

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Please refer to the printed publication.

FIGURE 13-18. Distal fractures of the radius and ulna. **A:** *A1,* Ulna; *A2,* simple radial; *A3,* multifragmentary radial. **B:** *B1,* Sagittal radial; *B2,* frontal radial. **C:** *C1,* Simple, metaphyseal simple; *C2,* simple, metaphyseal multifragmentary; *C3,* multifragmentary. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

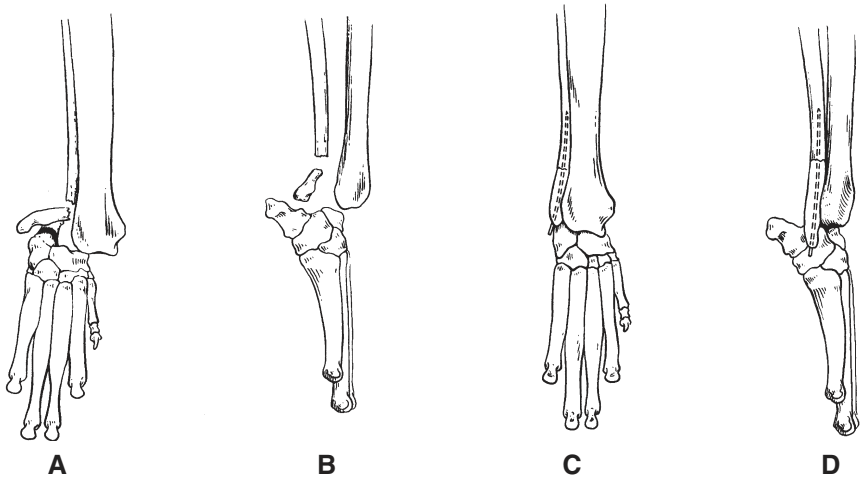


FIGURE 13-19. **A** and **B,** Type A1 fracture of the ulnar styloid with palmar luxation of the antebrachiocarpal joint. **C** and **D,** Intramedullary fixation of the styloid. If any ligament or the joint capsule is ruptured, it is repaired and a coaptation splint is added.

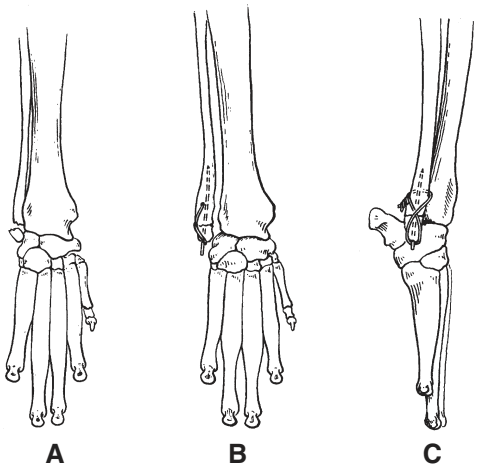


FIGURE 13-20. **A,** Type A1 fracture of the ulnar styloid. **B** and **C,** Fixation with a Kirschner wire and tension band wire to secure the short distal fragment and collateral ligament. Add a coaptation splint for stability, if indicated.

Closed Reduction and Fixation

Fixation by long-leg cylinder cast is appropriate for relatively transverse fractures (stable relative to shortening, fracture patient score 9 to 10) *in medium to large breeds,* especially if under 1 year of age.[4] (See previous discussion on cast fixation under Fixation Techniques.)

Open Reduction and Fixation

Bone Plates. The length of the distal fragment is the challenge for these fractures. A minimum of two screws (four cortices) are required in the bone, and three screws are ideal. For toy and miniature breeds, 1.5- to 2.0-mm screws and the mini T-plate or the VCP are the best implants. The T-plate must be applied cranially (Figure 13-21, *A*), but the VCP can be used medially (Figure 13-21, *B*)(see Fixation Techniques).

In medium-sized breeds, a 2.7-mm T-plate is suitable, as is a standard 2.7-mm plate applied medially. In large breeds a medial plate of 2.7- or 3.5-mm size is indicated.

External Fixators. As for plate fixation, the length of the distal fragment becomes the major consideration, and as with plates, two fixation pins are minimal and three are ideal. If the fragment is long enough, a type IA unilateral fixator may be sufficient (see Figure 13-3). Three pins in the distal fragment are achievable with the type 1B biplanar splint (Figure 13-22) or a hybrid type II-III splint (Figure 13-23). Acrylic fixation rods work very well in toy breeds and reduce costs of the splint as well.

Fracture Type 2-3-B; Distal, Partial Articular (Figure 13-18, *B*)

Fractures involving the styloid process of the radius give rise to instability of the antebrachiocarpal joint. Open reduction and internal fixation are indicated. Figure 13-24 presents examples of some of the various methods of fixation of a *type B1* fracture. In this oblique fracture of the radial styloid process, fixation may be done with two K-wires, a tension band wire, or a lag screw. The latter two methods provide better security than the simple K-wire fixation. Figure 13-25 depicts a *type B2* fracture combined with an A1 ulnar fracture. Because this fracture line is more directly in the weight-bearing surface of the radius, lag screw fixation is mandatory. In most cases, additional external support in the form

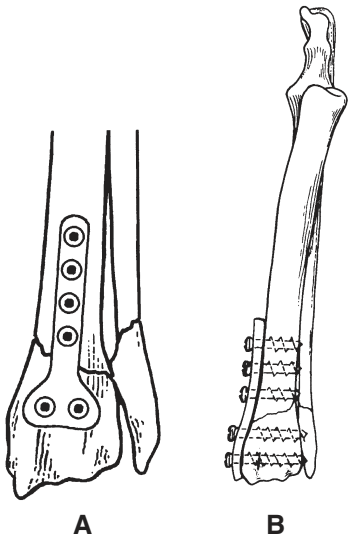


FIGURE 13-21. Type A2 simple distal radial fracture fixation. **A,** T-plate on the dorsal surface allows two screws to be placed in the short distal segment. **B,** Medial placement of T-plate increases the area's moment of inertia of the plate and the stiffness of fixation.

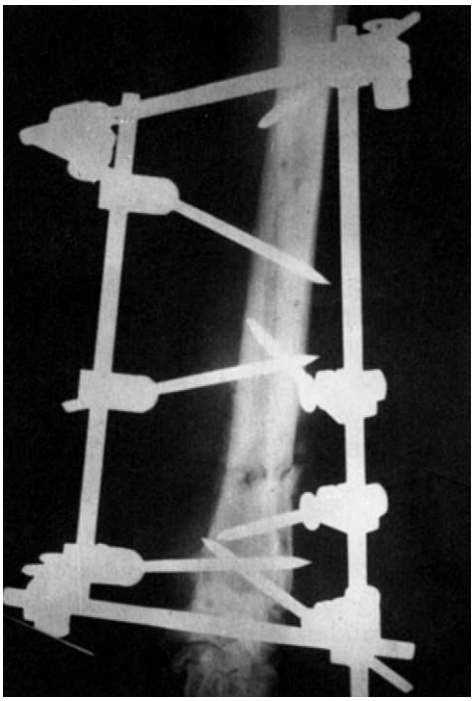


FIGURE 13-22. Placing three fixation pins in a type A2 simple distal radial fracture with a short distal fragment is possible by means of the type IB two-plane external fixator.

of a short caudal splint (see Figure 2-27) is indicated during the healing period (4-6 weeks).

Fracture Type 2-3-C; Distal, Complete Articular (Figure 13-18, *C*)

These injuries are rarely encountered,[2] which is fortunate, since they offer considerable challenge for adequate fixation, especially in toy or miniature breeds. *Type C1* and *type C2* fractures could be fixed by use of a medially placed plate

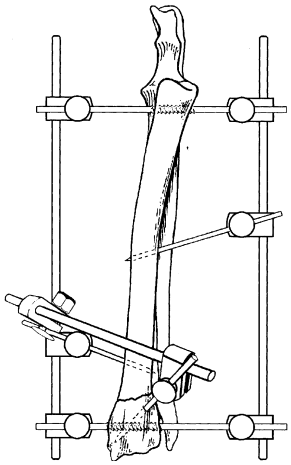


FIGURE 13-23. Fixation of this type A2 simple distal radial fracture with a very short distal fragment can be accomplished with a hybrid type I-II external fixator. In toy and miniature breeds the connecting bars and clamps are easily replaced by molded acrylic bars.

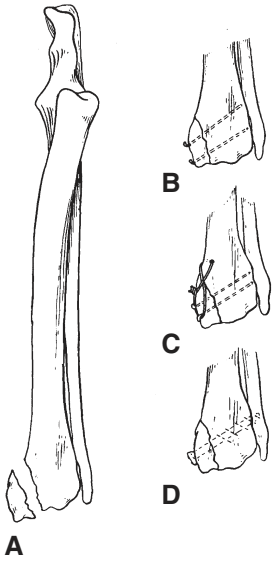


FIGURE 13-24. **A,** Type B1 distal partial articular fracture of the styloid process of the radius. Progressively more stable fixation can be achieved by **B,** two Kirschner wires; **C,** addition of a tension band wire; or **D,** a lag screw.

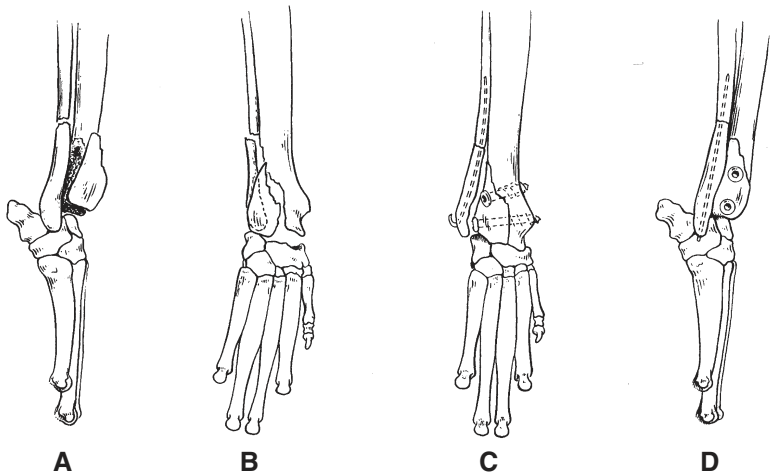


FIGURE 13-25. **A** and **B,** Combined type B1 and B2 partial articular fracture of the distal radius and distal ulna, **C** and **D,** Lag screw fixation of the distal radius with 4.0-mm cancellous screws and Kirschner wire, intramedullary fixation of the ulna. A coaptation splint is usually indicated for additional stability for the first 4 to 6 weeks postoperatively.

(Figure 13-21, *B*), with one or more of the distal screws placed in lag fashion to stabilize the articular fracture. It is highly unlikely that *type C3* fractures could be adequately reduced and fixed to provide a functional articular surface. Pancarpal arthrodesis is the most rational treatment of these injuries (see Chapter 14).

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14

Fractures and Other Orthopedic Conditions of the Carpus, Metacarpus, and Phalanges

OVERVIEW OF THE FOREPAW

Injuries of the forepaw may consist of fractures, ligamentous injuries, and various combinations. The paw constitutes a complex and highly critical structure, and the larger and more athletic the animal, the more devastating are injuries in this area. The horseman's cliché of "no feet, no horse" can also be applied to the dog. There is a tendency to treat ligamentous injuries in this area very conservatively, with cast immobilization, and to hope for sufficient fibroplasia to stabilize the joint. Although this may be moderately successful in small and inactive breeds, it rarely restores full function in large breeds. Randomly oriented collagen in scar tissue cannot withstand tensile stress and soon breaks down, leaving the joint permanently unstable. Such instability soon leads to degenerative joint disease, as described in Chapter 7.

Anatomy of the Forepaw

The bony anatomy of the forepaw is depicted in Figure 14-1, and the ligamentous structures are shown in Figure 14-2. Distal to the radius, the terms *cranial* and *caudal* are replaced by *dorsal* and *palmar.* The six bones of the carpus are arranged in a proximal and distal row, with three joint levels: the antebrachiocarpal, the middle carpal, and the carpometacarpal. The middle carpal is often referred to as the "intercarpal joint," but this term properly describes the joints between carpal bones of a given level. Ligaments of the carpus are generally short, with none spanning all three joints and most crossing only one joint level, connecting individual carpal bones. On the palmar side of the carpus, the joint capsule is well developed and blends with the palmar carpal fibrocartilage and ligaments. Note the dorsal sesamoids of the metacarpophalangeal and proximal interphalangeal joints in Figure 14-1; these bones are often mistaken for fractures of the metacarpal bones.

Surgical Approaches and Technique

The carpal joints are most frequently opened on the dorsal aspect of the midline, elevating and retracting the carpal extensor tendons medially and the digital

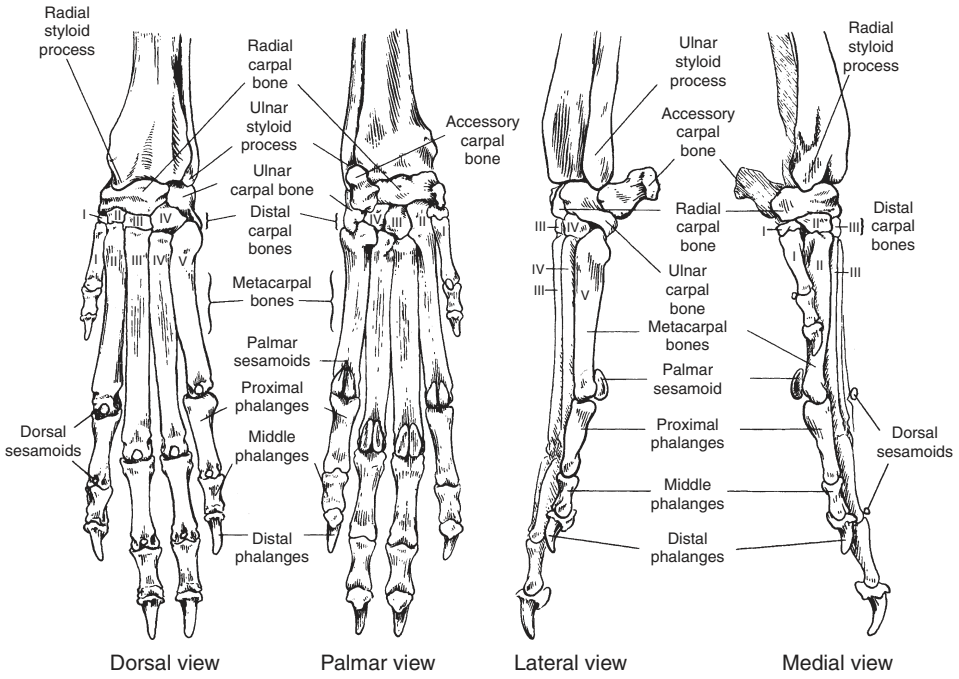


FIGURE 14-1. Bones of the carpus, metacarpus, and phalanges.

extensor tendons laterally (Figure 14-3, *A*).[1] The synovial capsule must be incised at each individual joint space because the synovium is adherent to each carpal bone. The palmar ligaments and carpal fibrocartilage can be exposed by an incision slightly medial to the midline. The flexor retinaculum is incised medial to the deep digital flexor tendon, which is then retracted laterally. From the dorsal aspect, metacarpal bones lie subcutaneously, covered only by digital extensor tendons and blood vessels (Figure 14-3, *B*).[1] Individual bones are exposed by incision of skin directly over the bone, with retraction of underlying vessels and tendons. Multiple bones are approached by parallel incisions or a variety of S-, U-, or H-shaped skin incisions.

Surgery of the lower limbs can be done with a tourniquet, which is invaluable for decreasing oozing hemorrhage and thus increasing visibility and decreasing operating time. Although pneumatic cuffs are the best way of creating the tourniquet more proximally in the limbs, distal tourniquets can be made more simply. Vetrap (3M Animal Care Products, St. Paul, Minn) elastic bandage material has proved very satisfactory for this purpose, as illustrated in Figure 14-4. Although the bandage is best sterilized in ethylene oxide, it can be steam sterilized at minimal time and temperature, similar to the method of sterilizing rubber gloves (250° F for 12 minutes). Use of the tourniquet is limited to about 60 minutes and has the disadvantage of producing more postoperative swelling. Application of casts or splints should be delayed 48 to 72 hours, with the lower limb supported in a Robert-Jones bandage during this time (see Figure 2-33).

Clinical Signs and Diagnosis of Injury

Most carpal luxations and fractures occur as a result of a fall or jump, but automobile trauma is also common. Affected limbs are non–weight bearing, have variable

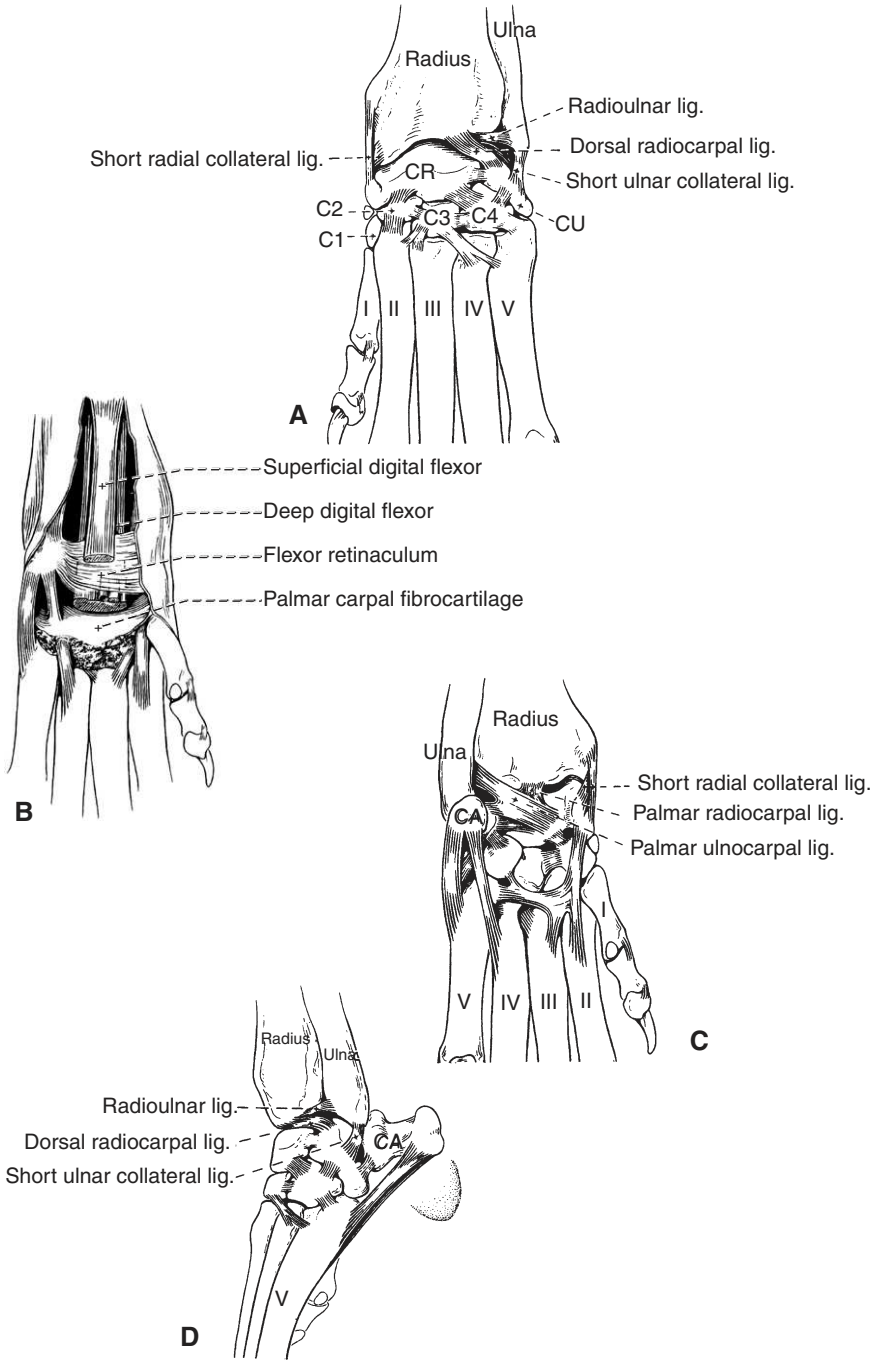


FIGURE 14-2. Ligaments of the carpus. **A,** Ligaments of the left carpus, dorsal aspect. *CR,* Radial carpal; *CU,* ulnar carpal; *C1* to *C4,* first, second, third, and fourth carpals; *I* to *V,* metacarpals. **B,** Superficial ligaments of the left carpus, palmar aspect. **C,** Deep ligaments in the left carpus, palmar aspect. *CA,* Accessory carpals; *I* to *V,* metacarpals. **D,** Ligaments of the left carpus, lateral aspect.

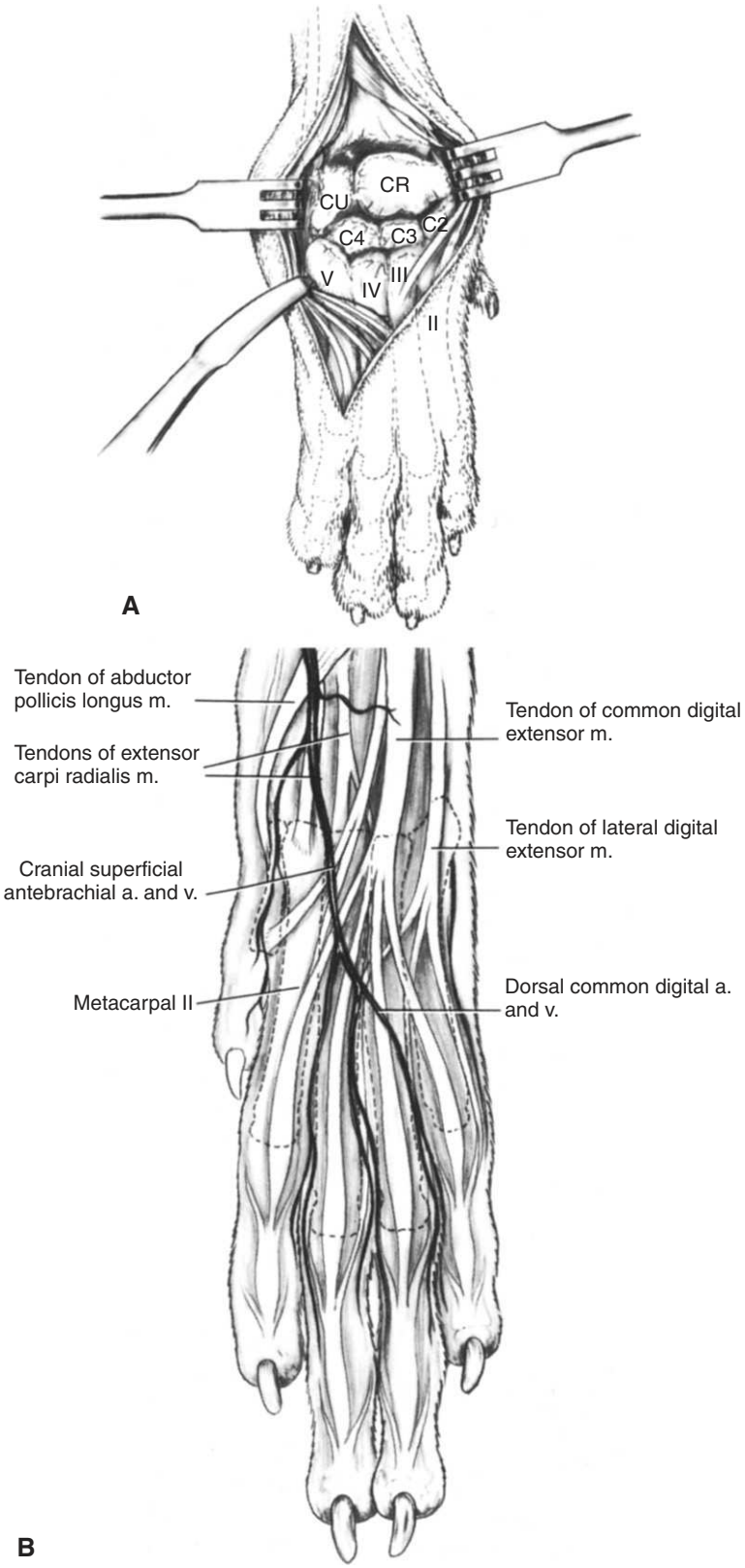


FIGURE 14-3. **A,** Approach to the distal radius and carpus through a dorsal incision. **B,** The most important vessels and tendons overlying the metacarpal bones are illustrated. Incisions to individual bones are made directly over the bones, and these structures are retracted as needed. Multiple bones are approached by parallel, C-shaped, or H-shaped incisions. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

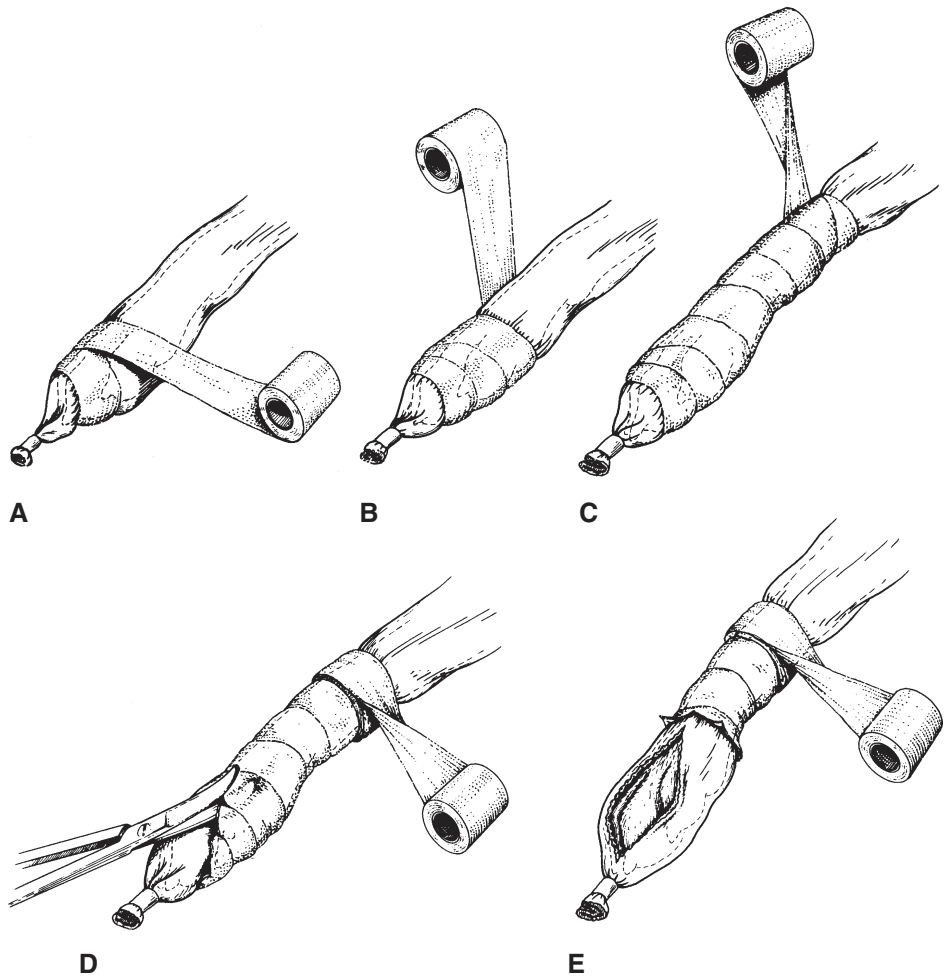


FIGURE 14-4. Application of a Vetrap tourniquet (3M Animal Care Products, St. Paul, Minn). **A,** After the foot has been draped in sterile stockinet bandage, a roll of 2-inch sterile Vetrap is secured around the toes. **B,** The Vetrap is wrapped very tightly as it is being wound proximally. **C,** When well proximal to the surgical field, the elastic bandage is wrapped several times in one area while the bandage is twisted 180 degrees. This forms the tourniquet. **D** and **E,** The stockinet and Vetrap are cut to expose the surgical field, in this case the phalanges.

swelling and joint effusion in the carpal region, and may show gross instability of the carpus when ligaments are injured. The limb is typically carried in abduction and flexed at the elbow and carpus.

Although clinical signs and palpation are usually sufficient to localize the area of probable injury, radiographs are necessary to verify the diagnosis and to localize the damage. Stress radiographs will show the area of instability. Standard cranial and lateral or medial views, plus oblique views, will identify ligamentous avulsions and fractures. Valgus- and varus-stressed cranial and standing lateral views are helpful to confirm subluxation and its location. Nonscreen film or fine-detail screens are essential.

THE CARPUS

Luxation of Antebrachiocarpal Joint

Total luxation of the antebrachiocarpal joint is fortunately a rare injury (Figure 14-5). Such total disruption of the ligamentous structure is disastrous. Panarthrodesis is usually the only means of restoring function (see Figures 14-22 and 14-23). Fusion of only the antebrachiocarpal joint has not been successful in our hands.

Subluxation of Antebrachiocarpal Joint

The most frequently injured ligaments at the antebrachiocarpal joint level are the radial collaterals, resulting in medial instability and valgus (lateral) deformity of the foot (Figure 14-6). Because the dog normally stands with the foot in valgus by a few degrees, the medial ligaments are always under tension. Injuries to the lateral

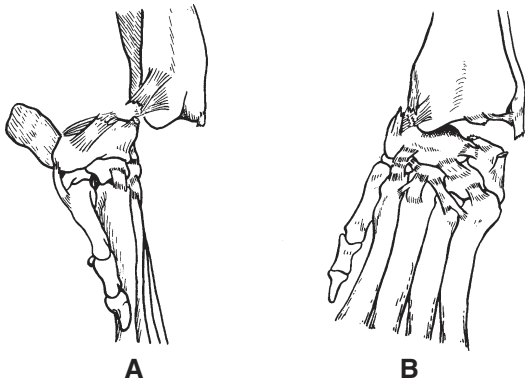


FIGURE 14-5. Luxation of the antebrachiocarpal joint. All the ligaments of the carpus are disrupted.

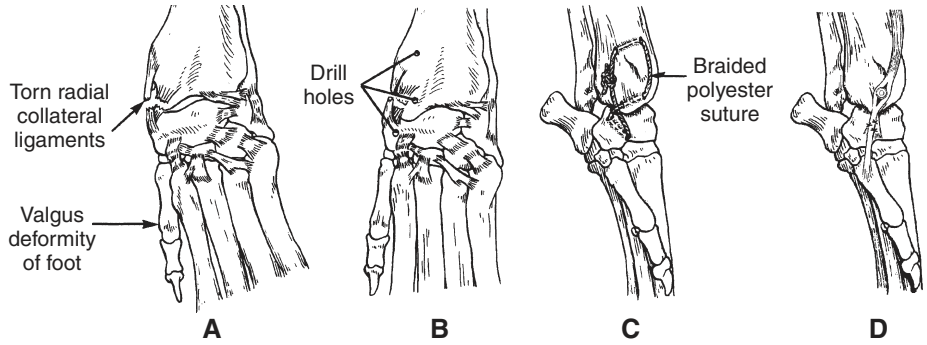


FIGURE 14-6. Subluxation of the antebrachiocarpal joint resulting from tearing of the radial collateral ligaments. **A,** Valgus deformity of the foot develops from medial instability. **B** and **C,** Synthetic braided suture is threaded through bone tunnels placed in the radial carpal bone and radius to simulate both the long and the short ligaments. An attempt is made to suture the ligaments, which have been omitted in these views for greater clarity. **D,** The abductor pollicis longus muscle has been elevated and moved into a position overlying the torn ligaments. It is secured proximally to the radius with a bone screw and spiked washer (Synthes, Ltd., Paoli, Pa) through the split tendon, and sutured distally at the radial carpal bone to remnants of the ligament.

ligaments are both less common and less serious because they are not subject to as much tension stress.

Surgical Technique

The long radial collateral ligament is important primarily when the joint is in extension. The short ligament limits and stabilizes mainly in flexion. Because the carpus slides in a dorsopalmar direction during flexion and extension, the function of these ligaments is complex. An attempt is always made to suture the ligaments, but this is particularly difficult in the short ligament. The area is exposed by a medial incision directly over the area. The ligaments are found immediately deep to the antebrachial fascia and the tendon of the abductor pollicis longus muscle. Bolstering a suture repair of the ligaments with synthetic material is usually advisable. Bone tunnels are drilled in the medial prominence of the radial carpal bone and in the radius (Figure 14-6, *B* and *C*). Braided polyester suture, size 0-2, is passed through these holes in a manner that simulates both the long and short ligaments. Although stainless steel wire is usually advised for such application, its use is not recommended for situations in which it is subject to alternate stretching and relaxation. Monofilament wire will quickly fatigue and break under such conditions and should be used only when it is under a continuous tension stress. The suture is tightened until the joint is stable but still mobile, then tied. The knot can be oversewn with fine wire or lightly seared with electrocoagulation to prevent untying.

Earley[2] was the first to report the use of autogenous tissue, such as the abductor pollicis longus or flexor carpi radialis muscle tendons, in replacing the radial collateral ligaments. The tendons were placed through bone tunnels in a manner similar to that used for the synthetic material. Additionally, the tendon of the abductor pollicis longus muscle can be directly attached to the sutured ligament, or the ligament can be replaced by securing the tendon to the bone and ligament. In Figure 14-6, *D,* the tendon has been secured to the radius by a small bone screw and plastic spiked washer (Synthes, Ltd., Paoli, Pa). Distally the tendon is sutured to remnants of the collateral ligament at its insertion on the radial carpal bone. The attachment procedure could be reversed, as the situation demands.

Aftercare

The carpus is immobilized in 10 to 15 degrees of flexion in a caudal splint for 4 to 6 weeks (see Figure 2-27). Strict confinement is continued through the eighth week, with a firm padded bandage in place after splint removal. A slowly progressive increase in exercise is then allowed, starting with leash walking, then short periods of free exercise. This program is slowly increased in intensity for another 4 to 6 weeks, at which point most patients are able to return to near-normal activity.

Luxation of Radial Carpal Bone

A relatively rare condition, luxation of the major bone of the carpus is possible following a jump or fall. The radial carpal bone pivots 90 degrees medially and in a dorsopalmar direction, coming to rest against the distopalmar rim of the radius (Figure 14-7, *A* and *B*). Severe lameness is always present with abduction of the limb and elbow flexion. Swelling is not remarkable, and the joint is not easily movable. Pain and crepitus are usually elicited by palpation, which easily reveals the displaced bone and a depression in its normal area.

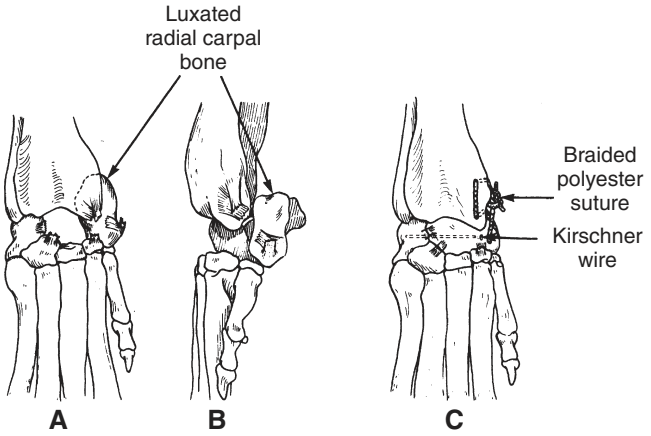


FIGURE 14-7. Luxation of the radial carpal bone. **A** and **B,** Dorsal and medial views illustrating the palmaromedial luxation of the radial carpal bone. The bone is rotated 90 degrees medially and dorsopalmar. **C,** The bone is reduced, and a Kirschner wire is driven through the bone into the ulnar carpal. Synthetic radial collateral ligaments stabilize the medial side of the joint.

Treatment

Closed Reduction

Surprisingly, the radial carpal bone can often be reduced closed if seen soon after injury. Functional stability is unlikely to result in large-breed dogs, however, because of damage to the radial collateral ligaments. Although splint fixation for a few weeks may well be justified in a toy-breed or small-breed dog, many patients will require surgical stabilization.

Open Reduction and Fixation

The joint is exposed by a dorsal midline approach as previously described. The following technique is a modification of the repair described by Punzet.[3] The lateromedial rotation is corrected first, and the bone is rotated in a palmodorsal direction to reduce it. A small pin or Kirschner wire is placed from the medial nonarticulating surface of the bone into the ulnar carpal bone. The pin is cut short and countersunk into the articular cartilage. A synthetic radial collateral ligament is constructed as detailed previously (see Figure 14-6). The remaining ligament is sutured if possible.

Aftercare

The carpus is immobilized in 10 to 15 degrees of flexion in a caudal splint for 4 to 6 weeks (see Figure 2-27). Strict confinement is continued through the eighth week, with a firm padded bandage in place after splint removal. A slowly progressive increase in exercise is then allowed, starting with leash walking, then short periods of free exercise. This program is slowly increased in intensity for another 4 to 6 weeks, at which point most patients are able to return to near-normal activity.

Fracture of Radial Carpal Bone

Fractures of the radial carpal bone, which, with the radius, forms the antebrachiocarpal joint—the major joint of the carpus—are usually manifested as chips or slabs off the articular surfaces (Figures 14-8, 14-9, and 14-10). These fractures are most often seen after injuries resulting from jumps or falls and in dogs undergoing heavy exertion, such as sled dogs, field trial dogs, and other working breeds. Fragments are apparently created by a compressive force combined with shear. There is little

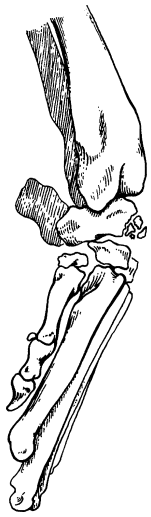


FIGURE 14-8. Comminuted dorsal slab fracture of the radial carpal bone. The fragments are excised in this type of injury.

tendency for these fragments to heal spontaneously, and the bony or cartilaginous fragments usually become "joint mice," creating an acute inflammatory reaction in the joint and leading to synovitis and degenerative joint disease. Lameness is severe but subsides somewhat in a few weeks. The dog may be sound when rested but becomes lame when exercised. Soft tissue thickening around the joint may become obvious after a few more weeks as a result of synovitis and arthritis.

Diagnosis requires a high index of suspicion because radiographs (nonscreen film or high-detail screens) must be made in oblique planes and in flexion and extension to verify the fracture. Sometimes, only a unilateral arthrosis is seen, but if the history supports a traumatic cause, this is sufficient justification for exploration of the joint.

Treatment

Closed Reduction

Undisplaced fragments may reattach if the joint is splinted for 4 weeks. The prognosis is uncertain, however, and many patients require surgery later.

Open Reduction and Fixation

Surgery may be performed with a tourniquet, and most fractures can be exposed from a dorsal approach. Considerable synovial proliferation and inflammation may complicate the exposure. When the fragment is located, the surgeon decides whether to reattach or remove the fragment. To be reattached, the fragment must be large enough to handle; moreover, the fracture surfaces should not be severely eburnated, as may happen in a chronic fracture. If small screws are used, their heads must not interfere with any other structures (Figure 14-9, *C* and *D,* and 14-10, *B* and *C*). Miniscrews 1.5 and 2.0 mm in diameter are the most useful sizes. Kirschner wires countersunk below the level of the cartilage or bone are also used (Figure 14-9, *E* and *F*). Fragments are often excised because they cannot be reattached because of chronicity and resulting eburnation (Figure 14-11). In this situation the desired result is an adequate fibrocartilage scar to fill in the defect.

Prognosis

The outlook for satisfactory function is usually good unless the bone is comminuted; this situation usually calls for arthrodesis (see Figure 14-22).

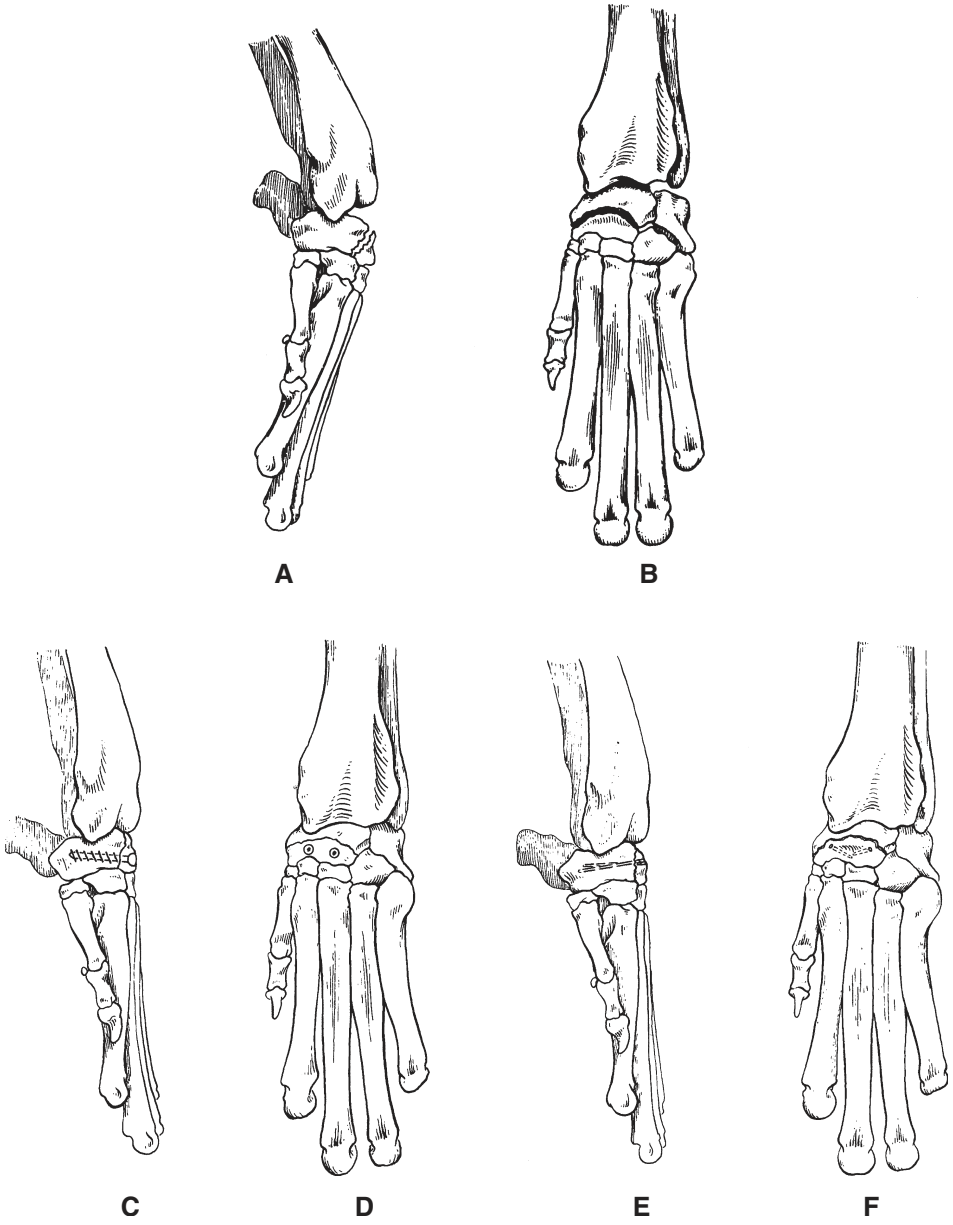


FIGURE 14-9. **A** and **B,** Dorsal slab fracture of the radial carpal bone. **C** and **D,** Two lag screws of 1.5-mm or 2.0-mm diameter are countersunk beneath the articular surface when the fragment is large enough. **E** and **F,** Smaller fragments may be secured by two or more Kirschner wires countersunk beneath the surface of the articular cartilage or bone.

Aftercare

A short, molded palmar splint or short cast (see Figures 2-27 and 2-22, respectively) is applied for 3 to 4 weeks after fixation of the fragments. Exercise is limited for 6 to 8 weeks, until there is radiographic evidence of healing. If the fragments are excised, the joint is rested in a similar splint for 10 days, after which light exercise is advisable through the fourth postoperative week.

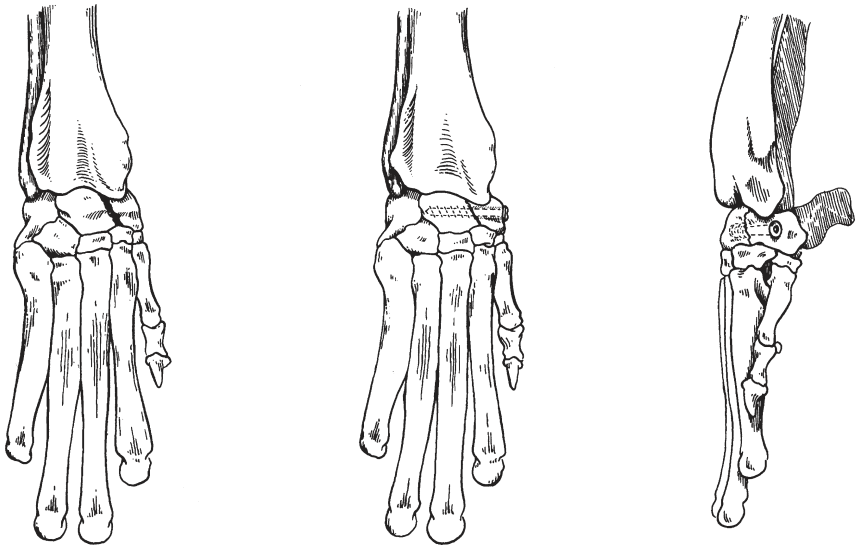


FIGURE 14-10. **A,** Oblique fracture through the body of the radial carpal bone. **B** and **C,** Lag screw fixation with a 2.7-, 3.5-, or 4.0-mm lag screw inserted from the medial surface of the bone. The screw is placed through the insertions of the radial collateral ligaments (see Figure 14-2). In this position, the screw head will not interfere with joint motion.

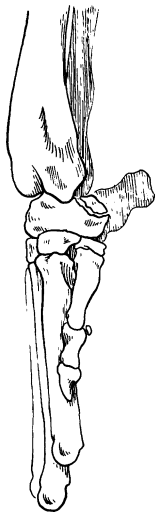


FIGURE 14-11. Fracture of the palmaromedial portion of the radial carpal bone (mediolateral view). Such fragments are simply excised because they are not on the main weight-bearing area of the bone.

Fracture of Accessory Carpal Bone

Fractures of the accessory carpal bone are seen most often in the racing greyhound but may be seen occasionally in most of the large breeds. Most fractures are self-induced avulsions (grade III sprains or strains; see Chapter 7), rather than caused by outside trauma. Johnson and colleagues[4,5] have described these fractures and proposed the following classification system.

Classification

Intraarticular Fractures

Type I, Distal Basilar. Avulsion fracture of the distal margin of the articular surface at the origin of the accessoroulnar carpal ligaments (Figure 14-12, *A*).

Type II, Proximal Basilar. Avulsion fracture of the proximal margin at the insertion of the ligaments to the radius, ulna, and radial carpal bone (Figure 14-12, *C*).

Extraarticular Fractures

Type III, Distal Apical. Avulsion fracture of the distal margin of the palmar end of the bone at the origin of the two palmar accessorometacarpal ligaments (Figure 14-12, *E*).

Type IV, Proximal Apical. Avulsion fracture of the tendon of insertion of the flexor carpi ulnaris muscle at the proximal surface of the palmar end of the bone (see Figure 14-14, *A*).

Combined Intraarticular and Extraarticular Fractures

Type V, Comminuted Fracture of the Body. May extend into the articular surface (see Figure 14-15).

Type I fractures constitute 67% of the injuries in the racing greyhound and occur almost exclusively in the right limb, whereas type III injuries are the least common and occur mainly in the left limb.[5] Type II injuries rarely occur alone; they are usually seen concurrently with type I fractures. In other breeds, type IV and V fractures predominate.

Clinical Signs

In track injuries, the dog usually comes off the track mildly lame, but clinical signs may not be noted until the day after the injury, when slight lameness and swelling are observed in the region of the accessory carpal bone. Clinical signs include swelling of the carpus, pain on digital pressure lateral to the accessory carpal bone, and pain on carpal flexion. Rest will lead to diminution of these signs, but a chronic

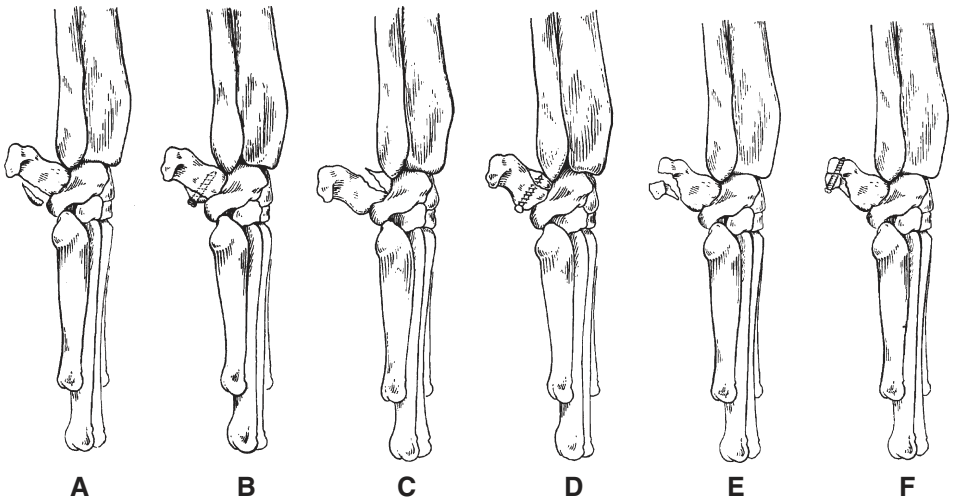


FIGURE 14-12. Fractures of the accessory carpal bone. **A** and **B,** Type I distal-basilar fracture and fixation of the fracture with a 2-mm screw. **C** and **D,** Type II proximal-basilar fracture and fixation with a 2-mm screw. **E** and **F,** Type III distal-apical fracture and fixation with a 2-mm screw.

low-grade lameness persists when exercise is resumed. There is minimal tendency for complete healing to occur with conservative treatment, such as external splinting or casting of the limb.

Treatment

Although simple excision of the fragment in type I injuries has been advocated, less than 50% of our animals so treated have ever returned to the track. With this technique, successful healing seems to depend on scar tissue reattachment of the distal ligaments to the bone. Failure to achieve this results in instability of the accessory carpal bone, leading to inflammation and degenerative joint disease. Because scar tissue does not have nearly the tensile strength of ligamentous tissue, it does not adequately replace the ligament in areas of high tensile stress. Screw fixation of type I, II, and III injuries has resulted in 91% of these dogs returning to training or racing, and 45% of those won one or more races.[6] Although these case numbers are small, nevertheless these results are encouraging and dramatically different from excisional treatment, and this approach is our preferred treatment (see Figures 14-12 and 14-13).

Open Reduction and Internal Fixation, Type I. A palmarolateral approach is made.[1] The fragment is reduced and clamped with small, pointed reduction forceps or Lewin forceps (Figure 14-13, *A*). Fixation is accomplished by a 2-mm screw (Figure 14-13, *B*). This is *not* placed as a lag screw because of the difficulty

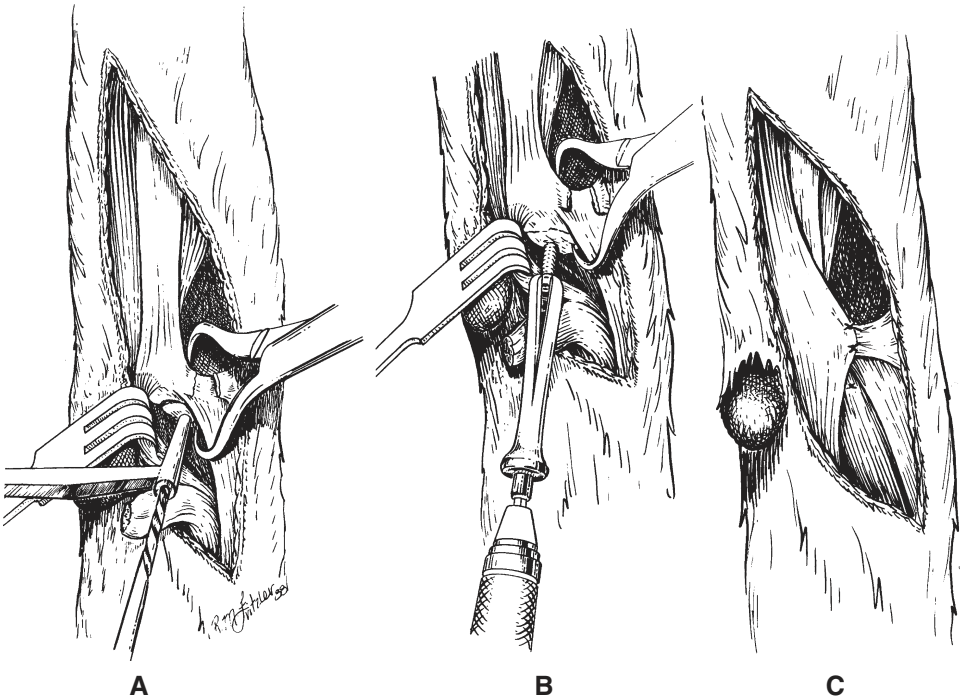


FIGURE 14-13. **A,** Screw fixation of accessory carpal bone fracture. The accessorometacarpal IV ligament is retracted medially. The fragment is reduced and clamped with small, pointed reduction forceps or Lewin forceps. A 1.5-mm drill is used to place a drill hole in the center of the fragment. If the drill is held parallel to the metacarpus, the angle will be correct to prevent entering the joint space. **B,** The hole is measured and tapped, and a 2-mm screw is driven with the clamp in place. This is not a lag screw; the clamp supplies compression. **C,** The tendinous slip from the ulnaris lateralis tendon is sutured, followed by the antebrachial fascia, and then the skin.

in determining the depth of the glide hole required for lag effect and because drilling with a 2-mm bit to produce a glide hole probably poses an unnecessary risk of splitting the fragment. The bone clamp is used to supply compression. Closure of the approach includes suturing of the abductor digiti quinti muscle and the tendinous slip from the ulnaris lateralis tendon to the accessory carpal bone (Figure 14-13, *C*).

Treatment of Other Fracture Types

Fractures seen most often in nonracing animals include the type IV proximal apical avulsion fracture of the free end of the bone (Figure 14-14, *A*) and type V body fracture with varying degrees of comminution of the bone (Figure 14-15). The type IV avulsion

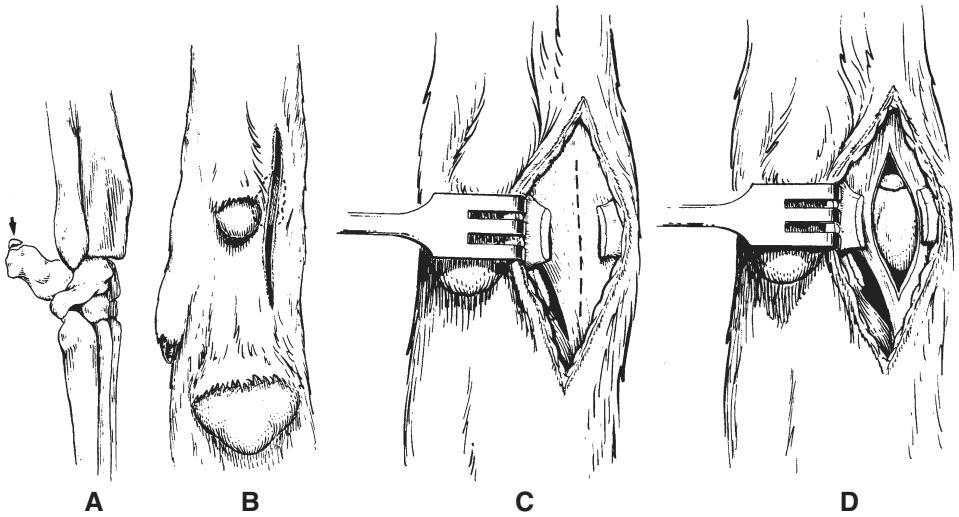


FIGURE 14-14. A, Avulsion of part of the insertion of the flexor carpi ulnaris muscle on the free end of the right accessory carpal bone (type IV fracture). **B,** Skin and antebrachial fascia incisions for removal of the fragment are slightly lateral to the bone. **C,** The tendinous slip from the ulnaris lateralis muscle is incised over the free end of the bone, and a midsagittal incision is made in the tendon of the flexor carpi ulnaris. **D,** Careful dissection through the tendon will reveal the fracture fragment, which is then dissected free; care must be taken to avoid unnecessary trauma to the tendon. The tendon incision is closed with interrupted sutures, followed by the tendinous slip over the free end of the bone, the antebrachial fascia, and the skin.

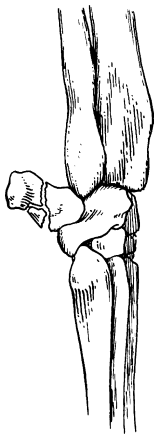


FIGURE 14-15. Comminuted nonarticular type V fracture of the accessory carpal bone. This fracture was splinted in 20 degrees of flexion and healed well.

is in the insertion of the flexor carpi ulnaris muscle and causes mild but persistent irritation until the fragment is removed (Figure 14-14, *B, C,* and *D*).

Internal fixation of type V comminuted fractures by miniscrew fixation is feasible, but most limbs treated for this injury are cast in 20 degrees of flexion with surprisingly good healing and function if the fracture is entirely extraarticular. If there is an intraarticular component, an attempt should be made to do an internal fixation of that part of the fracture.

Aftercare

After *screw fixation* a molded palmar splint or short cast (see Figures 2-27 and 2-22) is applied with the carpus flexed 20 degrees. The splint is maintained for 4 weeks. Complete confinement is enforced through the eighth postoperative week, followed by 4 weeks of gradually increasing activity. Regular training or activity is started by the 12th week.

After *excision of fragments* the splint is maintained for 2 weeks, followed by an elastic bandage for 2 weeks. Exercise is restricted for 4 more weeks. Splinting of a comminuted fracture is maintained until radiographic signs of healing are obvious, usually in about 6 weeks. Full exercise should not be started until 3 or 4 weeks after splint removal.

Subluxation of Accessory Carpal Bone

This injury is discussed later under Hyperextension of the Carpus.

Fracture of Ulnar and Numbered Carpal Bones

We have not observed fractures of the ulnar carpal bone. Fracture of the distal row of numbered bones is rare and usually manifests as a small chip or slab on the dorsal surface (Figure 14-16). Clinical signs of intermittent mild lameness and joint effusion are noted. Because these bones are smaller, radiographic diagnosis and reattachment of fragments are more difficult. Multiple oblique views are often necessary for visualization. Because these bones are all directly in contact with the synovium, adhesions form early between the fragments, or between the damaged articular surface, and the synovial membrane. Most of these fractures are treated by excision

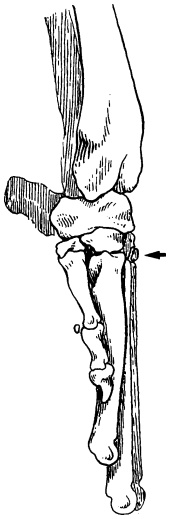


FIGURE 14-16. A small fracture *(arrow)* on the dorsal surface of the third carpal bone. This fragment was excised.

of fragments and curettage of the damaged articular surface to ensure fibrocartilaginous scar formation. Small, nondisplaced fragments may reattach and heal after 3 to 4 weeks of splinting the carpus.

Middle Carpal Luxation

Complete disruption of the middle carpal joint is unusual but does occur, as illustrated in Figure 14-17. This was a combined antebrachiocarpal and middle carpal luxation because the ulnar carpal remained attached to the distal carpal bones in this 10-pound mixed terrier. In this case the foot had twisted laterally (supination) about 60 degrees. A closed reduction was performed, and the lower limb was splinted for 6 weeks. Spontaneous ankylosis of the middle carpal joint adequately stabilized the carpus in this small animal. It is highly unlikely that adequate stability would occur in a larger animal that was treated conservatively in this manner. Hyperextension of the middle carpal joint would almost always develop, necessitating partial arthrodesis of the carpus (see Figures 14-20 and 14-21). Because of the complexity of the injury, primary repair and stabilization of a complete luxation, although technically possible, are not very feasible.

Middle Carpal Subluxation

Subluxation of the middle carpal joint, with medial instability, is a much more common problem than complete luxation. Dorsomedial ligamentous disruption between the radial carpal and carpal 2 and occasionally between carpal 2 and metacarpal II results in valgus deformity of the foot (Figure 14-18). Less easily appreciated is the frequent damage to the palmaromedial ligaments or carpal fibrocartilage, with resultant hyperextension (see later discussion). This hyperextension affects only the medial half of the carpus and therefore is not as dramatic as the examples shown later. The mediolateral projection stress radiographs (see Figure 14-19) will need to be taken with slight internal rotation (pronation) of the paw to demonstrate hyperextension in this situation. If hyperextension is *not* present, the repair can proceed as described here. If hyperextension *is* present, the medial wire augmentation repair

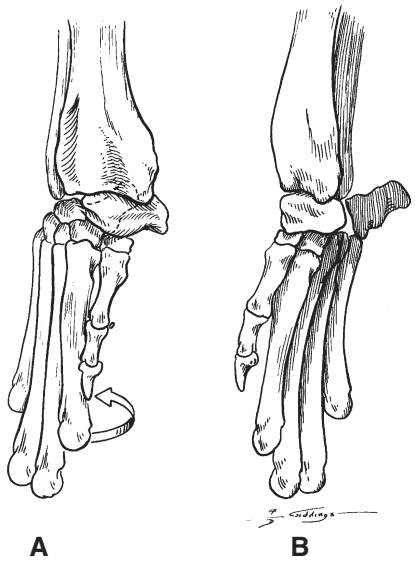


FIGURE 14-17. Middle carpal joint luxation, right limb. **A,** This is actually a combined middle and antebrachiocarpal luxation because the ulnar carpal bone has remained with the distal carpals. The foot has supinated 60 degrees. Dorsal view. **B,** Medial view showing supination of the foot.

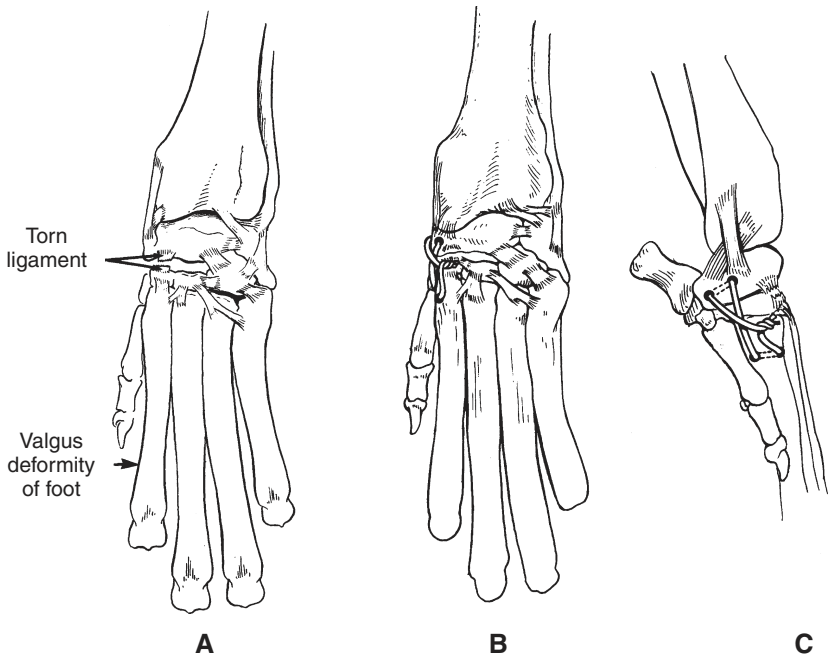


FIGURE 14-18. Middle carpal joint subluxation with medial instability. Left limb, dorsal view. **A,** Ligaments are torn between the radial carpal and carpal 2. **B** and **C,** Bone tunnels are drilled in the palmaromedial process of the radial carpal bone and in the base of metacarpal II. Stainless steel wire of 20 to 22 gauge (0.8-0.6 mm) is threaded through the holes in figure-of-8 fashion and the wire tightened enough to eliminate the valgus instability.

described here is performed, plus a partial arthrodesis of the medial half of the middle carpal and carpometacarpal joints (see Figure 14-20). The Kirschner wires seen in Figure 14-20 are placed in metacarpals II and III in this case.

Treatment

Closed Reduction and External Fixation

Conservative treatment can be considered for cats, toy, and small breeds when the observed laxity is minimal. A molded palmar splint or short cast (see Figures 2-27 and 2-22) is applied with the carpus flexed 20 degrees. The splint is maintained for 4 weeks. Complete confinement is enforced through the eighth postoperative week, followed by 4 weeks of gradually increasing activity. Regular training or activity is started by the twelfth week. Such treatment in larger breeds is reserved for type I and II sprain injury without laxity.

Open Reduction and Stabilization

The dorsomedial instability is reduced by a synthetic ligament reconstruction with monofilament wire because it is not possible to do a primary suture repair of the ligament. The incision for the dorsal approach to the carpus is positioned dorsomedially on the carpus. If a partial arthrodesis is to be performed concurrently, it is done first. (See following discussion under Hyperextension of the Carpus for details.) The wire placement proceeds by exposure of the medial aspect of the joint. A bone tunnel is drilled through the palmaromedial process of the radial carpal bone and through the base of metacarpal II (Figure 14-18, *B* and *C*). Stainless steel

wire, 18 gauge (1 mm) to 22 gauge (0.6 mm), is threaded through the holes in figure-of-8 fashion. The valgus deformity is reduced and the wire tightened until the instability is abolished. Care must be taken to turn the twisted end of the wire closely against the bone to minimize skin irritation. Closure of the skin completes the procedure.

Aftercare

The carpus is immobilized in 10 to 15 degrees of flexion in a caudal splint (see Figure 2-27) for 4 to 6 weeks. Strict confinement is continued through the eighth week, with a firm padded bandage in place after splint removal. A slowly progressive increase in exercise is then allowed, starting with leash walking, then short periods of free exercise. This program is slowly increased in intensity for another 4 to 6 weeks, at which point most patients are able to return to near-normal activity. If a partial arthrodesis was done, use the aftercare routine for that procedure, as described later.

Hyperextension of the Carpus

Among the most serious injuries to the canine carpus, hyperextension is also one of the more common, occurring in midsize and large breeds of dogs after falls and jumps. The structures responsible for maintaining the normal 10 to 12 degrees of carpal extension (Figure 14-19, *A*) are the palmar ligaments and palmar carpal fibrocartilage (see Figure 14-2, *B, C,* and *D*). It is commonly held that hyperextension

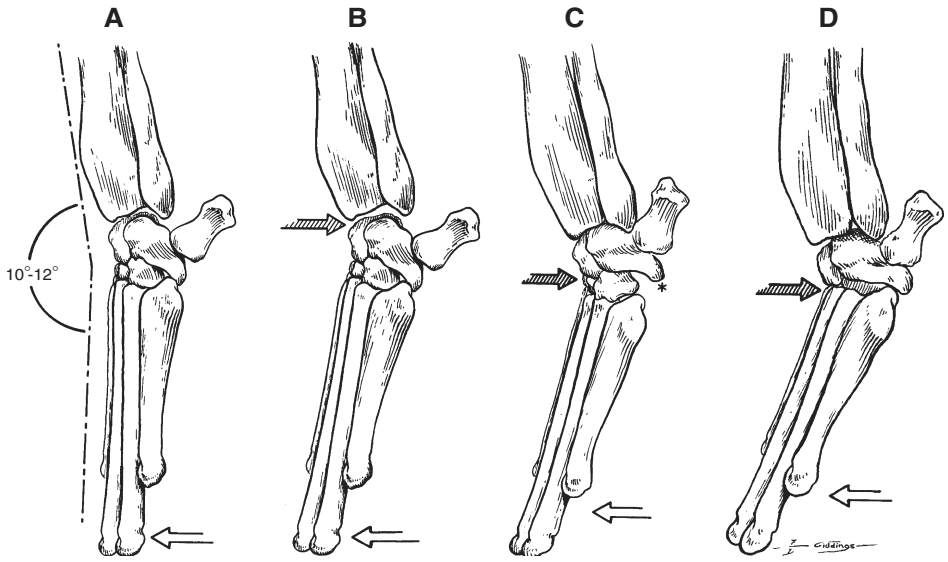


FIGURE 14-19. Stress radiographs for diagnosis of carpal hyperextension. Left limb, lateral views. **A,** Lateral view of a normal carpus with the foot stressed *(open arrow)* to maximal extension of 10 to 12 degrees. Note the angular relationships of the proximal carpal bones to the radius and to the distal carpal bones. Note also the angular relationship between the carpal and metacarpal bones. **B,** Lateral view of hyperextension at the antebrachiocarpal joint *(shaded arrow)*. The only difference from normal is the increased angle of extension. **C,** Lateral view of hyperextension at the middle carpal joint *(shaded arrow)*. Note the gap between the palmar process of the ulnar carpal bone (*star*) and the base of metacarpal V. **D,** Lateral view of hyperextension at the carpometacarpal level *(shaded arrow)*. The bases of the metacarpal bones appear to overlap the carpal bones.

of the carpus is a result of tendon injury, but in fact the only tendon that bears on carpal stability in extension is the flexor carpi ulnaris, which inserts on the accessory carpal bone. Sectioning of this tendon results in very slight hyperextension at the antebrachiocarpal joint. Diagnosis of this problem is relatively easy because there will be either a laceration of the skin or, in the case of spontaneous rupture or avulsion (rare), palpable evidence of soft tissue inflammation.

History and Clinical Signs

Invariably there is a history of injury caused by a fall or jump. If there is no history of injury and hyperextension has developed slowly, immune-mediated joint disease or degenerative conditions of the ligaments may be the cause (see Chapter 6). Surprisingly, minimal signs of pain and inflammation are associated with hyperextension injuries after a few days. Animals typically will attempt weight bearing within 5 to 7 days. A seal-like or plantigrade stance is characteristic but variable in appearance. Some animals may be walking on their carpal pads, but others may show only 20 to 30 degrees of extension. Pressure and abrasion sores are common sequelae.

Diagnosis

To select the proper treatment, it is important to know at which joint level the injury has occurred. In our experience the distribution of injuries has been as follows:

1. Antebrachiocarpal, 10%
2. Middle carpal, 28%
3. Carpometacarpal, 46%
4. Combined middle and carpometacarpal, 16%

A very rare injury, involving isolated subluxation of the base of the accessory carpal bone caused by rupture of the accessoroulnar ligaments, with associated mild carpal hyperextension, has been reported.[7]

Definition of the joint level involved is possible only by radiographic examination. A medial or lateral exposure is made with the limb stressed to maximal carpal extension (Figure 14-19). A palmar intraarticular fracture of the radius is often seen when hyperextension is present at the antebrachiocarpal level (Figure 14-19, *B*). When the injury is at the middle carpal level, the palmar process of the ulnar carpal bone becomes separated from the base of metacarpal V, and the process is easily identified (Figure 14-19, *C*). The accessory carpal bone may show evidence of subluxation and proximal angulation. With carpometacarpal injury the proximal carpal bones override the distal row (Figure 14-19, *D*). Chronic antebrachiocarpal level injuries show wearing of the palmar edge of the distal radius caused by the proximal carpal bones as they subluxate in a palmar direction. In chronic middle carpal instability the radial and ulnar carpal bones can pivot in a distopalmar direction, their dorsodistal edges coming to rest on the base of the metacarpals, creating a wide gap between the craniodorsal surface of the radius and the radial carpal bone. In chronic injuries at all levels, varying degrees of bony proliferation will be present where the more proximal bones override the distal bones.

In the case of subluxation of the accessory carpal bone mentioned earlier, there was increased space in the accessoroulnar joint space in lateral radiographs taken in flexion. When the carpus was stressed in extension, the accessory carpal bone and ulnar carpal bone shifted laterally, as visualized in dorsopalmar views.[7]

Treatment

Two basic types of arthrodesis are performed in the carpal region. Panarthrodesis involves surgical fusion of all three joint levels: the antebrachiocarpal, the

middle carpal, and the carpometacarpal. Partial arthrodesis involves fusion of only the middle and distal joints. Panarthrodesis has been a widely practiced method of treating carpal hyperextension, regardless of the joint level involved.[8] This has been a satisfactory method of treatment, with 97% of owners reporting improvement in gait and 74% reporting normal use of the limb.[8] Nevertheless, panarthrodesis destroys a normal joint (antebrachiocarpal) and requires the use of bone-plating equipment (see Figures 14-22 and 14-23, *A* and *B*) or external skeletal fixators (see Figure 14-23, *C*).

Partial arthrodesis (fusion of the middle carpal and carpometacarpal joints only) is probably a better approach for those injuries that involve only the middle and distal joints[9] (see Figures 14-20 and 14-21). With this technique, flexion of the major joint of the carpus—the antebrachiocarpal joint—is maintained, and gait is affected little. In performance dogs, partial arthrodesis has the potential for returning the dog to athletic pursuits, whereas panarthrodesis does not. Conversely, in chronic cases with marked degenerative joint disease, panarthrodesis will yield better results. Conservative treatment by splinting in flexion or hyperextension seems to have little application, since virtually all animals will break down again after return to weight bearing. Patients with mild hyperextension at the antebrachiocarpal level and smaller animals are the best candidates for treatment by splintage. Arthrodesis can be performed later if necessary.

Partial Arthrodesis

Partial, or subtotal, arthrodesis involves surgical fusion of only the middle level and carpometacarpal joints. Subluxation of the accessory carpal bone need not be addressed. The function of the carpus remains essentially normal in this technique because there is little motion normally present in these joint levels. The antebrachiocarpal joint, which is responsible for virtually all flexion of the carpus, remains functional. The major indication for partial arthrodesis is hyperextension of the middle carpal and carpometacarpal joint levels, which together account for 90% of all hyperextension injuries of the carpus. Both joints are fused when either is injured because of the technical difficulty of fusing either individually. On occasion, instability will develop medially at either of these joints and will not respond to treatment (see Figure 14-18); these cases could also be considered for partial arthrodesis. Attainment of a partial arthrodesis is more difficult to achieve than panarthrodesis. Some surgeons reserve partial arthrodesis for performance dogs.

Pin Fixation Method. A dorsal midline approach to the carpus is made, with the incision extending distally to the level of the metacarpophalangeal joints (Figure 14-20, *A*). A tourniquet can be used. Preoperative preparations and draping are made to allow collection of a cancellous bone graft from the proximal humerus of the same limb (see Chapter 3). Articular cartilage of the middle carpal, intercarpal, and carpometacarpal joints is debrided with a curette or high-speed bur. Care is taken to preserve the insertions of the extensor carpi radialis tendon on the proximal ends of metacarpals II and III. If the high-speed bur is used, slots are burred through the distal cortex of metacarpals III and IV at the level of the distal third of the shaft (Figure 14-20, *B*). Kirschner wires (0.045 or 0.062 inch; 1.2 or 1.6 mm) are introduced through the slots into the medullary canal in the manner of a Rush pin and driven proximally into the base of the metacarpal bone. The cortical slots must be long enough to allow the pin to bend as it is introduced into the medullary canal. Failure of the pins to drive easily up the medullary canal means that the pins are too large in diameter or that the slot is too short. Autogenous cancellous graft is collected from the proximal humerus and packed into the debrided

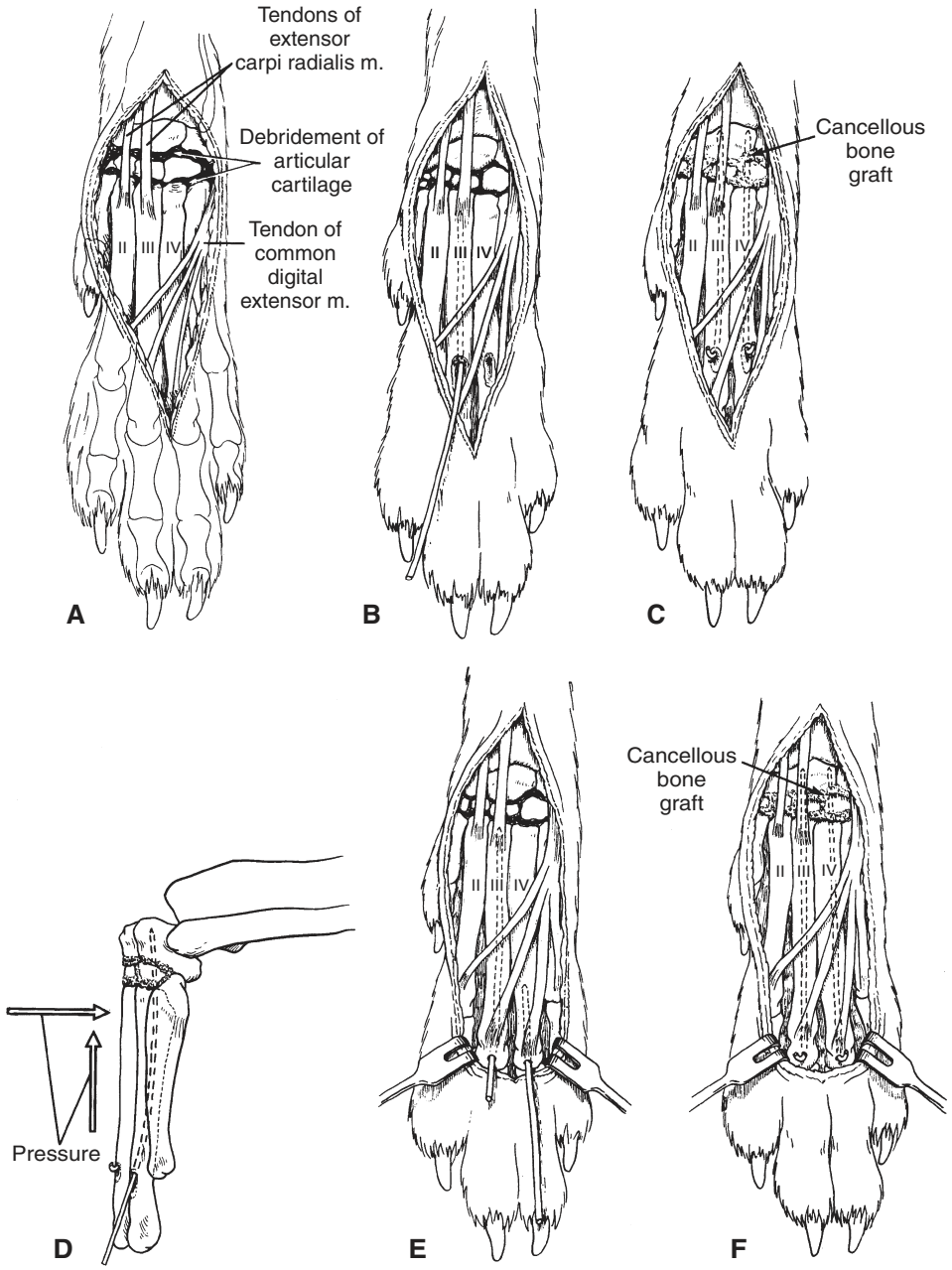


FIGURE 14-20. Partial arthrodesis of the carpus with pin fixation. **A,** The carpus is exposed by a dorsal midline incision. The middle carpal, carpometacarpal, and intercarpal joints are debrided of articular cartilage. **B,** Slots are burred in the dorsal cortex of metacarpals III and IV in the distal third of the bones. Kirschner wire (0.045 or 0.062 inch) is introduced into the medullary canal in the manner of a Rush pin. **C,** Both pins are seated (see also *D*), and the protruding end is bent into a hook shape and cut off. **D,** Autogenous cancellous bone graft is placed in all the prepared joint spaces. The carpus is flexed 90 degrees, and palmar and proximal pressure on the metacarpal bones is applied to position the carpal bones correctly relative to the metacarpals. The Kirschner wires are now driven into the proximal row of carpal bones as deeply as possible without penetrating the articular surface. **E,** An alternative method of placing the Kirschner wires is to drive them from the metacarpophalangeal joints proximally. Two pins are placed and driven to the base of metacarpals III and IV. **F,** Pins placed at the metacarpophalangeal joint are also bent to a hook shape and cut off.

joint spaces. With the carpus held in extreme flexion to reduce the subluxation of the middle carpal or carpometacarpal level, pins are driven proximally into the radial carpal bone (Figure 14-20, *D*). The pins must not penetrate the proximal articular cartilage of the radial carpal bone. The pins are backed out a few millimeters, then bent to form a hook at the distal end and cut off. The pins are then pushed or driven proximally to their original depth, after which the hook is rotated flat against the bone (Figure 14-20, *C*).

If no power bur is available, it is difficult to cut slots in the metacarpal bones; two methods can be substituted in this situation, as follows:

1. The pins can be driven from the metacarpophalangeal joint proximally into the shaft of the bone, similar to pinning a metacarpal fracture (see Figure 14-30). The pins should enter the bone slightly dorsal to the articular cartilage of the distal end of the metacarpal bone (Figure 14-20, *E*). After the pins are seated in the radial carpal bone, they are retracted a few millimeters, the distal ends are bent to form a hook, cut off, and driven back into their original depth. Finally, the hook ends are rotated flat against the bone (Figure 14-20, *F*).
2. Transfixation pins can be driven at an angle into the proximal carpal bones from metacarpals II and V (Figure 14-21, *A*) after reducing the joints as shown in Figure 14-20, *D*. The medial pin must be driven from metacarpal II proximally into

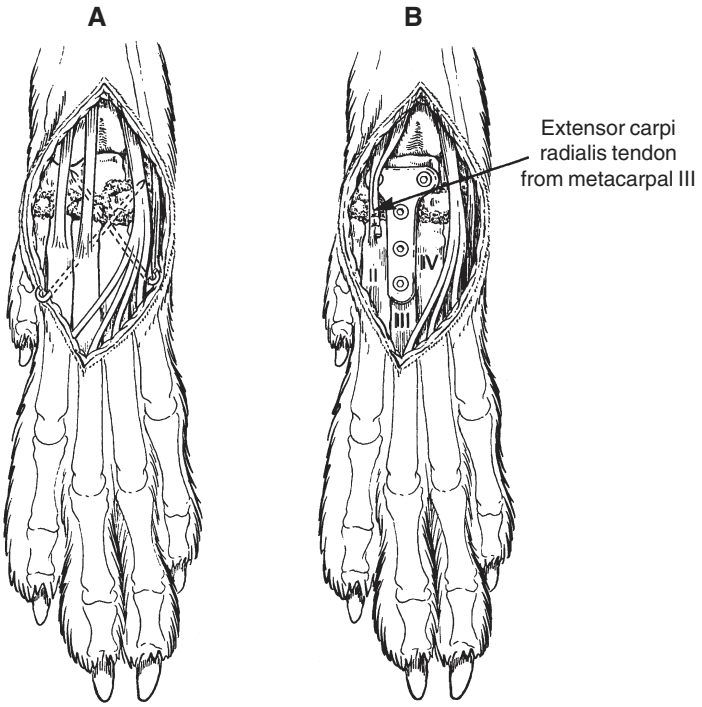


FIGURE 14-21. **A,** Alternative transfixation method of pinning the middle carpal and carpometacarpal joints for partial carpal arthrodesis. The medial pin is driven from metacarpal II proximally into the ulnar carpal bone. The lateral pin is driven from the articular surface of the radial carpal bone (with the joint flexed) distally into metacarpal V, where it is then pulled distally until buried beneath the articular surface of the radial carpal bone. **B,** Partial arthrodesis of the carpus using T-plate fixation. The plate is attached to the distal end of the radial carpal bone, the screws angling proximally. The first screw in the long end of the plate is placed in carpal 3 and the other two screws in the third metacarpal. The tendon of the extensor carpi radialis inserting on metacarpal III has been transposed to metacarpal II and is sutured there.

the ulnar carpal bone and the position of the tip of the pin verified to ensure it does not penetrate the articular surface, which will probably not be visible. The lateral pin is more easily driven from the articular surface of the radial carpal bone distally. The carpus is maximally flexed to allow the pin to be positioned under direct vision proximally in the radial carpal bone. After the pin exits metacarpal V distally, the pin chuck is reversed and the pin pulled distally until it is below the articular surface of the radial carpal bone. An advantage of this method is that the exposure does not need to extend as far distally. The disadvantage is that the pins are more difficult to direct to ensure that they penetrate the correct bones. A power drill is recommended because it is easier to direct than a hand chuck.

Bone Plate. A small T-plate can also be used for partial arthrodesis. However, the bones must be large enough to accommodate the plate without impinging on the radius. The joint is exposed, prepared, and bone-grafted as detailed previously for pin fixation. The plate is attached to the distodorsal surface of the radial carpal bone (Figure 14-21, *B*) and is placed as far distally on the radial carpal bone as possible to avoid interference with the dorsal rim of the radius. The two screws in the radial carpal bone are angled proximally to allow the plate to be properly positioned. The distal portion of the plate must lie over the third metacarpal bone, which necessitates cutting the tendon of insertion of the extensor carpi radialis. The tendon is sutured to the insertion of its paired tendon on metacarpal II. The two distal screws in the plate are placed in metacarpal III. The most proximal screw is either placed in carpal 3, as shown in Figure 14-21, *B*, or in the base of metacarpal III.

Aftercare. If a tourniquet was used, a padded support bandage is applied for several days, and after swelling has subsided, a molded splint or short cast (see Figures 2-27 and 2-22, respectively) is applied to the caudal surface of the limb. If no tourniquet was used, the splint can be applied immediately if desired. This support is maintained until radiographic signs of fusion are noted, typically 6 to 8 weeks later. A gradual return to normal exercise is allowed over the next 4 weeks. If the pins were driven from the metacarpophalangeal joint, they should be removed before allowing exercise. Other implants are removed only if they migrate (pins) or loosen (plates).

Prognosis. Good results have been reported for partial arthrodesis.[9] At an average of 32 months postoperatively, 25 of 25 owners reported to be pleased or very pleased with the function of their animals. Some degree of hyperextension persisted in 11% of cases, and degenerative joint disease was present in 15.5%. No cases required revision by panarthrodesis.

Panarthrodesis

Indications for panarthrodesis primarily involve the antebrachiocarpal joint: polytrauma (e.g., fractures, multiple ligamentous injuries), degenerative joint disease, and hyperextension injuries at the antebrachiocarpal level. Arthrodesis for total brachial plexus paralysis is not recommended because of the poor elbow function and self-mutilation of the foot that usually occur. It does not appear to be practical to fuse only the antebrachiocarpal level; therefore, when this level must be fused, the other two levels are also fused. Fusion of only the antebrachiocarpal joint is technically possible, but the stress placed on the metacarpal and carpometacarpal joints disposes them to increased laxity and degenerative changes. It should be remembered that because minimal motion occurs in the middle and distal joints of

the carpus, fusion of the antebrachiocarpal level effectively destroys all motion in the carpus. Although function remains good, there is pronounced circumduction of the lower limb during the swing phase of gait.

Either bone plate or external skeletal fixation can be applied for stabilization of this fusion. Plate fixation was originally applied dorsally,[8] but this position is mechanically unsound, since the plate is not on the tension side of the carpus and is therefore subject to bending forces. The plate will loosen or break unless the carpus is supported in a cast or splint until fusion is radiographically verified. Dorsal plating has been used successfully in the cat, and in a case of hypoplasia of the carpal bone, where the radius was fused directly to the metacarpus.[10,11] A palmar position for the plate is mechanically superior, which Chambers and Bjorling[12] found to be useful. This advantage may be negated by more difficult exposure (see next section). External skeletal fixators can also be applied in a variety of configurations and are especially valuable in the presence of open injuries.

Dorsal Plate Technique. A dorsal midline approach from the level of the distal radius to the midmetacarpal level is used after a tourniquet (±) has been placed. Preparations are made to collect a cancellous bone graft from the proximal humerus of the same limb (see Chapter 3). Articular cartilage of the antebrachiocarpal, the middle carpal, the carpometacarpal, and the intercarpal joints is debrided with a curette or high-speed bur. The tendons of the extensor carpi radialis on metacarpals II and III can be sacrificed. After debridement of articular cartilage of all three joint levels (Figure 14-22, *A*), a seven-hole (minimum) compression plate is applied to the dorsal surface of the distal radius, bridging the carpus and attaching distally to the third metacarpal (Figure 14-22, *B*). Plate and screw sizes vary with the size of the patient, with the width of the third metacarpal bone being the limiting factor. The screw diameter should not exceed 25% to 30% of the bone width, or the bone could be seriously weakened. Suggestions for sizes are as follows:

1. For large breeds over 60 pounds (27 kg), 3.5-mm screws/plates are used.
2. For breeds 20 to 25 pounds to 60 pounds (9-11 kg to 27 kg), 2.7-mm screws/plates are used.
3. For breeds 10 to 20 pounds (4.5-9.0 kg), 2.0-mm screws/plates are used. Cuttable plates (Synthes; see discussion in Chapter 2) work well here. Two 1.5-mm-thick plates are stacked together to span the distance from the radius to the most proximal metacarpal screw. A single-thickness plate extends distally for two or three more screw holes. This simplifies skin closure and lessens the problem of late loosening of the most distal screw, as discussed later. Another option with this method is the use of 2.7-mm screws in the radius and radial carpal bone and 2.0-mm screws in the metacarpal.
4. For cats and toy breeds, 1.5-mm screws/plates are used.[10] Two thicknesses of 1.0-mm-thick cuttable plates are used here. The 2.0-mm screws can be used in the radius and radial carpal bones and 1.5-mm screws in the metacarpal.
5. For medium-sized to large dogs, a tapered "hybrid" pancarpal arthrodesis plate is available in various lengths and has either all 3.5-mm holes or 3.5-mm holes for placement of screws in the radius and radiocarpal bone and 2.7-mm holes for placement of screws in the metacarpus (Jorgensen Laboratories, Inc., Loveland, Colo; Veterinary Instrumentation, Sheffield, United Kingdom).

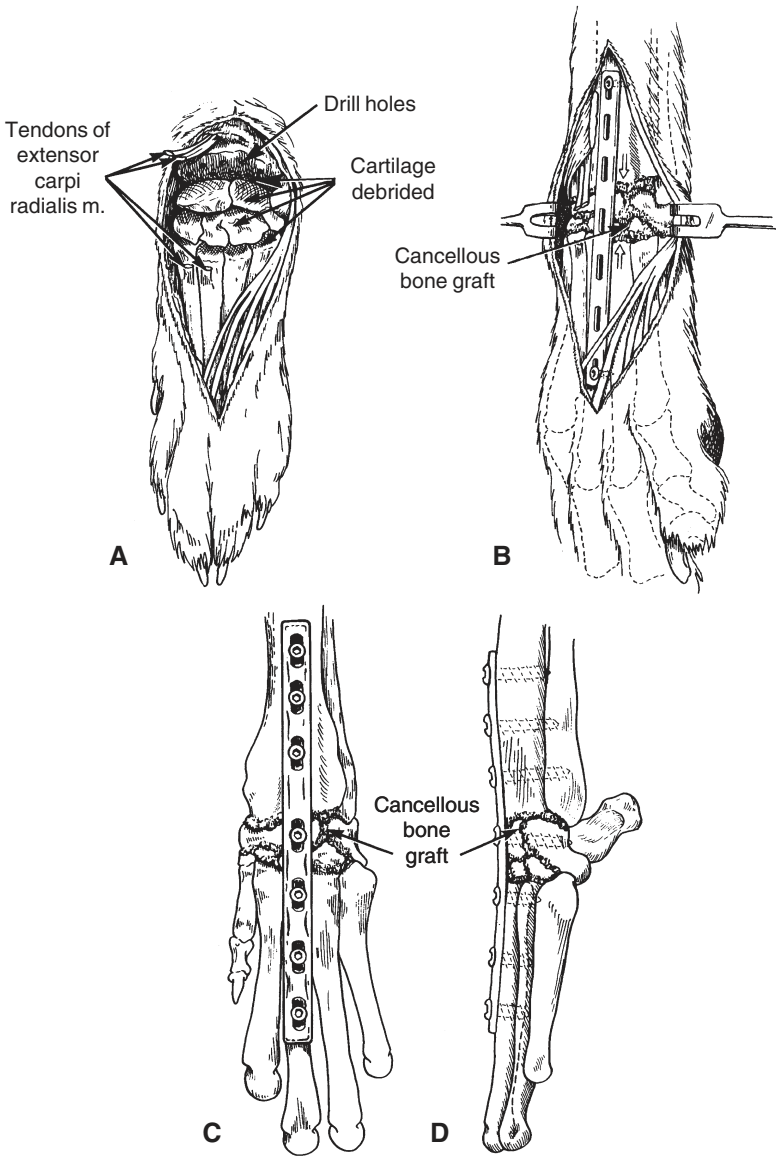


FIGURE 14-22. Panarthrodesis of the carpus with a dorsal plate. **A,** The left carpus has been exposed by a dorsal midline incision, and the tendons of the extensor carpi radialis have been severed at metacarpals II and III. Removal of articular cartilage is eased by maximum flexion of the joint. Multiple drill holes penetrate the distal radius to aid in vascularization. **B,** A seven- or eight-hole bone plate is contoured to provide 10 to 12 degrees of carpal extension (see *D*) and is attached distally to the third metacarpal and proximally to the radius. The abductor pollicis longus muscle must be cut to seat the plate on the radius proximally. The screws in this dynamic compression plate (Synthes) are placed in the load position to produce compression. It is important that the distal screw be placed first, in order to center the plate on metacarpal III. Autogenous cancellous bone graft is packed into the joint spaces. **C** and **D,** The bone plate is completely attached, with three screws in the radius, three in the third metacarpal, and one in the radial carpal bone. Autogenous cancellous bone graft is used to pack the joint spaces and under the plate. Note that about 10 degrees of carpal extension has been maintained.

Three screws are placed in the distal radius, one in the radial carpal bone, and a minimum of three in the third metacarpal bone. The distal screw must be placed first to center the plate over metacarpal III and thus ensure that the screws will be centered in this rather narrow bone. The self-compressing load position is used for the first two screws in the radius and metacarpal III to compress all the joint levels. Compression is not possible with cuttable plates. Plates are contoured to produce about 10 degrees of extension in the carpus (Figure 14-22, *C* and *D*). It is usually helpful to flatten the flare of the distal radius slightly by removing a small portion of bone with a rongeur or high-speed drill to avoid the need to double-curve the plate. Autogenous cancellous bone from the proximal humerus is used to pack all the joint spaces and space beneath the plate. Multiple drill holes directed from the articular surface of the distal radius into the radial metaphysis may assist vascular invasion and incorporation of the graft to hasten healing. The extensor carpi radialis tendons are sutured to the joint capsule in the area.

Aftercare. A short, molded palmar splint or cylinder cast (see Figures 2-27 and 2-22) or a bivalved cylinder cast is maintained until radiographic signs of fusion are noted, usually at least 8 weeks. Exercise is gradually returned to normal over the next 4 weeks. If function of the limb is good, most plates will need to be removed in 6 to 12 months because of loosening or irritation. The metacarpal bones are flexible enough to bend slightly during weight bearing, which may cause loosening of the distal screws because of the stiffness of the plate. Occasionally, fatigue fractures of metacarpal III occur at the end of the plate. The plate should be removed and the foot splinted until bone healing is well advanced, usually about 4 weeks.

Palmar Plate Technique. A palmaromedial approach to the distal radius and carpus is used to expose the area.[1] Preparations are also made to collect a cancellous bone graft from the proximal humerus of the same limb (see Chapter 3). Ligaments, palmar carpal fibrocartilage, and joint capsule are sharply dissected from the distal radius and carpal bones. Articular cartilage of all joint levels is removed by powered burs or curettes. This debridement is somewhat blind, since good visualization of the articular surfaces is difficult. Any bony prominences that prevent close contact of the plate and bone are removed in preparation for attaching an appropriate-size plate. The distal radius must be flattened quite aggressively to minimize contouring of the plate. Plate sizes are used as previously discussed and should be long enough to place at least three screws in the radius and in metacarpal III. The carpus is positioned in normal extension (10-12 degrees), and a Kirschner wire is drilled from the distal radius into the carpus to maintain the desired angle temporarily while the plate is contoured to fit the palmar surface of the distal radius and metacarpal III (Figure 14-23, *A* and *B*). The plate is attached first at the distal hole to ensure that the screw holes in metacarpal III will be centered in this narrow bone. The plate is then attached using the self-compressing load position for the first two screws in the radius and metacarpal III to compress all the joint levels. Cancellous bone graft is added to the joint surface areas and the Kirschner wire removed before closing the tissues in layers.

Aftercare. A padded support bandage is applied for several days, and after swelling has subsided, a molded splint may be applied to the caudal surface of the limb (see Figure 2-27). This splint is maintained until radiographic signs of fusion are noted, typically 6 to 8 weeks later. A gradual return to normal exercise is allowed over the next 4 weeks. If the animal can be closely confined, and if the use of a splint presents difficulties in treatment of soft tissue wounds, it is possible to dispense with use of the splint.

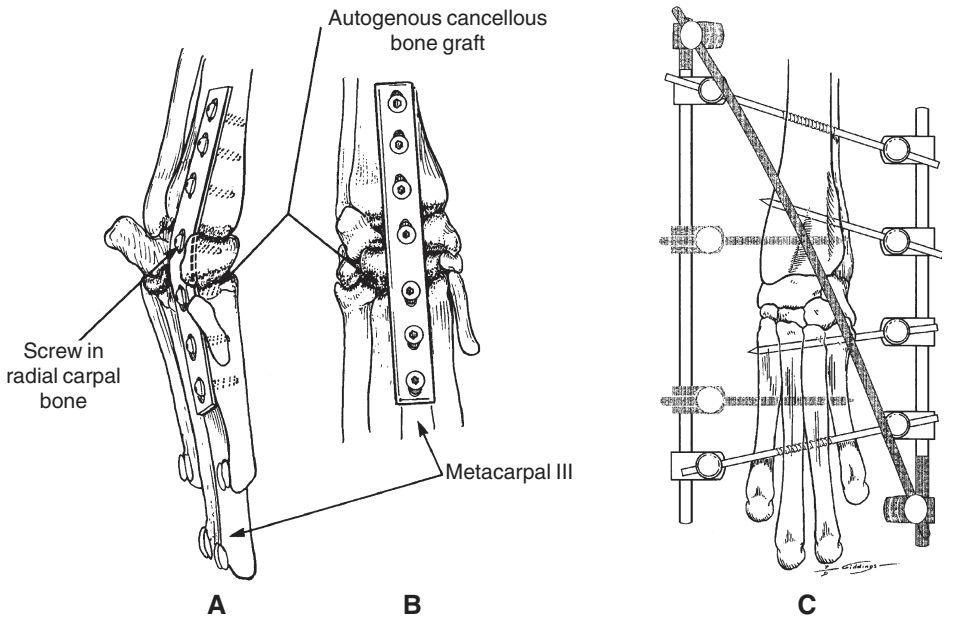


FIGURE 14-23. **A** and **B,** Carpal panarthrodesis with a palmar plate.[12] A palmaromedial approach to the distal radius and carpus[1] is made to allow plate placement on the distal radius and metacarpal bone III. Autogenous cancellous bone graft is used in the prepared articular surfaces. Plate size for large-breed dogs is typically 2.7 to 3.5 mm. **C,** A modified type IIB external fixator is applicable for panarthrodesis. Placement of the fixation pins is eased if the medial and lateral connecting bars are curved to match the normal extension angle of the carpus. The shaded fixation pins are used for maximum stiffness of the fixator, as is the shaded angular connecting bar, which is curved to arch dorsal to the paw.

External Skeletal Fixator Technique. In rare cases, it is desirable to perform panarthrodesis of the carpus in the presence of actual or potential infection. Open comminuted fractures and severe shearing injuries are the most common indications. Early stabilization will help in management of the soft tissue injury by improving blood supply and optimizing the local defense reaction. Considerable time and expense are also saved. It is wise, however, to treat the open wounds vigorously with copious lavage, debridement of necrotic tissue, and systemic antibiotics for many days before undertaking arthrodesis. Otherwise, contaminated and infected tissue may become deep seated and cause failure and further destruction of bone stock. If bone-plating equipment is not available, the external fixator represents an excellent method that is available to most practices.

The type IIB splint configuration shown in Figure 14-23, *C,* can be used to stabilize the joint after preparation of the joint surfaces, as described earlier. Curving the connecting rods is helpful in establishing the proper angle of the carpus. Acrylic resin connecting bars are useful in this application, especially in the small breeds. Type IIA splints can also be used, but it is quite difficult to align the intermediate pins to the second bar (see discussion in Chapter 2). Autogenous cancellous bone graft (see Chapter 3) can be safely used in the presence of infection, but this should be withheld if there is frank suppuration because the graft will be washed out of the site by the exudate and therefore wasted. It is better to wait until healthy granulation has covered the area and then elevate the granulation tissue and insert the graft.

Aftercare. Bone healing in open injuries will probably be delayed, and the splint will need to be maintained for 10 to 12 weeks. Radiographic fusion in closed injuries will usually be attained by 8 weeks. If bone pins loosen before fusion is radiographically visible, the pins can be either replaced or removed and followed with a few more weeks of immobilization in a short cast (see Figure 2-22).

Shearing Injury of the Carpus

This abrasion injury occurs when the dog's lower limb is run over by the tire of an automobile with its brakes locked attempting to avoid the animal. Soft tissues in contact with the pavement are simply ground away, often eroding skin, muscle, ligaments, and even bone. The medial carpal and metacarpal regions are most frequently affected, with the radial styloid process and radial collateral ligaments often completely destroyed (Figure 14-24, *A*). One or more carpal or metacarpal joints may be open, and varying amounts of debris are ground into all the tissues. The lateral side is less often involved and represents a less serious injury than a comparable injury on the medial side. Because the dog normally stands with a few degrees of valgus (lateral) deviation of the forepaw, ligamentous stability of the medial side of the carpus and metacarpus is much more critical than on the lateral aspect. Best results are obtained by treating these wounds in an open manner, with early aggressive stabilization of the joints and any accompanying fractures. Rarely is skin grafting indicated, and only if second intention healing does not adequately close the wound.

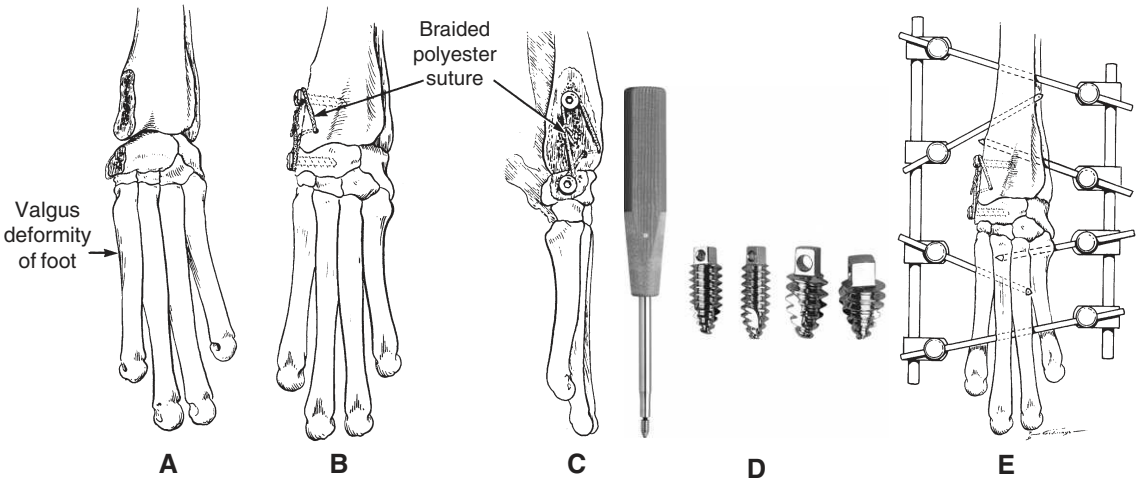


FIGURE 14-24. Shearing injury of the medial carpus. **A,** The radial styloid process and medial aspect of the radial carpal bone and the associated collateral ligaments have been ground away. **B** and **C,** Bone screws provide anchor points for the synthetic ligament of braided polyester suture. Placement of the screws and bone tunnel closely mimic the normal ligament. **D,** Suture anchor devices may be used as an alternative to bone screws and washers to attach suture to bone for synthetic ligaments (IMEX Veterinary, Inc., Longview, Texas). The anchor device has a hole to accept suture, which helps to prevent slippage. **E,** To simplify open treatment of soft tissues, the joint is stabilized in 10 degrees of flexion with external skeletal fixation (Kirschner-Ehmer splint). The connecting rods are bent to allow the desired amount of extension.

Early or delayed arthrodesis is indicated when it is not possible to restore reasonable joint function by ligamentous stabilization. Variables to be considered in choosing a plan of action include the following:

1. Assuming that the joint(s) can be stabilized, is there enough articular surface to allow good function? Loss of bone in the antebrachiocarpal articulation is critical. If the answer is "no," arthrodesis is indicated.
2. What will the owner accept as reasonable function? A large, active breed presents problems different from those of a small, sedentary animal. In the former, aggressive ligamentous repair, augmentation, or replacement is necessary, whereas in the latter it may be possible to obtain good results by very conservative methods. Stabilization of joints by scar tissue may well provide adequate support in the smaller and less active animals, but it rarely will support the tension loads of the medial side in large, athletic individuals.
3. How will support for the joints or fractured bones be provided? Regardless of which approach is taken to the ligamentous instability, the involved joints must be stabilized during the healing period. Because of the necessity for daily bandage changes for 2 to 3 weeks when treating these large open wounds, the use of conventional casts or splints is difficult. External skeletal fixation devices have greatly aided in solving this problem.

Treatment

Reconstruction

Initial debridement must be meticulous but not too aggressive, with emphasis on removal of dead tissue and foreign matter from both soft tissue and joint spaces. Copious irrigation with saline or Ringer's solution is very important at this time. Some recommend the addition of 10% povidone-iodine or 0.2% chlorhexidine. After adequate debridement, it may be possible to close the wound partially by suturing skin. This can be helpful, but care must be taken to do the following:

1. Leave adequate open area for unimpeded wound drainage. Placement of Penrose or tube drains under the sutured skin is usually advisable for 2 to 5 days.
2. Avoid closing skin under tension. Serious circulatory stasis develops because of the tourniquet-like effect of excessive skin tension in the lower limbs.
3. When in doubt about tissue viability, *do not suture skin*. Delayed primary closure can be done in a few days with no loss of healing time.

Several debridements over a number of days may be necessary to remove all devitalized tissue adequately because of the difficulty in determining viability of badly traumatized tissue. If there are portions of ligaments, joint capsule, or other tissues that can be sutured to support the joint and to close the synovial membrane, this should be done. Monofilament or synthetic absorbable suture is the most trouble-free material relative to later sinus tracts.

Reestablishment of the radial collateral ligament complex is usually hampered by loss of bone, and small bone screws may be used to anchor a synthetic ligament. There is a tendency to use monofilament wire in this contaminated area, but heavy, braided suture is a much more functional ligament and has resulted in very few problems related to suture sinus drainage tracts. Monofilament nylon fishing line of 40- to 60-pound test has also been successful. Two bone screws are positioned to mimic the normal ligaments as closely as possible (Figure 14-24, *B* and *C*). Precise placement of these bone screws for attachment of heavy, braided polyester suture

and adequate soft tissue debridement are necessary for successful treatment. The sutures are tied tightly enough to stabilize the joint, but motion without binding should still be possible. Washers can be used on the screws to prevent the suture from slipping over the head of the screw. Suture anchors may be used as an alternative to bone screws for attaching suture to bone when creating synthetic ligaments (Figure 14-24, *D*). Anchors have a hole to accept suture, which helps to prevent the suture from slipping. Treatment of the open wound is simplified by use of transarticular type IIB external fixator to stabilize the joint (Figure 14-24, *E*).

Fixation is maintained until granulation tissue has covered the defect, usually in 3 to 4 weeks. Sterile laparotomy sponges soaked in povidone-iodine or chlorhexidine solution are loosely bandaged to the limb for several days, and debridement is repeated daily or every other day until all dead tissue is removed. The wound must be kept moist and provision made for adequate drainage of exudate.[13] Moist gauze with copious absorbent padding covered by a moisture barrier (e.g., polyvinyl sheet) and dressing changes are used daily until healthy granulation covers the wound. Hydrocolloid, hydrogel, and polyethylene semiocclusive dressings have received considerable attention for treatment of full-thickness skin wounds. Hydrogel and polyethylene dressings were significantly better in all parameters tested in one study.[14] Once healthy granulation tissue is present, nonadherent dressings, either dry or with antibacterial ointments, and minimal absorbent padding are used in place of the moist dressings. Intervals between dressing changes can gradually be spread out as wound exudation lessens. The wound must be kept protected until it is well epithelialized, which may take up to 10 to 12 weeks.

Aftercare. When granulation tissue completely covers the wound, but not before 3 weeks postoperatively, the external fixator is removed. A firm elastic support bandage should be maintained for another 3 weeks with very restricted activity. Normal exercise is not allowed until weeks 8 to 12, depending on the stability achieved. Loosening of the bone screws and skin irritation from the screw heads are indications for removing the screws. The screw in the radial carpal bone is particularly prone to loosening because of its motion. This should not be done before 3 to 4 months postoperatively if possible. Failure to stabilize the joint adequately will result in degenerative joint disease and poor function. In such cases, arthrodesis offers the best chance of restoring function (see previous discussion).

Prognosis. A retrospective study of 98 shearing injuries by Beardsley and Schrader[15] revealed some previously unknown facts regarding the outcome of these cases. All were treated essentially as just described, except that none received joint stabilization by means of external fixators; all were supported in some form of external coaptation. Healing time ranged from 2 to 9 weeks, depending on the size and depth of the wound and the amount of the wound that was able to be closed by suture. A mean of 1.7 surgical procedures were performed on each patient, and a mean of 5.5 rechecks were required after hospital discharge. Good to excellent outcome was attained in 91% of the dogs, defined as clinically normal or with only minimal functional abnormalities after healing of the injury. Only one case required skin grafting.

As can be seen, these are expensive injuries because of the amount of care required, and those owners not prepared for this type of care would be well advised to consider amputation as a primary treatment. It is our subjective opinion that support with external fixators simplifies treatment because owners can do more

treatment at home because of the absence of the coaptation splint, but we do not have data to suggest that it shortens the healing period or affects the final outcome.

Arthrodesis

Some shearing injuries to the carpus are too extensive to be successfully reconstructed. These are invariably those with extensive bone loss of the medial radial styloid process. If the bone loss extends laterally into the articular surface of the radius, there may not be sufficient articular support for the radial carpal bone. Additionally, the ability to provide sufficient medial ligamentous support is questionable. In this situation, panarthrodesis of the carpus is the best method of maintaining limb function. Although it is possible to attempt reconstruction and then follow with arthrodesis if reconstruction fails, much time and expense can be wasted. Ideally, arthrodesis using a bone plate should be undertaken only after bacterial contamination is well under control. If infection is present, the debridement of articular surfaces and the presence of implants may well drive infection deeper into the bone.

By the use of external skeletal fixation (Figure 14-23, *C*), the arthrodesis can be performed very early, before the wound is healed, with a high probability of successful fusion and a low chance of bone infection. The procedure can be delayed for several days, until the debridement phase is complete and, it is hoped, some granulation tissue has begun to appear. The carpus is supported during this phase entirely by the bandage, sometimes augmented by thermomoldable plastic splints or wire frames. If it seems necessary to use the external fixator immediately to support the joint, the fusion is done at the same time. The technique is performed basically as described earlier under Hyperextension of the Carpus. The major difference is in the manner of applying the autogenous cancellous bone graft, since there must be sufficient soft tissue available to cover the graft and allow its early vascularization. Exudation is another contraindication to early grafting because the exudate may physically carry the graft fragments away. In this situation the joint debridement and fixation are completed as usual, but grafting is delayed until there is a healthy granulation tissue bed, without exudation. At that point the granulation tissue is carefully elevated from the joint surfaces sufficiently to allow the graft to be packed into the joint spaces. The area is kept covered by petrolatum-impregnated gauze sponges for several days, until granulation tissue again covers the area. Aftercare from this point onward is as previously described.

METACARPUS AND PHALANGES

Fractures of the Metacarpus

Fractures of the metacarpal bones occur in all three anatomical regions of the bone: the base (proximal end), the shaft, and the head (distal end).

Fracture of the Base

The medial (second) and lateral (fifth) bones are most frequently involved (Figures 14-25, *A,* and 14-26, *A*). Because these areas are points of ligamentous insertion, varying degrees of valgus (lateral) displacement of the foot are seen with fractures of the second metacarpal and varus (medial) displacement with fifth metacarpal fractures. Some injury of the carpometacarpal ligaments may be noted, which may also result in hyperextension at the carpometacarpal level (see earlier discussion).

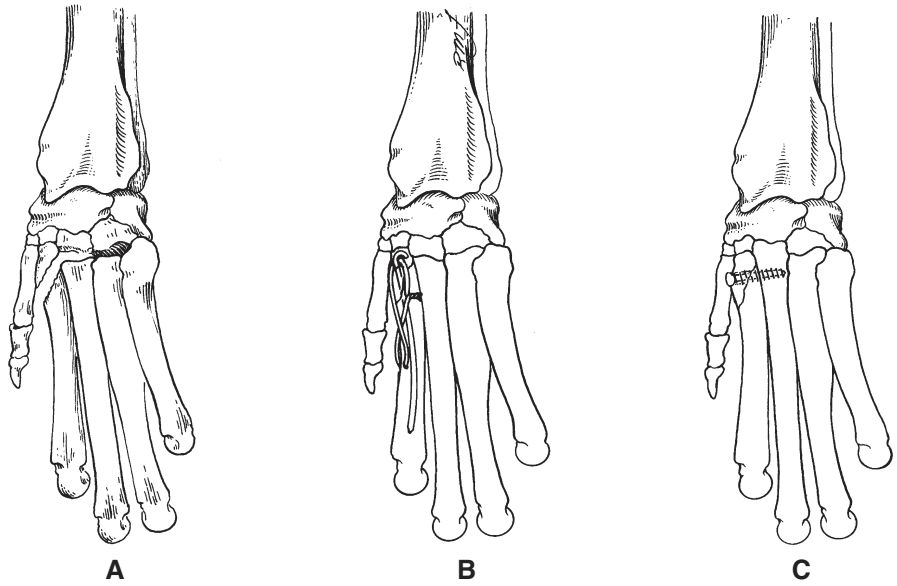


FIGURE 14-25. **A,** Fracture of the base of the second metacarpal bone is usually associated with valgus (lateral) deviation of the foot. **B,** Fixation with Kirschner wire and tension band wire. **C,** Fixation with lag screw.

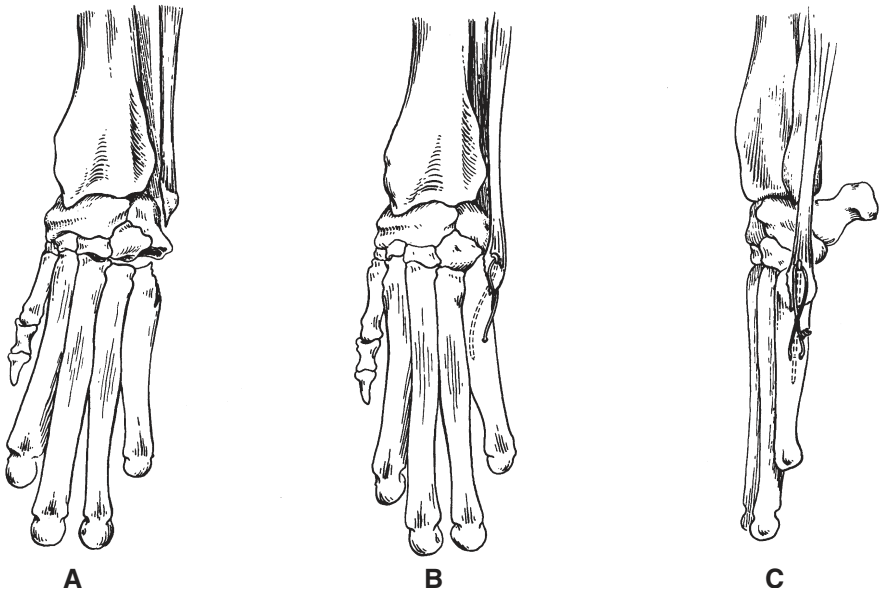


FIGURE 14-26. **A,** Fracture of the base of the fifth metacarpal bone. The tendon of insertion of the ulnaris lateralis muscle causes the fragment to be displaced proximally. Some varus (medial) deviation of the foot may be present. **B** and **C,** Fixation is by the tension band wire technique. The Kirschner wire is 0.045 inch in diameter, and the stainless steel wire is 22 gauge. This fracture could also be repaired with a lag screw.

Closed Reduction

Undisplaced fractures may be treated by external fixation, but there is usually some displacement of the fragment during healing and subsequent varus or valgus malunion. A secure molded splint or short cast (see Figures 2-27 and 2-22, respectively) must be used.

Open Reduction and Internal Fixation

Fixation of displaced fractures is usually done by the tension band wire technique (Figures 14-25, *B,* and 14-26, *B* and *C*). Lag screws are also useful in some cases (Figure 14-25, *C*). Comminuted fractures in larger breeds may be handled with small plates, combined with lag screws and/or cerclage wires (Figure 14-27).

Racing greyhounds are subject to stress fractures of the second metacarpal (and third metatarsal) of the right foot. These fractures are undisplaced and often show some callus formation (Figure 14-28, *A* and *B*). Fixation of acute injuries is by a palmar splint (see Figure 2-27), maintained for 4 weeks. Lag screw fixation with 2.0-mm miniscrews is indicated when there is no response to immobilization (Figure 14-28, *C*). Chronic injuries can be stimulated to start anew with a healing response by osteostixis.[16] Several 1.5- to 2.0-mm holes are drilled in the fracture area to stimulate a healing response, after which the foot is splinted for 4 weeks.

Aftercare

Primary fixation by casting or splinting will require the device to be worn for about 6 weeks, except with the stress fracture, which requires only 4 weeks. If internal fixation is used, a molded palmar splint or short cast (see Figures 2-27 and 2-22) is maintained for 3 to 4 weeks. Exercise is restricted for 3 to 4 weeks after splint removal.

Fracture of the Shaft

Fracture of one or even two metacarpals is not a serious injury, especially if the two middle bones are not involved. They heal quite readily in a simple palmar splint as a result of the splinting effect of the remaining bones. When three or all four bones are broken (Figure 14-29, *A*), the situation is quite different, however, especially in the large and giant breeds. In these cases, simple splints often create a delayed union or malunion at best, with nonunion often resulting. This is a problem

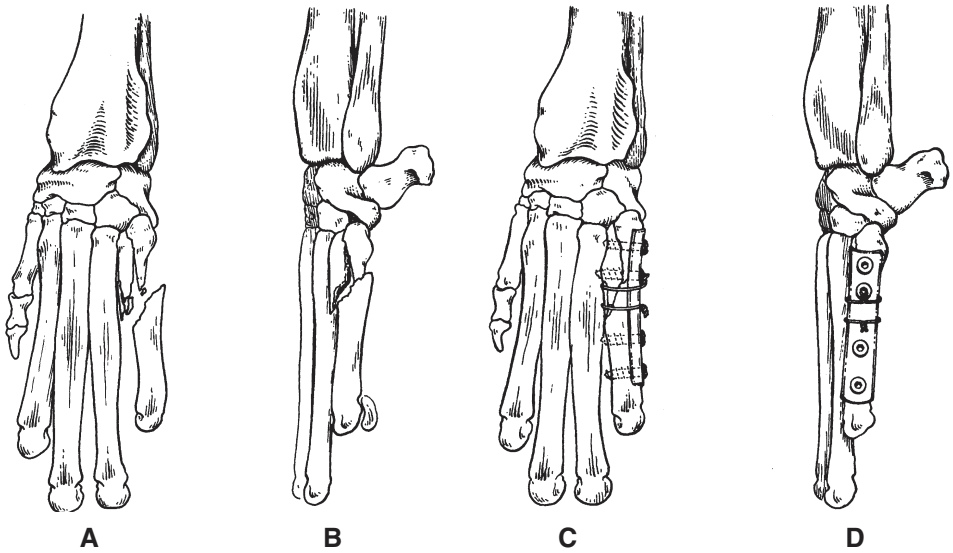


FIGURE 14-27. **A** and **B,** Comminuted fracture of the proximal shaft and base of the fifth metacarpal bone. **C** and **D,** One-third tubular plate, 2.7-mm screws, and 22-gauge cerclage wire fixation. The two proximal screws were applied in lag fashion.

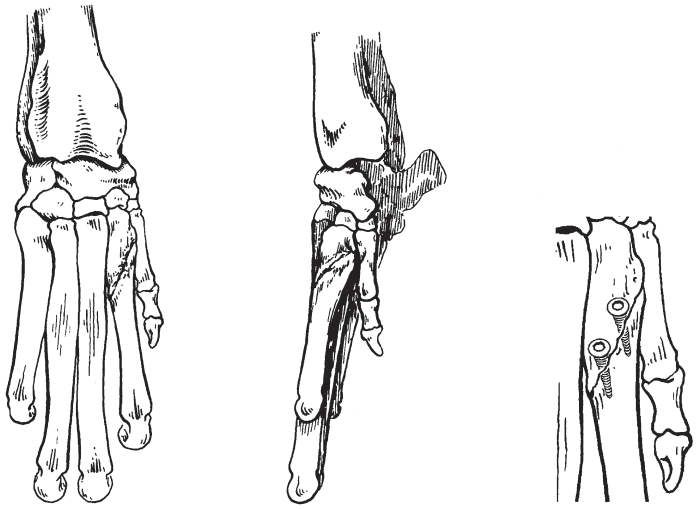


FIGURE 14-28. **A** and **B,** Stress fracture of the second metacarpal bone, right forefoot. This fracture is specific in the racing greyhound. The fracture is usually incomplete and undisplaced and may extend into the articular surface of the base; unless it is seen very early, it will have some periosteal callus formation, which is usually palpable. **C,** Fixation with 1.5-mm or 2.0-mm lag screws placed in a dorsal-palmaromedial direction.

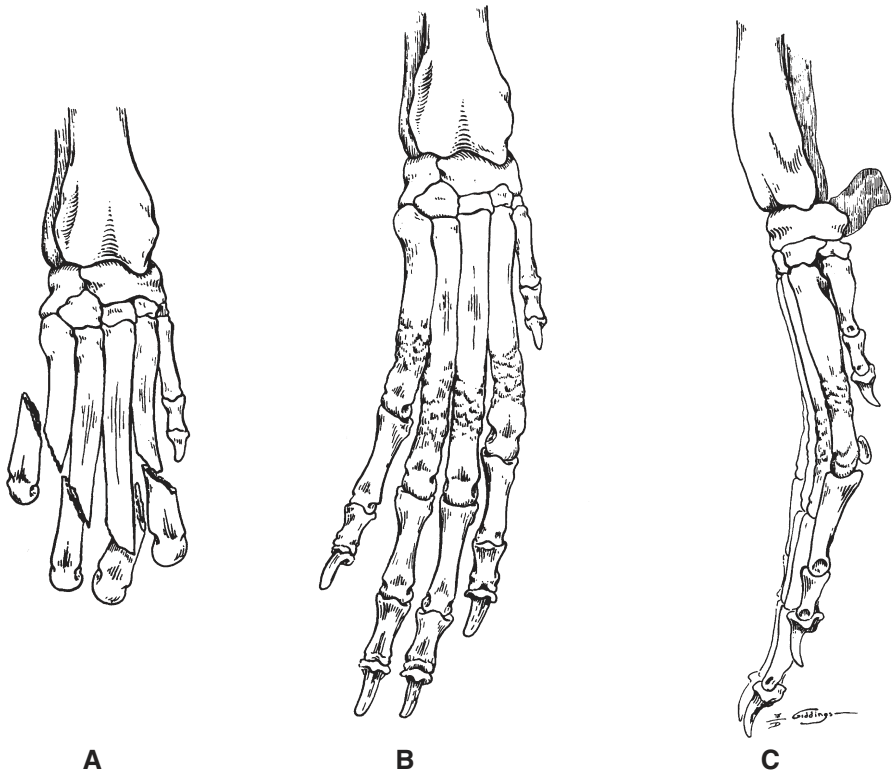


FIGURE 14-29. **A,** Multiple metacarpal shaft fractures. **B** and **C,** Closed reduction and inadequate external fixation resulted in valgus deformity and palmar bowing of the metacarpus.

particularly when preformed spoon splints are used. Additionally, a valgus deformity and palmar bowing of the bones may occur because they are not adequately supported in the spoon splint (Figure 14-29, *B* and *C*).

Closed Reduction

When closed reduction and external fixation are used, a molded splint or fiberglass short cast is advisable (see Figures 2-27 and 2-22). Because these devices are molded to the foot, the bony support is greatly improved. The splint or cast should be maintained until radiographic signs of healing are well advanced, which typically occurs within 4 to 8 weeks, varying with the age of the animal.

Open Reduction and Internal Fixation

Internal fixation is indicated when two or more bones are involved, especially if they are the middle bones. Other indications for internal fixation include severely fragmented or displaced fractures, nonunion, and malunion. Even simple single-bone fractures may warrant internal fixation for optimal functional results in large, athletic breeds.

Intramedullary Pins. Kirschner wires (K-wires), Steinmann pins, and Rush pins are all applicable to the metacarpal and metatarsal bones. These are indicated in transverse and oblique fractures that are not highly fragmented, often combined with cerclage wires in long oblique fractures. The pin should not fill the medullary canal too tightly because it will interfere with medullary blood supply and delay healing. K-wires of 0.045 to 0.062 inch (1.2-1.5 mm) generally suffice. In most cases it is best to think of the pin as merely an internal splint to maintain reduction of the bone and to rely on an external cast or splint to furnish much of the immobilization needed for fracture healing.

The metacarpal (and metatarsal) bones have thick cortices and small intramedullary (IM) canals, which creates difficulty in passing IM pins or K-wires. A method of introducing the pins that does not damage or interfere with motion of the metacarpophalangeal joint will produce the best functional results and allow the external coaptation to be removed as soon as there is sufficient callus to support the pin. One acceptable method is to introduce the pin from the distal end of the bone at the dorsal edge of the articular cartilage. Although this causes the pin to enter the bone at a slight angle, if the pin is not too large and stiff to bend slightly, it still should glide proximally in the medullary canal. The fracture is reduced and the pin driven into the proximal fragment until it is well seated in the base of the bone. The pin is then retracted 5 mm, a hook is bent and the end cut, and then the pin is driven back into the bone until the hook is close to the bone surface. In this manner, minimal pin is protruding from the bone to irritate the joint, yet the pin is easily removed (Figure 14-30). This method is difficult in small-breed dogs. Some advocate retrograde insertion (from the fracture site), but it is difficult to avoid penetrating the distal articular surface with this method. Another method to start the IM pin obliquely in a metacarpal bone is to drill a small slot in the dorsal cortex with a high-speed bur, either distally or proximally to the fracture, depending on the location of the fracture, to allow introduction of the pin to the medullary space without affecting the joint surface (Figure 14-30, *C;* see also Figure 14-20, *B* and *C*). In a final method, if the bone is large enough to accept a 1/16-inch (1.5-mm) Rush pin (Osteo-Technology International, Inc., Hunt Valley, Md), the surgeon will not need to bend the hook and can insert the pin at some distance from the articular surface (Figure 14-31, *C*). Generally, a Rush pin will provide more rigid fixation than a straight IM pin.

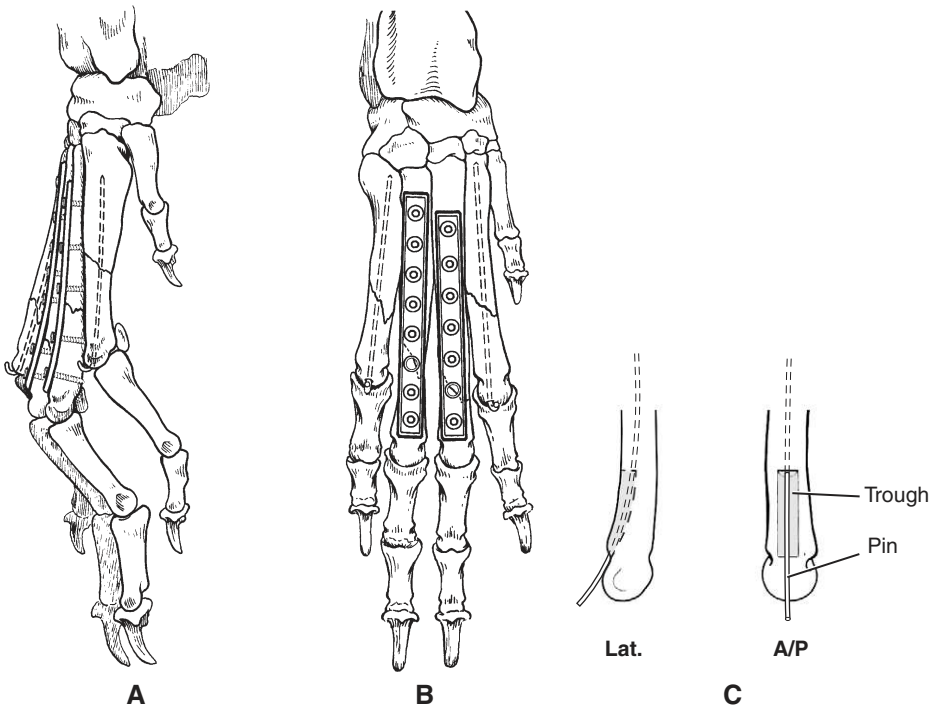


FIGURE 14-30. **A** and **B,** Combined bone plate and intramedullary fixation of multiple metacarpal fractures. Kirschner wires are inserted in the distal segment of metacarpals II and V, staying as close as possible to the dorsoproximal edge of the metacarpophalangeal joint capsule. The fracture is reduced, and the pins are driven proximally into the base of the bone. The pins are then bent to a hook shape and driven as close to the bone as possible to allow more extension of the toes and easier removal of the pins. Plate fixation is ideal for fixation of metacarpals III and IV, which are the major weight-carrying bones. Veterinary cuttable plates (Synthes, Ltd., Paoli, Pa) are the most adaptable plate for this application. **C,** A trough has been created with a high-speed bur in the distal segment to allow oblique cortical pinning. Pinning of all four metacarpals is acceptable if plating is not possible. In either case, the foot must be supported in coaptation for several weeks.

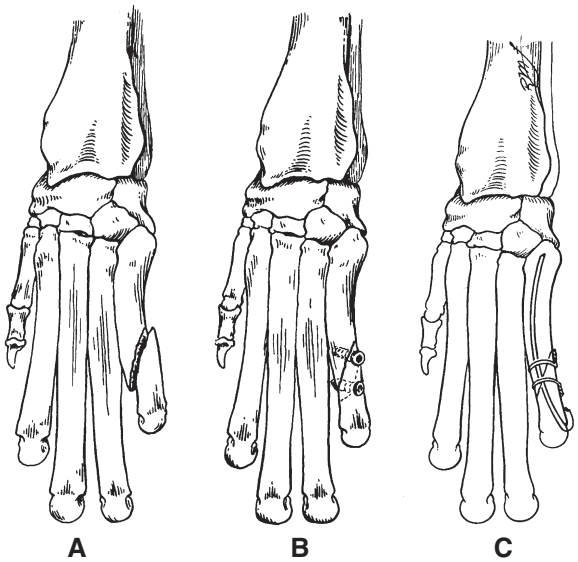


FIGURE 14-31. **A,** Oblique shaft fracture of the fifth metacarpal in a racing greyhound. **B,** Fixation by 2.7-mm lag screws. This method was chosen over pinning or cerclage wiring because there is less joint and soft tissue irritation. Primary bone union was achieved. **C,** Cerclage wires and $^{1}/_{16}$-inch diameter Rush pin. The articular surface is not invaded.

Aftercare. The metacarpophalangeal joint is kept in flexion in a splint or cast (see Figures 2-27 and 2-22), and the pins are removed after healing. If the pins do penetrate articular cartilage, the splint should be maintained until healing is complete and the pins are removed, before allowing active weight bearing. Rush pins do not generally require removal.

Cerclage Wires. The general rules given in Chapter 1 apply to application of wires in the metacarpus or metatarsus. Useful wire sizes vary from 20 gauge (0.8 mm) to 24 gauge (0.4 mm). Of primary importance is that the cerclage wire must be tight or it will devascularize the underlying bone because of movement of the wire. An important difference in the metacarpus/metatarsus from their application in long bones is that cerclage wires occasionally are used as primary fixation. This is possible because external casts or splints are always used to support the internal fixation. More often, however, cerclage wires are combined with IM pins (Figure 14-31, *C*).

Lag Screws. Interfragmentary fixation with lag screws, as with cerclage wire, is occasionally used as primary fixation in the metacarpus/metatarsus when supported with an external cast or splint. The advent of 1.5- and 2.0-mm screws has increased the usefulness of this method in long oblique or spiral fractures. It is rarely possible to combine IM pinning with lag screws because of the small size of the bones; thus, screws are generally used alone (Figure 14-31, *B*) or in conjunction with bone plates (see Figure 14-37, *C* and *D*). The same general guidelines as discussed in Chapter 1 apply to the application of lag screws here.

Bone Plates. Small plates are valuable in larger breeds for fixation of very unstable fractures (see Figure 14-30) and for nonunion fractures (Figure 14-32). Because of their stability, external support does not need to be maintained as long as with other methods. Four weeks in a cast or splint is typically sufficient to allow limited active use of the limb. Plate and screw sizes typically range from 1.5 to 2.7 mm; both flat and semitubular plates are useful. Cuttable plates (Synthes) have proved especially valuable in this application, since they allow placing of more screws in a given unit of length than conventional plates, and their low profile minimizes problems with soft tissue coverage (see Chapter 2).

Aftercare. In all cases of internal fixation, the foot should be supported in a molded splint or cast (see Figures 2-22 and 2-27) until radiographic signs of bone healing are obvious, typically 3 to 6 weeks. Bone plates are usually removed in 3 to 4 months, especially in athletic animals. Bone screws and cerclage wires can usually be left with no harmful effects. IM pins inserted from the distal joint area should be removed as soon as callus formation is well established. Rush pins can usually be left in place if desired.

Fracture of the Head

One of the most common injuries in the metacarpal head is a fracture of the condyle. Such a fracture results in instability and luxation or subluxation of the metacarpophalangeal joint (Figure 14-33) because the collateral ligaments of the joint originate on the condyle. The condylar fragment may be quite small (Figure 14-33, *A*), or it may involve half the head.

Treatment

Closed reduction and external casting usually result in an unstable joint, or the intraarticular alignment of the fragments may be poor, resulting in degenerative

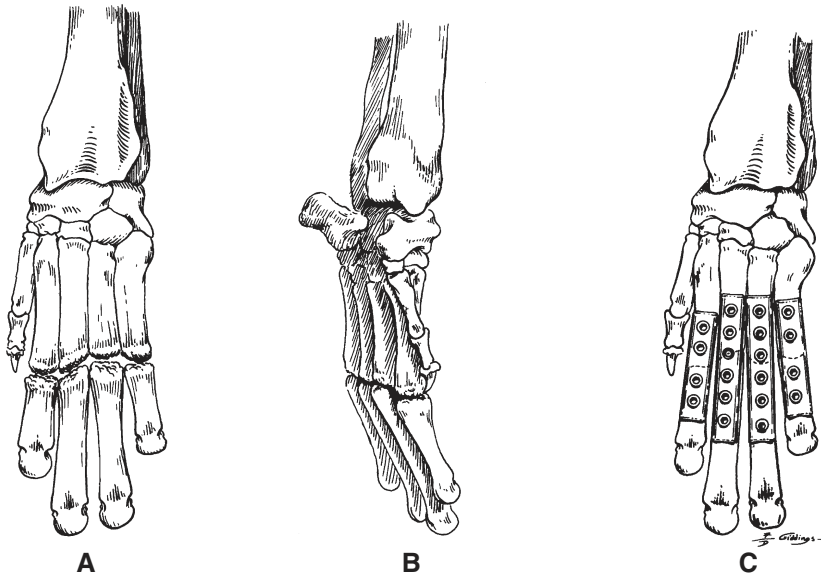


FIGURE 14-32. **A** and **B,** Nonunion fracture of all metacarpals, 9 months' duration. **C,** Multiple bone plate fixation. Size of plate will vary from a 1.5- to 2.7-mm screw size. Good healing was achieved using 2.7-mm plates and screws in this 80-pound (36-kg) dog.

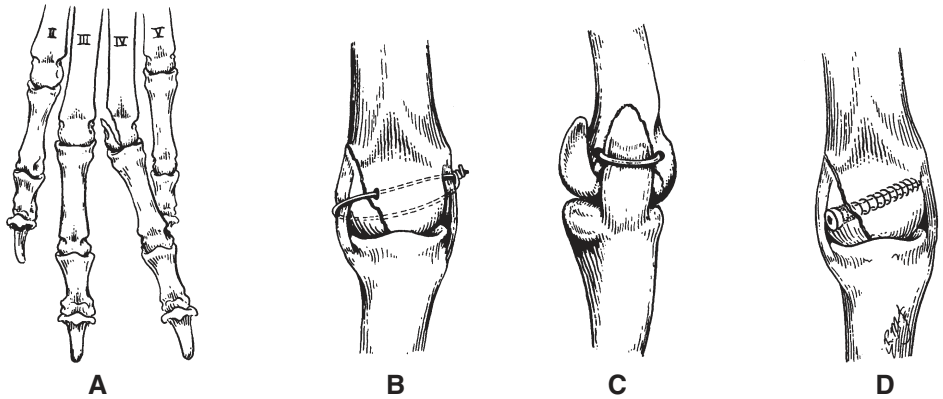


FIGURE 14-33. **A,** Fracture of the medial condyle of the head of the fourth metacarpal bone. Valgus deformity of the toe results. **B** and **C,** Wire fixation of fragments. To avoid drilling a hole through the small fragment, two holes are drilled in the metacarpal bone, and the wire (22 gauge in a 60-pound animal) is passed through the holes and around the fragment. If the wire can be passed through the ligamentous tissue, it will have less tendency to slip off the fragment. **D,** Lag screw fixation with 1.5-mm or 2.0-mm screws is ideal if the fragment is large enough.

joint disease. Internal fixation offers the best chance for return to normal function, especially in the athletic animal. The approach is by incision of skin directly over the injury. Internal fixation may be done with wire (Figure 14-33, *C* and *D*) or lag screws (Figure 14-33, *D*). Failure to repair these injuries may necessitate amputation at the metacarpophalangeal joint to restore function in the athletic animal, especially if the third or fourth bone is involved (see later discussion on amputation).

Aftercare

A molded palmar splint or cast is applied for 4 weeks, and exercise is limited for 6 to 8 weeks.

Fractures of the Phalanges

Treatment

Fractures of the phalangeal head and base are handled in much the same way as described for metacarpal fractures, except that the fragments are often smaller and more difficult to secure (Figure 14-34). As a result, amputation may need to be considered more often. Fractures of the shaft are most frequently treated by closed reduction and external fixation (Figure 14-35), although internal fixation should be considered for a performance animal (Figures 14-36 and 14-37). Surgical exposure is quite simple because the bone is immediately beneath the skin. As with metacarpal fractures, both cerclage wires and lag screws are suitable as primary fixation when supplemented with external support.

Aftercare

A molded plastic bivalve splint is applied either as primary fixation or as support for internal fixation (see Figure 2-28). Splinting for 3 to 6 weeks is usually needed for primary fixation, and 3 to 4 weeks is sufficient for support of internal fixation.

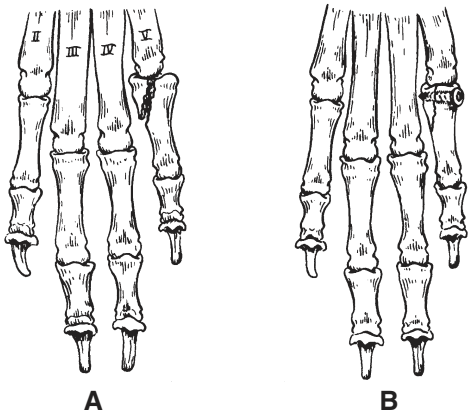


FIGURE 14-34. **A,** Fracture of the base of the first phalanx. **B,** Lag screw fixation using a 2.0-mm or 1.5-mm screw.

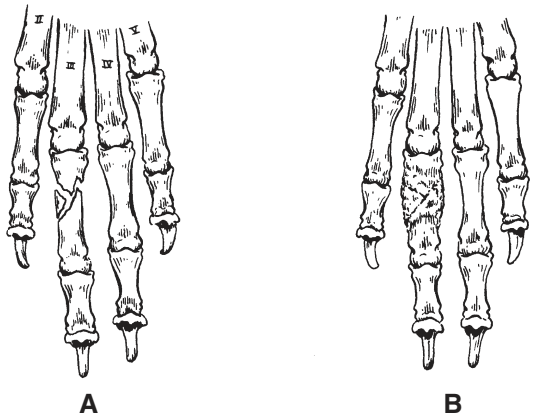


FIGURE 14-35. **A,** Comminuted fracture of the first phalanx. **B,** Four weeks after coaptation splintage. Although there is considerable callus at this stage, good alignment of the bone has been maintained.

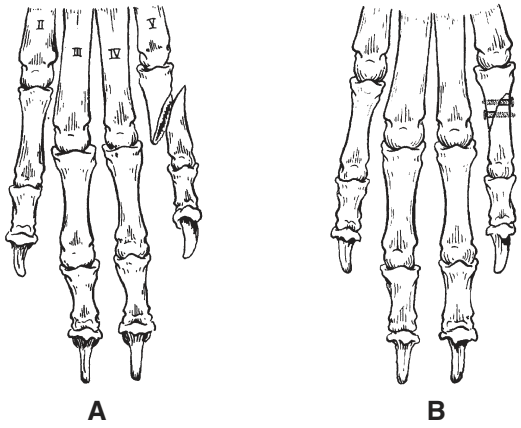


FIGURE 14-36. Because of the need for perfect reduction and rapid return to function, internal fixation with 1.5-mm or 2.0-mm lag screws was chosen. Such fixation must be protected by casting or splinting for several weeks.

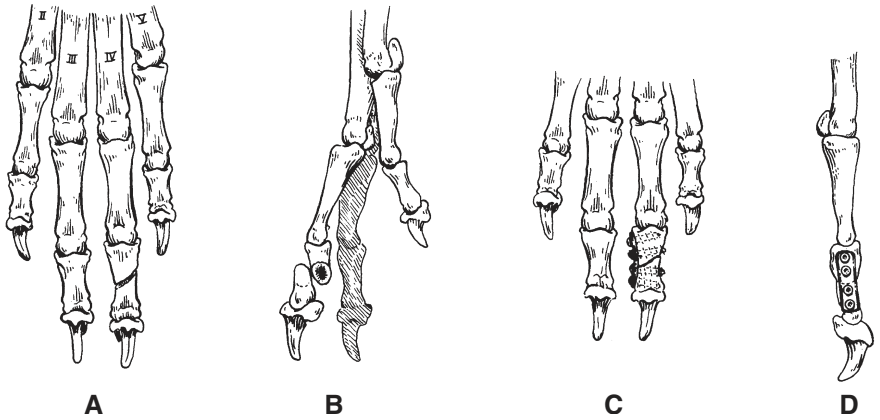


FIGURE 14-37. **A** and **B,** Short oblique fracture of the second phalanx in a racing greyhound. **C** and **D,** Because the fracture line was too short for a lag screw, a miniplate was used with 2.0-mm screws. Excellent functional result was obtained. The plate was left in place because it had not affected the dog's performance.

Fracture of Proximal Palmar Sesamoids

Large-breed dogs are the primary victims of fractures of the proximal palmar sesamoid bones of the metacarpophalangeal joint, although they are seen sporadically in dogs of all sizes. This is a common injury of the racing greyhound, and the immature Rottweiler seems predisposed. Excessive tension on the digital flexor tendons can cause the sesamoid bone, which is quite long and banana shaped, to fracture near its midportion, although vascular compromise and bone necrosis have been proposed as a cause.[17] For convenience the sesamoids can be numbered from medial to lateral; because there are two sesamoids at each metacarpophalangeal joint, they are numbered from 1 to 8 (Figure 14-38, *A*). The sesamoids that are most often injured are the second and seventh (Figure 14-38, *B* and *C*). Either the forelimbs or hindlimbs can be involved. Sudden lameness occurs, accompanied by swelling, pain on palpation, and crepitus. This lameness rapidly subsides, and the animal shows lameness only on exercise. Tenderness on deep palpation over the bones remains. Bilateral injuries may occur. High-detail screens or nonscreen radiographic techniques are helpful in diagnosing these fractures.

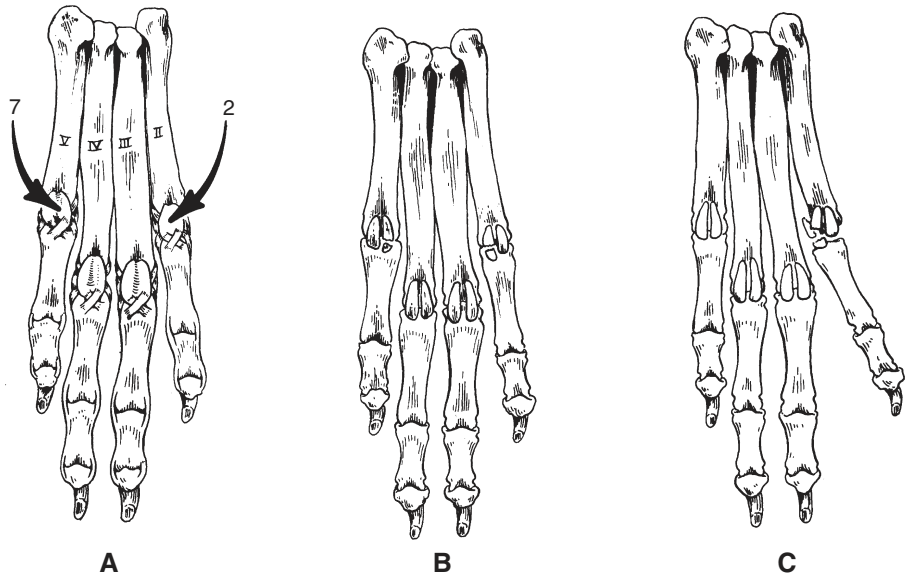


FIGURE 14-38. **A,** Ligaments of the palmar sesamoids of the metacarpophalangeal joints. The sesamoids are numbered from medial to lateral, 1 to 8, with 2 and 7 injured most often. **B,** Fractures of the distal third of sesamoid 7 and midportion of sesamoid 2. Only the small fragment of 7 is removed, whereas all of 2 is removed. **C,** Fracture of sesamoid 2 with fracture of the base of the second metacarpal bone. The sesamoid is excised and the metacarpal fracture wired or lag-screwed as in Figure 14-33.

Treatment

In the acute stage, treatment may consist of splinting (see Figure 2-28). Some phalangeal fractures will heal sufficiently with splint fixation, but many will require surgery later for excision of the bone fragments. All animals with chronic conditions and persistent clinical signs should undergo surgery. The bone is exposed by an incision just medial or lateral to the large central pad, directly over the joint.[1] The fragments are sharply dissected free of their ligamentous attachments. On occasion, only a small portion of the bone is fractured. If this piece is less than one third of the total bone, the usual approach is to leave the larger fragment and remove the smaller one. When the fracture is in the midportion, both fragments are removed.

Aftercare

A snug bandage is maintained for 7 to 10 days postoperatively. Activity is restricted until 6 weeks postoperatively. A good prognosis can be given for surgically treated patients.

Fracture of Dorsal Sesamoids

The dorsal sesamoid bones of the metacarpophalangeal bones are attached proximally to the common digital extensor and interosseous muscles and distally by a ligament to the proximal phalanx (see Figure 14-1). These small bones are rarely involved with any injury or pathological process, although they are often mistaken for chip fractures of the joint when seen radiographically. However, a dog was seen in our practice that had chronic lameness and exhibited pain and crepitus on flexion of the digits. Radiographic signs of enthesiophytes on the dorsal sesamoid

bone and degenerative joint disease of the metacarpophalangeal joint were present. The lameness and clinical signs were relieved by surgical excision of the affected dorsal sesamoid.

Luxation of Metacarpophalangeal and Interphalangeal Joints

Luxation or subluxation of the phalanges can occur at any joint level (Figure 14-39), but the distal interphalangeal (IP) joint is most often involved. These injuries are confined almost exclusively to racing greyhounds and working dogs. In greyhounds the toe is usually luxated to the left side, that is, the inside of the track. In other breeds the distribution is more random.

Clinical Signs

Lameness is usually absent to minimal at a walk when the animal is presented. Only when the dog is worked at faster gaits does it become evident that the dog is favoring a foot. Swelling, pain, and crepitus are not prominent, but the instability can be appreciated by careful palpation. The IP joints must be extended when palpating for stability to avoid rotational movement being mistaken for instability.

Diagnosis

Confirmation of the clinical diagnosis by radiographs is essential to rule out fractures and to allow identification of avulsions, which are treated as shown in Figure 14-33. Both total luxations and subluxations are seen.

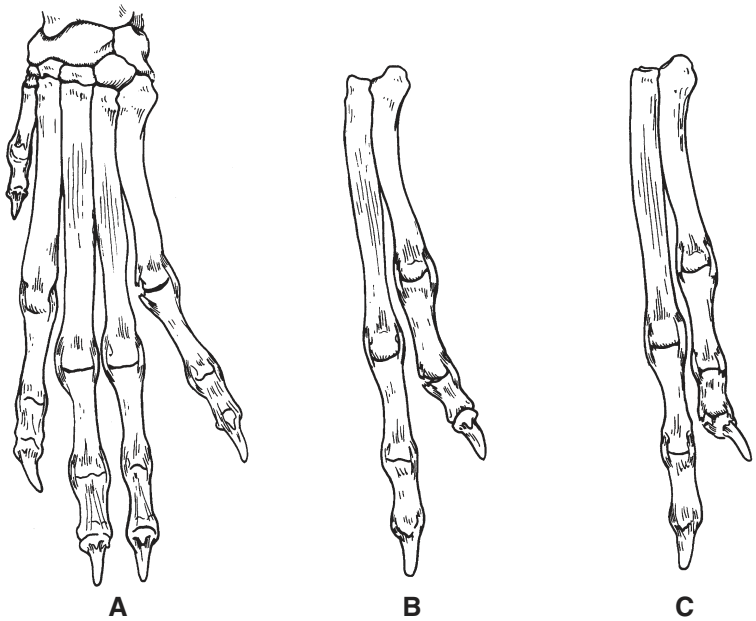


FIGURE 14-39. Luxation and subluxation of the phalanges. **A,** Lateral subluxation of the metacarpophalangeal joint with rupture of the medial collateral ligaments. **B,** Lateral subluxation of the proximal interpahalangeal joint with rupture of the medial collateral ligaments. **C,** Lateral subluxation of the distal interphalangeal joint with rupture of the medial collateral ligaments.

Treatment

These luxations are serious injuries for a running or working dog and should not be dismissed lightly. Aggressive surgical repair has yielded much better results than more conservative approaches, such as closed reduction and splintage. Many of these animals end up with instability of the joint and chronic degenerative changes in the joints that slow them greatly or leave them reluctant to traverse hard ground.

Suture Reconstruction

Surgical treatment by suture repair of collateral ligaments and joint capsule (Figure 14-40) works best when performed within the first 10 days after injury (the earlier, the better). Fibroplasia of these structures makes accurate suturing more difficult after 10 days. Failure to stabilize the joint leaves only the alternative of amputation (see Figures 14-41 and 14-42) or arthrodesis (see Figure 14-43). The IP joint is exposed through a dorsal incision (Figure 14-40, *A*). The torn joint capsule and collateral ligaments are visible beneath the skin. Three mattress

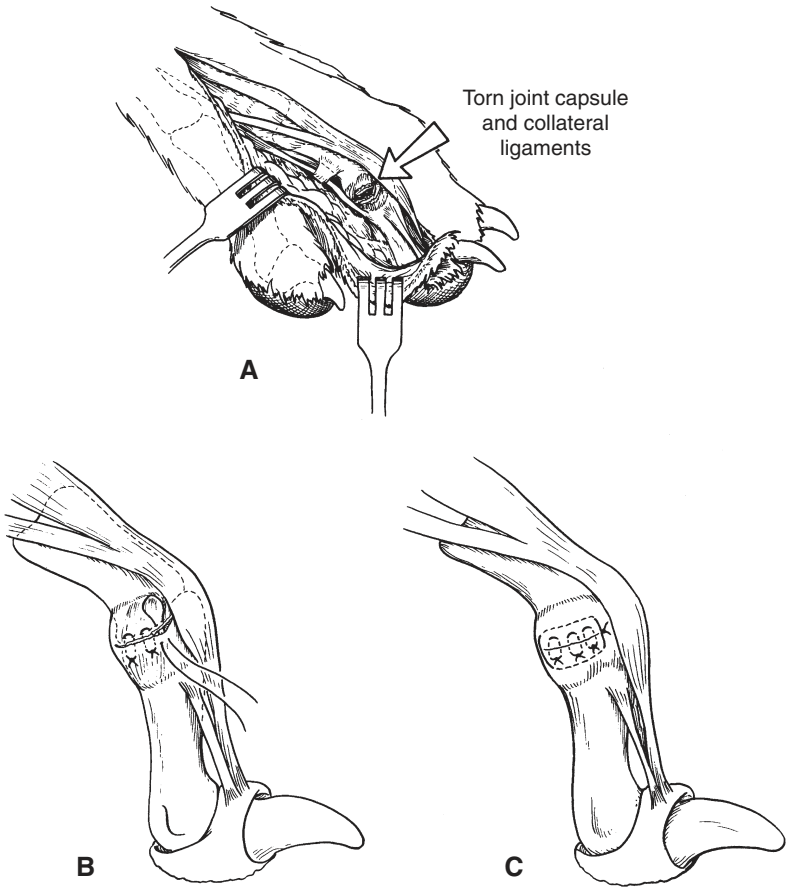


FIGURE 14-40. Suture repair of proximal interphalangeal subluxation. **A,** The affected joint is exposed by a dorsal incision, with reflection of tissues on the side of the instability.[3] Tearing of joint capsule and collateral ligaments can be seen below the arrow. **B,** Three main mattress sutures of 4-0 monofilament or synthetic absorbable material are placed across the torn capsule and collateral ligaments. **C,** A purse-string–like suture encompasses the other sutures.

sutures of 4-0 nonabsorbable monofilament or synthetic monofilament absorbable suture material are placed vertically to the tear in the capsule and collateral ligaments (Figure 14-40, *B*). These sutures are then encompassed within a single, large, purse-string mattress suture (Figure 14-40, *C*). Occasionally the extensor tendon apparatus will be slightly luxated as a result of tearing of its retinaculum. A few sutures are placed in the edge of the tendon and joint capsule to stabilize it. After reduction of total luxations, usually only one side of the joint is unstable, and that side is sutured. If both sides of the joint are loose after reduction, suture repair is performed bilaterally.

Aftercare. A molded plastic bivalve splint is applied to the foot for 3 weeks (see Figure 2-28). After splint removal, exercise is severely limited for 1 week, after which activity is slowly resumed to normal 6 weeks postoperatively.

Amputation of Toe

Amputation of the second or fifth toe at any joint level is not too serious in most dogs. In the middle toes, however, the results are not as good because these toes are the main weight-bearing digits; the more distal the amputation, the better the prognosis. Although amputations usually give good results in working animals, the outcome in racing animals is more difficult to predict; some animals will run well, and some will not.

The surgical principles of toe amputation vary little with the joint level involved. The skin incision is made to preserve the pad when amputation is at the IP level (Figure 14-41, *A*), but the toe pad is removed for a metacarpophalangeal (MCP) amputation (Figure 14-42, *A*). The joint is disarticulated by sharp dissection, which also involves section of both the flexor and the extensor tendons. It is desirable to remove the palmar sesamoids when amputation occurs at the MCP joint. The distal condyle of the proximal remaining bone is always removed. In the case of a distal IP amputation, the distal third of the middle phalanx is removed to provide more soft tissue between the skin and bone end (Figure 14-41, *B*). When amputating at the MCP level, the condyle is removed when metacarpal III or IV is involved, but bones II and V are beveled for a more cosmetic closure (Figure 14-42, *B*). Skin suturing may involve removal of skin "dog ears" to result in smooth skin closure (Figure 14-41, *D* and *E*).

Aftercare. A snug padded bandage is maintained for 10 days, and normal activity is not resumed until 3 weeks postoperatively.

Arthrodesis

Arthrodesis is a rational approach to MCP and proximal IP chronic instability in the racing animal. The most precise and predictable method of arthrodesis involves the use of miniplates or cuttable plates (Synthes) and 2.0-mm or 1.5-mm bone screws (Figure 14-43, *A*). K-wires and a tension band wire are also applicable (Figure 14-43, *B*). Minimal functional disability results from such a fusion, and joint pain is eliminated.

The joint is exposed by a middorsal approach as for amputation. The extensor tendon is reflected to one side by incising its retinaculum at the joint capsule. The joint is opened and articular cartilage removed by rongeurs or high-speed bur, conforming the surfaces to achieve good contact at the functional angle, which is judged by an adjacent toe. A four-hole or five-hole, straight miniplate or cuttable plate (Synthes) is contoured to the dorsal surface of the bone and attached with 2.0-mm or 1.5-mm screws (see Figure 14-43, *A*). An attempt is made to lag-screw across the

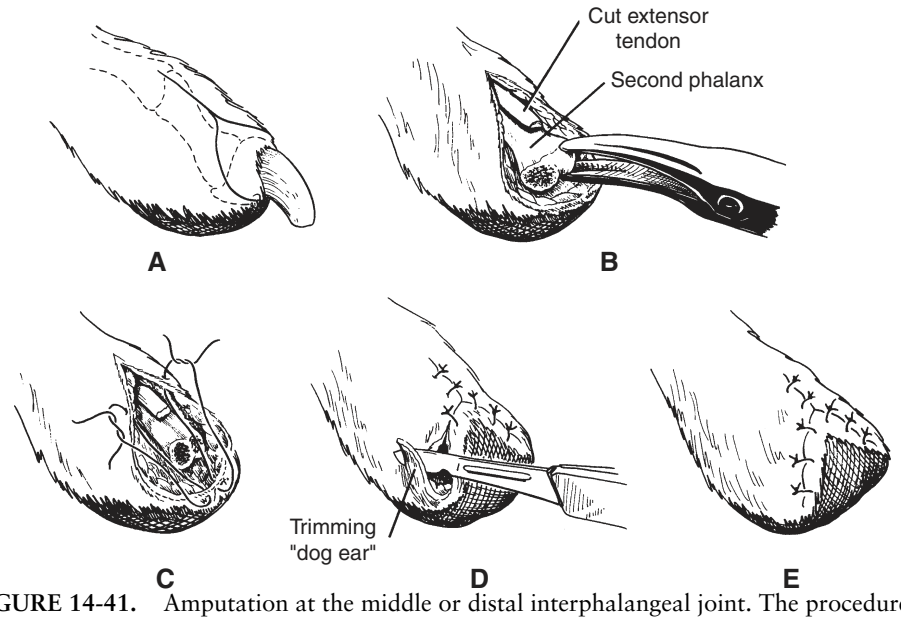


FIGURE 14-41. Amputation at the middle or distal interphalangeal joint. The procedure is drawn for the distal interphalangeal joint but does not differ in principle from a middle joint amputation. **A,** The skin incision encircles the nail, sparing the digital pad, and continues proximally over the bones for a short distance. The incision shown would have to be extended proximally a short distance to expose the middle joint. **B,** Soft tissue is sharply dissected away from the bone to be removed, and disarticulation is performed at the desired level. Rongeurs are used to remove the condylar portion of the remaining phalanx. **C,** Skin sutures are placed to create a Y-shaped incision and to pull the pad over the cut end of the bone. **D,** Excess skin is trimmed to allow smooth skin closure. **E,** Skin suturing has been completed.

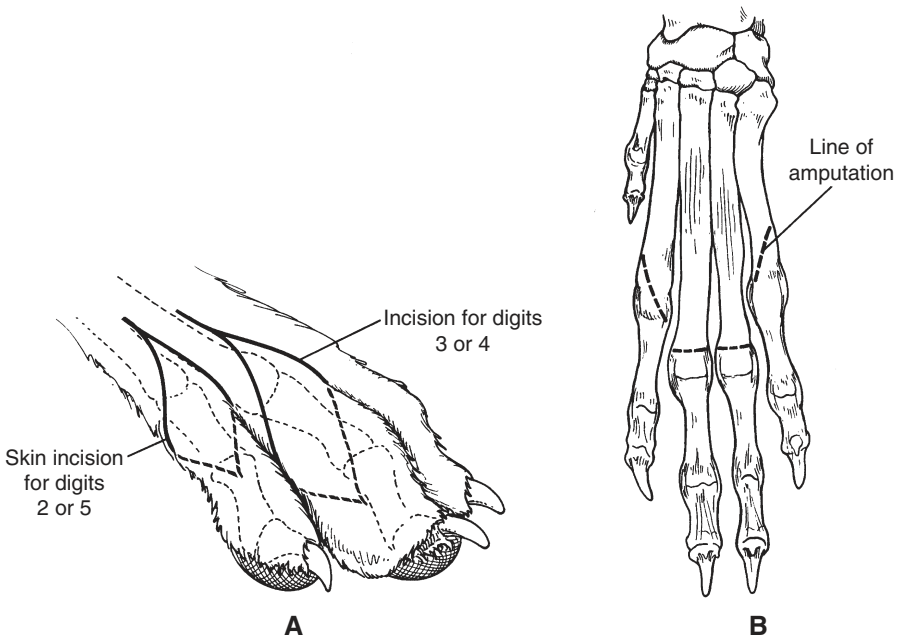


FIGURE 14-42. Amputation at the metacarpophalangeal (or metatarsophalangeal) joint. **A,** Skin incisions are designed to remove the digital pad, and when sutured, they both create a straight line. **B,** After disarticulation to remove the phalanges, the metacarpal bone is amputated at the indicated level. Beveling the medial and lateral bones improves the cosmetic appearance, especially on the lateral side.

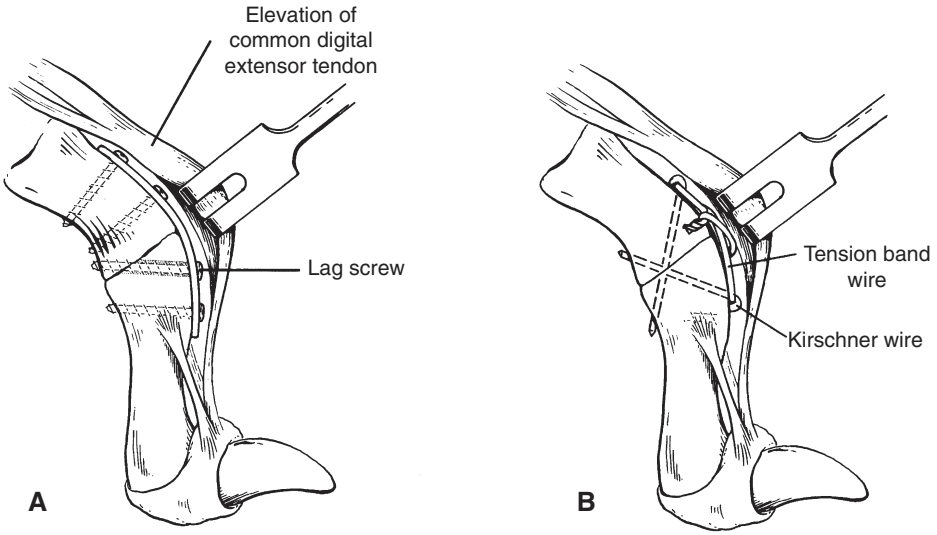


FIGURE 14-43. Arthrodesis of the proximal interphalangeal joint. Similar technique can be employed at the metacarpophalangeal (or metatarsophalangeal) joint. **A,** AO/ASIF straight miniplate (Synthes) has been contoured over the dorsal surface of the proximal and middle phalangeal bones after removing articular cartilage at the joint. Mini L-plates (AO/ASIF) can also be applied medially or laterally. Screws of 1.5- to 2.0-mm diameter are used to attach the plate. One screw has been lagged across the joint through the plate. **B,** Kirschner wires and a tension band wire can also be used to stabilize this arthrodesis.

joint with at least one screw. Bone grafting is not necessary. Alternatively, K-wires can be driven across the joint and the joint compressed with a tension band wire (Figure 14-43, *B*).

Aftercare. A molded bivalve splint (see Figure 2-28) is maintained for 6 weeks, at which time radiographic signs of healing should be seen. Exercise is slowly increased for 3 to 4 weeks before full activity is allowed.

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15
Fractures of the Pelvis

Fractures of the pelvis are relatively common, and in many veterinary practices they constitute 20% to 30% of all fractures. Most fractures are multiple, in that three or more bones are involved. Pelvic fractures rarely are open or compound.

ANATOMY

Structurally, the pelvis roughly forms a rectangular box and is made up of the ossa coxae (ilium, ischium, and pubis), sacrum, and first coccygeal vertebra (Figures 15-1 and 15-2). The structure is well covered with muscles and soft tissues. In fractures with minimal displacement, the muscles serve very effectively in supporting the bones. If there is gross displacement of the fracture segments, spastic contraction of the muscles increases the difficulty of surgical reduction and fixation.

FRACTURE CATEGORIES

Pelvic fractures can be grouped into six anatomical areas, as follows[1]:

- **Sacroiliac fracture/luxation:** Luxation of the sacroiliac joint, fracture of the sacral wing, or partial sacroiliac luxation with partial fracture of the sacral wing.
- **Ilial wing fracture:** Fracture of the non–weight-bearing and nonarticular portion of the ilial wing.
- **Ilial body fracture:** Ilial fracture between the sacroiliac joint and the acetabulum.
- **Acetabular fracture:** Any fracture involving the articular surface; may extend into the ilium or ischium.
- **Ischial fracture:** Fracture of the ischial body or ramus or fracture/avulsion of the tuber ischium.
- **Pelvic floor fracture:** Fractures of the pelvic symphysis, pubic body or ramus, and ischial ramus.

HISTORY AND EXAMINATION

The patient's history usually includes traumatic injury and a sudden onset of symptoms. Because of the degree of trauma necessary to fracture the pelvis or cause a

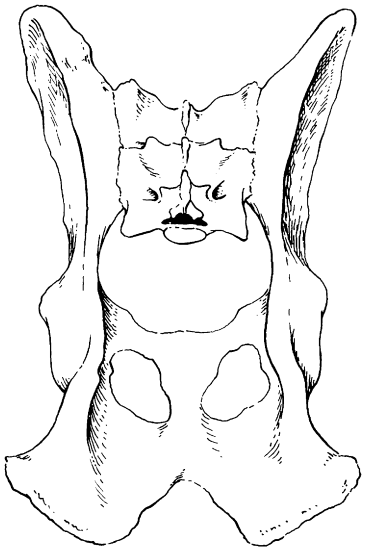


FIGURE 15-1. Pelvis, caudodorsal aspect.

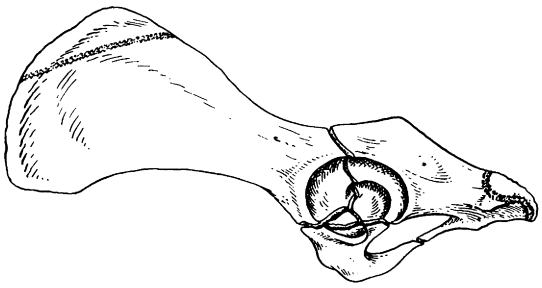


FIGURE 15-2. Left os coxae of young dog, lateral aspect, showing the acetabulum made up of the ilium, ischium, pubis and acetabular bones, and physes of ilium and ischium.

fracture-luxation, adjacent tissue and surrounding organ systems must be carefully evaluated. Fractures of the pelvis are always multiple in nature (excluding bite and gunshot wounds), and if displacement is present, at least three or more bones are assumed to be fractured. Dogs typically are weight bearing on three legs with unilateral injuries, but they also may be weight bearing on all limbs with bilateral injuries. Inability to stand may be associated with neurological injury or extreme pain, which is seen most often with sacral injuries.

Examination should include the following:

1. Physical examination and evaluation of the entire body.
2. Special emphasis on some of the more common complicating injuries: traumatic lung syndrome, traumatic myocarditis, pneumothorax (chest radiographs are taken routinely), rupture of the bladder or urethra, fractures of the spine, fractures of the femoral head and neck, and neurological deficits.
3. Neurological examination of the rear limbs should be evaluated with the reservation that pain may obtund some reflexes, such as proprioception and withdrawal. Include observation for voluntary leg movement while supporting the trunk, deep pain reflexes on all four toes of each foot, femoral nerve reflex (knee jerk), sciatic nerve reflex (withdrawal), as well as observations of the rectum and perineal reflex.
4. Palpation of the pelvic bones, with emphasis on normal relationships between the bony prominences, such as the tuber coxae and ischii, and the greater trochanter.

Palpation is rarely adequate to form a good picture of the bone damage, and radiographs are always imperative. A gentle digital rectal examination will provide some information about pelvic canal compromise caused by displaced bone fragments. Blood on the glove should lead to suspicion of rectal perforation or laceration, and inability to palpate the prostate in males would suggest urethral avulsion.

5. Radiographs including ventrodorsal and lateral views. A lateral radiograph is taken with the affected side down, the lower hip flexed, and the upper hip extended. Tilting the pelvis to produce a slightly oblique view helps to separate the two sides. Extension of the hindlegs for the ventrodorsal view can often be painful; the frog-leg position is adequate for initial evaluation. Complete radiographic examination may require anesthesia because of pain and therefore may have to be postponed until the patient is stable. If surgical treatment is expected based on the initial films, more definitive views can be obtained when the patient is anesthetized for surgery.

PRINCIPLES OF TREATMENT

In regard to treatment, pelvic fracture patients may be divided into nonsurgical and surgical groups.[2,3]

Nonsurgical Group

Included in the nonsurgical group are patients with little or no displacement of the fracture segments, an intact acetabulum, and continuity of the pelvic ring remaining essentially intact. The pelvic musculature serves very effectively in immobilizing the fracture segments. Perfect anatomical alignment of fractures involving the bones of the pelvis (other than articular surfaces) is not necessary for healing or function. Posttreatment function may be adequate for most pets, but the prognosis is much less certain for performance animals.

Management of the patient usually consists of cage rest, limitation of activity, and measures to ensure regular urination and defecation. To help prevent the development of decubital ulcers, a well-padded kennel is needed, particularly for animals that are temporarily nonambulatory; many patients are able to stand up and move around in 1 or 2 days or, in the case of multiple fractures, 1 or 2 weeks. For large breeds, an enclosed space that can be covered with a thick layer of clean straw makes excellent bedding that will carry urine away from the skin. Healing time for bones of the pelvis is approximately the same as for other bones in the body.

Surgical Group

Surgical intervention should be considered in animals with pelvic fractures characterized by one or more of the following[2,3]:

1. Marked decrease in the size of the pelvic canal.
2. Fracture of the acetabulum (displacement of articular surfaces).
3. Instability of the hip caused by fracture of ilium, ischium, and pubis.
4. Unilateral or bilateral instability, particularly if accompanied by coxofemoral dislocation or other limb fractures.

Careful study of the radiographs can show the type and location of the fractures involved and can suggest the appropriate surgical approach. In some multiple fractures,

it may be necessary to use a combination of approaches to expose the involved areas and to accomplish reduction and fixation. Most pelvic fractures are accompanied by extensive muscle trauma, hemorrhage, and soft tissue injury. Such conditions usually result in increased surgical risk. The condition of the patient may prohibit carrying out all of the surgery that may be indicated. Traumatic lung or myocardial syndromes may complicate anesthesia and delay surgery for 3 to 6 days. Reduction and fixation are accomplished much more easily and accurately if undertaken within the first 4 days of injury. Each day of delay adds to the injuries to major nerves and blood vessels and to the time required to obtain reduction of the bones. In some cases a prolonged delay may limit or prevent surgical repair. The chief advantages of early reduction and fixation are minimal hospitalization time, early ambulation, and minimization of fracture disease.

The various means of fixation for pelvic fractures typically include intramedullary pins, Kirschner wires, bone plates, bone screws, and interfragmentary wiring, or a combination of these techniques. Clinical experience indicates that the highest percentage of successful cases have been treated with bone plates and screws. For surgical treatment of pelvic fractures, *major emphasis is placed on the sacroiliac joint, ilium, and acetabulum*. If these three areas are properly reduced and fixed, the other areas (ischium, pubis) as a rule will be adequately reduced and stabilized and, with very few exceptions, need no specific surgical treatment. In most cases, it is to the surgeon's advantage to proceed in the order of sacroiliac joint, ilium, and acetabulum if all three are involved. If the ilium and acetabulum are involved, reduction and fixation of the ilium first gives stability to the cranial portion of the acetabulum; thus, there is a stable segment to build on for reduction and fixation of the remaining portion.

SACROILIAC FRACTURE-LUXATION

In sacroiliac (SI) fracture-luxation the ilium is usually displaced craniodorsally, with a portion of the sacral wing often remaining attached to it. Displacement is always accompanied by fractures of the pubis and ischium or by separation along the pelvic symphysis, making half the os coxae unstable. In some bilateral SI luxations the rest of the pelvis may remain intact. Injuries of the lumbosacral trunk in the form of sensory, voluntary motor, and reflex neurological abnormalities are common accompanying injuries. In two studies of pelvic fractures, 11% had peripheral nerve injury, and 41% of these were SI fracture-luxations.[1,4] Perineal, sciatic, and femoral nerve function should be assessed before undertaking surgery. Minor luxations of the SI joint with little or no displacement may be treated conservatively with restricted activity. Indications for internal fixation chiefly include pain and instability. Inability to control adduction of the limb due to pain may present a problem in some cases. In many animals, this condition is accompanied by considerable discomfort and a prolonged period of favoring the involved rear limb, particularly when the lumbosacral nerve trunk is traumatized. Reduction and stabilization facilitate healing of the nerve trunk. Contralateral injuries may dictate stabilization of the SI joint to allow weight bearing to be shared between the hindlimbs and to ease the load on the contralateral internal fixation. As a generalization, SI joint instability creates fewer problems in smaller breeds than large breeds, and there is less need for internal fixation.

Open Approach and Reduction

The sacroiliac area may be exposed dorsally by the dorsolateral approach to the wing of the ilium and dorsal aspect of the sacrum (Figure 15-3) or ventrally by the

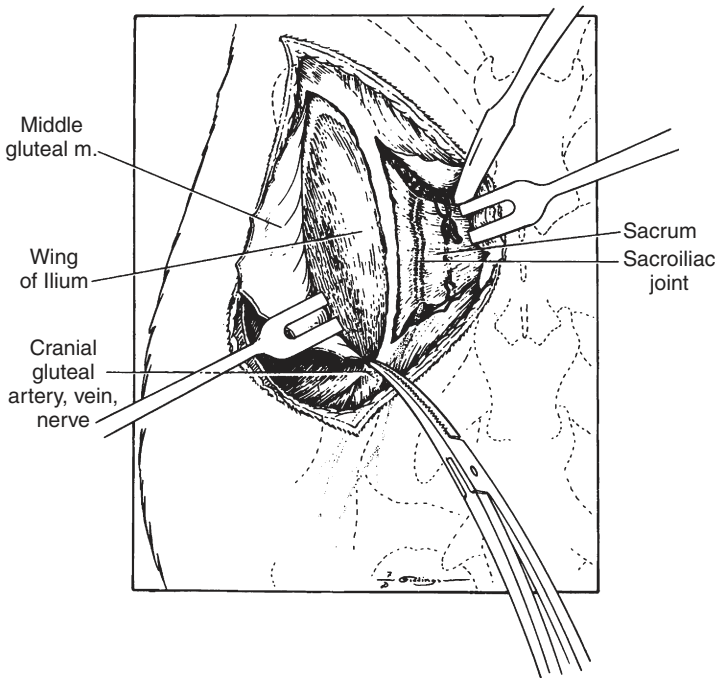


FIGURE 15-3. Dorsolateral approach for sacroiliac fracture-separations.[5] A skin incision is made over the crest of the ilium and extended caudally along the dorsal iliac spine. The middle gluteal muscle is incised at its origin just inside the cranial and dorsal borders of the wing and subperiosteally elevated from the ilium. As the caudal end of the straight portion of the dorsal iliac spine is approached during this elevation, a curved hemostat is used to run along the dorsal iliac spine to locate the caudal border of the sacrum. The cranial gluteal vessels and nerve pass from medial to lateral over the caudal iliac spine and enter the middle and deep gluteal muscles. The inserted hemostat helps to locate this area and also helps to avoid severing the cranial gluteal vessels and nerve. The hemostat is retained in place, and the subperiosteal reflection stops just short of this area, thus avoiding injury to the gluteal vessels and nerve. In most cases the tissue between the iliac crest and adjoining sacrum is separated, and little additional cutting or blunt dissection is necessary to expose the opposing surfaces of the sacrum and wing of the ilium. Additional soft tissue is reflected off the dorsal surface of the sacrum to expose the sacroiliac joint. The hemostat remains in place during the entire procedure, including dissection, reduction, and fixation, because it helps to protect the cranial gluteal vessels and nerve and serves as an aid in keeping anatomical landmarks in mind.

lateral approach to the ilium (Figure 15-4).[5] Either approach may be used. The dorsal approach lends itself to fracture separations alone or in conjunction with ipsilateral acetabular fractures and to contralateral fractures of the os coxae. The ventrolateral approach lends itself to fracture separations alone or in conjunction with fractures of the ilium on the same side.

From the dorsal approach, the articular surface on the medial side of the ilium lies just ventral to the dorsal iliac spine in the caudal half of the wing (Figures 15-5 and 15-6, *C*). After location or visualization of the fracture-separation surface on both the ilium and the sacrum, reduction is accomplished by grasping the edge of the iliac wing with a bone-holding forceps and moving it caudally into position. A countering cranial force on the sacrum by use of a hemostat is helpful in accomplishing reduction (see Figure 15-5). It is highly recommended that the surgeon visualize these areas on a cadaver specimen and be able to compare the anatomical positions

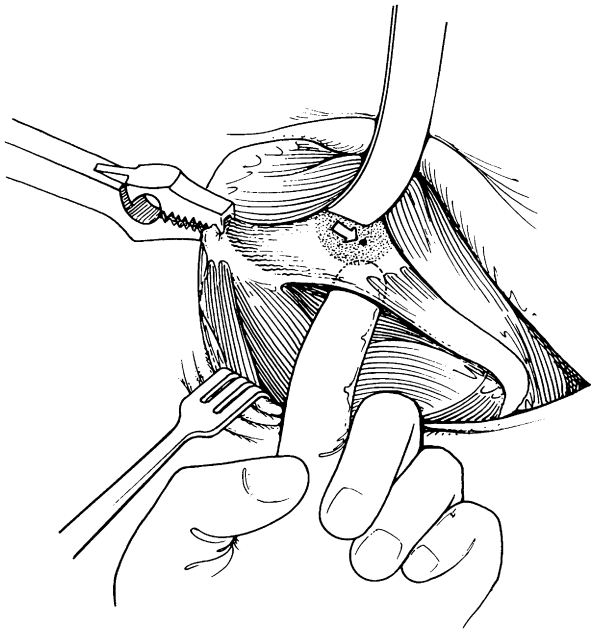


FIGURE 15-4. Ventrolateral approach for a sacroiliac fracture-separation is the same as the lateral approach for the ilium (see Figure 15-9). In addition, the iliacus muscle is incised and subperiostally elevated along the ventromedial border of the iliac body as needed to allow insertion of one finger in the pelvic inlet.[9] The inserted finger is used to palpate the area of synchondrosis of the ilium and sacrum for reduction and screw placement. The Kern bone-holding forceps is used to move the ilium into reduction on the sacrum. The arrow and dot indicate the approximate location for inserting the lag screw through the ilium and into the body of the first sacral vertebra. This is the same location for placement of the lag screw as in a dorsolateral approach.

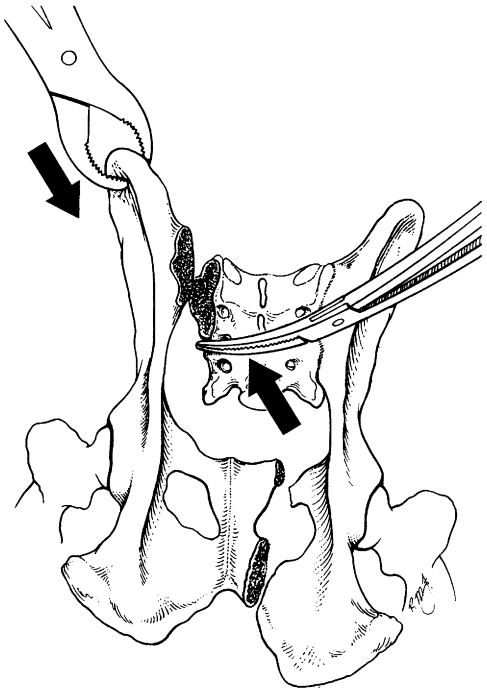


FIGURE 15-5. In a fracture-separation of the sacroiliac joint, the wing of the ilium lies in a craniodorsal position in relation to the sacrum. From a dorsolateral approach, reduction is usually accomplished by grasping the wing of the ilium with a bone-holding forceps and exerting a caudal and downward force. This is countered by a directly opposite force exerted on the sacrum by a curved hemostat or scissors.

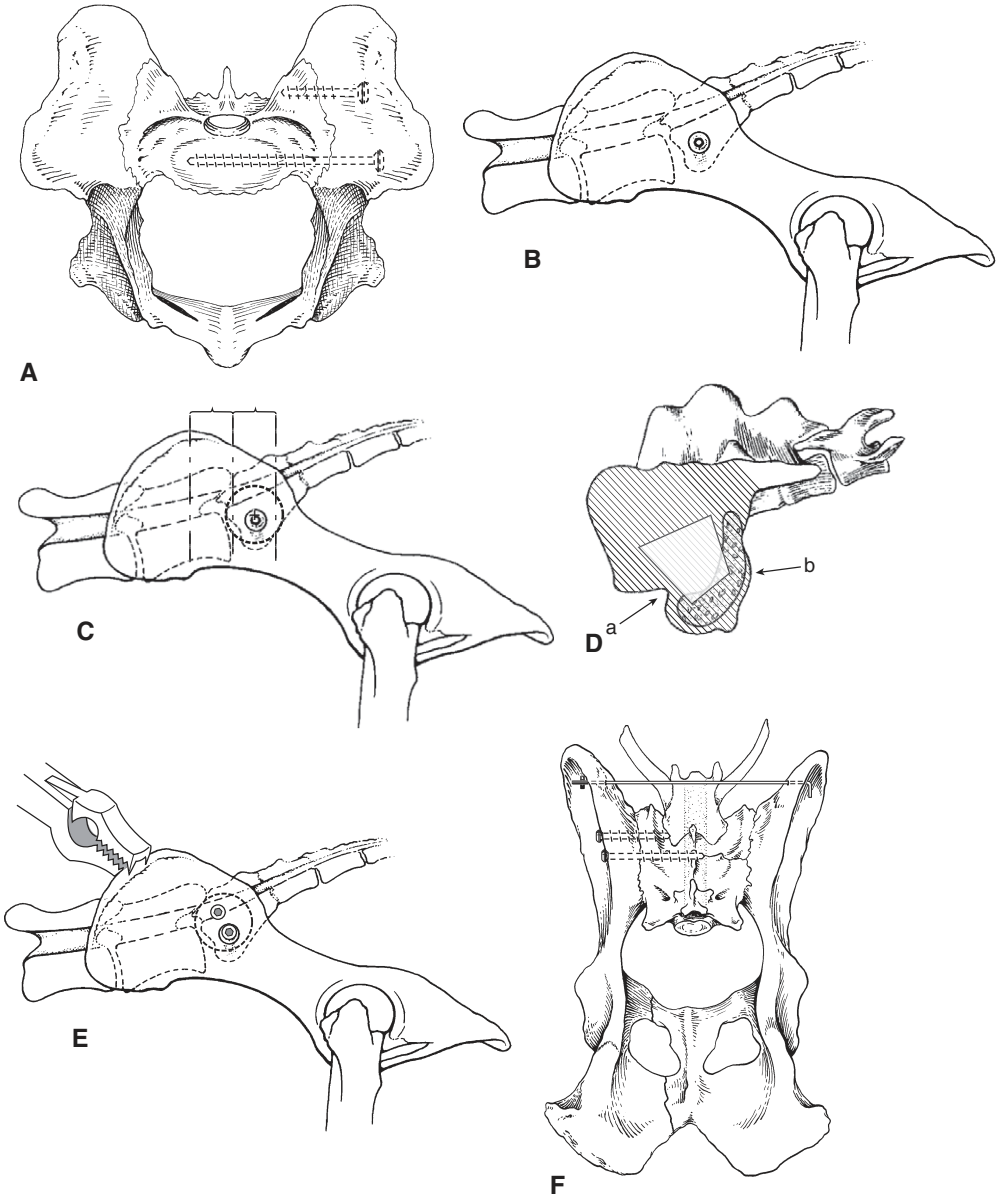


FIGURE 15-6. Reduction and fixation. **A,** Craniocaudal view of the pelvis showing proper position of the lag screw into the sacral body. Penetration is usually about 60% the width of the sacral body. A second screw may be inserted for two-point fixation. **B,** Schema of lateral view of pelvis with screw inserted into the body of the sacrum. **C,** Lateral view of the ilium; + marks the spot for drilling and inserting the lag screw. Craniocaudally, the + is located in the center of the caudal half, and proximodistally, it is located in the proximal one third of the ilial width. **D,** The area of the lateral surface of the sacral body available for proper screw placement is only slightly larger than 1 cm in the average-size dog, as denoted by the clear area. The cross-hatched area represents a thinner portion of the sacral wing, which can only accommodate short screws. This means that for many cases, there is only room for placement of one screw within the area of the sacral body. The notches *(a)* along the cranial border of the sacrum and the crescent-shaped auricular cartilage *(b)* are used as landmarks in locating the area for screw insertion into the sacral body. **E,** The first lag screw is inserted through the ilium and then, directed by sight, into the hole previously drilled into the sacral body. The first screw is completely tightened. When a second screw is inserted, it is usually located slightly cranial and proximal. The depth for drilling this hole and length of the lag screw to be inserted are determined from the ventrodorsal radiograph. The drill hole and screw should stop just short of the neural canal. Two-point fixation is preferred in most cases. **F,** If additional fixation is indicated for stabilization, a transilial bolt passing through the wings and over the dorsal surface of the seventh lumbar vertebra (L7) may be inserted.

of the ilium and sacrum with a bone specimen during surgery. Anatomical reduction is essential to allow for stable screw fixation.

Internal Fixation

Stabilization of the SI joint is accomplished by inserting a lag screw(s) (see Figure 2-66) through the body of the ilium into the body of the sacrum. Two screws are stronger than a single screw of the same size, and two small screws are stronger than a single large screw.[6] Thus the ideal fixation would be two screws of the largest possible size.

Looking at the lateral surface of the ilium, the area for insertion of the screw through the ilial body and into the sacral body is indicated by the "+" mark on Figure 15-6, *C*. This point is located by first dividing the length of the straight portion of the dorsal iliac crest into two equal parts. The craniocaudal location of + lies in the center of the caudal half. The dorsoventral location of + lies near the proximal third of the ilial width in this area. The first screw goes into the sacral body (Figure 15-6, *B*). If a second screw is inserted, it is usually located just cranial and slightly dorsal to the first, and the length is just short of the neural canal (Figure 15-6, *A*). The ilial body hole should be glide-hole diameter if full-threaded screws are to be used. Screw length is measured on the dorsoventral view of the radiograph. A second screw is desirable, particularly where a portion of the sacrum is fractured or the first screw is not ideally placed in the body of the sacrum.

Drilling of the sacral body for the screw from the dorsal approach requires first visualizing the notch on the lateral surface of the sacrum (Figure 15-6, *D*). Pulling the wing ventrally and laterally aids in locating this area.[7,8] The tap hole into the sacral body should be drilled just caudal to this notch and cranial to the crescent-shaped auricular cartilage. The clear area on Figure 15-6, *D,* shows the area in which the screw can be inserted for maximum holding and the area that is free of important structures.[8] Although a perfectly placed central sacral body screw can penetrate the entire body, if there is any doubt about the location of the hole, drilling should proceed cautiously to a premeasured depth that will not take the drill into the neural canal. This hole is then tapped to receive the selected screw. The screw is advanced through the ilial hole, and when the tip appears on the medial side, the fracture is reduced and the screw directed and inserted into the predrilled sacral hole.

From the ventrolateral approach, a finger is used to palpate the area of synchondrosis on the ilium and the ventral portion of the sacrum[9] (see Figure 15-4). A bone-holding forceps placed on the cranial ventral iliac spine is used to accomplish reduction. A Kirschner wire is inserted through the ilial wing and into the sacrum for temporary stabilization until one or two lag screws are inserted through the wing into the sacrum. The sacrum must be drilled "blind" because it cannot be exposed for predrilling, as previously explained. It is recommended that the surgeon visualize and palpate these areas as well as review the anatomical position of the ilium and sacrum on a bone specimen.

Note: Accurate reduction and placement of screws are at times challenging, especially if a week or more has elapsed since the injury. A common error involves screw placement in lumbar articular processes, the lumbosacral disk space, or the seventh lumbar vertebra or missing the sacrum entirely.

In some cases (e.g., extremely overweight dogs, impacted fractures involving a portion of the sacrum, some bilateral fractures), an additional stabilizing bolt improves stability. This device passes transversely through the iliac wings and dorsal to the seventh lumbar vertebra (Figure 15-6, *F*). It can be either a partially threaded Steinmann pin, bent at the smooth end and with a nut placed on the threaded end, or a Hagie pin, which has a positive-thread-profile tip and a negative-profile thread at the other end to accept a nut.

Case Studies

Case 1

Figure 15-7, *A,* shows a mature Saint Bernard with a unilateral fracture-separation of the SI joint and fractures of the ischium and pubis. On the fourth day after the trauma occurred, the animal still exhibited considerable pain on attempting to move and was unable to rise. Two cancellous bone screws were used for fixation of the SI joint (Figure 15-7, *B*). Reduction and fixation of the SI joint also aided in stabilization of the other fractures. The animal was able to stand and walk on the first postoperative day.

Case 2

Figure 15-8, *A,* depicts a large mixed-breed dog with bilateral SI luxations, a coxofemoral luxation, and fractures of the pubis and ischium. The animal was unable to rise and lay with its hindlimbs in the "spread-eagled" abducted position. Reduction and fixation were done using two cancellous bone screws on each side (Figure 15-8, *B*). It was necessary to stabilize the acetabulum before reduction of the hip joint could be maintained. An open approach was performed to reduce the hip joint and suture the joint capsule. The legs were hobbled together for 6 days (see Figure 15-27) to protect against abnormal abduction.

ILIAL WING FRACTURE

Because these fractures involve neither a weight-bearing nor an articular area, they are ordinarily not treated surgically. Cosmetic considerations might be an indication for internal fixation under some circumstances. Pins, interfragmentary wire, lag screws,

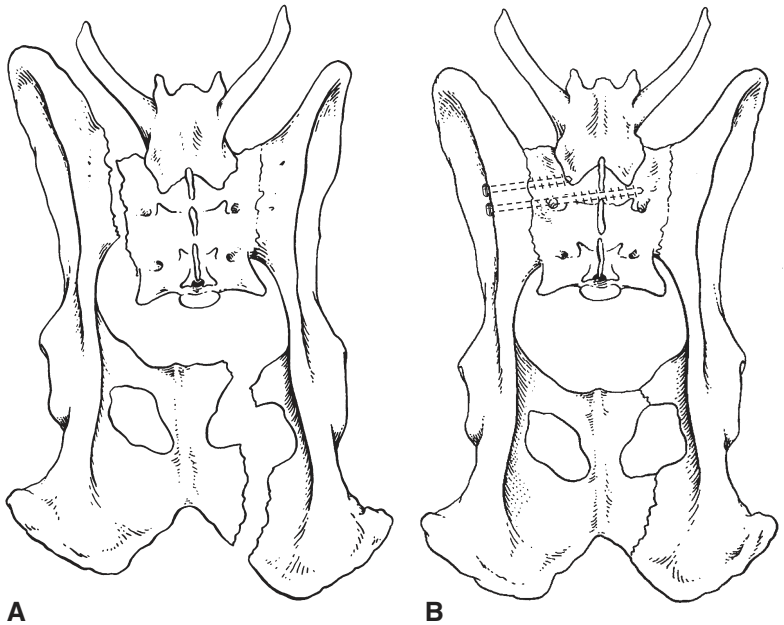


FIGURE 15-7. **A,** Mature Saint Bernard with a unilateral fracture-separation of the sacroiliac joint and fractures of the ischium and pubis. **B,** Postoperative view showing two cancellous bone screws used for fixation.

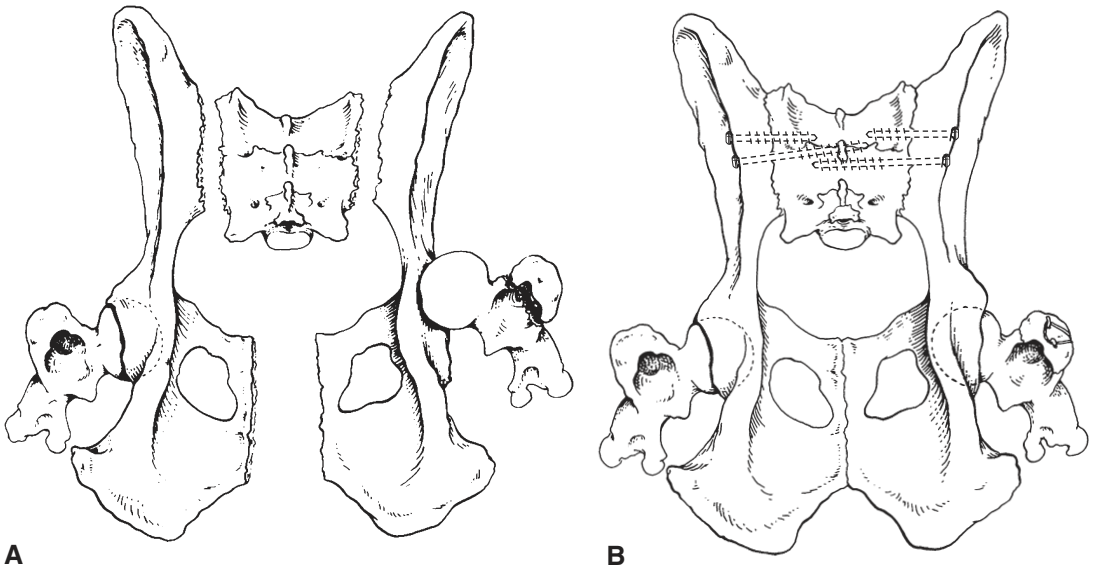


FIGURE 15-8. **A,** Large dog with bilateral sacroiliac separations, a coxofemoral dislocation, and fractures of the pubis and ischium. **B,** Postoperative view showing two cancellous bone screws on each side used for fixation. The acetabulum must be stabilized before reduction of the hip joint can be maintained. A dorsolateral approach was used to expose the hip joint; after reduction, the ruptured joint capsule was sutured in place.

or small plates could be employed. The dorsolateral approach (see Figure 15-3) is used for exposure.

ILIAL BODY FRACTURE

Most fractures of the ilial body are oblique, and the caudal segment is depressed medially, resulting in decreased size of the pelvic canal[2,3] (see Figure 15-10). Some fractures are multiple, and most are accompanied by fractures of the ischium and pubis. Neurological injury to the lumbosacral trunk may accompany ilial fracture and should be assessed before undertaking surgery. Often these injuries are transient. Reduction and stable fixation of ilial body fractures aid in lining up and stabilizing fractures of the ischium and pubic bones (see Figure 15-10, *C* and *D*). If the body of the ischium is also fractured, the hip joint will be quite unstable (see Figure 15-11). Internal fixation of ilial body fractures is the most common surgical repair of the pelvis.

Open Approach and Reduction

Figure 15-9 shows an approach to the lateral surface of the ilium that is sufficient for fixation application in most ilial body fractures.[5] Reduction usually consists of a combination of levering, traction, and rotation. The caudal segment generally needs to be levered out from underneath (medial, or deep, to) the cranial segment. A bone-holding forceps on the greater trochanter (Figure 15-10, *D*) may be helpful in maneuvering and realigning the caudal segment. If the ischium is not fractured, a bone-holding forceps on the ischiatic tuberosity, as shown for acetabular fracture reduction (see Figure 15-15, *A*), can also be used. Final reduction and fixation will

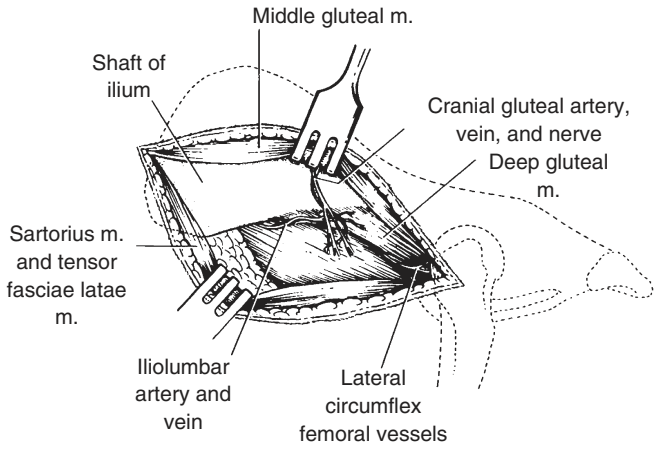


FIGURE 15-9. Approach to the lateral surface of the ilium.[5] Subperiosteal reflection upward of the middle and deep gluteal muscles exposes the ventral border and lateral surface of the body and wing of the ilium. The primary structures of importance encountered in this approach are the lateral circumflex femoral vessels (just cranial to the acetabulum), the cranial gluteal nerve (midway), and the iliolumbar vessels (located at the caudal iliac spine). The iliolumbar vessels are cut and ligated in carrying out the approach. The cranial gluteal vessels and nerve may be cut if necessary to obtain adequate exposure.

vary according to the type fixation used. Application of a bone plate does not require total reduction initially, as explained later.

Caudal ilial body fractures are located immediately cranial and/or dorsal to the acetabulum, without invading the joint. If fixation is anticipated to extend over the dorsal aspect of the acetabulum, a more extensive approach to the os coxae may be indicated (see Figure 15-21).

Internal Fixation

Many methods of fixation for fractures of the ilium have been presented and used. The highest percentage of successful cases, as well as ease of application, can be attributed to the use of bone plates. Plating of the ilium is very straightforward, requires a fairly small inventory of implants, and is an excellent place to gain experience in bone plating before doing long-bone fractures. In certain cases (e.g., long oblique fractures and in relatively lean animals), the insertion of lag screws or pins and compression wire is very effective.

Bone Plates

There are two methods of plate application for ilial body fractures, as follows:

1. If the fracture can be adequately reduced, self-retaining bone forceps (e.g., compression, speed-lock, or Verbrugge forceps) are helpful in accomplishing and maintaining reduction while fixation is applied (Figure 15-10, *D*). A Kirschner wire driven across the fracture line (see Figure 15-13, *B* and *C*) will help prevent sliding motion at the fracture line if there is difficulty maintaining stability with the forceps.
2. When the fracture can only be semireduced, the prebent plate is first applied to the caudal segment (see Figure 15-10, *B*). Lateral traction is exerted on the trochanter major along with medial pressure on the cranial end of the plate

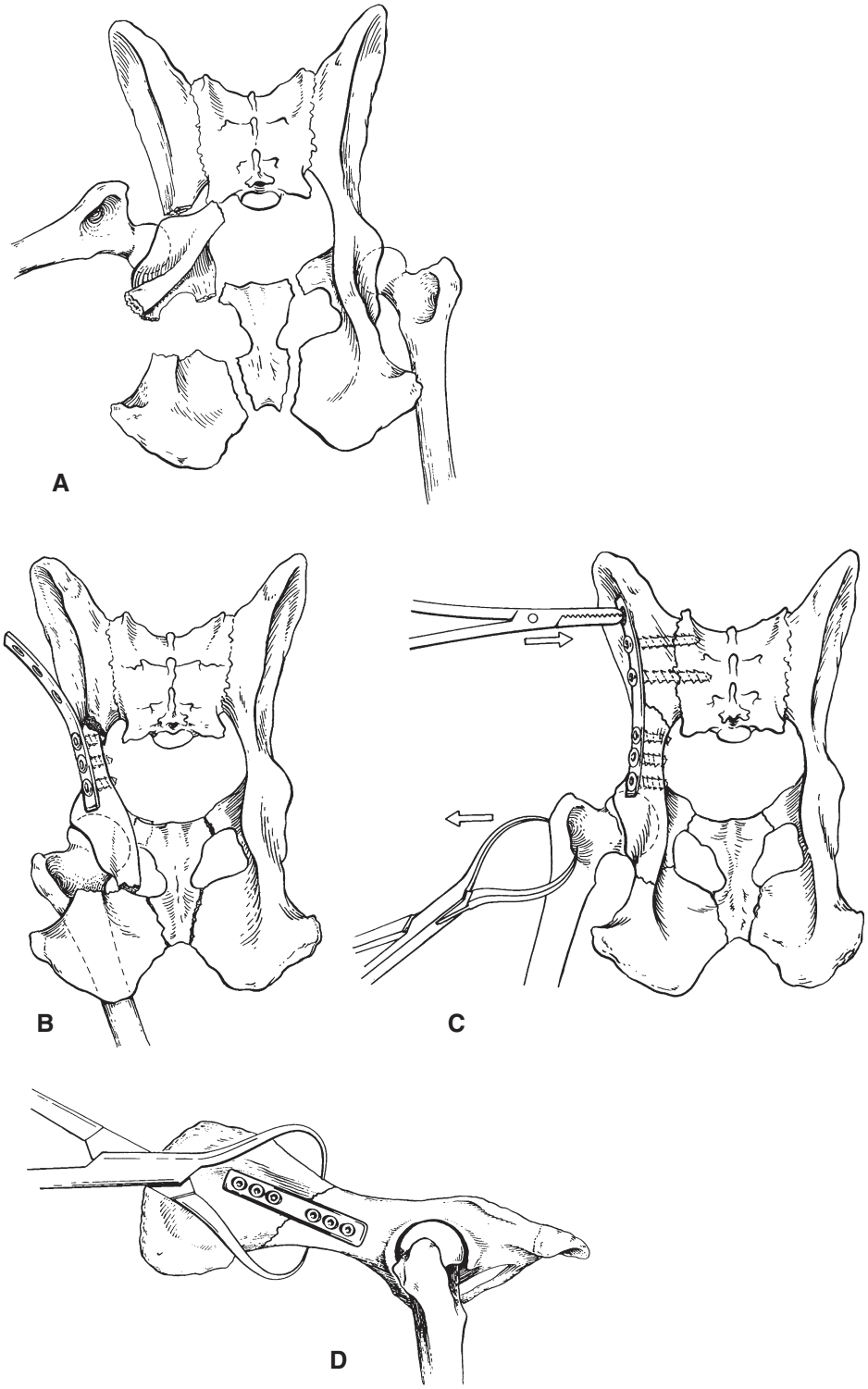


FIGURE 15-10. **A,** Reduction and plate fixation of an iliac shaft fracture with accompanying fractures of the ischium and pubis. **B,** A contoured plate is first attached to the caudal iliac segment. **C,** Lateral traction by way of the trochanter major and medial pressure on the cranial end of the bone plate bring about reduction of all the fractures. Cranial screws are then placed. **D,** Bone-holding forceps maintain reduction while cranial screws are placed.

before and during insertion of the bone screws into the cranial segment, which should proceed from caudal to cranial (see Figure 15-10, *C*). Driving the screws through the contoured plate acts to reduce the fracture (see later discussion).

The length and type of bone plate depend on the location of the fracture line, the limiting factor being the distance between the fracture line and the acetabulum. If there is sufficient room, a six-hole straight plate is applied, as in Figure 15-10, *D*. Anchoring one or more screws in the body of the sacrum greatly increases the holding power of the cranial screws. The cranial part of the wing of the ilium is thin, and screws may strip easily. Compression of the fracture line is desirable but seldom possible because of the obliquity of the fracture line. Two screws are sufficient in the caudal segment if the distance is short. If the distance is too short for two screws in a straight plate, T-plates, L-plates, or reconstruction plates (see Figure 15-17, *B*) may be necessary. However these plates are thin and bend easily.

The ilial plate must be bent slightly more concave than the normal curvature of the ilium, which is judged from the contralateral side on the dorsoventral radiograph. This is essential to help restore the normal size of the pelvic canal, which will always collapse slightly postoperatively because of the animal's tendency to lie on the operated side.

Figure 15-11 shows an oblique fracture of the ilium along with fractures of the ischium and pubis and sacroiliac luxation on the opposite side. If attention is directed toward reduction and fixation of the sacroiliac separation and the fractured ilium, the rest of the fractures will usually align in a satisfactory manner. The SI joint was treated first and stabilized with two cancellous screws; this made reduction easier on the opposite side. The lateral approach was used to expose the ilium, which was fixed by the use of a bone plate. Note how the plate is contoured in a

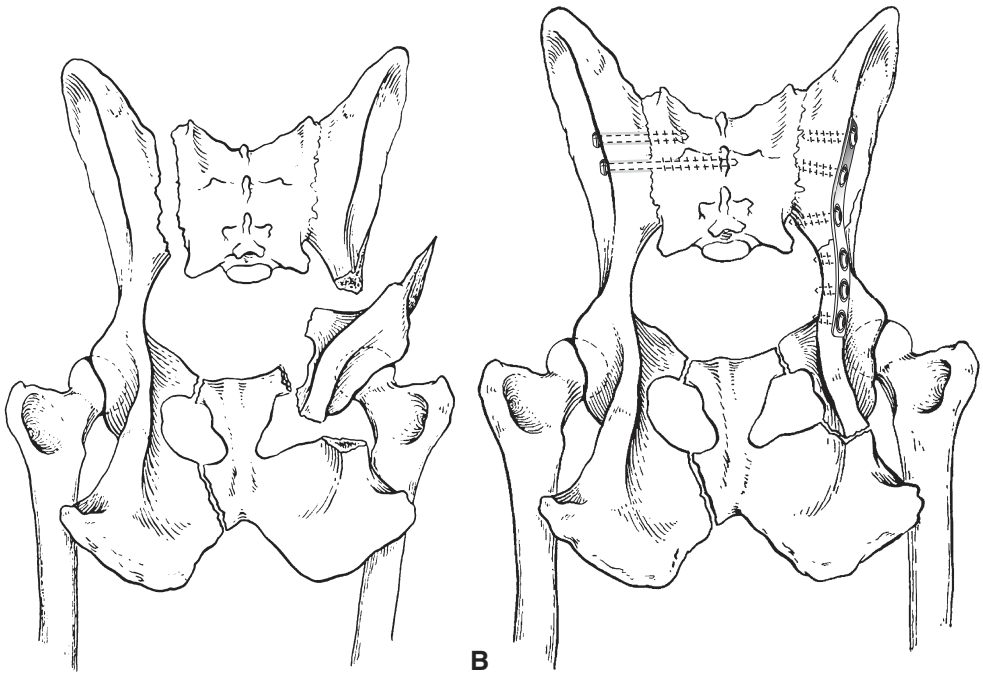


FIGURE 15-11. **A,** Oblique fracture of the ilium, along with fractures of the ischium and pubis; sacroiliac separation on opposite side. **B,** The sacroiliac joint is stabilized by two cancellous screws; a lateral approach exposes the ilium, which was fixed by use of a bone plate.

concave manner to restore the pelvic canal to normal size and to realign the fractured ischium.

When the location of the ilial fracture is immediately cranial or extending dorsal to the acetabulum, the plate application may need to extend over the dorsal rim of the acetabulum. Contouring a plate for this location can be a daunting task but is simplified by applying a simple torque to a straight plate (Figure 15-12) or by using a reconstruction plate, which facilitates contouring in three dimensions.

Lag Screws

Mechanical and case studies have shown that two or more lag screws (Figure 15-13, *A*) can be an effective method of stabilizing oblique fractures of the ilial body when the length of the fracture line is equal to two times the dorsoventral measurement of the ilium.[10,11] Shorter obliquities do not allow the screws to be placed at an effective angle to provide angular stability. The fracture is exposed by the lateral approach to the ilial body (see Figure 15-9).[5] The iliacus muscle is elevated from the ventral edge of the ilium and is retracted medially with a Hohmann retractor to allow drilling into the ilial body. If the animal is heavily muscled or obese, it may be difficult to obtain the proper angle for the drilling. In this case, a smooth intramedullary pin can be used for drilling the screw hole, since the pin can be introduced into the exposed bone after passing it through soft tissues at the required angle. A cancellous screw can be used if the threads do not cross the fracture line; otherwise, a full-threaded screw and glide hole are necessary. Self-tapping screws are advantageous because it can be difficult to introduce a tap at the required angle. The ilial bone may also be soft enough to allow the use of a nontapped cortical thread screw without cutting threads in the bone with a tap.

Pins and Compression Wire

The pin and compression wire technique can be substituted for the screw technique, especially in smaller breeds, where screw size can be a problem (Figure 15-13, *B* and *C*). It is essential that a minimum of two pins be used to ensure angular stability

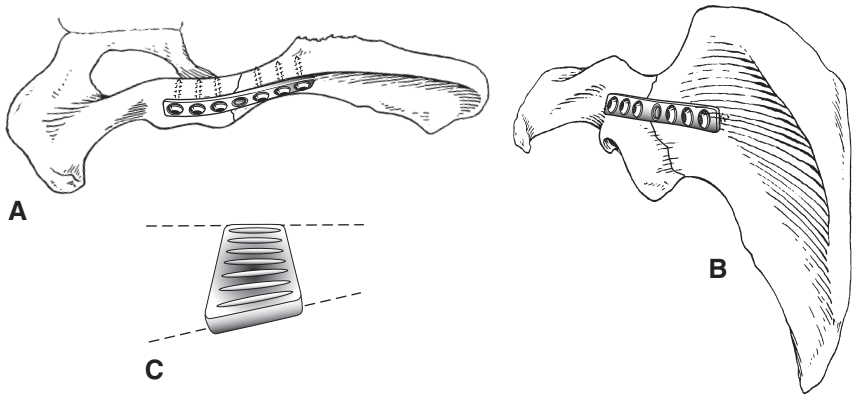


FIGURE 15-12. **A,** Straight plate may be contoured with a simple torque to facilitate extending the plate over the acetabulum if the ilial fracture is immediately adjacent to the acetabulum. This is the dorsal view. **B,** Cranial view demonstrating placement of the ilial plate dorsal to the acetabulum. **C,** End-on view of the simple torque contour required for placement of a straight ilial plate dorsal to the acetabulum.

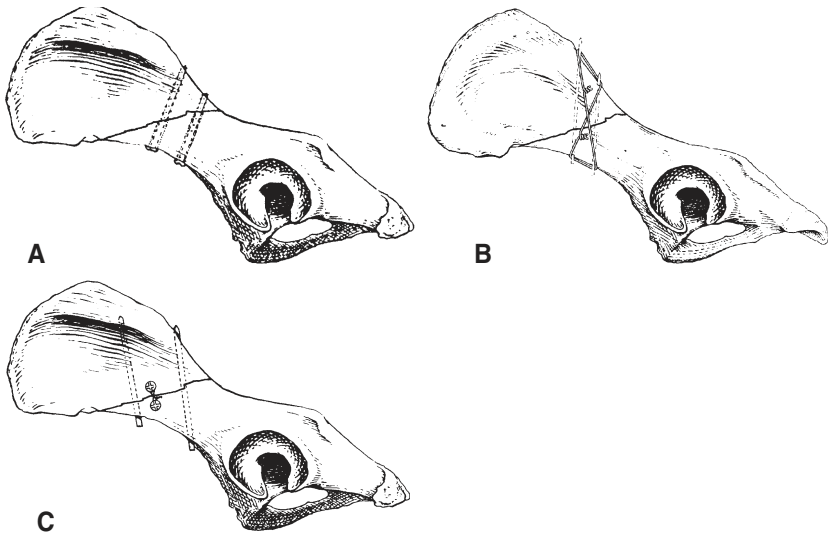


FIGURE 15-13. Ilial body fracture fixation methods. **A,** Lag screw fixation is as stable as plate fixation but is technically difficult in small breeds, in heavily muscled breeds, and in obese patients. **B,** Two Kirschner wires and an interfragmentary wire to provide compression offer good stability and can be applied to small breeds. There is no specific advantage to crossing the wire in this application. **C,** Another method of providing interfragmentary compression with Kirschner wire fixation is to place the compression wire between screws set on each side of the fracture line. Less dorsal muscle elevation is required compared with *B*.

and that the wire be tight enough to provide interfragmentary compression. The wire can be placed around the protruding ends of the pins or between two short screws in the ilium.

FRACTURES OF THE ACETABULUM

Conservative Treatment

Fractures of the acetabulum in skeletally immature animals that show no displacement on ventrodorsal and lateral radiographs may be treated conservatively, with marked restriction of activity indicated for 3 to 4 weeks. In most cases, it is advantageous to place the leg in a non–weight-bearing or Ehmer sling for 10 to 14 days (see Figures 2-31 and 2-32). Conservative treatment of apparently nondisplaced or non–weight-bearing area fractures in adult animals often yields disappointing results in the long run, with degenerative joint disease being the all-too-common sequela. Femoral head and neck excision arthroplasty or total hip replacement is indicated in this situation if medical treatment is not successful (see Chapter 16).

Surgical Treatment

Open approach and internal fixation are indicated for those cases in which dislocation or instability of the fractured segments is present and for any performance animal.[2,3,12] Crepitation is usually felt on movement of the hip joint. If these cases are untreated, pain and permanent lameness follow as a result of abnormal wear and ensuing degenerative joint disease. Another reason for surgical treatment is that the animal frequently lies on the affected side, which further displaces the fracture fragments.

Early surgical intervention is needed to prevent chondromalacia of the femoral head resulting from abrasion from the acetabular fracture fragments.

If there is fragmentation of the fracture, the chances of successful internal fixation are reduced, especially if the fragments are too small to be stabilized or when they involve the articular surface. This is often difficult to ascertain from preoperative radiographs. Therefore the owner must often be given an uncertain prognosis preoperatively. Femoral head and neck excision arthroplasty is a reasonable primary treatment for irreducible acetabular fractures, and this should be discussed preoperatively with the owner. If delayed total hip replacement is considered for long-term treatment, some reduction and stabilization are desirable to provide a reasonably intact acetabulum for later anchorage of the acetabular prosthesis. Fractures of the caudal fifth of the acetabulum are difficult to repair because of the small size of the distal fragment, its contour, and interference with the sciatic nerve.

Open Approach and Reduction

Figure 15-14 shows the approach to the craniodorsal and caudodorsal aspects to the hip joint with osteotomy of the greater trochanter.[5] The tendons of the obturator and gemellus muscles are only cut when access is needed to the most caudal part of the acetabulum.

The method of reduction varies with the type and location of the fracture. Acetabular fractures are often combined with ilial body fractures; in such cases it is best to reduce and stabilize the ilial fracture first because it then provides one stable fragment for the acetabular reduction (see Figures 15-21 and 15-22). In many patients, reduction consists of a combination of traction, countertraction, levering, and rotation. The caudal segment is always angled ventrally and rotated because of the combined pull of the hamstring and external rotator muscles. Reduction is assisted by attaching a Kern or Lane bone forceps to the tuber ischii by means of a small cutdown over the tuber (Figure 15-15, *A*). In many cases a bone hook moved down along the medial surface of the caudal segment is helpful in the reduction procedure.

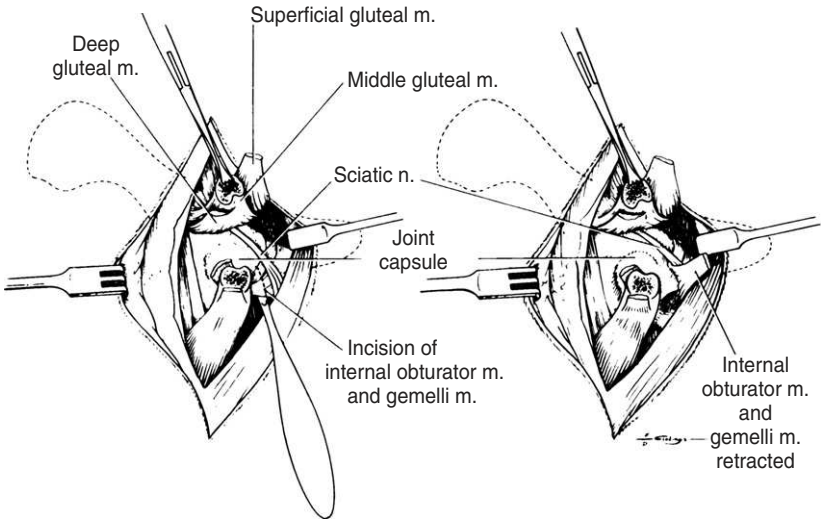


FIGURE 15-14. Dorsolateral approach to the hip joint with osteotomy of the greater trochanter.[5] Transection of the external rotator muscles close to the trochanter exposes the caudal acetabular and ischial area, and the retracted muscles protect the sciatic nerve.

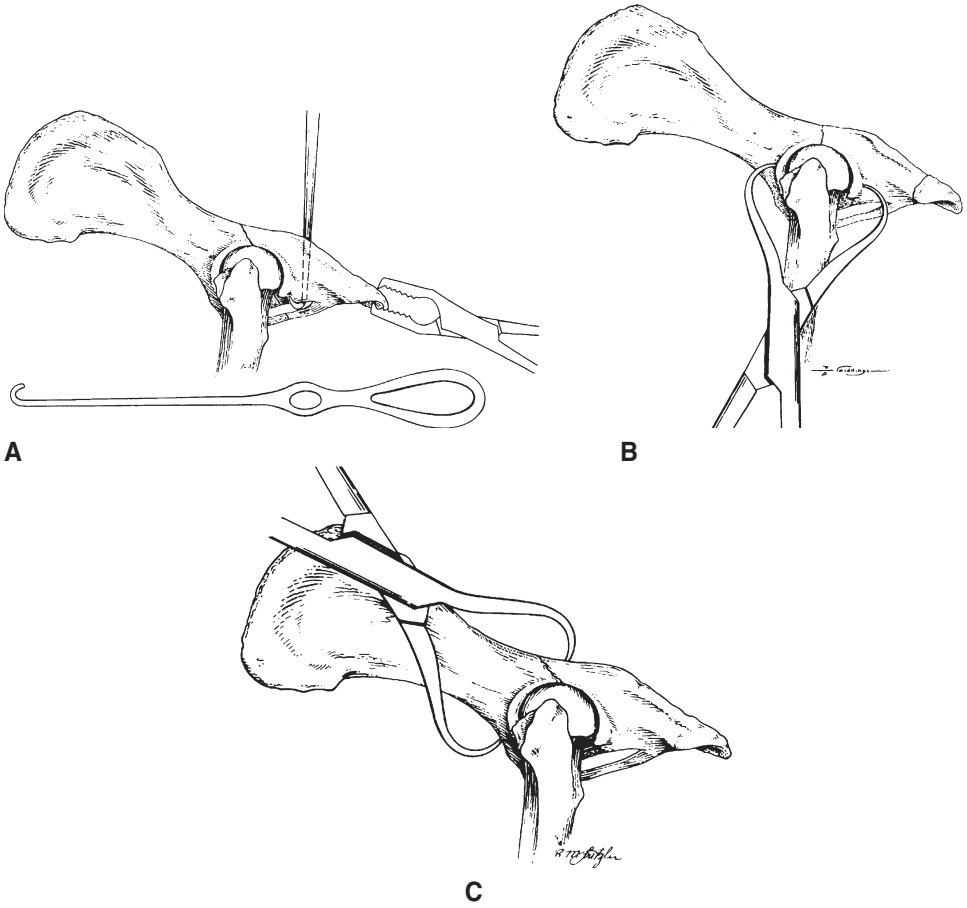


FIGURE 15-15. Procedures to aid reduction of acetabular fractures. **A,** Because the caudal fragment is always rotated and displaced ventrally, a small hook placed in the obturator foramen is helpful to elevate the ischium. Distraction and rotational control are achieved by placing a bone-holding forceps on the ischial tuberosity after a short cutdown approach directly over the bone. **B,** Compression of a transverse fracture can be achieved by application of a pointed reduction forceps across the acetabulum. The pointed jaws of the forceps can be introduced through soft tissues, taking care to avoid the sciatic nerve. **C,** In a similar manner, the pointed reduction forceps is seen here compressing an oblique fracture. Avoidance of the sciatic nerve is again a consideration.

Rarely is the fracture stable after reduction. The fracture must be held in the reduced position while fixation is being applied. Use of a reduction forceps that straddles the trochanter major and anchors on the cranial and caudal rims of the acetabulum is helpful in maintaining reduction and compression in a stable fracture (Figure 15-15, *B*). If the fracture is oblique, the compression forceps is placed at right angles to the fracture line (Figure 15-15, *C*). At times, when locking forceps cannot be used effectively because of fracture configuration, reduction pressure on the tuber ischii with a Kerns bone-holding forceps or intramedullary pin may be sufficient to allow plate application (Figure 15-15, *A*). Extreme care must be exercised to protect the sciatic nerve during reduction.

Anatomical reduction is a necessity in acetabular fractures. Final reduction is checked by observing the fracture line, the acetabular rim, and the articular cartilage inside the acetabulum through a small capsular incision. Particular attention must

be paid to rotational reduction to ensure that the central portion of the acetabular fossa is realigned.

Internal Fixation

Bone Plates

The method of fixation varies with the type of fracture, but bone plates and screws have yielded the best percentage of success.[2,3,12] The various types of bone plates that may be contoured and used on acetabular fractures include standard straight, acetabular (Synthes, Ltd., Paoli, Pa) (Figure 15-16), reconstruction (Synthes) (Figure 15-17), cuttable (Synthes), and various small fragment plates. (See Figure 2-75 for correct

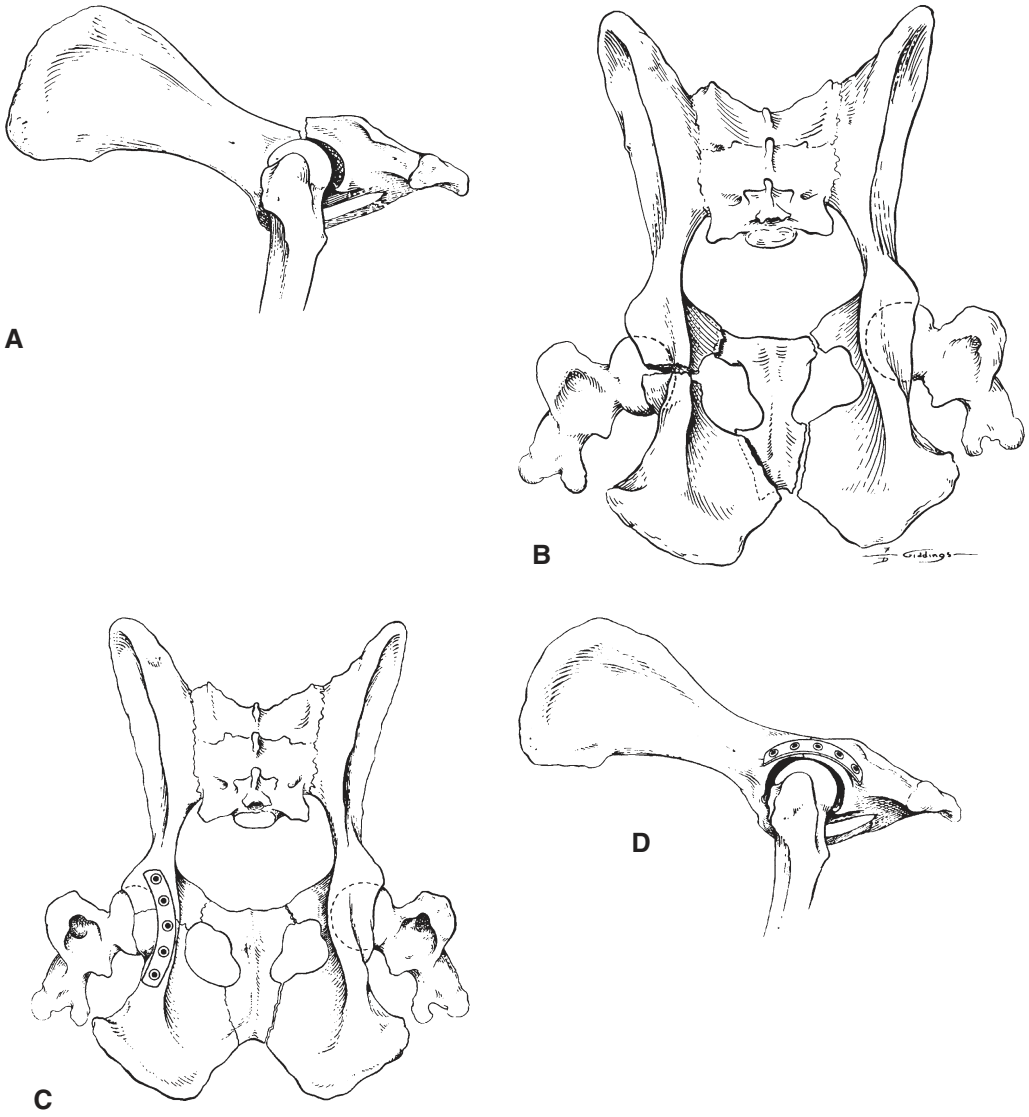


FIGURE 15-16. **A** and **B,** Serrated transverse fracture of the acetabulum and fracture of the ischium and pubis. **C** and **D,** With bone plate fixation, at least two screws should be inserted on each side of the fracture line. The plate should be contoured so that it fits the surface to which it is applied. In cases such as this, any one of the various types of plates could have been used: reconstruction, acetabular, standard straight, or small fragment.

plate size relative to body weight.) Reconstruction and acetabular plates lend themselves to easy contouring, which is helpful because it is essential that the plate conform perfectly to the reduced bone surface. Failure to do so results in displacement of the fracture surfaces as the screws are placed and tightened. In multifragment fractures the individual fragments are reduced and stabilized by Kirschner wires and/or 1.5-mm or 2.0-mm lag screws in preparation for plate application (see Figure 15-17).

Lag Screws

Oblique two-piece fractures often present the opportunity to use lag screws as the primary fixation. When properly placed and inserted, lag screws provide very stable fixation. To attain the correct angle for screw insertion, it may be necessary to work a tap sleeve through muscle to protect the drill bit and tap. The two most common fracture types treated in this manner are seen in Figures 15-18 and 15-19.

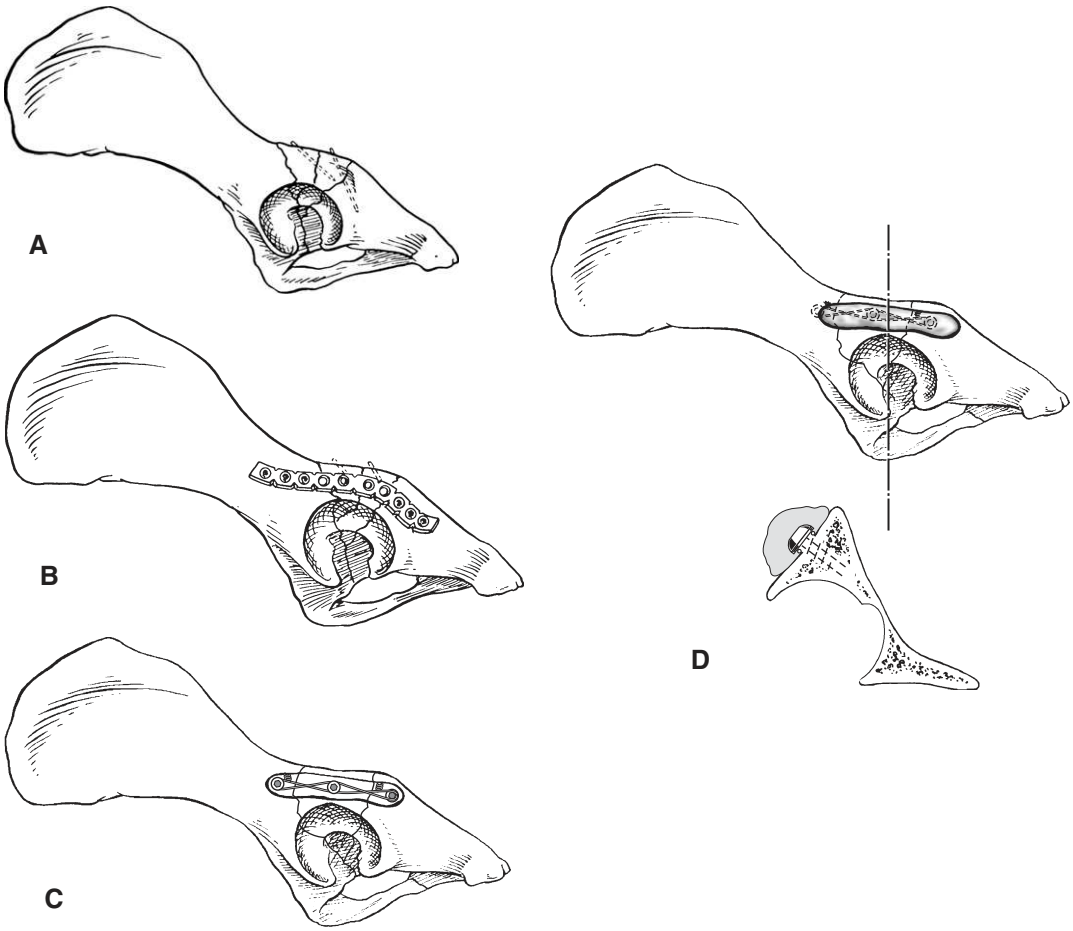


FIGURE 15-17. **A,** Multiple fractures of the acetabulum; as pieces were reduced, they were skewered into place with Kirschner wires, one at a time. **B,** Bone plate contoured and applied; the center two fragments are too small for screw fixation. A reconstruction plate contours very easily and is very adaptable to fractures of this type. **C** and **D,** Screws are partially inserted in each segment, leaving two screw threads exposed. Figure-of-8 wire connects each fragment, and **D,** the dough stage of polymethyl methacrylate is placed around the implants and dorsal acetabulum. (The wires are omitted for clarity.)

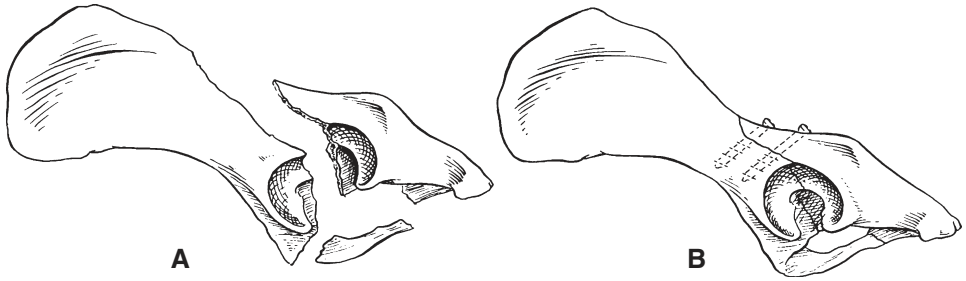


FIGURE 15-18. **A,** Oblique fracture through the cranial part of the body of the ilium and acetabulum. **B,** Two lag screws are preferable if there is room for insertion.

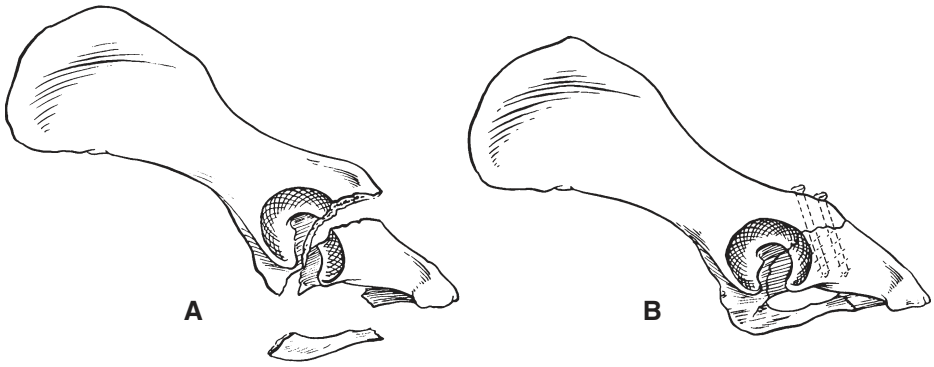


FIGURE 15-19. **A,** Oblique fracture through the caudal part of the body of the ischium and acetabulum. **B,** Two lag screws are inserted for fixation.

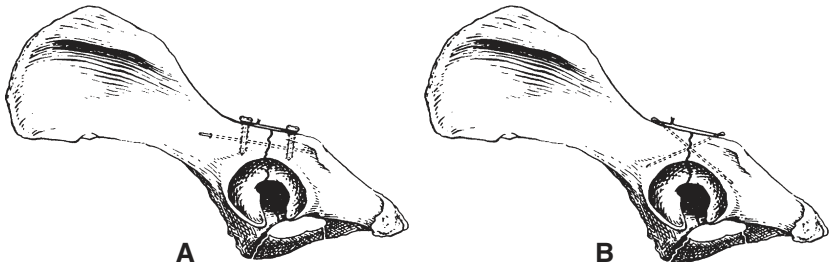


FIGURE 15-20. Additional fixation methods applicable to nonfragmented transverse fractures. **A,** Tension band wire is placed between bone screws inserted on each side of the fracture. It is *imperative* that a small pin or Kirschner wire be placed across the fracture surface to neutralize shear loads. **B,** Similar fixation with only pins and tension band wire. At least one pin must cross the fracture line.

Tension Band Wire

Tension band wire fixation can be used only on interlocking, stable two-piece fractures (Figure 15-20). The dorsal side of the acetabulum is used for tension band fixation, and it is essential that a small intramedullary pin and Kirschner wire cross the fracture line to prevent shearing motion at the fracture surfaces. Simply compressing the fracture will not prevent this type of motion. This type of fixation is not as stable as a plate or lag screw and is best reserved for small breeds, in which plates and screws can be more difficult to insert.

Screws, Wires, and Polymethyl Methacrylate

Acetabular or comminuted fractures that cannot be repaired by conventional plates may have screws partially inserted (leaving the screw head and two threads visible) into bone segments and figure-of-8 wire applied for compression. While held in reduction, the fracture repair is stabilized by wrapping the dough stage of methyl metracrylate around the protruding implants and dorsal acetabulum[13,14] (see Figure 15-17, *C* and *D*).

Multiple Fractures

Fractures of the ilial body are the most common significant fractures to accompany acetabular fractures (Figures 15-21, *B,* and 15-22, *A* and *B*). Both fractures can be simultaneously reduced through the approach to the os coxae (Figure 15-21, *A*).[5] The ilial fracture is reduced and fixed first because this will provide one stable fragment for reduction of the acetabular fracture. Fixation for each fracture is done as detailed earlier (Figures 15-21, *C,* and 15-22, *C*). If the ilial body fracture is close to the acetabulum, a long reconstruction plate (see Figure 15-17) can be used for both fractures. Because of the intricate contouring involved in fitting such a plate, considerable intraoperative time can be saved by contouring the plate to a similarly sized pelvic specimen preoperatively. Only minor corrections then need to be made intraoperatively. Reconstruction plates bend easily, so care must be taken to anchor

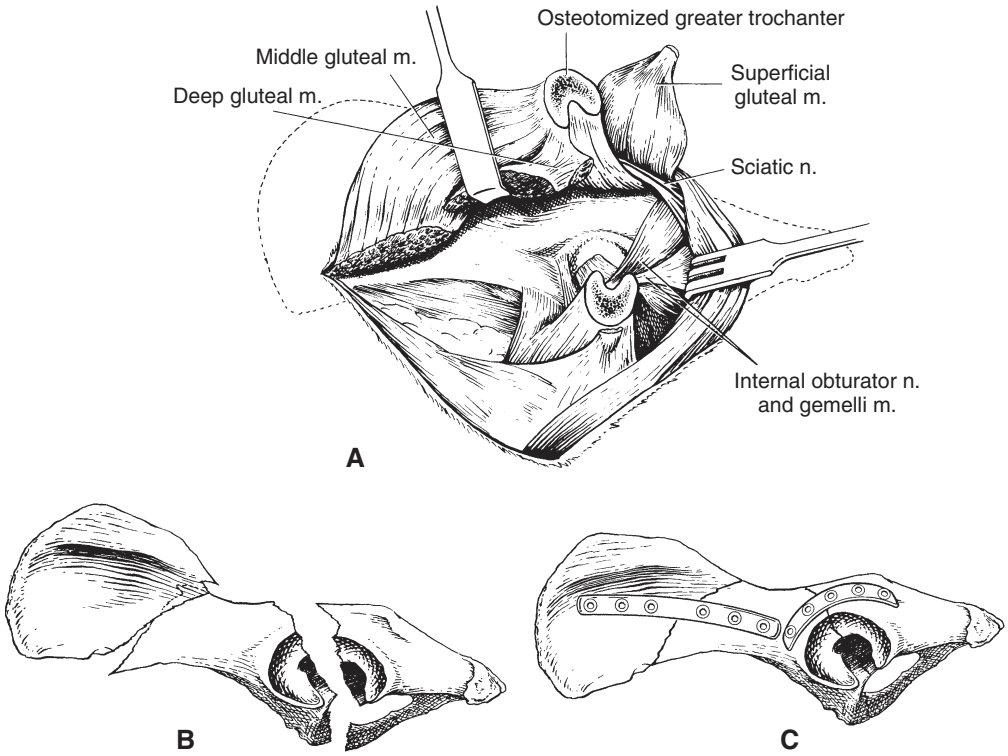


FIGURE 15-21. Exposure and fixation of a common multiple fracture combination. **A,** Oblique fracture of the ilial shaft and acetabular fracture. **B,** This combination of fractures may be exposed by a combined lateral exposure to the ilium and dorsal approach to the hip joint (approach to the os coxae[5]). **C,** The ilial fracture is reduced first and fixed with a bone plate, with at least one of the screws placed through the sacrum for maximum anchorage in the soft ilium. The acetabulum is then reduced and stabilized with an acetabular plate.

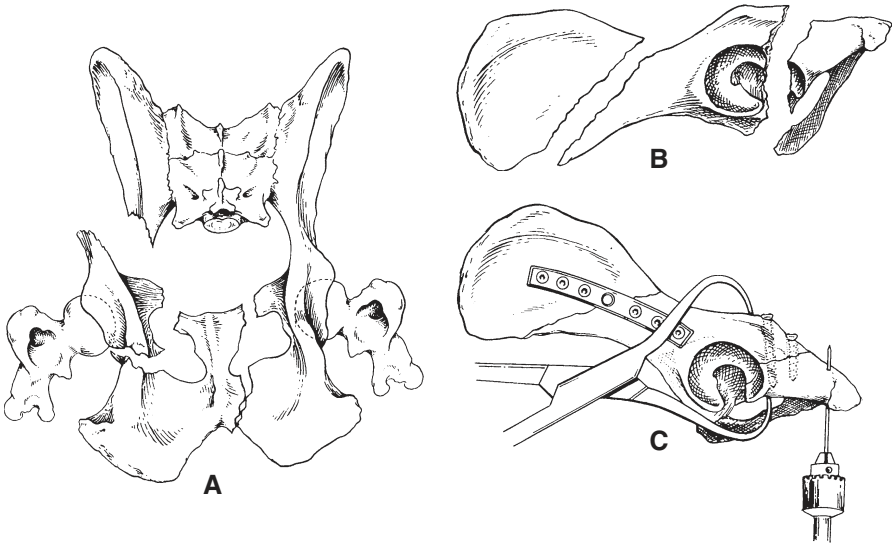


FIGURE 15-22. **A** and **B,** Oblique fractures of the ilium, ischium, and acetabulum. **B** and **C,** Reduction and fixation of the ilium rigidly stabilized one segment of the acetabulum, thereby facilitating reduction of the acetabular fracture. A pin through the tuber ischii and compression forceps assisted and maintained reduction while lag screws were inserted.

the plate to stable bone cranially and caudally to prevent bending of the plate and loss of reduction and alignment in the postoperative period.

Closure of Soft Tissues

Secure soft tissue closure is important in restoring good stability to the hip joint. This consists of suturing the joint capsule, the deep gluteal muscle, and when cut, the combined tendons of the internal obturator and gemellus muscles. The osteotomized tip of the trochanter major is fixed with the tension band wire technique. The remaining muscles—the superficial gluteal, the biceps femoris, and tensor fasciae latae—are sutured in place, followed by the gluteal fascia, subcutaneous tissue, and skin.

Aftercare

Ideally the animal would be allowed early active use of the hip joint. This requires totally stable internal fixation, good owner compliance with confinement and exercise restrictions, and a patient that will not overstress the repair because of hyperactivity. If any of these elements is less than optimal, an Ehmer sling (Figure 2-31) or an off-weight-bearing sling (see Figure 2-32) is advisable for 2 to 3 weeks. Exercise should be severely restricted for 6 weeks, with a gradual return to unrestricted activity at 10 to 12 weeks.

FRACTURES OF THE ISCHIUM

Most fractures of the ischium accompany other fractures (e.g., ilial body, acetabulum, or sacroiliac fracture-luxation).[2,3] If these fractures are properly reduced and immobilized, the ischium often needs no further treatment. When an ischial fracture is of primary concern (e.g., fracture of ischial body and pubis with marked dislocation),

reduction and fixation may be indicated when speed of recovery is important, when cosmetic concerns are present, when the animal is in great pain, and if optimal athletic function is desirable. Ischial fractures are displaced ventrally by the powerful hamstring muscles and eventually heal in an extremely abnormal position.

Open Approach and Reduction

The cranial part of the ischial body can be exposed from the dorsolateral side by the approach to the caudal aspect of the hip joint and body of the ischium (Figure 15-23).[5] Another approach involving osteotomy of the ischial tuberosity provides more exposure to the body.[15] The caudal body, ramus, and tuberosity are exposed from the caudomedial side by the approach to the ischium.[5]

Internal Fixation

Ischial Body

Fixation is usually accomplished by the use of an intramedullary pin or Kirschner wire with a tension band wire or by a small bone plate. After open reduction, the pin is usually inserted in the region of the tuber ischium, and insertion is continued cranially beyond the fracture site until good anchorage is obtained (Figure 15-24, *A*). The addition of a tension band wire is important for stability because of the muscular bending forces; thus the pin is less apt to loosen and work itself out before clinical union.

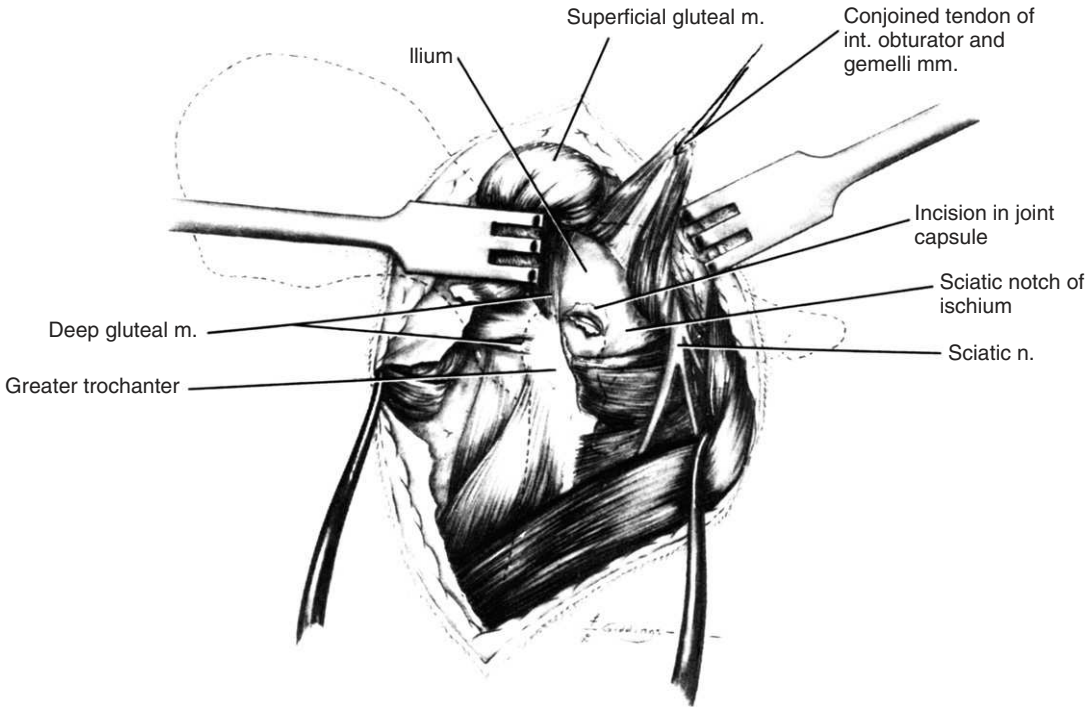


FIGURE 15-23. Caudal aspect of the acetabulum and body of the ischium can often be exposed without trochanteric osteotomy of the greater trochanter or tenotomy of gluteal muscles. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

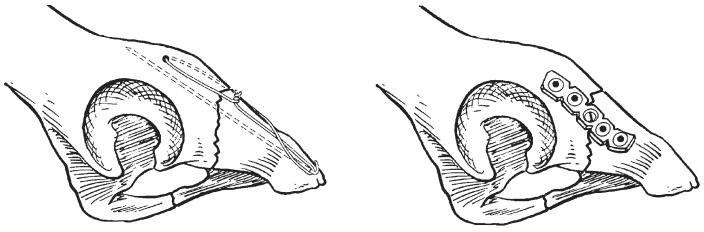


FIGURE 15-24. Fixation of ischial shaft fractures. **A,** Pin from the ischial tuberosity and tension band wire are biomechanically very effective. This is much easier to insert in the cat than in the dog. **B,** The reconstruction plate (Synthes, Ltd., Paoli, Pa) lends itself to the intricate contouring required in the ischiatic notch area.

The wire is usually inserted first, the pin next, and the wire then tightened. Space in this area is usually very limited because of the location of the sciatic nerve. The twists of the wire are always of concern because of potential sciatic nerve irritation.

In larger dogs a small bone plate can be placed laterally in the ischiatic notch. The ischial tuberosity approach mentioned above would be advantageous here. Contouring of the plate is difficult; the reconstruction plate shown in Figure 15-24, *B,* is useful.

Ischiatic Ramus and Tuberosity

Most fractures of the ischiatic ramus and tuberosity respond satisfactorily to conservative treatment. In some patients a sizable bone segment is fractured and pulled distally, causing considerable discomfort. The ventral surface of the ischiatic tuberosity gives rise to the powerful hamstring muscles: the biceps femoris, the semitendinosus, and the semimembranosus. Contraction of these muscles pulls the fracture segment distally (Figure 15-25, *A*). In these cases, surgical treatment may be indicated. The tuberosity fragment is fixed in place with pins, and a dorsal tension band wire is looped over a screw, or the fragment is fixed with screws alone in large breeds (Figure 15-25, *B*). Small Kirschner wires are used to hold the fragment in the reduced position while the fixation is inserted.

FRACTURES OF THE PELVIC FLOOR

As a result of traumatic injury, the os coxae may become separated at the pelvic symphysis. This may be accompanied by fracture-luxation of the sacroiliac articulation (Figure 15-26, *A*). With this injury, the animal loses the ability to adduct the legs; the rear legs abduct, and the patient is unable to stand. The condition is seen most frequently in an immature animal before the symphysis has ossified. If other fractures are present (e.g., in ilium or acetabulum, fracture-separation of sacroiliac articulation), proper treatment of these fractures usually gives sufficient stability so that surgery in the pelvic symphysis area is not necessary. Primary treatment of these injuries is usually confined to adhesive tape hobbling of the hindlimbs to prevent abduction (Figure 15-27). Usually about 1 week of hobbling will allow the animal to walk on a surface that is not slippery.

Infrequently, reduction and stabilization are accomplished by a ventral midline approach and insertion of interfragmentary wires (Figure 15-26, *B*). Pubic fractures may also need stabilization during ventral abdominal hernia repair.

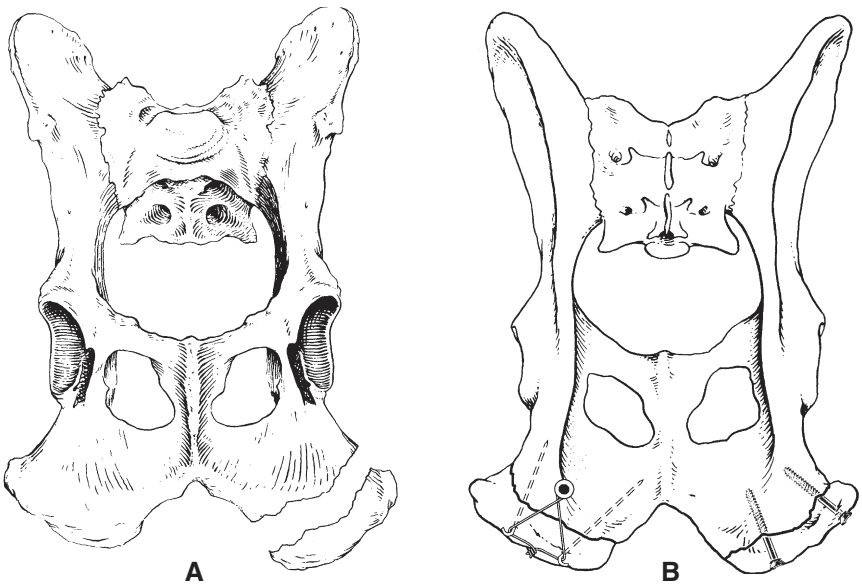


FIGURE 15-25. **A,** Ventral surface of the ischial tuberosity gives rise to powerful hamstring muscles: biceps femoris, semitendinosus, and semimembranosus. **B,** This dorsal view shows the tuberosity fragment fixed in place with pins and a tension band wire looped over a screw on the left, or with screws only on the right. Temporary Kirschner wires were used to hold the fragment in reduced position while the screws were inserted.

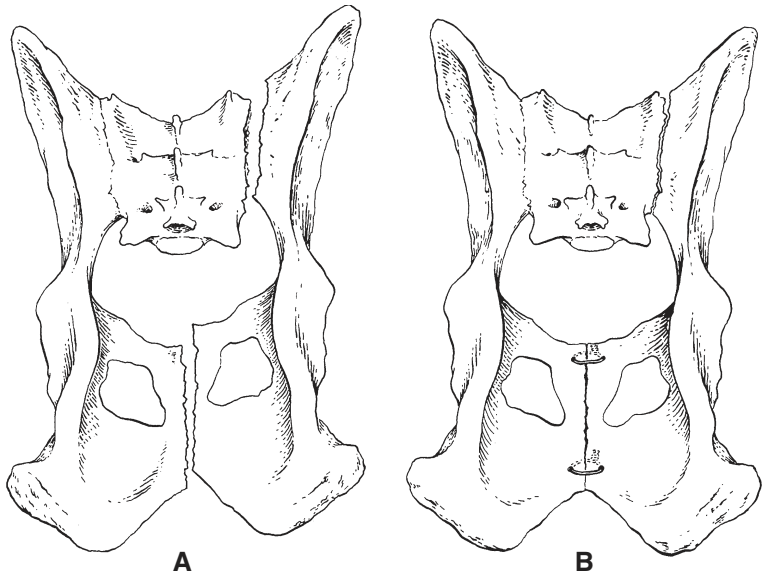


FIGURE 15-26. **A,** Fracture-separation of pelvic symphysis and sacroiliac articulation; gross dislocation of the os coxae. **B,** Reduction and fixation by use of two stainless steel wires. Two lag screws inserted to stabilize the sacroiliac articulation would achieve the same effect.

MALUNION FRACTURES CAUSING COLLAPSE OF PELVIC CANAL

Healed fractures of the pelvis resulting in a marked decrease in size of the pelvic cavity are shown in Figure 15-28. This condition may be accompanied by constant or

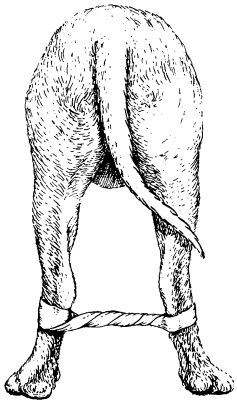


FIGURE 15-27. Rear legs hobbled together to restrict abduction until healing is underway and power of adduction is recovered.

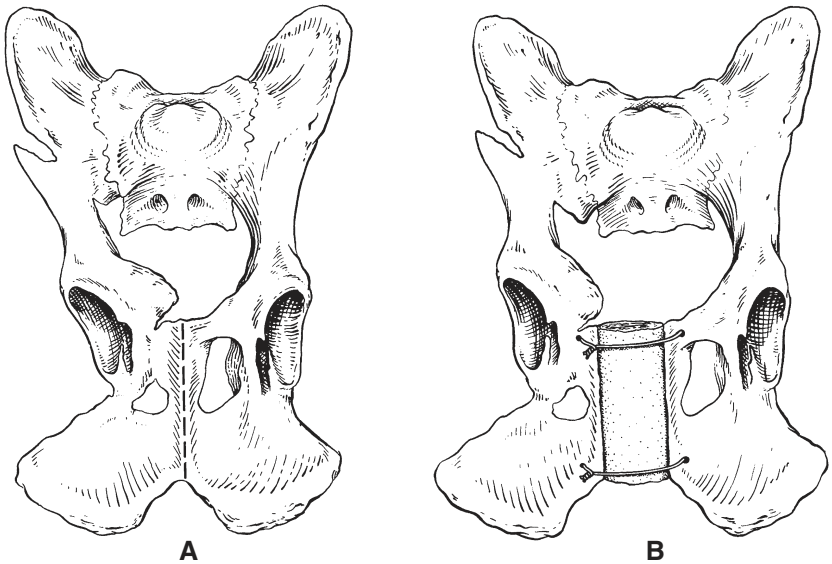


FIGURE 15-28. Healed, unreduced fractures collapsing the pelvic canal. **A,** Healed fractures of the pelvis resulting in marked decrease in size of pelvic cavity, accompanied by constant or intermittent constipation or obstipation. **B,** Midline ventral approach exposes pelvic symphysis area. The symphysis is split longitudinally with an osteotome. The two halves are spread, and an allograft (wing of ilium) is inserted and fixed in place using two wires. This increases the diameter of the pelvic canal and facilitates defecation.

intermittent obstipation. Surgical treatment is indicated when medical treatment is ineffective in controlling bowel function.

One method of treatment involves a midline ventral approach to expose the pelvic symphysis area. The symphysis is split longitudinally with an osteotome, the two halves are carefully spread, and an allograft (body of ilium or rib) is inserted and fixed in place using two stainless steel wires. This greatly increases the diameter of the pelvic canal and returns defecation to normal, provided neurological control of defecation is normal.[2,3] Occasionally, it may be necessary to osteotomize the ilial shaft unilaterally to allow adequate spreading of the pelvis. Caution must be taken because the lumbosacral trunk may be incorporated in the bony callus on the medial side of the ilium. Plate fixation is used on the ilium.

Triple pelvic osteotomy can also be used (see Chapter 16), although the ilial body malunion complicates fitting of the osteotomy plate. Cats are more likely than dogs to develop obstipation and constipation from pelvic malunion. Partial pelvectomy with femoral head and neck excision and subtotal colectomy have been described as successful treatment strategies for this difficult problem in cats.[16,17]

POSTOPERATIVE MANAGEMENT OF PELVIC FRACTURES

Hemostasis before closure creates a smoother recovery period and minimizes complications in the surgical area. A good anatomical closure by layers, particularly in the hip area, aids in rapid restoration of function and stability of the hip joint. A good skin closure is mandatory. Avascular necrosis of skin is a rare problem. If it occurs, however, it may be caused by the original trauma in the area, by unnecessary subcutaneous dissection during surgery, or by a combination of both. Conservative treatment is usually sufficient for a small area of necrosis, but debridement followed by secondary closure may be indicated if a large area is involved. Good nursing is an essential part of the aftercare. Particular attention must be paid to the patient's appetite, urination, defecation, and cleanliness. If the patient is temporarily nonambulatory, decubital ulcers may become a secondary complication. A dry, well-padded bed and frequent turning from side to side are good preventive measures.

Movement and restriction of activity will vary greatly with the individual case, the degree of trauma, and the stability of fixation. If good, rigid stability can be achieved, limited restricted movement should be encouraged. Local restriction of activity in the form of an Ehmer or non–weight-bearing sling (see Figures 2-31 and 2-32) for 5 to 10 days is usually indicated in fractures involving the acetabulum and femoral head and neck or in a reduced coxofemoral dislocation. If adduction is a problem, resulting from multiple fractures in the pelvic symphysis area or from muscle trauma, a restriction bandage or hobble is indicated for 5 to 7 days to limit abduction (see Figure 15-27). Marked restriction of activity is always indicated when many fractures are present.

Fractures of the pelvis require the usual span of time for healing, which is normally 6 to 10 weeks. Some alteration in gait can be expected during this period. In general, bone plates and bone screws are not removed unless specifically indicated. Long-term follow-ups usually show no radiographic indications of loosening or alteration in bone density.

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16
The Hip Joint

LUXATIONS OF THE HIP

Coxofemoral (CF) luxations in dogs and cats are generally the result of external trauma, with 59% to 83% caused by vehicular trauma.[1,2] Most CF luxations are unilateral injuries, and because of the massive forces required to produce the luxation, about 50% have associated major injuries, often chest trauma.

Soft tissue damage varies considerably; in all luxations, however, a portion of the joint capsule and the round ligament are torn. In more severe cases, one or more of the gluteal muscles may be partially or completely torn. Damage to the articular cartilage of the femoral head or acetabulum may be present. Rarely, portions of the dorsal rim of the acetabulum are fractured, or part of the femoral head may be fractured. This is usually an avulsion fracture at the insertion of the round ligament.

The goals of treatment for luxation of the hip are to reduce the dislocation with as little damage to the articular surfaces as possible and to stabilize the joint sufficiently to allow soft tissue healing, with the expectation of normal clinical function. Most patients can be treated by closed reduction. More chronic cases and those with multiple injuries may require open reduction. Some of these patients may need supplementary fixation to maintain reduction. In certain cases, hip luxation is irreparable because of preexisting dysplasia, severe abrasion to the articular cartilage of the femoral head, and irreparable concomitant fractures of the acetabulum or femoral head. Such patients are generally treated with excision arthroplasty or total hip replacement, which are covered later in this chapter.

Clinical Studies

Because of the usual history of trauma with CF luxations, clinical signs are associated with sudden onset, pain, deformity, crepitus, and limited or abnormal movement of the limb. The specific signs vary somewhat, depending on the location of the femoral head in relation to the acetabulum. (See Chapter 1 for a discussion of physical examination of the hip.)

Craniodorsal Luxation

Craniodorsal is the most common type of CF luxation, seen in 78% of affected dogs and 73% of cats.[1] The head of the femur rests dorsal and cranial to the acetabulum

(Figure 16-1, *A* and *B*). The limb is shorter than the opposite limb when positioned ventrally and extended caudally. The thigh is adducted, and the stifle is rotated outward and the hock inward (Figure 16-1, *C*). On palpation, the trochanter major is elevated compared with the normal side, and the space between it and the tuber ischii is increased (see Figures 1-3 and 1-4).

Caudodorsal Luxation

Caudodorsal luxation is a rare condition and may simply be a craniodorsal luxation with a great deal of instability, allowing the femoral head to move caudally. In this case the head of the femur rests caudal and dorsal to the acetabulum, and there is some risk of sciatic nerve injury (Figure 16-1, *D* and *E*). There is a slight increase in leg length when the limb is extended caudally but a decrease when the leg is positioned ventrally. The thigh is abducted, with inward rotation of the stifle and outward rotation of the hock. On palpation, there is a narrowing of the space between the trochanter major and the tuber ischii.

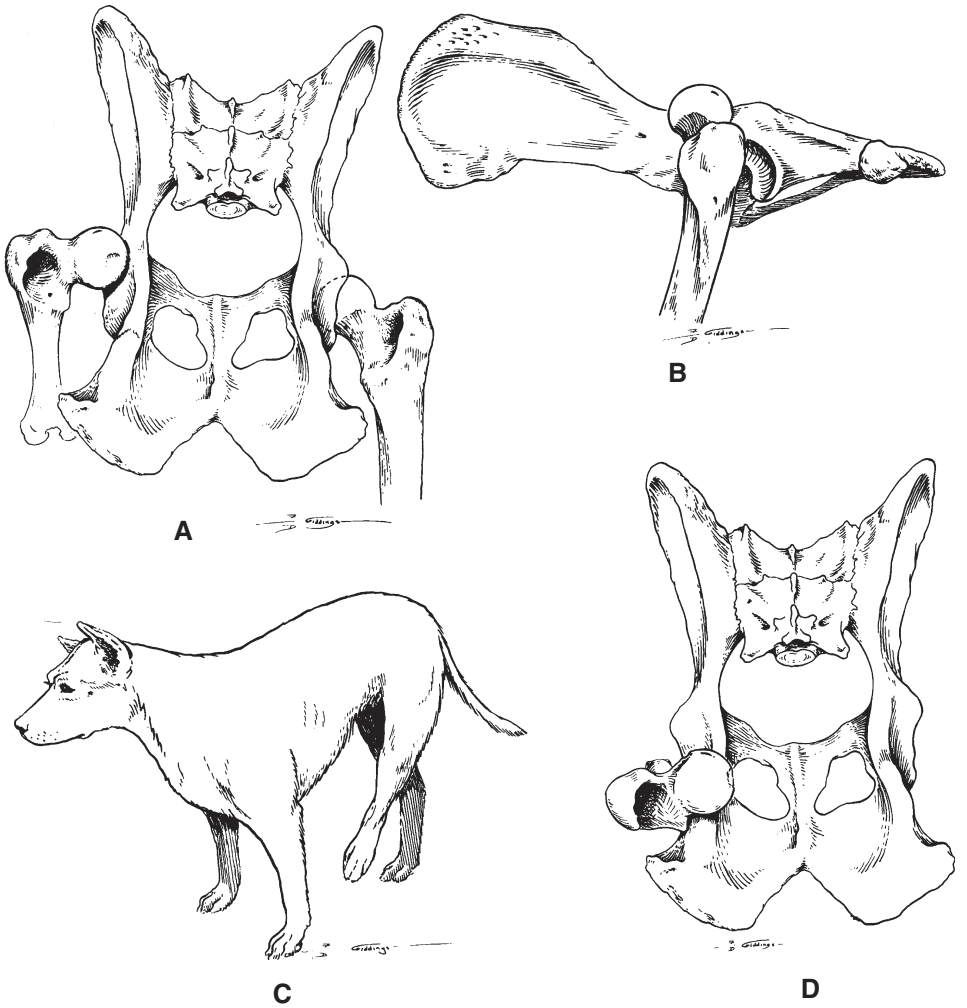


FIGURE 16-1. Luxation of the hip. **A,** Craniodorsal luxation, dorsal view. **B,** Craniodorsal luxation, lateral view. **C,** Typical stance of a dog with a craniodorsal luxation. The leg is externally rotated and adducted. **D,** Caudodorsal luxation, dorsal view.

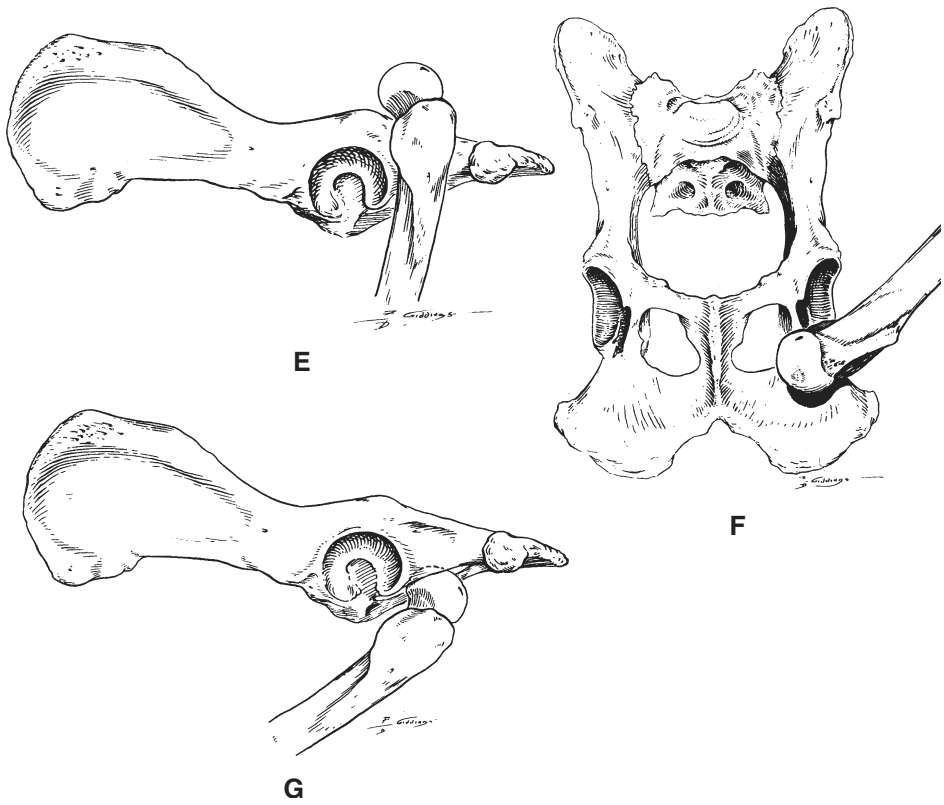


FIGURE 16-1. *Continued* **E,** Caudodorsal luxation, lateral view. **F,** Ventral luxation, ventral view. **G,** Ventral luxation, lateral view.

Ventral Luxation

Ventral luxation is relatively rare (1.5%-3.2% in reported case studies[3,4]) and may occur as a separate entity or may be associated with an impaction fracture of the acetabulum. In nonfracture cases the head of the femur rests ventral to the acetabulum, usually in the obturator foramen or cranial to it, hooked under the iliopectineal eminence. *Cranioventral* luxations are probably craniodorsal luxations that have been manipulated to the ventral position before diagnosis. *Caudoventral* luxations, however, occur spontaneously from trauma and may be accompanied by fracture of the greater trochanter. The trochanter major is very difficult to palpate (Figure 16-1, *F* and *G*). There is a definite lengthening of the limb.

Diagnosis

Although the presence of a luxation can usually be determined on the basis of clinical signs, it is imperative that radiographs be made for each case to rule out several other injuries that present similar clinical signs and that will not respond to treatment for luxation. These injuries include fractures of the acetabulum, luxation of the hip and fracture of the acetabulum, and fracture of the capital femoral physis or fracture of the head or neck. Also, the presence of dysplasia or Legg-Calvé-Perthes disease will generally prevent stabilization of a dislocated hip after reduction. Avulsion fracture of the insertion of the round ligament generally prevents successful closed

reduction (see Figure 17-5); furthermore, on the rare occasion when closed reduction is successful, the presence of the bone chip generally creates degenerative joint disease. All these conditions require an open approach and specific treatment of the pathology present, as outlined in Chapters 15 and 17. If luxation follows trivial trauma (e.g., falling down two stairs), beware of underlying hip laxity associated with hip dysplasia.

Treatment

Closed Reduction

With *craniodorsal* luxation, the joint capsule can theoretically rupture in three places (Figure 16-2): midway between the acetabulum and neck of the femur *(type A)*, avulsion from the acetabulum *(type B)*, or avulsion from the neck *(type C)*. Type A is probably the most common type and perhaps the kind that responds well to closed reduction. Type B results in a very unstable hip, since the fibrous lip or labrum of the acetabulum that normally aids femoral head coverage is missing. If grinding is palpated just as the femoral head reduces into the acetabulum during reduction maneuvers, type B avulsion of the joint capsule may be present. When type C is encountered, the joint capsule lies across the acetabulum "like a hammock," preventing deep-seated reduction. On closed reduction attempts, the femur moves to the right area but "just doesn't feel right"; it does not reduce with a "pop" or "snap."

When there are no complicating factors, most simple luxations can be reduced closed if they are treated within the first 4 to 5 days after the injury. As time passes, many factors will interfere with closed reduction. After several days, simple muscle contracture greatly limits the veterinarian's ability to reduce the luxation, particularly in large breeds. Soft tissue (e.g., joint capsule, hematoma, hypertrophy of round ligament and fat pad) within the acetabulum will block the acetabulum and prevent adequate reduction of the femoral head. In addition, the joint capsule may undergo further degeneration. Maceration of the acetabular joint capsule by crushing and movement of the luxated femoral head reduces potential femoral head coverage by the capsule within 7 to 10 days after trauma. Fibrous scar tissue will begin to fixate the displacement of the luxation within 14 to 21 days after traumatic injury. Reattachment of the round ligament to the gluteal muscles or to the shaft of the ilium will securely anchor the femoral head in some chronic cases. For all these

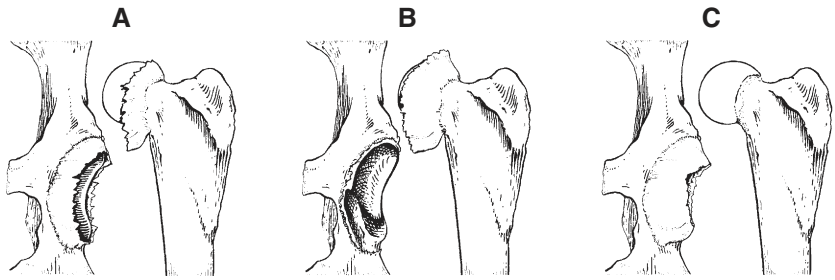


FIGURE 16-2. Types of capsular tears. **A,** Type A, capsule is torn midway. **B,** Type B, the capsule has avulsed from the dorsal rim of the acetabulum. **C,** Type C, the capsule has avulsed off the neck of the femur, resulting in a "hammock-like" obstruction to reduction.

reasons, it is best to attempt closed reduction as soon as general anesthesia can be administered safely. Good relaxation of the animal is essential for the reduction process. For successful closed reduction to occur, the hole in the joint capsule and possibly torn muscle must be found and the femoral head returned through these holes to seat into the acetabulum.

The manipulative technique for the *craniodorsal* luxation begins by anesthetizing the animal and placing it in lateral recumbency with the affected hip uppermost. A soft cotton rope is placed in the groin area, where it can be grasped by an assistant or anchored to the rail of the surgical table to serve as countertraction. This gives the operator a fulcrum with which to exert traction on the affected leg. With one hand on the trochanter major and the other hand grasping the leg in the hock region, the stifle is rotated inward (Figure 16-3, *A*). An alternative method favored by many involves first externally rotating the femur, followed by traction and internal rotation to clear the femoral head from rubbing on the pelvis (Figure 16-3, *B*). This is followed in both methods by abduction of the limb and firm pressure on the trochanter to guide the femoral head toward the acetabulum. With this firm downward pressure on the trochanter and sufficient abduction and internal rotation combined with traction on the limb, the femoral head can usually be felt to "pop" into the acetabulum. The movement can be felt by the hand on the trochanter. If reduction is not possible, traction is applied in different directions to find these "holes" in the soft tissues. If after "reduction" there is binding with hip flexion, the femoral head is located cranial to the acetabulum and ventral to the ilium. Reduction can then be accomplished by internally rotating the femoral head while pushing laterally and caudally on the femoral head with the other hand. After reduction is achieved, the trochanter is firmly pressed toward the acetabulum while the hip is rotated, flexed, and extended to force blood clots, folded joint capsule, or granulation tissue out of the acetabulum. These latter factors interfere with firm seating of the femoral head (Figure 16-3, *B*). Once this reduction is accomplished, the hip joint is moved through a full range of motion with only light pressure on the trochanter major. In this way, the stability of the reduced joint can be determined.

A similar technique is used for *caudodorsal* luxations. If the femoral head stays in position through a full range of motion without pressure being exerted on the trochanter, the reduction is probably stable. If the femoral head luxates out of the acetabulum rather easily or seems to bind on flexion, indicating cranial reduction, additional measures need to be taken, as discussed later.

Closed reduction of *ventral* luxations varies with the type. *Cranioventral* luxations can be either manipulated directly back into the acetabulum or converted to craniodorsal luxations and reduced as just described. No attempt should be made to similarly manipulate *caudoventral* luxations, however, because damage may be done to bone and soft tissues. The limb is placed in traction with one hand (left hand for left limb, right hand for right limb) while the other hand applies countertraction against the ischium. The traction hand then applies a levering or lifting action on the proximal femur that is aided by the thumb of the opposite hand. The effect is to lift the femoral head laterally into the acetabulum.[4]

Aftercare

In most cases, it is appropriate to apply an Ehmer sling for 7 to 10 days (see Figure 2-31). If the femoral head snaps in somewhat loosely but seems to be

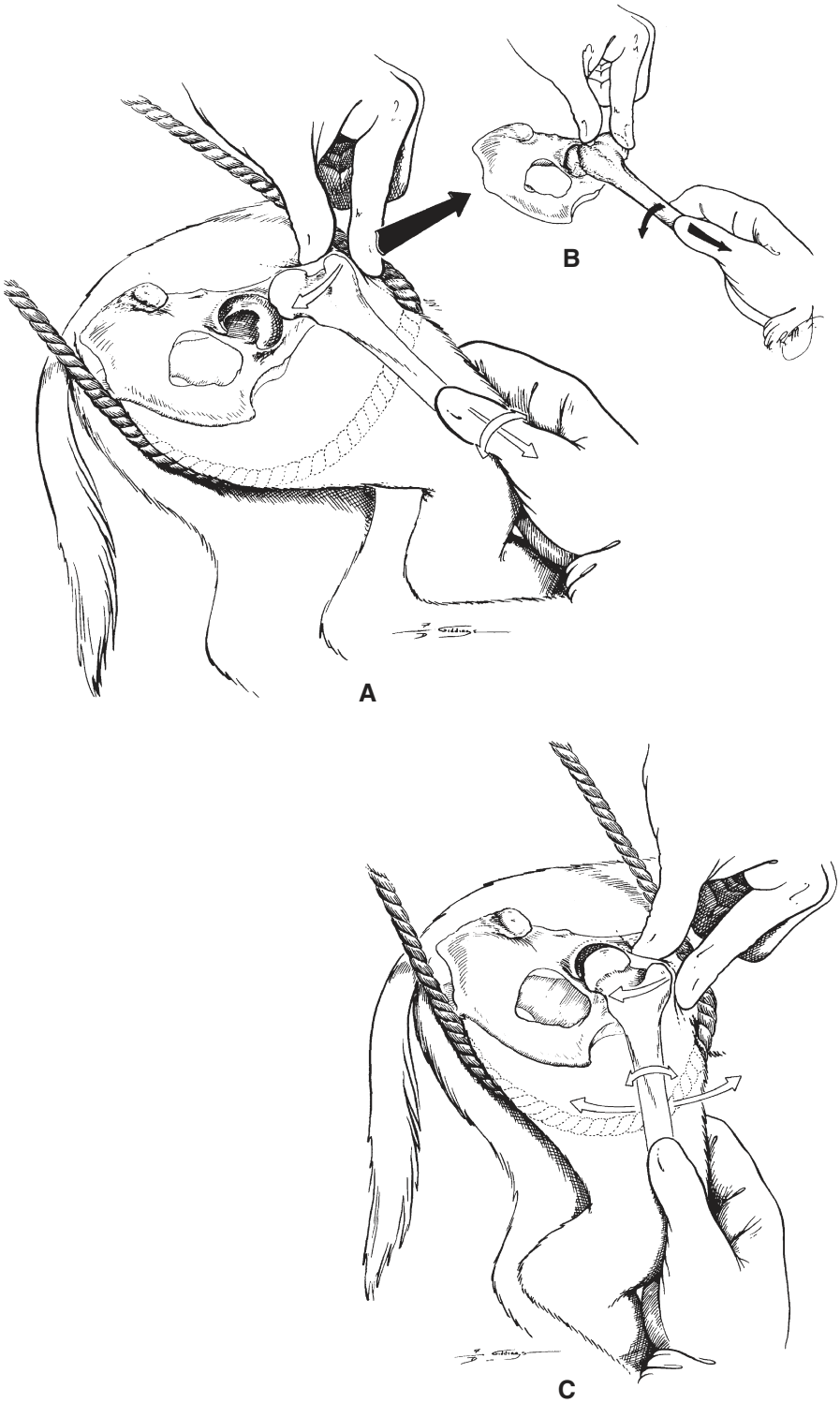


FIGURE 16-3. Closed reduction of a craniodorsal hip luxation. **A,** The animal is secured to the table with a rope around the groin. The right hand pulls and internally rotates the femur to turn the femoral head toward the acetabulum while the fingers of the left hand are placed on the trochanter to help guide the femoral head. The right hand continues to pull and internally rotate the femur while abducting the limb. The left hand guides the trochanter and head over the acetabular rim. **B,** Alternatively, the femoral head is first externally rotated as traction begins, followed by internal rotation. **C,** Pressure is applied to the trochanter with the left hand while the femur is rotated, flexed, and extended to force soft tissue out of the acetabulum and to test stability of the luxation.

reasonably stable, an Ehmer sling is always indicated and is generally left in place for 10 to 14 days. A very unstable hip is likely to need surgical intervention. Continued successful reduction may be assessed by palpating the relative location of the trochanter major (see Figures 1-3 and 1-4). If swelling or obesity prevents this assessment, a radiograph should be carefully taken 3 to 5 days after reduction. If the hip has reluxated, successful surgical repair is more likely early than if undertaken 2 to 3 weeks later.

To stabilize a ventral luxation, the leg is maintained in adduction by hobbling the rear legs together for 10 to 14 days (see Figure 15-27). Constructing the hobbles at the level of the stifle reduces stifle abduction, which is beneficial for treatment of ventral luxation. Stifle hobbles require a supporting band over the dorsum attached to the hobbles to prevent the hobbles from slipping distally (Figure 16-4). An Ehmer sling is contraindicated because the reduced head is forced ventrally where the joint capsule is ruptured. Additional restricted activity is advised for another 3 to 4 weeks.

Prognosis

Failure rates of 47% to 65% have been reported for single attempts at closed reduction.[1,2] The presence of degenerative joint disease or hip dysplasia significantly lowers the chance of success in closed reduction, but attempts at closed reduction probably do not reduce the success of later open reduction procedures. Bilateral CF luxations present quite a dilemma. If after reduction both feel unstable, bilateral toggle-pin fixation (discussed later) can be used, or repair of one hip early followed by surgery on the second side 10 to 14 days later can be attempted. Cage restrictions should be maintained for another 3 weeks.

If a hip stays reduced for 3 weeks, the prognosis is excellent for continued reduction unless another trauma is introduced or if there is underlying hip laxity (dysplasia). Palpating the opposite hip for instability may confirm an underlying factor.

Cats with CF luxation present the orthopedist with a challenge. Cats frequently will not tolerate external bandages or coaptation. If closed reduction is not achieved or if relaxation occurs, open techniques can be used. Often, however, cats function well with a dislocated hip. The dilemma is whether to recommend more expensive reconstructive techniques (that could also fail) or to wait and see how the cat performs and consider femoral head and neck excision (discussed later) later if function is unacceptable.

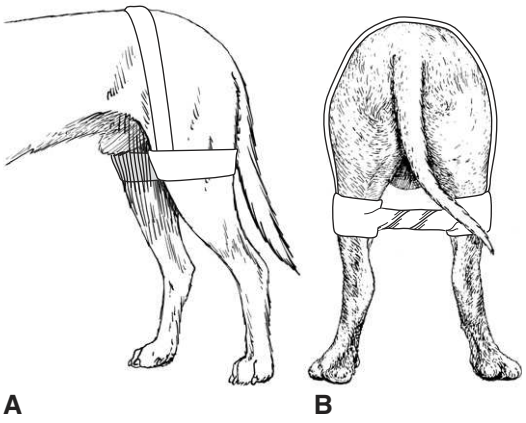


FIGURE 16-4. Hobbles may be constructed at the level of the stifle to help prevent abduction of the stifle and maintain joint reduction after treatment for caudoventral coxofemoral luxation (**A**). Multiple layers of white tape adhering to itself prevents the hobble from sticking to the skin. A separate band is constructed to extend dorsally over the cranial aspect of the pelvis (**B**), which prevents slippage of the hobble distally.

Open Reduction—Dorsal Luxations

Situations in which the hip remains very unstable following reduction or the femoral head cannot be reduced require an open approach. Open reduction is also necessary for avulsion fractures of the femoral head and when immediate mobility of the patient is needed to treat concurrent injuries better. If possible, the hip should be reduced before the approach because it makes dissection much easier. The choice of approach varies with the situation. If the hip is reducible, the craniolateral approach is adequate. If the joint capsule cannot be adequately sutured, or if the hip cannot be reduced, the craniolateral approach is expanded by incising the deep gluteal tendon. If still insufficient, tenotomy of the superficial gluteal tendon and osteotomy of the trochanter major (dorsal approach) can be done. This approach is the method of choice for chronic luxations (>5-6 days) or when extensive reconstruction is required.

After the joint has been exposed, the objectives are (1) to remove or reduce any soft tissue that may be blocking the acetabulum, (2) to reduce the femoral head into the acetabulum, and (3) to stabilize the femoral head in the acetabulum. Exposure of the acetabulum is facilitated by placing a Hohmann retractor (or curved scissors) in or under the acetabulum and levering the proximal femur caudally. Soft tissue in the acetabulum should be carefully identified. Hematomas, hypertrophic round ligaments or fat pads, and muscle fragments are excised, but all joint capsule tissue is preserved. Avulsed bone fragments are removed, except in rare cases where they are large enough to be fixed in place (see Chapter 1). After removal, a judgment must be made regarding the potential stability of the remaining femoral head. If it seems that the remaining head will not provide an adequate articular surface, a femoral head and neck excision arthroplasty or total hip replacement can be performed. Fortunately, the fracture fragment rarely is too large that it cannot be simply excised.

After reduction, several choices are available to maintain reduction. If there is nonfrayed capsule on each side of the dislocation (type A; see Figure 16-2), simple closure with relatively heavy-gauge, synthetic, absorbable or nonabsorbable sutures (0 to 2-0) is used. If there is no capsule on which to anchor the sutures on the acetabular side (type B), bone screws and washers or holes drilled in the labrum can be used to attach the capsule to the pelvis. If the capsule avulses off the neck (type C), often the sutures may be attached to the muscles surrounding the trochanter major. If there is insufficient capsule on both sides, the anchorage techniques for types B and C may be used. Alternatively, suture can be anchored to the intertrochanteric fossa with a screw and washer, or holes can be made at the base of the trochanter major or bony bridge of the neck (synthetic or prosthetic capsular repair). See the description in Figure 16-5 for details

If the capsule can be closed securely, fixation will often be sufficient, although additional stability may be provided by reattaching the trochanter major distal and caudal to its original position (Figure 16-5). This causes a temporary retroversion and a relatively more varus position of the femoral head as a result of femoral abduction and thus seats it more deeply in the acetabulum.

When the capsule cannot be securely closed, additional measures must be taken to ensure stability of the joint until the capsule is repaired by fibroplasia. The method chosen should artificially provide stability for 3 to 4 weeks, by which time the joint should have been restored to its original stability. The method chosen is not important to success, since all the methods suggested next have about the same rate of good to excellent results; therefore the choice is a method that appeals to the surgeon and is compatible with the equipment at hand.

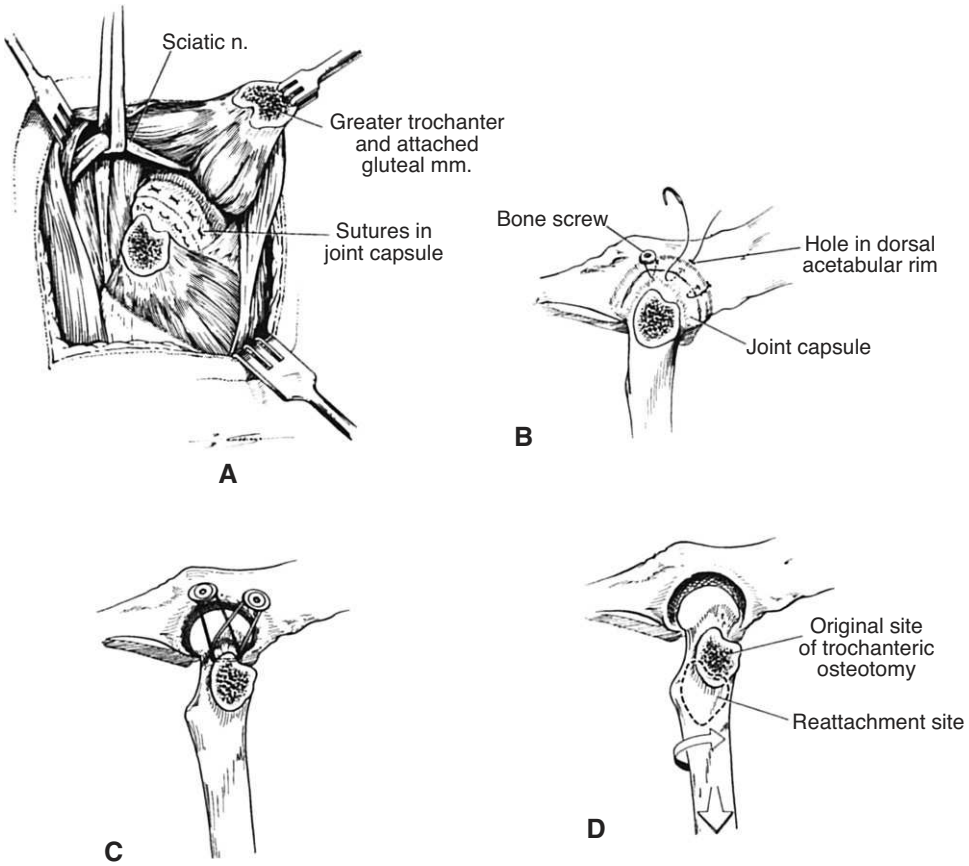


FIGURE 16-5. Open reduction of coxofemoral luxation. **A,** The right hip has been exposed by osteotomy of the trochanter major.[5] The hip joint has been reduced and several mattress sutures are taken in the torn joint capsule. Size 3-0 to 0 synthetic absorbable or nonabsorbable suture material is used. **B,** When the joint capsule cannot be reached to the acetabular side, a bone screw on the dorsal acetabular rim or holes drilled in the labrum can be used to anchor sutures. Nonabsorbable material is used with the bone screw, and synthetic absorbable material is used in the bone tunnels. Usually, two screws are necessary to achieve good attachment of the entire capsule. **C,** When no joint capsule is available on either side of the joint, two bone screws are placed on the dorsal acetabular rim, at the 11- and 2-o'clock positions (or 10 and 1 o'clock for the left hip). A hole is then drilled transversely through the bony bridge of the femoral neck. Size 1-5 nonabsorbable sutures are tied with the limb abducted and internally rotated. Washers help prevent the sutures from slipping off the screw heads. **D,** When the trochanter major is being reattached, additional stability may be gained by moving the trochanter slightly distal and caudal to its original site. Increased abduction and internal rotation of the femur results.

Synthetic Capsule Technique

The synthetic capsule technique is simple and effective (Figure 16-5, *C*).[6,7] After reduction as explained earlier, two bone screws of suitable diameter (2.7-4.0 mm) are inserted in the dorsal rim of the acetabulum at the 10- and 1-o'clock positions for the left hip and the 11- and 2-o'clock positions for the right hip. Care must be taken to ensure that the screws do not penetrate the articular surface. Metal or plastic washers are placed on the screws to prevent the suture from slipping off the head of the screws. Pretying a half square knot of suture material under each washer is performed before screw and washer insertion. This is helpful if difficulty has been encountered

in tying the knot after the screw and washer are already inserted. Two lengths of monofilament polyester (size 1-5) or nylon (20 to 40 pound, or size 1-3) suture are attached through a transverse hole created in the bony bridge between the femoral head and trochanter (Figure 16-5, *C*). The head is reduced and leg positioned to mimic its location in an Ehmer sling while the sutures are tied tightly. A few degrees of internal rotation of the limb is probably useful because doing so creates femoral head retroversion, which adds stability, but external rotation must be avoided as the sutures are tied. A third screw and washer placed in the trochanteric fossa can be used to replace the drill hole.[7]

An alternative to using a screw and washer for the prosthetic capsule technique is the use of soft tissue anchors (see Figure 14-24, *D*). Tissue anchors have various fixation configurations that allow attaching a suture directly to bone without having a large screw head present.

Toggle-Pin Fixation

If the capsule has been severely damaged or if the luxation is chronic, it may not be possible to stabilize the joint sufficiently by suturing the capsular remnants. In this case, other techniques must be used in addition to reconstruction of the joint capsule.

A modified Knowles toggle-pin technique has worked well in a variety of situations, such as chronic luxations, multiple limb injuries, mild hip dysplasia, and when early use of the luxated limb is desirable.[8] The synthetic round ligament that is created is not expected to function indefinitely, but it will maintain stability until the soft tissue damage in the region of the hip joint has undergone healing, with maturation of the scar tissue and re-formation of the joint capsule. No evidence has ever shown that the suture material used to create the synthetic round ligament created a problem in the joint. In those cases that have reluxated and undergone repeat surgery, the broken suture material has been encapsulated in the regenerating round ligament and thus was no longer intrasynovial.

After a dorsal open approach with osteotomy of the trochanter major,[5] a hole is drilled through the femoral head and neck starting at the fovea capitis and continuing laterally to exit the femoral shaft in the region of the third trochanter (Figure 16-6, *A*). The size of the hole is either 7/64 or 5/32 inch (2.8 or 4.0 mm), depending on the size of the toggle pin used (Figure 16-7). This relatively small hole minimizes additional devascularization of the femoral head. The drill is then used to create a hole in the upper end of the acetabular fossa (Figure 16-6, *B*).

The stainless steel toggle pin is attached to two lengths of size 0-5 braided polyester suture. The toggle pin is then placed in the acetabular hole and pushed through to the medial side (Figure 16-6, *C*). By means of alternate tugging on the suture ends, the toggle pin is made to turn 90 degrees to lock itself on the medial cortex of the acetabulum (Figure 16-6, *D*). These sutures are then pulled through the drill hole in the femoral neck (Figure 16-6, *E*) and held taut while the hip is returned to the reduced position (Figure 16-6, *F*). A hole is drilled from cranial to caudal through the lateral femoral cortex, slightly proximal to the exit hole of the sutures. One pair of sutures is pulled through the second drill hole and then tied to the opposite pair on the lateral side of the femoral cortex (Figure 16-6, *G*). The joint capsule is sutured to the extent possible (see Figure 16-2, *A*), and the trochanter major is reattached with two Kirschner wires or a tension band wire (see Figure 17-7, *D*).

Triple Pelvic Osteotomy[9]

Triple pelvic osteotomy (TPO) has been used to treat recurrent traumatic CF luxation in adult, large-breed dogs with a mild degree of hip dysplasia. Even mild hip dysplasia is a major contributing factor to reluxation, and increasing dorsal acetabular

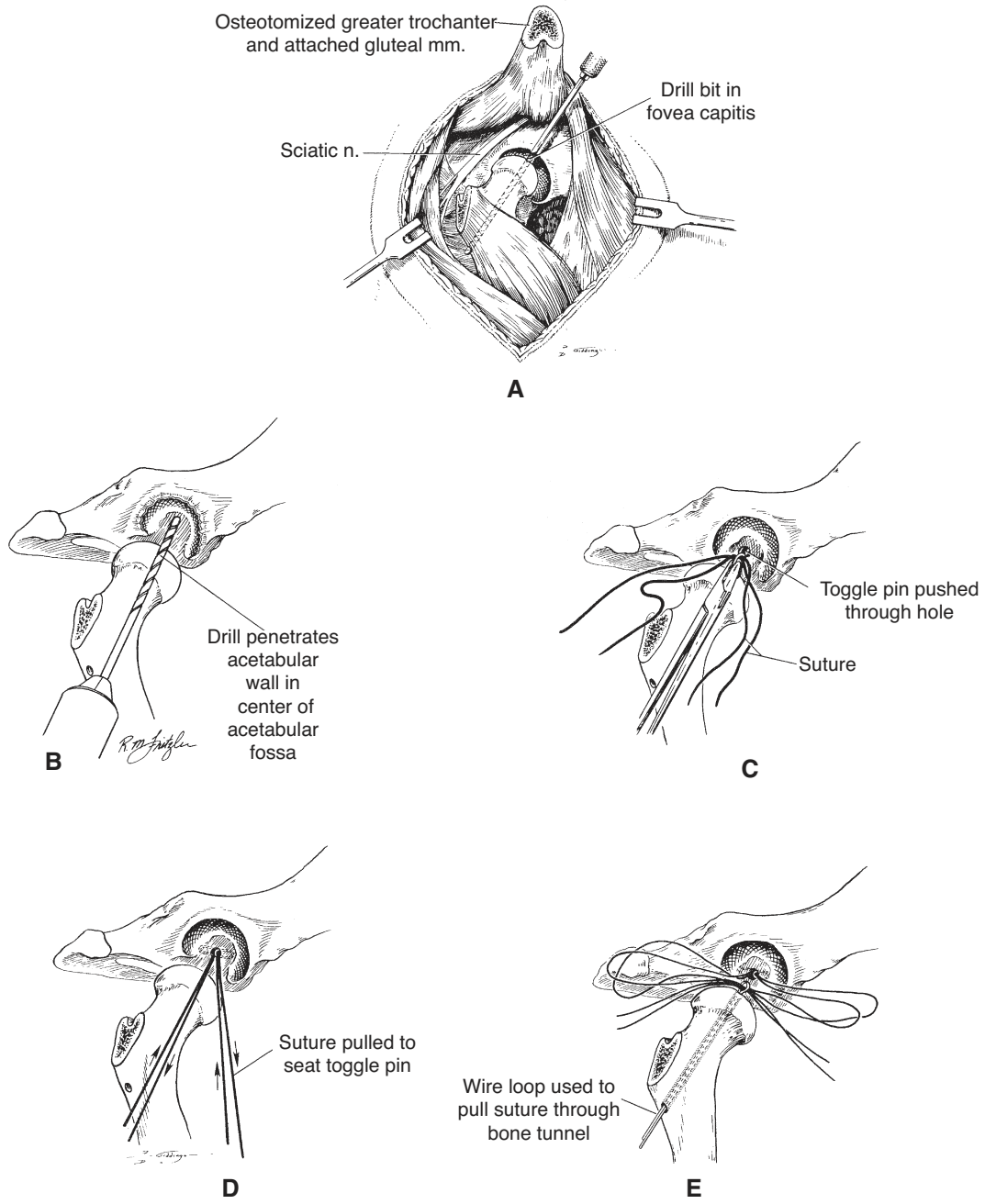
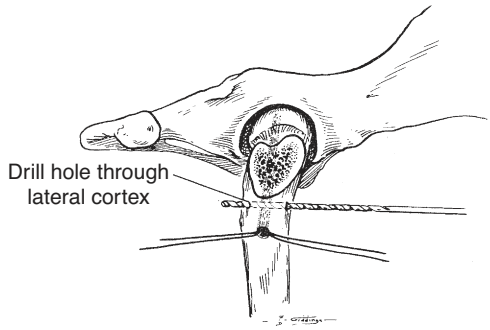
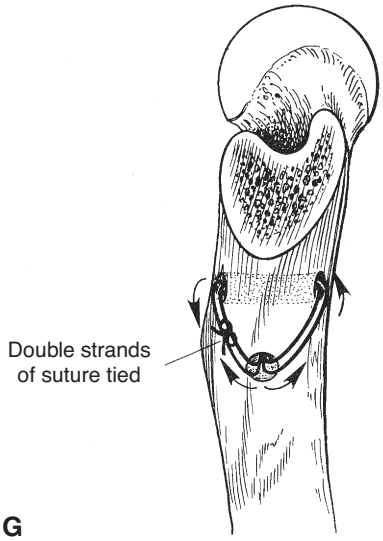


FIGURE 16-6. Toggle-pin fixation of a dislocated hip. **A,** The right hip has been exposed by means of a dorsal approach with osteotomy of the trochanter major.[5] A hole is drilled from the fovea capitis, through the neck to emerge along the crest of the third trochanter. (For proper drill size, see Figure 16-7.) **B,** With the hip luxated, the drill is passed through the acetabular fossa wall. Care must be taken not to penetrate too deeply. **C,** The hip has been reluxated. Two strands of braided polyester suture, size 0-5, are threaded through the toggle pin (see Figure 16-7). With the pin held in forceps, it is then pushed through the acetabular hole. **D,** The ends of the suture are alternately pulled back and forth to cause the toggle pin to turn 90 degrees and seat against the medial cortex of the acetabulum. **E,** All four ends of the sutures are pulled through the bone tunnel with a piece of bent wire. The sutures are pulled taut, and the hip is reduced.

Continued



F



G

FIGURE 16-6. *Continued* **F,** A small hole is drilled in the lateral cortex in the craniocaudal direction between the osteotomy and the bone tunnel. **G,** One set of sutures is passed through the proximal bone tunnel and tied to the other suture set.

coverage with TPO helps to maintain reduction of the joint (see Figure 16-10). TPO may be used in conjunction with other stabilization techniques. In one report, long-term hip reduction was successful, and three of the four dogs did not have radiographic progression of coxofemoral degenerative joint disease at 1-year follow-up.[9] TPO is contraindicated in treatment of hip luxation in dogs with moderate to severe dysplastic changes.

Transarticular Pinning[10]

This technique pins the femoral head to the acetabulum. Complications such as pin breakage or colorectal penetration can occur, and transarticular pinning should be avoided if possible. This technique starts as described for the toggle pin, with a suitable size of intramedullary pin or Kirschner wire being driven from the fovea capitis laterally through the neck and exiting the bone on the lateral femoral cortex distal to the third trochanter (Table 16-1 and Figure 16-8, *A*). After reduction, the femoral head is held firmly reduced with the hip positioned as it would be in an Ehmer sling while the pin is driven through the acetabular wall into the pelvic canal. A few degrees of internal rotation of the limb is probably useful because it creates femoral head retroversion, which adds stability, but external rotation must be avoided as the pin is driven. The entire point of the pin (5-6 mm) should be within the pelvic canal, and this is checked by rectal palpation by an assistant. The protruding (lateral) end of the pin is cut short but long enough to allow later removal (Figure 16-8, *B*). The joint capsule is closed to the extent possible.

An Ehmer sling is applied postoperatively for 10 to 14 days, at which time the sling and the pin are removed. If the hip is very unstable at the time of reduction, the pin and Ehmer sling are removed in 3 weeks. Maintaining an Ehmer sling is imperative to prevent pin breakage or migration. Again, this technique is to be avoided because of high morbidity and the availability of better techniques.

Aftercare

Following all CF reduction techniques, the limb is usually supported in an Ehmer sling for 7 to 10 days unless otherwise noted (see Figure 2-31). Exercise is limited

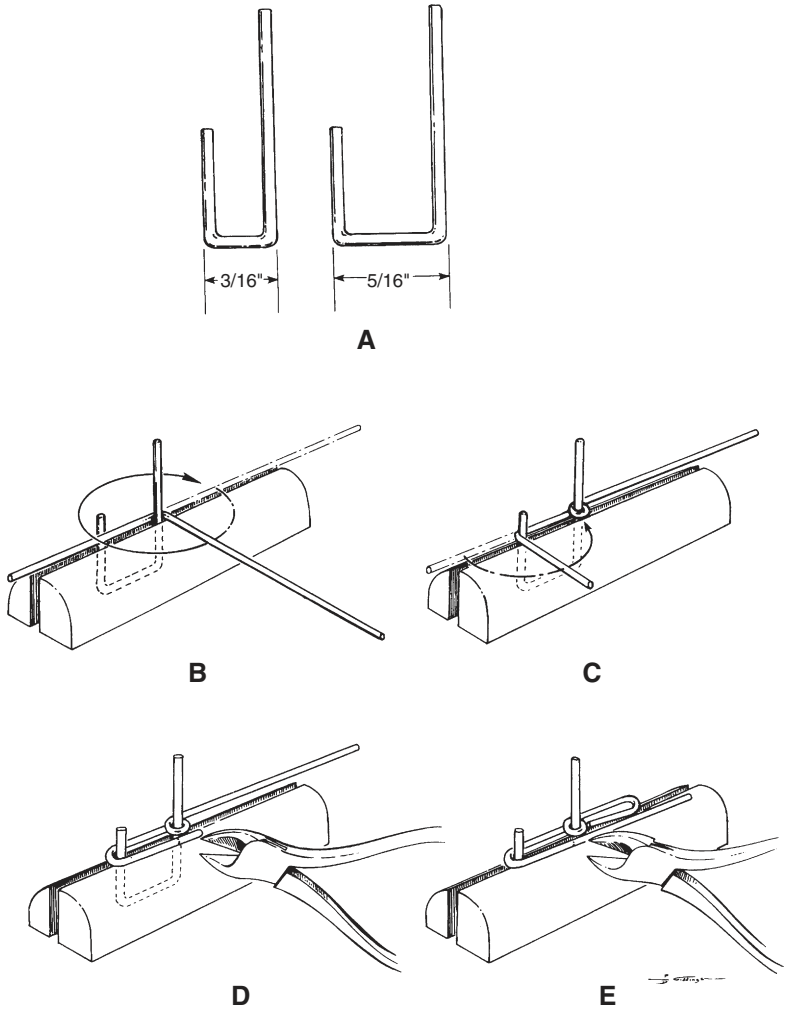


FIGURE 16-7. Fabrication of a toggle pin. Small pins are used in animals weighing up to 9 kg, and large pins are used in animals weighing over 9 kg. **A,** The pins are made from Kirschner wire bent around a jig that is clamped in a vise. The small jig is 3/16 inch wide and is made of 0.035-inch Kirschner wire. The large jig is 5/16 inch wide and is made of 0.045-inch Kirschner wire. **B,** The pins are formed from the same-diameter wire as the jig. The long end of the wire is bent 360 degrees around the taller post of the jig. **C,** The wire is repositioned on the jig. One end is bent 180 degrees around the short arm of the jig. **D,** The wire is cut just short of the center hole. **E,** The partially completed pin is rotated end-for-end and inverted to allow the second end to be formed, as in *D*. The entire pin is then compressed with pliers to ensure that the small pin will pass through an 1/8-inch drill hole and that the large pin will pass through a 5/32-inch drill hole.

TABLE 16-1. PIN SELECTION ACCORDING TO BODY WEIGHT

Weight (kg)	Diameter (mm)	Diameter (inches)
4-7	1.6	1/16
8-11	2.0	5/64
12-19	2.3	3/32
20-29	2.7	7/64
≥30	3.1	1/8

From Hunt CA, Henry WB: *J Am Vet Med Assoc* 187:828, 1985.

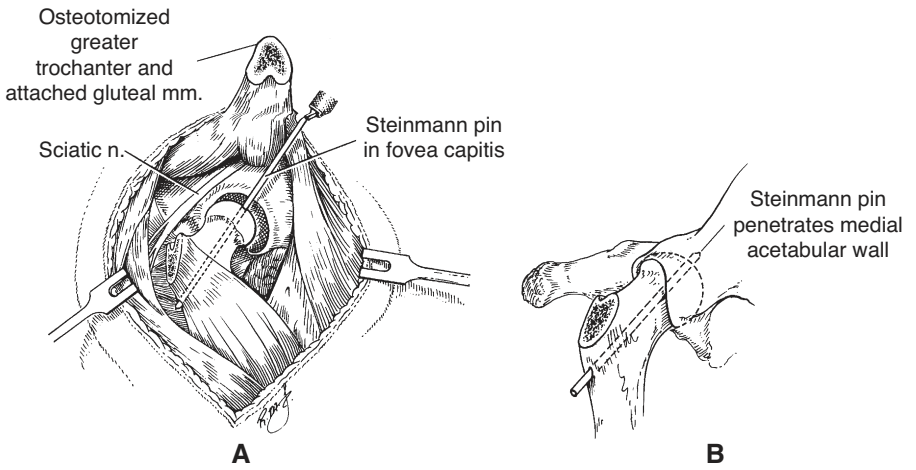


FIGURE 16-8. **A,** Transarticular pinning of the hip joint. Following an open approach (here a dorsal approach with osteotomy of the trochanter major), cleaning of the acetabulum, and a trial reduction of the femur, a small Steinmann pin is driven from the fovea capitis laterally through the head and neck (see Table 16-1). It should exit the lateral cortex distal to the trochanter major. **B,** With the hip reduced and the limb fixed at a normal standing angle, the pin is carefully driven through the acetabular wall. It should protrude not more than 1/4 inch (6 mm) into the pelvic canal. The joint capsule is then sutured to the extent possible before closing.

to the house or leash for 3 weeks, then gradually increased to normal over a 2- to 3-week period. Sometimes when limb fractures are on the opposite side, no sling bandage is used, and early, limited weight bearing is allowed. Bilateral luxations have also been repaired without the use of postoperative slings but require meticulous postoperative care, which includes towel support under the lower abdomen when outdoors, strict house inactivity, and avoidance of stairs.

Prognosis

The prognosis for open reduction varies with the stability achieved after reduction and with the time interval between luxation and reduction. Cases that are reduced early with adequate stability carry a good prognosis, and essentially normal function may be anticipated in 70% to 75% of these patients. Those cases that have been luxated for a considerable time, especially in skeletally immature animals, may result in increased degenerative joint disease and at times avascular necrosis of the femoral head. Occasionally, a hip may reluxate after reduction, although this is rare if reduction is maintained for 7 to 8 days unless there is preexisting hip laxity (hip dysplasia). Varying degrees of osteoarthritis may develop if there has been sufficient damage to the acetabulum or femoral head. Hips that are even slightly dysplastic often will reluxate. Reluxation is an indication for femoral head and neck resection arthroplasty or for a prosthetic hip joint.

Open Reduction—Caudoventral Luxations

Although most caudoventral luxations can be handled by closed reduction,[4] some cases require open reduction. Typically, a craniodorsal approach[5] is used if the greater trochanter is fractured, since this allows access to the acetabulum as well as to the trochanter. The joint is debrided as previously described, the hip is reduced, and any available soft tissues are sutured. Once the greater trochanter is repaired

(see Chapter 17), the joint is usually very stable.[3] If the joint is somewhat unstable, a prosthetic restraint may be constructed with a single screw and washer placed at the 9:30 to 10-o'clock position for the left hip and 2-o'clock to 2:30 position for the right hip, with a figure-of-8 nonabsorbable suture attached to a hole drilled through the femoral neck. This prosthetic restraint prevents caudal displacement of the femoral head and assists in preventing reluxation.[11]

Some cases, however, remain very unstable after reduction, and it has been suggested that a deficiency in the ventral transacetabular ligament is responsible.[12] A ventral approach will allow inspection of this area.[5] Two techniques have been reported for stabilizing these luxations. An autogenous corticocancellous bone graft from the iliac crest was implanted on the ventral acetabular region with success in four cases.[12] In another case, the pectineus muscle was used to stabilize the femoral head.[13] The muscle was detached distally and directed caudally ventral to the femoral neck, then dorsally and cranially over the femoral neck and deep to the gluteal muscles. The remaining free portion of the muscle was then sutured to any soft tissue available to hold the pectineus in position.

Remaining portions of the joint capsule are sutured and the hindlimbs are hobbled together for 2 to 3 weeks postoperatively (see Figure 16-4). Slow return to normal activity is allowed over the next 2 to 3 weeks. Because of the small number of cases available for evaluation, the prognosis in this situation is uncertain.

HIP DYSPLASIA

Hip dysplasia is an abnormal development or growth of the hip joint, usually occurring bilaterally. It is manifested by varying degrees of laxity of surrounding soft tissues, instability, malformation of the femoral head and acetabulum, and osteoarthrosis.

Incidence

One of the most prevalent disorders of the canine hip, hip dysplasia is the most important cause of osteoarthritis of the hip in the dog. Incidence ranges from 0.9% for the borzoi to 47.4% for the Saint Bernard in dogs radiographically evaluated by the Orthopedic Foundation for Animals (OFA).[14] This is not the true incidence for any breed or the general population because most radiographs with recognizable dysplasia are not submitted, but it does indicate the relative incidence among the breeds, and most of the large working and sporting breeds are well represented.

The disease rarely occurs in dogs that have a mature body weight of less than 11 to 12 kg. Although hip dysplasia has been observed in toy breeds and cats, their unstable hips do not typically produce the bony changes common in heavier dogs. However, coxofemoral luxation after trivial trauma is seen.

Pathogenesis

Comprehensive reviews of hip dysplasia provide the basis for most of the following discussion.[15-17] A book intended for the lay public is an excellent source for dog owners and breeders.[18] The *International Symposium on Hip Dysplasia and Osteoarthritis in Dogs,* published for a veterinary and scientific audience, is an excellent source of scientific information.[19]

Many observations have been made regarding the etiology of this complex disease. The more important points include the following:

1. There is a polygenic predisposition to congenital dislocation of the hip, with multiple factors that influence and modify the disease.
2. Environmental factors are superimposed on the genetic susceptibility of the individual.
3. The genes do not affect the skeleton primarily but rather the cartilage, supporting connective tissue, and muscles of the hip region.
4. The biochemical explanation of hip dysplasia is that it represents a disparity between primary muscle mass and disproportionately rapid skeletal growth.
5. The hip joints are normal at birth. Failure of muscles to develop and reach functional maturity concurrently with the skeleton results in joint instability. Abnormal development is induced when the acetabulum and femoral head pull apart and initiate a series of changes that end in the recognizable disease of hip dysplasia.
6. Bony changes of hip dysplasia are a result of failure of soft tissue to maintain congruity between the articular surfaces of the femoral head and acetabulum.
7. The disease is preventable if hip joint congruity is maintained until ossification makes the acetabulum less plastic and the surrounding soft tissues become sufficiently strong to prevent femoral head subluxation. Under usual circumstances, tissue strength and ossification progress sufficiently to prevent the disease by 6 months of age.
8. Dogs with greater pelvic muscle mass have more normal hip joints than those with a relatively smaller pelvic muscle mass.
9. The onset, severity, and incidence of hip dysplasia can be reduced by restricting the growth rate of puppies.[20]
10. The frequency and severity of osteoarthritis in dysplastic dogs is reduced by limiting food intake and therefore body weight in adult dogs.[21]
11. The occurrence of hip dysplasia can be reduced, but not eliminated, by breeding only dogs that have radiographically normal hips. Only 7% will be normal if both parents are dysplastic.[18,22-24]

History and Clinical Signs

Clinical findings in hip dysplasia vary with the age of the animal.[15] Often, no signs are appreciated by pet owners. There are two recognizable clinical groups of dogs, as follows:

1. Young dogs between 4 and 12 months of age.
2. Animals over 15 months of age with chronic disease.

Young dogs often show sudden onset of unilateral disease (occasionally bilateral), characterized by sudden reduction in activity associated with marked soreness of the hindlimbs. They will show sudden signs of difficulty in arising with decreased willingness to walk, run, jump upward, and climb stairs, and the muscles of the pelvic and thigh areas are poorly developed. Often the client has noted short, choppy steps and a "bunny-hopping" gait in the rear quarters while running. Most will have a *positive Ortolani sign* (see Chapter 1). This is the click produced by the movement of the femoral head as it slips in and out of the acetabulum with adduction and proximal pressure applied to the distal femur followed by abduction (see Figures 1-11 and 16-10, *C* and *D*). Radiographically, the conformation of the femoral heads usually appears normal; however, some degree of subluxation may be seen, and if the

process has been present for a few months, the angle of inclination of the femoral neck may increase beyond 146 degrees (valgus), and occasionally some lipping of the ventral aspect of the femoral head will be seen radiographically.

The sudden onset of signs in young dogs is caused by occurrence of microfractures of the acetabular rims. When femoral heads are subluxated, the area of contact of the femoral head with the dorsal acetabulum is limited to the area between the 10- and 2-o'clock positions, with an extreme buildup of stress in that area. This eventually overloads the acetabular rim, producing tissue fatigue, loss of tissue elasticity and contour, and eventual microfracture. Pain results from tension and tearing of nerves of the periosteum. Sharpey's fibers rupture, bleed, and form osteophytes on the acetabulum and femoral neck. These usually do not become radiographically visible until 17 or 18 months of age but may be seen as early as 12 months.[15] These fractures heal by the time of skeletal maturity, with the result that the hip joints become more stable and pain is greatly decreased. Most dysplastic dogs between 12 and 14 months of age walk and run freely and are free of significant pain, despite the radiographic appearance of the joint. Most exhibit a bunny-hopping gait when running.

Older dogs present a different clinical picture because they have chronic degenerative joint disease and its associated pain (see Chapter 6). Lameness may be unilateral but is usually bilateral. The signs may become apparent over a long period or may occur suddenly after brisk activity that results in a tear or other injury of soft tissues of the abnormal joint. Most clinical signs result from prolonged degenerative changes within the joint. The dog has lameness after prolonged or heavy exercise, a waddling gait, and often crepitus and restricted range of motion of the joint. This crepitus is best detected by placing the examiner's ear or stethoscope bell directly on the proximal trochanter major region while applying proximal pressure during abduction/adduction maneuvers with different degrees of hip extension. The dog often prefers to sit rather than stand and arises slowly and with great difficulty. Thigh and pelvic muscles atrophy greatly, with the result that the greater trochanters become quite prominent and even more so if the hip is subluxated. Concurrently, shoulder muscles hypertrophy because of the cranial weight shift and increased use of the forelimbs. The Ortolani sign is rarely present in older larger dogs because of the shallowness of the acetabulum and fibrosis of the joint capsule. The hip dysplasia seemingly "worsens" with two other common problems: (1) either full or partial cruciate ligament tears and (2) spinal problems such as disks or degenerative myelopathy. Stifle palpation and radiographs help in detecting the additional knee problems, and a delayed or absent conscious proprioception test is helpful in distinguishing spinal problems.

Diagnosis

Radiographic Signs

Radiographic confirmation is essential in establishing a positive diagnosis of hip dysplasia. The OFA has formed a hip dysplasia registry (University of Missouri, Columbia) and, as a result of examining many radiographs, has established seven grades of variation in congruity of the femoral head and acetabulum. The dog must be over 2 years of age to apply the following gradations; the first three are considered within the range of normal:

1. *Excellent:* Nearly perfect conformation.
2. *Good:* Normal conformation for age and breed.

3. *Fair:* Less than ideal but within normal radiographic limits.
4. *Borderline:* A category in which minor hip abnormalities often cannot be clearly assessed because of poor positioning during radiographic procedures. It is recommended that another radiograph be repeated in 6 to 8 months.

Dysplastic animals fall into the following three categories:

1. *Mild:* Minimal deviation from normal with only slight flattening of the femoral head and minor subluxation.
2. *Moderate:* Obvious deviation from normal with evidence of a shallow acetabulum, flattened femoral head, poor joint congruency, and in some cases, subluxation with marked changes of the femoral head and neck.
3. *Severe:* Complete dislocation of the hip and severe flattening of the acetabulum and femoral head.

Dogs in moderate and severe grades are most likely to be clinically affected. Many continually show lameness or discomfort.

Radiographic evaluation of dysplasia requires adequate relaxation for proper positioning in dorsal recumbency, with the femurs extended parallel to each other and to the cassette and the patellas centered on the femoral condyles. Evaluation of properly exposed radiographs is done by reference to several landmarks, as illustrated in Figure 16-9, *A*. The more important points are as follows:

- The femoral head should be congruent with the cranial acetabular margin, which in turn should be perpendicular to the midline.
- The intersection of the physeal scar with the dorsal acetabular rim defines the amount of the femoral head that is under the acetabular rim. At least 50% of the head should be covered by the acetabulum.
- Variable amounts of femoral head flattening and remodeling may obscure the fovea capitis. The head becomes more oval in outline as osteophytes build on the femoral neck at the insertion of the joint capsule. In later stages the acetabulum becomes filled with bone, and the medial wall appears very thickened.

Reliability of radiographic evaluation for dysplasia is a function of age of the dog. In the German shepherd (Alsatian), it is 70% at 12 months, 83% at 18 months, and 95% at 24 months. In general, evaluation between 12 and 18 months has a reliability of 77% to 85% compared with evaluation at 24 months.[14,25]

Physical Examination

The ability to diagnose hip dysplasia early in life is economically useful to breeders and could eliminate considerable distress for owners who become very attached to a pet only to find later that the dog has hip dysplasia. Palpation of 6- to 8-week-old puppies for hip joint laxity by the method of Bardens[26] has been demonstrated to be statistically significant in predicting hip dysplasia in at-risk breeds.[27] Bardens reported an accuracy of 83% in predicting dysplasia in puppies. The technique is best done on 8- to 9-week-old puppies and requires deep sedation or light general anesthesia. With the pup on its side, the thumb of one hand is rested on the tuber ischii and the middle finger on the dorsal iliac spine. The index finger of the same hand is placed on the greater trochanter as the opposite hand lifts the femur laterally, raising the femoral head out of the acetabulum. The amount of lift can be estimated by observation of the index finger on the acetabulum. This is a subjective and inconsistently reproducible technique and is not currently used in young puppies to predict dysplasia. Although this is a subjective measurement, a simple lever device

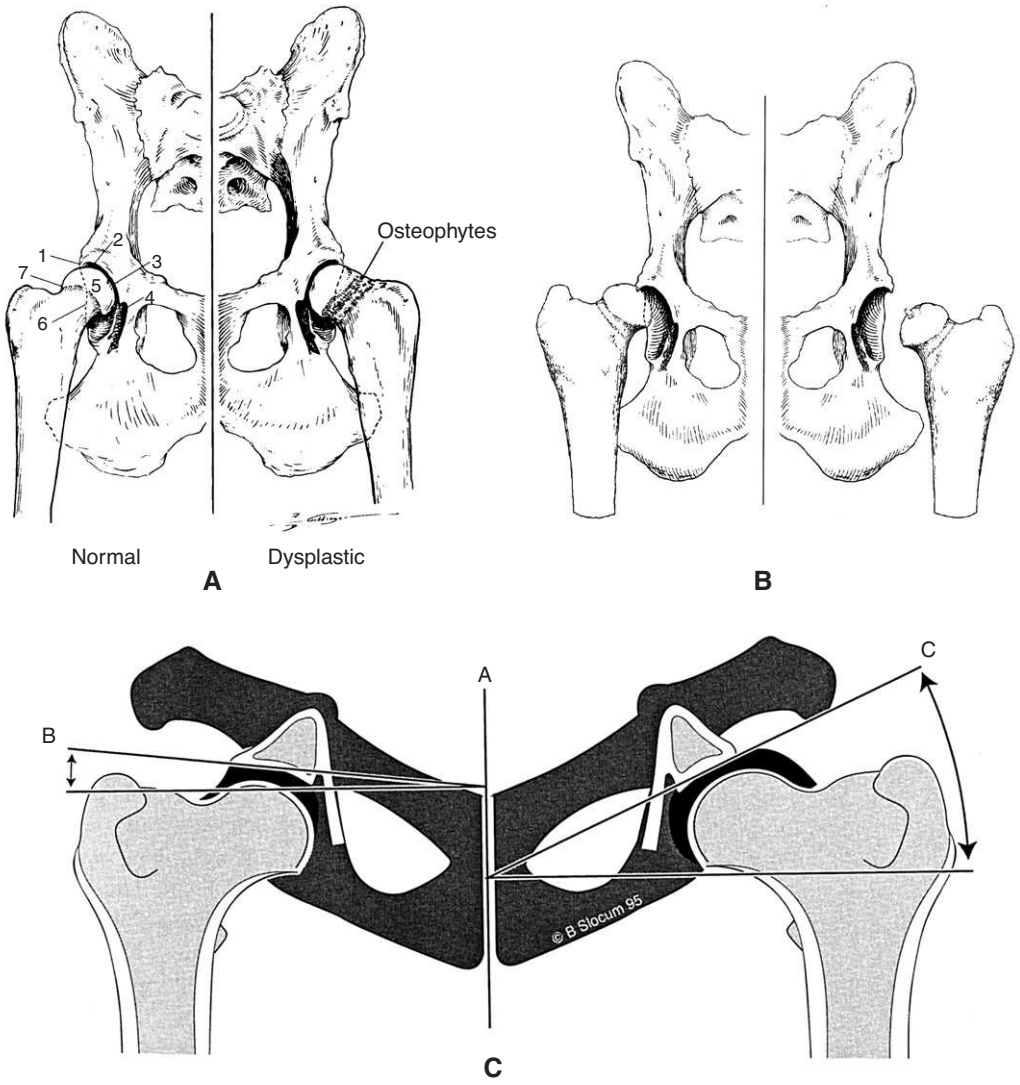


FIGURE 16-9. Hip dysplasia. **A,** The right side is normal with several landmarks identified: *1,* craniolateral rim; *2,* cranial acetabular margin; *3,* fovea capitis; *4,* acetabular notch; *5,* femoral head; *6,* dorsal acetabular rim; and *7,* physeal scar. (See text for details.) The left side is dysplastic: the femoral head is flattened and not congruent with the cranial acetabular margin; the intersection of the physeal scar and the dorsal acetabular rim shows only about 40% of the femoral head under the acetabular rim; and osteophytes have formed at the intersection of the joint capsule and the femoral neck, giving it a very thickened appearance. **B,** The right side shows obvious subluxation. The craniodorsal rim is underdeveloped because of pressure upon subluxation. Dramatic incongruency is noted between the femoral head and the cranial acetabular margin, and the intersection of the physeal scar and dorsal acetabular rim shows less than one third of the femoral head under the acetabular rim. The femoral head has lost its spherical shape. The left side shows complete luxation with secondary changes of the femoral head and neck. **C,** Dorsal acetabular rim (DAR) view of the pelvis, providing a tomogram-like cross-sectional view of the acetabuli. Line *A* is the sagittal plane of the pelvis. Lines *B* and *C* are tangent to the dorsal acetabular rims and form angles with a line perpendicular to the sagittal plane that define the angle of the dorsal acetabular rims. Normal dogs typically have an angle of not more than 15 degrees, as seen on the left, while dysplastic dogs show increased angulation. (Redrawn from Slocum B, Devine T: *Vet Clin North Am Small Anim Pract* 22:645-682, 1992; and Slocum B, Devine T: *J Am Anim Hosp Assoc* 26:289-296, 1990. Drawing courtesy B. Slocum.)

has been described that allows an objective measurement.[27] There is a correlation, however, between the degree of laxity and the presence of hip dysplasia at 12 months of age.

The usefulness of the Ortolani sign (see Figures 1-11 and 16-10, *C* and *D*) as a predictor of dysplasia has not been documented in puppies of this age range, but a similar correlation would be expected because both methods measure hip joint laxity. Palpation for joint laxity in mature animals is usually unrewarding because of the fibrosis of the joint capsule and shallowness of the acetabulum. The general orthopedic and radiographic examination is more important in this situation.

The definitive diagnosis of hip dysplasia must be based on the radiograph. In young dogs with beginning lameness, however, the radiographs may not show much change at all. Palpation for Ortolani motion is often helpful and is not a painful maneuver. The Bardens technique to palpate for hip laxity is somewhat painful in the young adult. In the older dog, listening for crepitus with the examiner's ear or stethoscope bell on the trochanter major is often helpful. Diagnosing the origin of lameness when there are concurrent problems such as cruciate ligament rupture or luxating patellas is problematic, especially when each of these conditions is known to be occasionally asymptomatic. If the dog has sustained a cruciate ligament injury, this problem is usually addressed first. After recovery from surgery, if lameness is still present, the hips are then treated.

Additional Diagnostic Methods for Hip Dysplasia

The need for earlier predictors and improved accuracy of diagnosis continues to stimulate the development of additional radiographic methods for diagnosis and characterization of hip dysplasia in dogs. Each method attempts to quantify a specific radiographic characteristic of subluxation or laxity of the hip joint, with the expectation that a strong correlation exists between hip laxity and the development of degenerative joint disease (DJD). Breeding programs based on elimination of animals with expressed physical characteristics (phenotype) of hip laxity can expect success in making slow improvements in the genetic stock of specific breeds.[22-24] Even the newest diagnostic radiographic indices cannot be expected to eliminate hip dysplasia from any breed of dog because of the existence of phenotypically negative genetic carriers of the disease. As the canine genome becomes more fully characterized in the future, we can now anticipate diagnostic improvements in genetic testing for hip dysplasia that will eclipse all previous testing based on physical characteristics.

Norberg Angle[28]

Norberg angle is a radiographic characteristic of the standard ventrodorsal radiograph used as a measure of hip joint laxity in research studies and as a selection criterion in some hip registries and breed standards. This measurement characterizes the relationship of the center of the femoral head to the craniolateral aspect of the dorsal acetabular rim. A general Norberg angle of 105 degrees or greater has been considered to be normal for all breeds; however, one study has indicated breed-specific Norberg angles. It is suggested that 99.9 degrees for Labrador retrievers, 101.9 degrees for Rottweilers, 92.6 degrees for golden retrievers, and 100.3 degrees for German shepherds are breed-specific normal limits for Norberg angle.

Distraction Stress Radiography

Techniques for adding stress to the coxofemoral joints during radiographic evaluation have been well characterized to improve sensitivity and specificity of detection of joint laxity in puppies as young as 4 months of age.[29-32] *Distraction index* is a radiographic measure of passive hip joint laxity. Breed-specific differences are noted for

measurements of the distraction index; however, a general distraction index of less than 0.3 indicates a separation between normal dogs and dogs with conformation susceptible to DJD from hip dysplasia. The measurement of distraction index is reported to be a more reliable predictor of DJD in hip dysplasia than Norberg angle, Ortolani sign, or OFA measurement of hip conformation.[30,31]

Dorsolateral Subluxation

Other radiographic methods distinguish between passive laxity and passive subluxation of the coxofemoral joint.[33] Passive subluxation is described radiographically with the coxofemoral joints in a weight-bearing position, without lateral stress applied, as described for the distraction index. A strong correlation between the dorsolateral subluxation score and distraction index suggests that minimal practical difference exists between the two methods.

Treatment

Conservative Therapy

Many dogs with hip dysplasia show no signs of pain; others have only mild, intermittent signs. Indeed, in 68 dogs in which hip dysplasia was diagnosed at an early age, 76% had minimal gait abnormalities at a mean of 4.5 years later.[34] A large number of these animals can be treated by conservative methods, including minimizing exercise below the threshold level that the hips can tolerate without clinical signs of pain and fatigue. This might include retiring the dog from strenuous athletic competition or moderating the amount of exercise demanded in some pet situations, such as Frisbee chasing or jogging with the owner. This will often cause relief of signs with no other treatment. Weight reduction is essential for obese animals. During acute flare-ups, exercise should always be curtailed.

The use of analgesics and other antiinflammatory agents is indicated in many animals (see Chapter 6 for further discussion of osteoarthritic drugs). *Aspirin* and *sodium salicylate* do much to improve the well-being of the dog and improve the quality of life. *Buffered aspirin* is generally the first choice, in a twice-daily dose of 325 mg (5 grains) for a 25- to 30-pound animal (25 mg/kg). Aspirin is inexpensive and accessible to most clients at any pharmacy. Newer *nonsteroidal antiinflammatory drugs* (NSAIDs) are available to veterinarians that have scientifically controversial selectivity for the cyclooxygenase-2 (COX-2) enzyme partially responsible for inflammatory components of arthritic pain. Although these products theoretically have fewer adverse side effects than aspirin, any NSAID may cause adverse effects to the gastrointestinal (GI), renal, and hepatic systems. All these products are relatively expensive and available by prescription only. Carprofen (Rimadyl, Pfizer) is useful and often seems to be more effective than aspirin in many individual dogs. A therapeutic dose is 2.2 mg/kg orally twice daily, but once-daily dosing is also available. Side effects are less common than for aspirin but may include stomach or GI irritation. Hepatic toxicosis is reported rarely and may warrant monitoring liver enzymes during treatment, especially in older patients.[35] Etodolac (Etogesic, Fort Dodge) is another useful NSAID for arthritis; therapeutic dose is 10 to 15 mg/kg orally once daily. Adverse effects are uncommon, although GI irritation has been observed. Deracoxib (Deramaxx, Novartis), a recent addition, may be the most specific COX-2 drug available; dosing for chronic osteoarthritis is 1 to 2 mg/kg/day. Early reports indicate a low rate of adverse effects with deracoxib, although GI, renal, and hepatic effects have been observed, as with other medications. Older NSAIDs include phenylbutazone and meclofenamic acid (Arquel, Fort Dodge).

These products may find some use in dogs, but for the most part, they have been replaced by carprofen, etodolac, and deracoxib, which have fewer adverse effects. Corticosteroids hasten degenerative changes in the joint and should be avoided for chronic use in most canine patients.

Hannan and associates[36] have demonstrated a chondroprotective effect by *polysulfated glycosaminoglycan* (Arteparon, Luitpold Werk, Munich, FRG; Adequan, Luitpold Pharmaceutical Inc., Shirley, NY) following experimental meniscectomy. This is also supported by limited clinical experience in treating hip dysplasia. Dosage of 1 mg/kg intramuscularly every 4 days for six doses often produces clinical improvement. This dose is then repeated to effect, usually every 4 to 6 weeks. The drug had previously been approved only for use in horses in the United States, but it now has been approved for use in dogs. In a double-blind study of dogs with advanced hip dysplasia arthritis, however, Adequan did not improve clinical performance compared with placebo.[37]

Oral "disease-modifying osteoarthritis agents" are now widely used for symptomatic treatment in human and veterinary patients. These compounds are not approved by the Food and Drug Administration (FDA) and thus are marketed as "oral nutritional supplements." They have also been described as "chondroprotectants." Combinations of glucosamine and chondroitin sulfate are most often used. *Glucosamine* acts by providing stimulus and raw materials for the synthesis of glycosaminoglycans and also decreases stromelysin in ribonucleic acid (RNA) in chondrocytes.[38] *Chondroitin sulfate* stimulates glycosaminoglycan and proteoglycan synthesis and also competitively inhibits degradative enzymes in cartilage and synovium.[38] A significant antiinflammatory effect by these supplements has been documented in an experimental model of joint inflammation.[39] Numerous formulations are available and are dosed per individual manufacturer instructions.

Surgical Therapy

The veterinary orthopedist is truly in a quandary when trying to decide on a course of treatment for an individual dog when the clinical signs of hip dysplasia develop at an early age. Although the results of triple pelvic osteotomy (TPO) are very encouraging, they must be balanced against the observation that 76% of dogs diagnosed with hip dysplasia at a young age never had serious clinical signs of dysplasia at follow-up 4 1/2 years later.[34] One might ask if these dogs would not develop problems later in life. However, if these figures hold true, only 10% to 17% of the affected puppies really will benefit from TPO or intertrochanteric femoral osteotomy. Conversely, it is impossible to predict how any individual puppy will fare later in life. Thus the decision to pursue early surgical treatment needs to be carefully considered, since the results are predictable. If the animal is destined to be primarily a house or yard pet, a conservative approach is probably rational. If pain becomes a problem, femoral head and neck ostectomy or total hip replacement is an alternative. If the dog is to be a sporting or working "canine athlete," a more aggressive approach should be pursued at an early age, when the chances of success for a reconstructive approach are best.

Surgical therapies can be broken down into two groups: (1) therapies that provide relief from pain and (2) therapies that prevent or lessen the amount of future DJD.

The preventive surgeries are performed on young, large, growing dysplastic dogs. The theory behind these surgeries is to realign the pelvis or femoral head so that the femoral head seats more deeply into the growing acetabulum. This results in better head coverage by the acetabulum, reducing the amount of subluxation present. TPOs, pubic symphysiodesis, and possibly intertrochanteric osteotomies are examples of

the preventive therapies. Pain relief may result from pectineal myectomy, femoral head and neck ostectomy, and total hip arthroplasty.

Pelvic Osteotomy

Pelvic osteotomy is indicated for young dogs with clinical signs of hip dysplasia, as discussed earlier, and who demonstrate signs of instability (laxity, subluxation) of the hip joint. The procedure provides axial rotation of the acetabulum to stabilize the femoral head within the acetabulum in a functional position (Figure 16-10, *A* and *B*). It has been shown to be a clinically effective method of treating dysplasia, especially in young animals.[40-42] Theoretical analysis has suggested that the procedure may reduce the magnitude of forces acting on the femoral head.[43] Force plate analysis has confirmed that weight-bearing forces improve in operated versus nonoperated hips.[44]

Patient Selection. The operation should be done early, most often between 4 and 8 months of age, to take advantage of the remodeling capacity of immature bone and before the articular cartilage is badly damaged. With instability and subluxation over time, the acetabulum becomes filled with new bone that covers the original surface, thus preventing congruency and stability between the femoral head and acetabulum. These changes become increasingly severe by age 10 to 12 months, although age is not the most important criterion for determining success. The primary consideration is the condition of the joint surfaces, that is, the degree of degenerative changes that has occurred. If the acetabulum is filled with bone, if the dorsal acetabular rim (labrum) is lost because of eburnation, or if the cartilage of the femoral head is destroyed, pelvic osteotomy will not result in a successful outcome.[40,41]

Radiographic examination.[45,46] In selecting patients for pelvic osteotomy, standard ventrodorsal and lateral radiographs are taken and analyzed for the pathology previously described (see Figure 16-9, *A* and *B*). Of particular interest is the shape of the dorsal acetabular rim, which will become increasingly cupped or S-curved in its outline. This is probably a result of lack of development caused by pressure from the subluxated femur and abrasion from the femoral head. Osteophytes form first at the joint capsule insertion on the femoral neck and are responsible for the thickened appearance of the neck. Osteophytes on the acetabular rim are signs of advanced degenerative changes. Filling of the acetabulum with new bone is evidenced by a loss of definition of the original deep acetabular outline, replaced by a less well-defined surface that is farther from the medial acetabular cortex than normal. The lateral views are examined closely for signs of loss of cartilage thickness. As the bright white lines of the subchondral bone approach each other without the intervening radiolucent cartilage, they indicate cartilage thinning. Acetabular osteophytes are well defined in this view as a radiographic density dorsal to the acetabulum. The "frog-leg" view is used to determine the depth of the acetabulum. In dorsal recumbency the femurs are abducted 45 degrees, with the femurs perpendicular to the pelvis and spine. This stress forces the femoral head deeply into the acetabulum, and if the head is not deeply seated, it indicates bony filling of the acetabulum or hypertrophy of the round ligament as a result of instability of the femoral head. Abduction of the femurs more than 45 degrees can cause the dorsal acetabular rim to contact the femoral neck, especially in the presence of acetabular osteophytes, and can lever the femoral head ventrolaterally out of the acetabulum.

Additionally, the *dorsal acetabular rim* (DAR) view[46] is helpful in "ruling in" or "ruling out" a given animal for pelvic osteotomy. The animal is placed in sternal recumbency, the hips are flexed, and the stifles are fixed against the body wall with

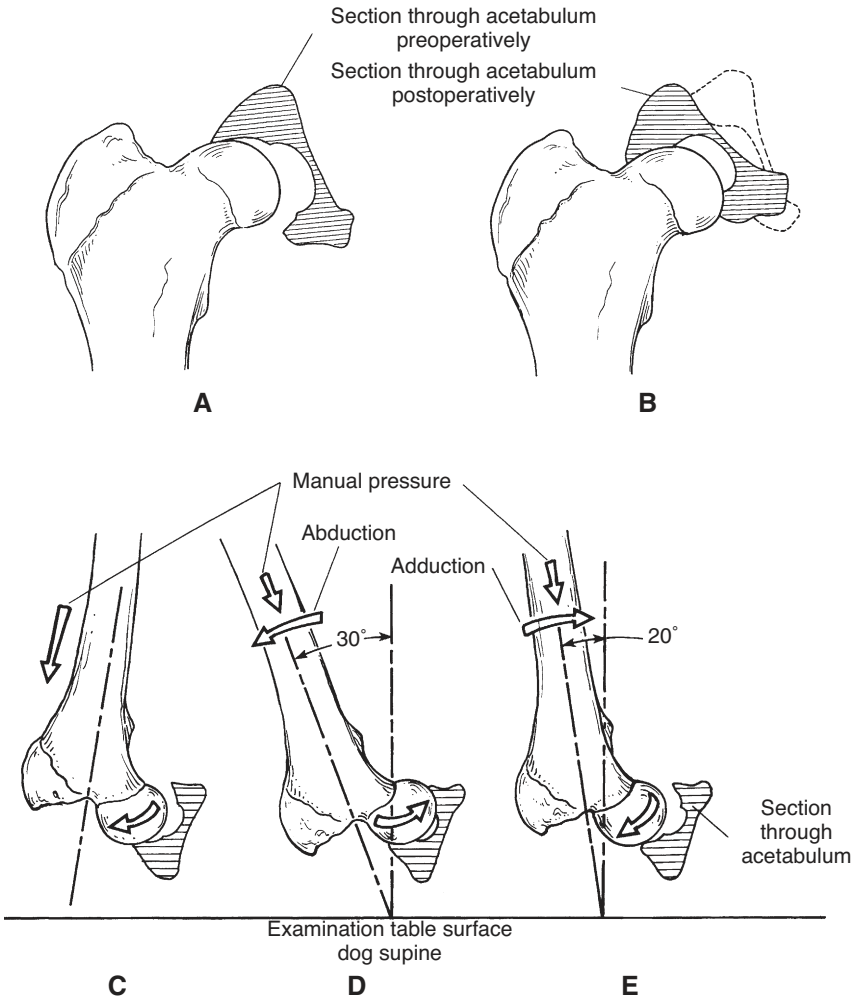


FIGURE 16-10. Triple pelvic osteotomy. **A,** Preoperatively, the femoral head is riding loosely in the acetabulum and contacting only a small area of the dorsal acetabular rim, setting the stage for the structural changes we identify as "hip dysplasia." **B,** After osteotomy, the acetabular portion of the pelvis has been rotated laterally over the femoral head, greatly increasing the contact area between head and acetabulum and thus decreasing local bone and cartilage loads. **C, D,** and **E,** Finding the acetabular rotation angle.[45,46] **C,** With the dog supine, the Ortolani sign (subluxation of the femoral head) is elicited by *adduction* and pressure on the femur directed toward the table. This is most easily done bilaterally, which eliminates the problem of the dog rotating when pressure is applied. **D,** While continuing to apply pressure to the femur, the femur is slowly *abducted.* At some point a distinct click or popping sensation will be felt and perhaps heard as the femur reduces into the acetabulum. In addition, a visible motion will be seen in the inguinal region as the femur returns medially. The angle of the femur relative to the sagittal plane (i.e., the plane 90 degrees to the tabletop) is identified as the "reduction angle" and represents the maximum angle the acetabulum would need to be rotated to stabilize the femur. In this example the angle measured 30 degrees. The optimal angle of rotation is about 5 to 10 degrees less than the angle of reduction. **E,** With the femur in the reduced position, it is slowly *adducted* while maintaining pressure toward the table. Again, a distinct point will be appreciated visually, audibly, and by palpation that represents the femur luxating from the acetabulum. This is measured as in *D* and is called the "angle of luxation," 20 degrees here, and represents the minimum angle of rotation of the acetabulum.

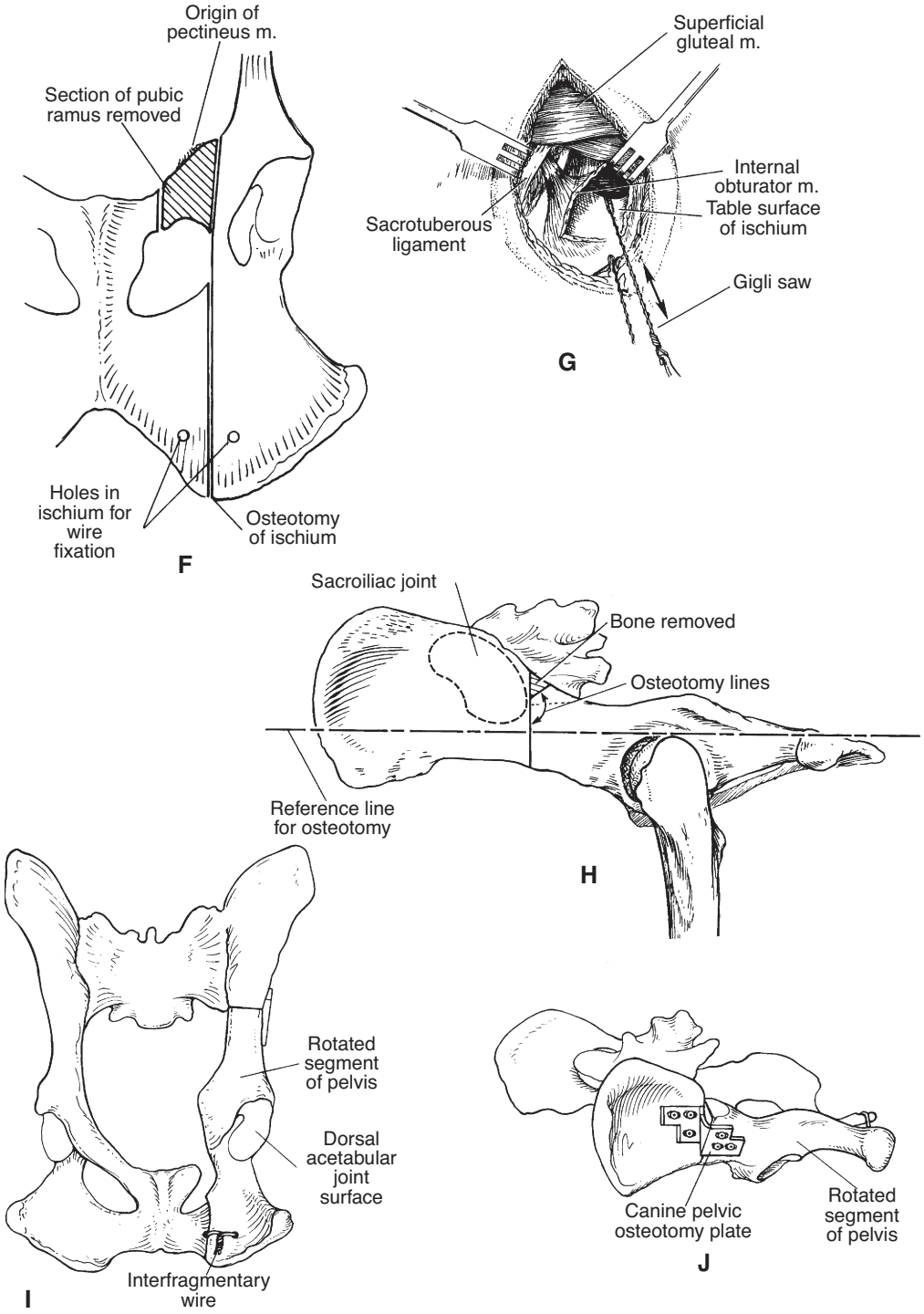


FIGURE 16-10. *Continued* **F** and **G,** Pubic ostectomy and ischial osteotomy. **F,** A section of the pubic ramus is removed through a ventral approach and detachment of the pectineus muscle at its origin (see text). **G,** A caudal approach to the ischium allows elevation of the internal obturator muscle and osteotomy of the ischial table from the lateral border of the obturator foramen caudally on a line parallel to the midline. The results of this osteotomy are seen in *F,* as are the 2-mm drill holes, through which 20- or 18-gauge (0.8- to 1-mm) wire is threaded but not tightened at this time.

Continued

FIGURE 16-10. *Continued* **H,** Osteotomy of the iliac shaft. A horizontal reference line is created by passing a small, blunted Steinmann pin from the dorsal surface of the tuber ischii cranially to a point one-third the distance from the ventral to the cranial dorsal iliac spines. The transverse osteotomy is 90 degrees to the horizontal line and at the caudal aspect of the sacroiliac joint. The sciatic nerve must be protected when the osteotomy is made (see text). A triangular piece of bone will be removed dorsally after the plate is attached. **I** and **J,** The completed triple pelvic osteotomy procedure. The iliac osteotomy is stabilized with a Canine Pelvic Osteotomy Plate (Slocum Enterprises, Eugene, Ore) and the ischial osteotomy with a twisted interfragmentary wire. A standard 2.7- or 3.5-mm plate can be twisted to provide a similar effect. Note how the rotated acetabular segment would provide greater dorsal coverage for the femoral head.

tape or a strap. When the tuber calci are elevated 2 to 4 inches (5-10 cm), depending on body size, above the tabletop, the pelvis is vertical to the table, and the x-ray beam can be directed through the long axis of the pelvis. The acetabuli can then be seen in cross section in the frontal plane (see Figure 16-9, *C*). A line is drawn tangentially to the curvature of the dorsal aspect of the acetabular surface where it contacts the femoral head. The angle formed by this line can be measured against a reference line drawn between the dorsal acetabular rims or against a vertical line drawn in the sagittal plane. Normal dogs will have a summed angle of 15 degrees from horizontal (165 degrees from vertical) or less; 15 to 20 degrees is suspicious of hip dysplasia, and animals with greater than 20 degrees will have the other signs of dysplasia previously mentioned.[45,46] The normal acetabular rim is quite sharp, and wearing of the rim is evidenced by rounding and loss of definition and sclerosis. Most of the information gained from the DAR view can be inferred from the other radiographs and palpation, but the DAR is useful in documenting the acetabular changes.

Palpation. Equally as important as the radiographs is palpation of the hips with the dog anesthetized or deeply sedated. The objective is to assess passive laxity (subluxation) of the hip both quantitatively and qualitatively. The *trochanteric compression test* is done with the dog on its side while moderate pressure is applied to the greater trochanter. If chronically subluxated, the hip will be reduced by this pressure, and the change in position of the trochanter will be sensed.

With practice the examiner can recognize breakdown of the dorsal acetabular rim and the condition of the cartilage of the femoral head by the character of the "click" evidenced during testing for the *Ortolani sign*. The sign of Ortolani is elicited with the dog on its back, with the femur held vertically and the stifle flexed (Figure 16-10, *C*, *D*, and *E*). The femurs are grasped distally, and gentle pressure is applied proximally (toward the pelvis), causing the femoral head to subluxate and rest on the dorsal acetabular rim because of capsular laxity. This movement may or may not be appreciated at this time; it will be more evident later in the test. As the femur is abducted with the pressure maintained, a distinct "click" or "clunk" is heard and felt when the femoral head reduces. The angle of the femur from vertical at this point is the *angle of reduction*. Reversing the procedure by adducting the femur results in another, softer "click" when the head subluxates from the acetabulum, and the angle of the femur from vertical at this point is the *angle of subluxation*. If the articular cartilage is undamaged, these clicks will be appreciated as abrupt motions of the femoral head with a smooth and crisp feeling. The sensation of the reduction phase produces a solid-feeling "clunk." The subluxation phase is less dramatic. Wearing of the cartilage of the femoral head and acetabular rim causes a muffling of the sounds and

a less crisp, to a grating, fibrillated, or crepitant feeling as the femoral head glides over the acetabular rim. The reduction motion, particularly, is less abrupt and crisp when the dorsal rim is lost and the acetabulum becomes shallow as a result of filling with new bone.

The angle of reduction (AR) increases as capsular laxity increases, and the angle of subluxation (AS) increases as the acetabular rim is lost due to wear.[45] As the capsule becomes thickened due to fibrosis and the acetabulum fills with bone, the angles approach each other in value, and the Ortolani sign cannot be elicited because the femoral head is permanently subluxated and supported mainly by the capsule. The femoral head cannot be reduced because there is no functional acetabulum. This is typical of the mature dog with hip dysplasia. Occasionally, young dogs will show a positive AR (e.g., 15 degrees, with an AS of 0 degrees). This may represent a situation of passive laxity without functional laxity, and although in the absence of clinical signs it does not require pelvic osteotomy, this situation does merit monitoring for future degenerative changes. Although passive hip joint laxity is closely associated with development of DJD,[31] considerable difference apparently exists between breeds regarding this correlation.[47]

The *ideal candidate for pelvic osteotomy* would be 5 to 7 months of age with clinical signs of hip dysplasia and would show minimal or no signs of degenerative changes radiographically and on palpation. The trochanteric compression test would be negative, and the summed DAR angles would be 20 degrees or less. The AR would be 30 degrees or less and the AS 10 degrees or less, indicating an acetabulum without filling and with an intact dorsal acetabular rim. As the AR increases above 30 degrees and the AS above 10 degrees, the prognosis declines because of the preexisting changes in the acetabulum. An AR/AS reading of 45/20 degrees is the highest value to rate a good prognosis with pelvic osteotomy.[45]

Contraindications. Pelvic osteotomy is contraindicated when there are radiographic or palpable signs of advanced DJD, breakdown of the dorsal acetabular rim, shallow acetabulum, or neurological disease.

Surgical Technique. The TPO technique of Slocum and Devine has proved most dependable in our hands.[40,41,45] The AR represents the probable maximum angle the acetabulum needs to be rotated to achieve stability, whereas the AS represents the minimal angle of rotation of the acetabulum that will produce instability of the hip. These two angles are used to select the appropriate implant for axial rotation of the acetabular segment of the pelvis.[41] To prevent overrotation of the pelvis and subsequent impingement of the dorsal acetabular rim on the femoral neck and excessive narrowing of the pelvic canal, the angle selected should usually be closer to the AS than to the AR and should not exceed 45 degrees. In an in vitro study using computed tomography (CT), Dejardin and colleagues[48] reported the effect of axial rotation of the acetabular segment on contact area and articular coverage in the hip joint. Contact area within the dysplastic hip joint increased from 0 to 30 degrees of acetabular ventroversion, and articular coverage increased from 0 to 20 degrees of acetabular ventroversion. This study supports that the angle of rotation selected for TPO should be at the lower end of the range.

Slocum has devised a bone plate for this procedure, the Canine Pelvic Osteotomy Plate (CPOP, Slocum Enterprises, Eugene, Ore), using 3.5-mm screws. The CPOP is made in three angles of rotation: a 20-degree plate with a fixed angle, a 30-degree plate that can be twisted to angles between 20 and 40 degrees, and a 45-degree plate that can be molded between 35 and 60 degrees. In practice it is rarely necessary to rotate the acetabulum more than 30 degrees, since further rotation usually causes

difficulty in abduction as the femoral neck impinges on the dorsal acetabular rim. It is our practice to limit the rotation to 30 degrees and supplement this with femoral neck lengthening (see later) when the Ortolani sign is not abolished by 30 degrees of rotation. The CPOP device has proved most satisfactory and easy to use and is our method of choice (Figure 16-10, *I* and *J*). It is superior to a twisted, conventional bone plate because it provides eight potential points of fixation (six screws, two cerclage wires) and thus minimizes fixation failure. It also lateralizes the acetabular portion of the pelvis and thus widens the pelvic canal. A standard five-hole to seven-hole, 2.7-mm or 3.5-mm straight plate can be used by twisting the plate in its midsection. However, studies have confirmed the advantages of the CPOP in providing superior dorsal acetabular coverage and minimal disruption of normal pelvic architecture compared with twisted plates.[49,50]

The procedure is performed in three stages. The limb is prepared and free-draped so as to allow access to both the inguinal and the lateral aspect of the pelvis. With the animal in dorsal recumbency and the limb held in a vertical position, the pubic ramus is exposed through a ventral approach[5] (Figure 16-10, *F*). The pectineus muscle is severed close to its origin on the iliopectineal eminence and the prepubic tendon. The muscle belly is allowed to retract and is not sutured. Elevation of the gracilis muscle caudally and the abdominal muscles and prepubic tendon cranially exposes the pubic ramus. Most of the ramus is removed after two cuts in the bone, one near the medial limit of the obturator foramen and the other at the junction of the pubis with the ilium, medial to the iliopubic eminence. It is important to make this cut as close as possible to the body of the ilium to minimize the length of the bone spike that will be turned into the pelvic canal.[51] The obturator nerve must be protected during this cut because it lies very near the caudal limit of the cut. The abdominal muscles and prepubic tendon are sutured to the cranial border of the gracilis muscle, and the rest of the tissues are sutured in layers.

The dog is returned to lateral recumbency, and a second incision is made over the medial angle of the ischiatic tuberosity. After elevation of the internal obturator dorsally and the semimembranosus and quadratus muscles ventrally, the ischiatic table is osteotomized in a paramedian plane, beginning cranially at the lateral aspect of the obturator foramen (Figure 16-10, *F* and *G*). This can be done with a Gigli wire saw, a hand saw, or a power saw, but not with an osteotome, because there is a good chance of cutting into the ramus of the ischium. Drill holes are placed 5 mm from the cut edges, and a 1-mm (18-gauge) wire is threaded through the holes but not tightened.

Next, a lateral approach is made to the shaft of the ilium,[5] and the gluteal muscles are elevated from the body and ventral wing of the ilium. Taking care to protect the cranial gluteal, obturator, and sciatic nerves, all muscles are elevated from the iliac shaft ventrally, medially, and dorsally. An iliac osteotomy is performed just caudal to the sacrum (Figure 16-10, *H*). The cut is made perpendicular in both planes to a line between the dorsal side of the ischiatic tuberosity and the ventral third of the iliac crest. This line is established by inserting a small Steinmann pin from the dorsal surface of the tuber ischium cranially toward the cranial ventral iliac spine, where it is positioned by palpation one third of the distance between the ventral and dorsal iliac spines. The pin can then be used to establish the proper angle for the iliac osteotomy. The object of this exercise is to make the osteotomy perpendicular to the axis of rotation of the acetabular portion rather than perpendicular to the long axis of the ilium. The resulting angle of the osteotomy is approximately 20 degrees to the long axis of the ilium and allows for optimal contact of the bone surfaces, while minimizing the decrease of pelvic inlet area and increasing the interischiatic tuberosity distance and acetabular version.[49]

After this osteotomy, the acetabular segment is moved cranially and laterally with bone-holding forceps, and the sharp spike of ilium dorsal to the plate is removed to prevent irritation of the gluteal muscles. The plate is now attached to the caudal segment with 3.5-mm screws. If the CPOP is used, at least one of these screws is placed in the load position to compress the angular step against the bone. The acetabular segment is rotated laterally and the plate temporarily clamped cranially to the cranial iliac segment. The hip should now be stable with no Ortolani sign; if not, the plate is removed and twisted more or replaced with another plate of increased angle. If the Ortolani sign is eliminated but there is still lateral translational movement of the femoral head of more than a few millimeters, transposition of the greater trochanter (see Figure 16-5, *D*) can be used to augment the stability of the femoral head.[42] Another alternative in this situation is femoral neck lengthening, as described later. Neck lengthening is the equivalent of adding 10 degrees of acetabular rotation.[45] Even without either of these ancillary procedures, most hips will stabilize within a few weeks because of the basic stability afforded by the pelvic osteotomy, and definitive guidelines for these procedures await longer term experience. After the proper angle is found for the acetabular segment, the ischial wire is tightened, and the plate is then fixed to the cranial iliac segment (Figure 16-10, *I* and *J*). In very young dogs, the screw fixation can be supplemented with a hemicerclage wire through holes in each end of the CPOP. The triangular bone fragment from the ilium or the pubic ramus fragment can be cut into small fragments and used as bone graft in the osteotomy site to hasten healing. Both surgery sites are closed routinely by layers.

Aftercare. Postoperatively, the dog is confined to the house or leash exercise for 4 to 6 weeks, at which time the opposite side undergoes surgery if indicated. In severely dysplastic, 4- to 7-month-old puppies, the opposite side should be repaired in 2 to 3 weeks because the bony structures and joint cartilage are remodeling rapidly.

Prognosis. Slocum and Devine[41] reported on follow-up evaluation of 138 dogs that underwent TPO. Of these dogs, 122 had hip dysplasia: 30% had grade 4 dysplasia, 33% grade 3, and 34% grade 2. Regarding age at surgery, 13% were less than 6 months; 47% were 6 to 12 months; 22.5% were 1 to 2 years; and 17% were more than 2 years. At postoperative evaluation, 86.2% were fully active with normal weight bearing and activity. In another study, 92% of operated limbs showed remission of lameness at 28 weeks postoperatively, and progression of detectable DJD was minimal, despite gross and microscopic degenerative changes being similar in treated and untreated hips.[44] In another long-term prospective study, 40% of dogs that had TPO developed progression of DJD, and 76% had good or excellent at-home activity scores.[52] Preoperative DJD and long-standing DJD were not associated in this study; however, the risk of DJD was increased with age at surgery. A dog that had TPO surgery at age 12 months was seven times as likely to have DJD compared to a dog that had surgery at age 6 months.[52]

Femoral Neck Lengthening

In addition to the mechanical stability afforded the femoral head by a deep acetabulum with a normal dorsal acetabular slope, a dynamic component of hip stability is caused by muscular forces, primarily the internal and external rotator muscles. These muscles all insert on the greater trochanter; therefore, increasing the length of the femoral neck increases the lever arm over which these muscles operate, and thus increases the medially directed force they apply to the femur.

Indications. Femoral neck lengthening has been proposed as primary treatment for dysplastic dogs that have adequate dorsal acetabular coverage, but whose hips are unstable because of insufficient muscular force to prevent the hip from subluxating.[53] These dogs typically have a short femoral neck, and some breeds (e.g., chow chow, Akita) are prone to this problem. Suitable candidates for primary neck lengthening should have an AS of 0 degrees or less and a normal dorsal acetabular rim angle.[54] The second indication for neck lengthening is mentioned earlier with TPO. If the acetabular rotation angle needed to obliterate the Ortolani sign (approximately equal to the AR) exceeds 30 degrees, it is probably better to add neck lengthening rather than exceed 30 degrees of rotation, since doing so creates problems with abduction of the hip. Neck lengthening has the same stabilizing effect as 10 degrees of acetabular rotation.[45]

Surgical Technique. The proximal femur is approached by detaching the vastus lateralis muscle from its origin on the proximocranial aspect of the femoral neck and shaft.[5] A parasagittal osteotomy is made in the proximal femur, starting at the junction of the greater trochanter and the femoral neck and ending distally at the lateral cortex 1 to 2 cm distal to the lesser trochanter (Figure 16-11, *A* and *B*). Before the osteotomy is made, a 2-mm hole is drilled at the distal end of the intended osteotomy, and the osteotomy ends at this hole. The purpose of the hole is to prevent cracks from propagating beyond this point when the trochanter is forced laterally. A 3.5-mm cortical-thread lag screw is placed transversely just distal to this hole as additional insurance against cracking the lateral cortex.

A second 3.5-mm cortical screw (typically about 35 mm long) is placed in the greater trochanter, threaded only in the first cortex. The tap hole is drilled only to the depth of the osteotomy. As the screw is tightened, the tip of the screw contacts the trabecular bone of the femoral neck, and as tightening of the screw continues, the trochanter is distracted laterally. This distraction is slowly continued until the

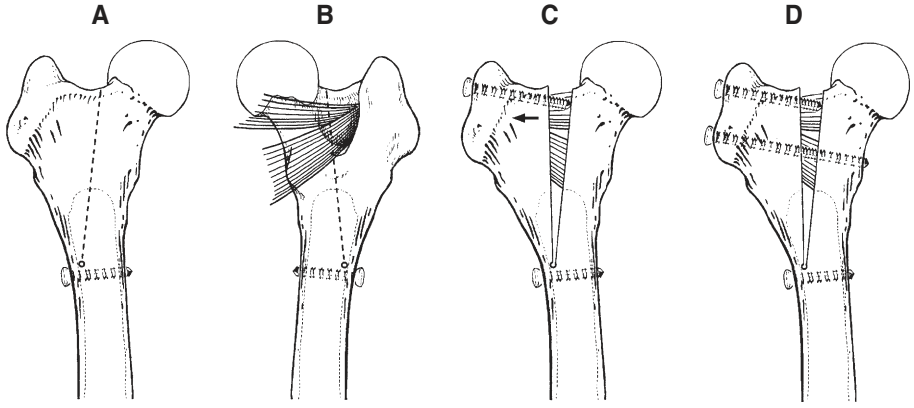


FIGURE 16-11. Femoral neck lengthening. **A,** Cranial view of the femoral head and neck region showing the line of osteotomy. A 2-mm drill hole at the end of the osteotomy and a positional screw are placed to prevent distal fissuring of the bone. **B,** Caudal view to show the osteotomy deep and medial to the insertions of the obturator-gemellus muscles on the greater trochanter. **C,** A 3.5-mm screw is inserted to the osteotomy line after drilling and tapping only the lateral cortex. As the screw is tightened, the tip of the screw bears against the bone of the femoral neck, and the trochanter is distracted laterally along the screw threads. Distraction is continued until lateral translational motion of the femoral head is abolished. ***D,*** A positional screw, threaded in both cortices, is placed distal to the distraction screw to maintain the lateralized position of the trochanter.

lateral translational laxity of the femoral head is abolished (Figure 16-11, *C*). At this point, a third 3.5-mm cortical screw is placed 1 cm distal to the distracting screw (Figure 16-11, *D*) and is threaded in both cortices (positional screw). If the distracting screw protrudes lateral to the trochanter, it is replaced with a shorter screw. The origin of the vastus lateralis muscle is sutured to the cranial border of the deep gluteal muscle.

Aftercare. Postoperatively, the dog is confined to the house or leash exercise for 4 to 6 weeks. The opposite side undergoes femoral neck lengthening after 3 or 4 weeks if indicated.

Pubic Symphysiodesis

Induced pubic bone growth arrest has been shown to result in beneficial acetabular rotation in experimental animals and puppies with hip dysplasia.[55-57] This new and simple technique has potential use in some dysplastic puppies. Clinical trials are underway that will help define the limits of pubic symphysiodesis, but early results are encouraging. Pubic bone physeal closure is induced either with a simple stapling technique[56] or an electrocautery technique.[57] Premature pubic physeal closure results in clinically insignificant (24%) reduction of pelvic inlet area, but it also causes a 40% and 46% improvement in acetabular angle and dorsal acetabular rim angle, respectively, compared with control dysplastic puppies.[57] A successful case has pelvic rotation and conformation similar to that seen with a healed bilateral TPO. The improvement that can be expected in pubic symphysiodesis is age related, with best acetabular results if symphysiodesis is performed at 12 to 16 weeks of age. If pubic physeal closure is completed at an older age, up to 24 weeks, acetabular rotation develops, but to a lesser degree that may not be beneficial for the dog.

This technique is dramatically simpler and less invasive than pelvic osteotomy. A practical concern will be that most dogs with hip dysplasia present for diagnosis and treatment at a later age than would be suitable for symphysiodesis. Combined with client education and early screening techniques, pubic symphysiodesis may find a useful niche for the treatment of hip dysplasia. Selection of cases will remain controversial until more clinical trials are completed.

Surgical Technique. Anesthesia is achieved, and the dog is positioned in dorsal recumbency. A 2- to 3-cm ventral approach is made to the cranial aspect of the pelvic symphysis. The skin, subcutaneous tissue, rectus abdominis muscle, adductor muscle, and aponeurosis of the gracilis muscle are incised and minimally reflected from the midline to expose the pubic portion of the pelvic symphysis.[5] Insertion of the rectus abdominis may be released from the pelvic brim, which allows the surgeon to insert a finger dorsal to the pubis to deflect the rectum and urethra and to judge the depth of cauterization (Figure 16-12). Standard electrocautery is used to induce closure of the pubic symphysis. A unipolar spatula or needle-tip electrode may be used to apply cautery at approximately 2-mm intervals. A 30-W coagulation setting is delivered for about 10 seconds at each site to a depth of approximately 6 mm.[57] The surgeon's finger in the pelvic canal judges depth of penetration and monitors heat generation. Fascial and skin layers are closed with standard technique.

Aftercare. Minimal analgesic is required, and the dog may be discharged the day of surgery. Exercise should be moderate for 2 to 3 months after surgery while bony and articular structures are remodeling.



FIGURE 16-12. Juvenile pubic symphysiodesis. Induced pubic bone growth arrest has been demonstrated to cause beneficial acetabular rotation in experimental animals and puppies with hip dysplasia. **A,** Standard electrocautery is used to induce closure of the pubic symphysis. **B,** A unipolar spatula or needle-tip electrode may be used to apply cauterization to the pubic symphysis at approximately 2-mm intervals. (Photos courtesy Dr. Loic Dejardin.)

Intertrochanteric Varus Osteotomy of Femur

The true angle of inclination of the canine femoral neck in relation to the diaphysis is about 146 degrees.[58] In animals with hip dysplasia, this angle increases as much as 30 to 35 degrees, leading to the condition known as *coxa valga* (Figure 16-13, *C*). This is caused by subluxation of the hip joint and subsequent lack of normal stress on the femoral neck, which is necessary for development of the normal angle. This valgus angle of the head and neck contributes to further subluxation and instability, perpetuating a vicious cycle. Additionally, the femoral neck inclines farther cranially (anteversion) from the normal angle of about 27 degrees and again contributes to subluxation and instability.[5]

The principle of varus derotational osteotomy for treatment of congenital hip luxation and instability is well established in humans and in the dog.[59,60] By making the femoral neck more perpendicular to the femoral shaft *(varisation)* and reducing anteversion, the femoral head can be placed more deeply within the acetabulum, and forces acting on any given area of the bone and cartilage of the acetabulum and femoral head can be reduced by distributing weight-bearing loads through greater congruency over a greater percentage of the articular cartilage. When the osteotomy is done in an immature animal with a high potential for bony remodeling, there can be permanent improvement in joint congruity. In the mature animal with DJD and instability, pain may be relieved by reducing forces on the acetabulum and femoral head and redistributing weight-bearing forces more uniformly over the diseased cartilage.

The purpose of intertrochanteric osteotomy is to improve the biomechanics of the hip and to reduce hip pain.[59] It is more effective when done before DJD is present, between the ages of 4 and 10 months in most patients. Patient selection is identical to that for TPO, with careful radiographic evaluation and palpation of the joints to aid in evaluating the condition of the joint surfaces. Contraindications include DJD that is radiographically obvious, shallow acetabulum, and loss of the dorsal acetabular rim. Because the amount of increased dorsal acetabular coverage does not seem to be as great as with TPO, we reserve intertrochanteric osteotomy for less severe cases.

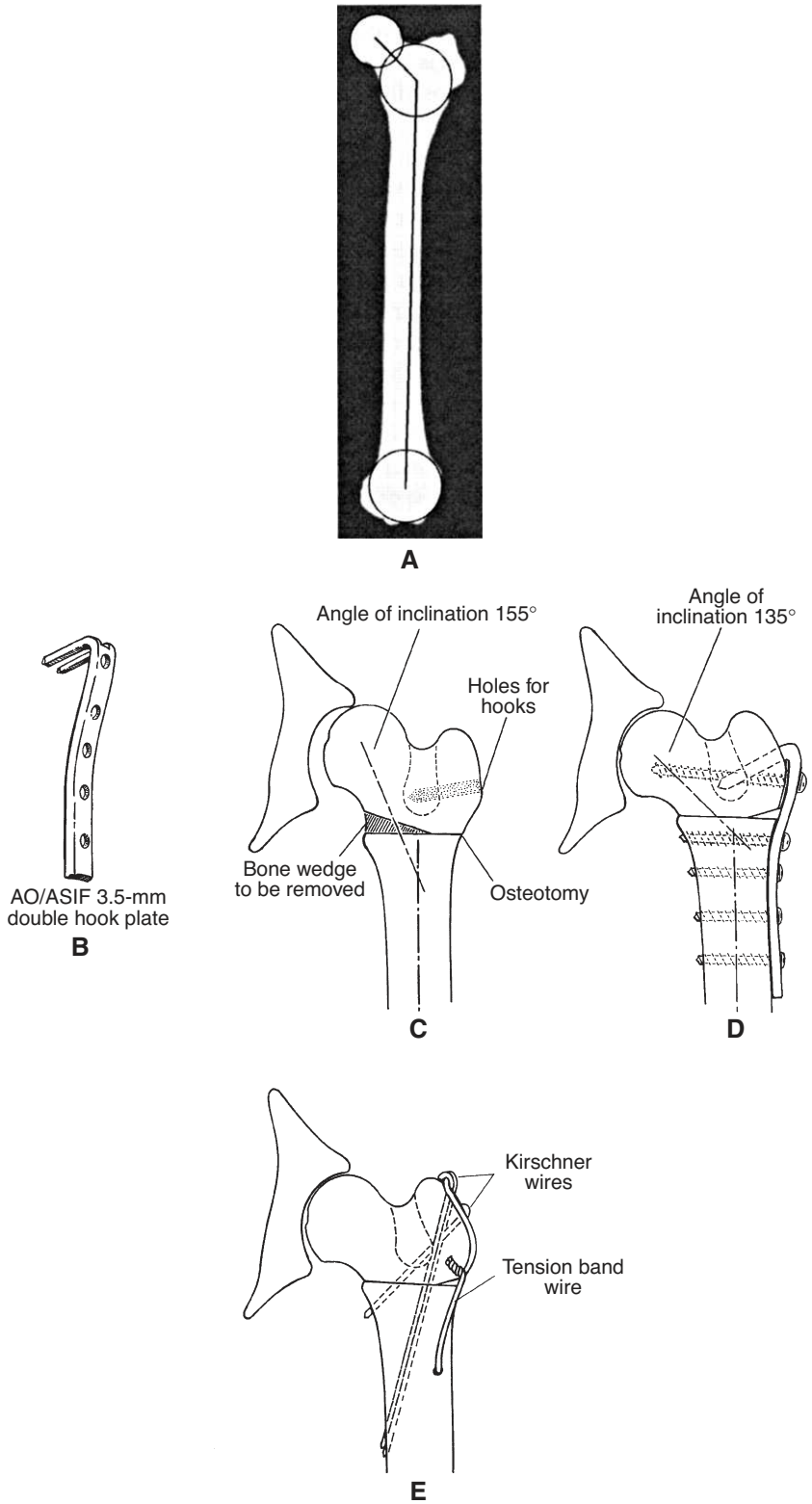


FIGURE 16-13. **A,** Finding angle of inclination of the femoral neck by the symmetric axis-based method.[61] Tracings are made from the ventrodorsal pelvic radiograph, with the hips extended, femurs parallel to the cassette, and the patellae centered (see Figure 16-9, *A*).

Continued

FIGURE 16-13, *Continued* Best-fit circles are superimposed on the femoral head, the femoral neck–trochanter region, and the femoral condyles. Connecting the center points of the circles provides the angle of inclination. **B, C,** and **D,** Intertrochanteric varus osteotomy using AO/ASIF 3.5-mm double hook plates (Synthes, Ltd., Paoli, Pa). (See text for details.) **B,** The hooks on the proximal end of the plate are placed in holes in the trochanter major. **C,** Instability of the hip joint is created by the valgus angle of inclination of the femoral neck. Removal of the wedge of bone will create a slightly varus 135-degree angle and restore stability. **D,** The bone wedge has been removed and the intertrochanteric osteotomy fixed with the double hook plate. Note the improved congruity of the joint surfaces, and compare with Figure 16-10, *B*. **E,** In dogs too small for the double hook plate, a multiple pin and tension band wire fixation technique can be used.

Preoperative Planning. Extensive planning is necessary to establish the proper angles for osteotomizing the femoral neck in order to end with an inclination angle of 135 degrees.[59] This is about 10 degrees less than normal, thus a varus position, because in this position the femoral head is more deeply placed within the acetabulum and therefore is more stable (Figure 16-13, *D*). It is first necessary to establish the angle of inclination of the femoral head and neck. A well-positioned radiograph is needed (see Figure 16-9, *A*). It is particularly necessary that the patella be well centered on the femoral condyle and that the femur be as parallel to the x-ray cassette as possible; this may require general anesthesia because the hip is often painful in extension. Tracing paper can then be used to produce a drawing similar to Figure 16-13, *A*.[61] Best-fit circles are superimposed on the femoral head, the femoral neck and trochanter, and the femoral condyles. The centers of these circles are connected, and the angle formed by the femoral neck and femoral midlines is the *angle of inclination of the femoral head and neck*.

The apparent angle of inclination is influenced by the degree of anteversion; increasing anteversion increases the projected angle of inclination seen in the radiograph. Measurement of anteversion can be performed, but it is not essential to do so. If anteversion is normal, the lesser trochanter will protrude only slightly beyond the medial cortex if the patella is centered on the femoral condyle. If the lesser trochanter is prominent, it can be assumed that anteversion is increased and that the measured angle is larger than the true angle. Experience has shown that reducing the measured angle by 5 degrees is satisfactory for planning purposes. Surgical reduction of anteversion does not depend on measurements because the angle can only be estimated intraoperatively.

Planning continues by drawing a line transversely across the femur from a point just proximal to the lesser trochanter (Figure 16-13, *C*). This represents the first osteotomy of the femur. The angle of the wedge of bone to be removed is determined by subtracting 135 from the final determined angle of inclination. Using a protractor, this angle is drawn so that the wide end of the wedge is medial and the proximal line intersects the medial cortex just distal to the femoral neck. A new drawing can now be made by tracing the femoral head with the bone wedge removed and placing it on the femoral shaft in its final position (Figure 16-13, *D*). The bone plate, or a tracing of it, can be superimposed on the final drawing to determine the position of the holes for the hooks. This is transferred back to the original drawing to indicate the position of the holes in the proximal segment before the first osteotomy.

Surgical Technique. Special AO/ASIF 3.5-mm hook plates (Figure 16-13, *B*), drill jigs, and cutting jigs are available from Synthes, and the technique of using

them has been described.[59,62,63] Application of this hook plate for other osteotomies and certain fractures has also been reported.[64] In principle, an intertrochanteric osteotomy is performed, a wedge of bone is removed from the medial side of the base of the femoral neck, and the hook plate is used to create rigid internal fixation of the osteotomy (Figure 16-13, *D*). The femoral head is also rotated caudally (retroverted) until the anteversion angle is about 5 to 10 degrees in relation to the femoral shaft.

Although the double hook plate and its accompanying instrumentation represent an elegant and precise method of accomplishing this osteotomy, the plate is too large for use on most dogs weighing less than 20 kg. Multiple pin and tension band wire fixation is a satisfactory method in these animals (Figure 16-13, *E*). Preoperative planning is similar to that previously explained, and the AO/ASIF jigs can be used to assist in the osteotomies, although with some practice they can be done "freehand" with good accuracy.

Aftercare. Postsurgical care is uncomplicated and consists primarily of restricted exercise for 3 to 4 weeks, followed by a slow return to normal exercise by 6 weeks. The opposite hip can be surgically repaired as early as 3 weeks postoperatively if indicated.

Prognosis. Walker and Prieur[59] reported on 183 dogs with hip dysplasia that received intertrochanteric femoral osteotomies. At follow-up 1 to 7 years postoperatively, 89.6% of these dogs had good to excellent function. Most animals had only one hip repaired. Those animals operated on before DJD was present did better than those in which the disease was established at surgery. Other clinical studies report contradictory information. In one study, 82% of dogs were functionally good or normal at an average 15 months' follow-up, although DJD had progressed radiographically.[60] Evers and colleagues[65] reported that a comparison of physical examination results between preoperative examination and up to 4 years after surgery did not show significant improvement. The selection of intertrochanteric osteotomy is now less common than TPO because of its equivocal success.

Total Hip Replacement

Total hip replacement (THR) consists of implanting a high-density polyethylene acetabular cup and stainless steel or titanium femoral head and femoral stem component. The implantation is preceded by removing the femoral head and neck and preparing the acetabulum by reaming and the femoral medullary canal to accept the implants. These prostheses are usually permanently bonded to bone by polymethyl methacrylate bone cement (Figure 16-14), although cementless prostheses have received limited clinical application in dogs. Various sizes of prostheses are available, allowing replacement in most dogs weighing more than 18 kg (40 pounds). The procedure should not be done before the physes are closed. Thus, most large breeds cannot undergo surgery before 12 to 14 months of age, but there are no specific upper age limits. The Richards Canine II prosthesis (Richards Manufacturing Co., Memphis, Tenn) has been replaced in our hands by the Modular Canine Total Hip Replacement System (BioMedtrix, Allendale, NJ). The latter system is more versatile because of the increased choice of sizes of the acetabular, femoral head, and femoral stem components. Specialized instruments necessary for implantation are available for both systems.

Indications. In addition to hip dysplasia, THR can be used in dogs larger than 18 kg to replace hip joints damaged by DJD from causes other than hip dysplasia;

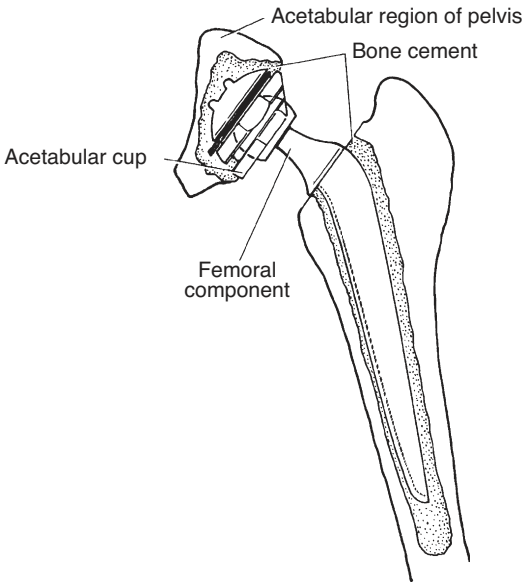


FIGURE 16-14. The Richards Canine II Total Hip Replacement (Richards Manufacturing Co., Memphis, Tenn). Polymethyl methacrylate bone cement anchors the high-density polyethylene acetabular cup to the pelvis and the cobalt-chrome alloy femoral component to the femur.

nonunion or malunion of femoral head, neck, or acetabular fractures; traumatic hip luxation; or avascular necrosis of the femoral head. Chronically luxated hips should be approached with caution; they can be very difficult to reduce after implantation of the prostheses because of chronic contracture of the gluteal and external rotator muscles and scar tissue adhesion of the displacement.

Contraindications. Not every dog with hip dysplasia is a candidate for THR because not all dysplastic dogs show clinical signs. Such animals should be periodically reevaluated for deterioration of their condition. Extreme wearing of the dorsal acetabular rim is seen occasionally in older dogs and makes good seating of the acetabular component difficult; the result is eventual loosening of the cup. It is often suggested that THR might be done in dogs with unsatisfactory function after femoral head and neck excision (discussed later). The bone remodeling that follows excision arthroplasty makes THR extremely difficult to do in this situation and is not recommended. Neurological causes of abnormal gait must be carefully eliminated as a cause of the dog's problems. Degenerative myelopathy is the most common problem in these patients, but ruptured intervertebral disk, spinal or nerve root tumor, and cauda equina disease are other possibilities. When hindlimb lameness suddenly worsens in a known dysplastic dog, there is a strong tendency to blame it on the dysplasia, but rupture of the cranial cruciate ligament is a much more common cause. Any infectious process, such as dermatitis, otitis, anal sac disease, dental disease, cystitis, or prostatitis, must be successfully treated before THR to prevent contamination of the surgical site.

Surgical Technique. The THR technique most widely used in North America was perfected by Olmstead and Hohn.[66,67] The original techniques have been slightly modified to utilize the BioMedtrix modular prosthesis.[68] The operation is technically demanding and unforgiving of errors in technique. Adequate instrumentation and assistance must be available to the surgeon to allow the procedure to be completed within 2 hours, or the infection rate will be unacceptable. Special training should be obtained before attempting this operation, such as mentoring from a

surgeon familiar with the technique or enrolling in specific short courses.* The following description is intended only to familiarize the reader with the surgical technique in a general manner (Figure 16-15).

The most aseptic precautions, with careful preparation of the patient and surgeons, draping, and speed of surgery are necessary to minimize complications of infection. Intraoperative and postoperative cephalosporin-type antibiotics are used routinely as an adjunct to good aseptic technique. A craniolateral approach[5] is made, and the femoral head is ostectomized, leaving most of the ventral portion of the neck intact (Figure 16-15, *A*). Templates or the femoral prosthesis are positioned over the bone

*Total hip replacement workshop, Division of Continuing Education, College of Veterinary Medicine, Ohio State University, Columbus.

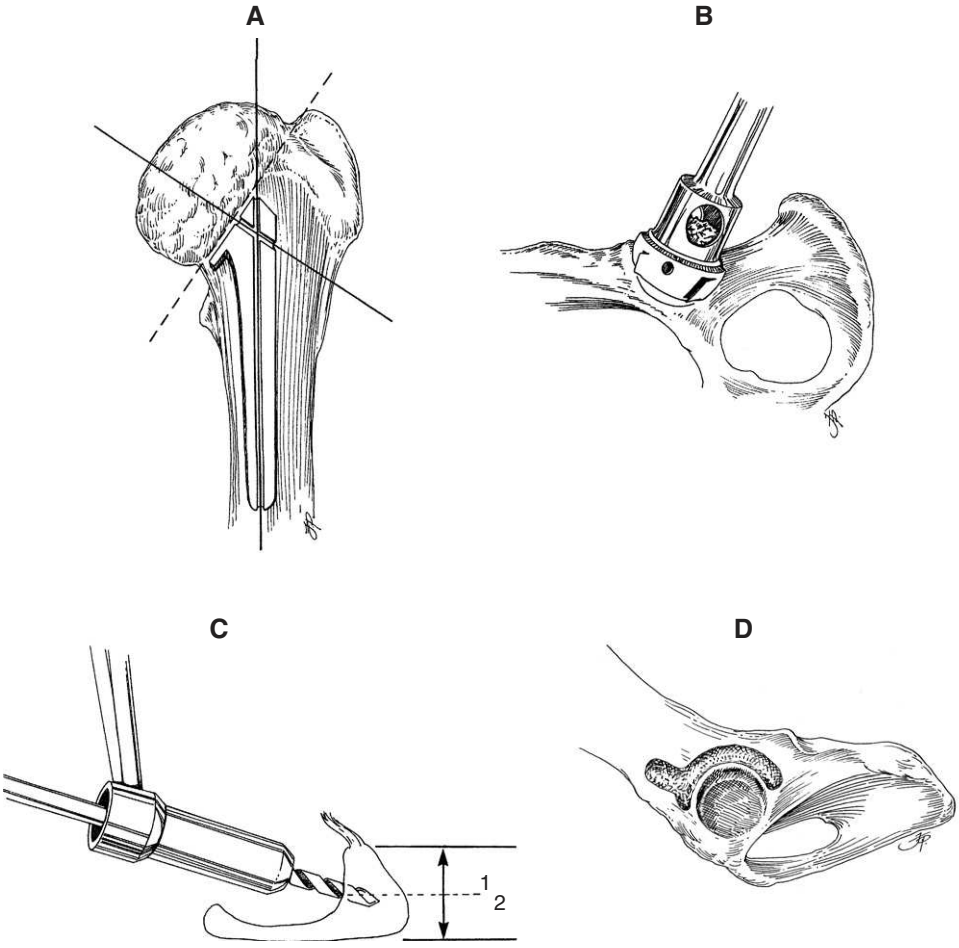


FIGURE 16-15. Basic steps in total hip replacement using a modular cemented prosthesis. These steps are for orientation only and do not represent a detailed description of the surgery. **A,** Resection of the femoral head using a template that is aligned with the axis of the shaft and of the head and neck. **B,** An acetabular reamer is used to enlarge and deepen the acetabulum to receive the acetabular cup. **C** and **D,** Three or four holes are drilled around the craniodorsal acetabular bed to allow better penetration of bone cement. Attention to placement of the drill between the deep acetabular cortex and the acetabular rim is needed to prevent penetration of cortical bone. These holes are connected by curetting the exposed cancellous bone.

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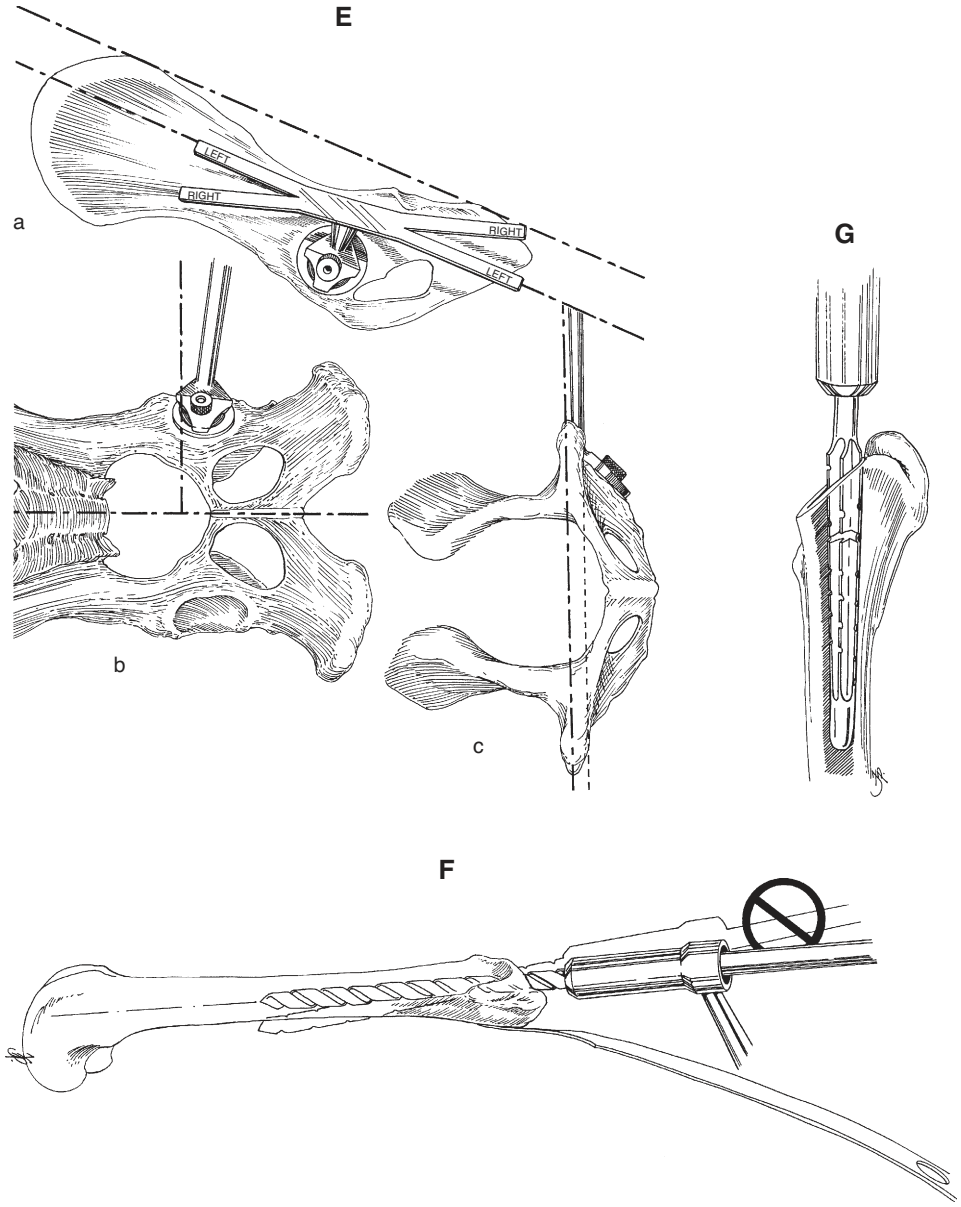


FIGURE 16-15. *Continued* **E,** The acetabular cup is cemented with the aid of a positioner that allows proper orientation of the cup. *(a)* Lateral view showing the horizontal arm of the positioner aligned with the iliac crest and the tuber ischium. *(b)* The positioner is retroverted approximately 10 degrees, as seen in this ventral view. *(c)* From the caudal view, the vertical bar of the positioner is parallel to a line through the tuber ischii. **F,** Enlargement of the femoral canal starts with a large drill that must be centered in the canal and aligned with the axis of the bone to prevent penetration of the cortex. A Hohmann retractor is used to elevate the proximal femur above the pelvic muscles. **G,** The femoral canal is further enlarged by first passing a fluted reamer to remove cancellous bone from the neck and shaft.

to ensure the correct angle. The cut must also be made at near 0 degrees anteversion for maximum stability of the femoral component relative to the acetabulum.

The acetabulum is reamed with a hemispherical reamer to accept the polyethylene cup (Figure 16-15, *B*). The correct-diameter cup can be estimated from preoperative radiographs and verified at surgery. Choosing too large a diameter will result in too

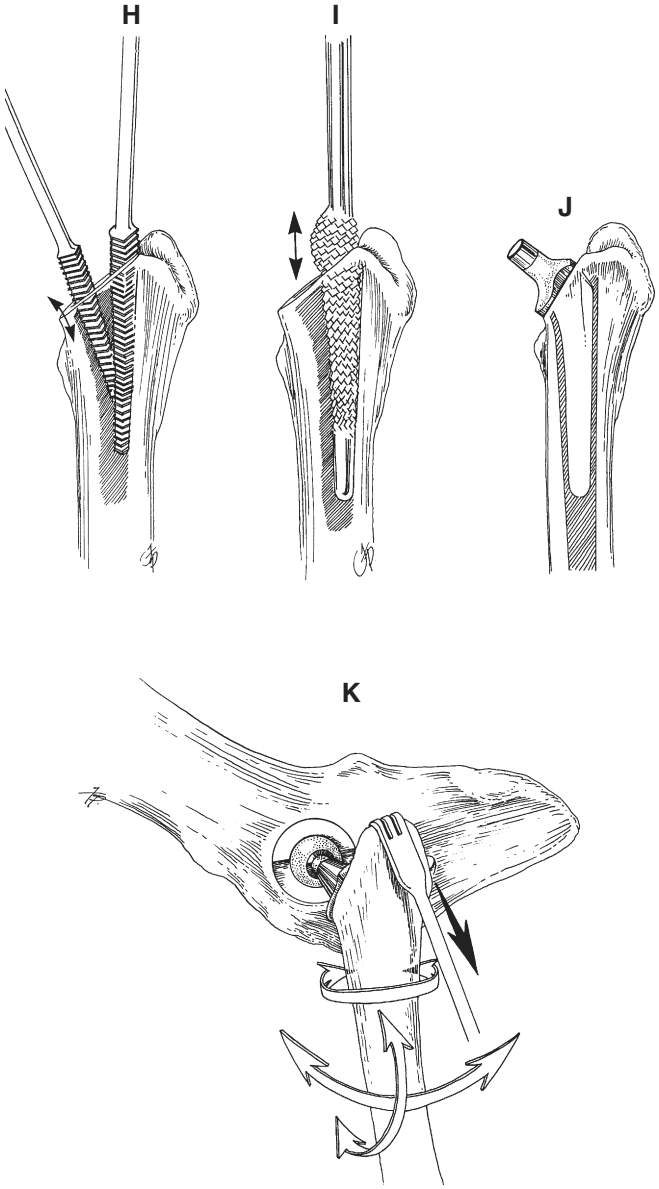


FIGURE 16-15. *Continued* **H,** A file is used to further remove bone from the endosteal surface. **I,** A rasp, sized to the femoral prosthesis, is used to obtain a good fit of the femoral component (**J**). Space is needed around the prosthesis for a mantle of bone cement. **K,** A trial femoral prosthesis and femoral head is positioned and the hip is reduced to allow testing for positioning of the components, range of motion, and lateral or ventral translational laxity. Once satisfied with all these criteria, the surgeon cements the permanent prosthesis to the femur. (All illustrations courtesy BioMedtrix, Allendale, NJ.)

much loss of the bone of the dorsal rim and can lead to late loosening of the cup. The reaming is carried medially into the acetabulum through the bone that has filled the acetabulum, often to a depth of 5 to 10 mm. To attain maximum depth of the cup, the reaming continues to the medial cortex of the acetabulum. An angled curette is used to remove the exposed cancellous bone in the acetabular area. Removing cancellous bone into the iliac shaft, along the dorsal rim, and caudally into the ischial shaft provides space for more bone cement and creates an irregular

surface for the attachment of cement to the bone. Drilling into the ilial and ischiatic shafts and dorsal acetabular rim is another method of achieving this (Figure 16-15, *D*); long drill bits and drill sleeves to protect soft tissues are necessary. Once the acetabulum is prepared, a trial insertion of the prosthesis is done to ensure proper fit. The acetabular component is then cemented in place (Surgical Simplex P bone cement, Howmedica International, Ltd., London; Howmedica, Inc., Rutherford, NJ), using a positioner to ensure proper orientation (Figure 16-15, *E*). The positioner must be oriented so that the handle is aligned with a line from the ischiatic tuberosity to the dorsal iliac spine. Also, the shaft of the positioner must be vertical to the sagittal plane of the pelvis and inclined caudally about 10 degrees.

Preparation of the femoral canal is completed with the ideal goal of orienting the cemented femoral stem parallel to the long axis of the femur, surrounded distally by a symmetric cement mantle, with no contact distally between the stem and the endosteal surface of cortical bone. Implantation technique and femoral anatomy variations may affect femoral stem placement and therefore implant mechanics and longevity.[69,70] The technique as described next is considered to be "standard" technique.

The femoral canal is enlarged to the appropriate size with a powered drill and tapered reamer (Figure 16-15, *F* and *G*). Reaming is often facilitated by removing the thin bone of the caudal femoral neck that remains after excision of the head, thus opening the trochanteric fossa and allowing better centering of the reamer in the femoral shaft. This is followed by hand filing and rasping with a broach to fit the femoral component completely within the femoral medullary canal and firmly in contact with the femoral neck ostectomy (Figure 16-15, *H*, *I*, and *J*). A trial prosthesis with a femoral head attached is inserted, and the hip is reduced and checked for stability (Figure 16-15, *K*). If the chosen femoral head is of the correct neck length, the hip will be moderately difficult to reduce and there will be virtually no lateral translational movement of the head with vigorous pulls laterally on the femur. The femoral head prosthesis is replaced as necessary to achieve this goal. Once satisfied with the combination of trial femoral head and stem, the surgeon joins the permanent implants together; tapping the head with a mallet produces an interference fit that maintains the head on the stem. The head can be attached either before or after the femoral component is cemented. Bone cement is introduced into the femoral canal, preferably by injection of liquid-phase cement, and the prosthesis is placed into the canal, with care to prevent anteversion. Additional mixing and implantation techniques are described elsewhere that improve the quality of the cement mantle. The goal of any advanced cementing technique is to develop a consistently high-quality cement mantle, free of air pockets and other defects, that will be less susceptible to cracking and subsequent loosening. After hardening of the cement, the hip is reduced, the joint capsule is closed with several interrupted sutures, and the remaining tissues are closed by layers.

Aftercare. No external support is used on the limb after THR. Oral cephalexin is started as soon as possible and continued for 3 days. Close confinement and limited leash exercise are stressed for the first month postoperatively. Most dogs are walking comfortably by 2 weeks and trotting easily at 4 weeks. At this time, a physical evaluation for range of motion, evidence of pain, and degree of function is done, and if all is well, the exercise is slowly increased over the second month. If functionally sound, the animal is released to return to normal activity, although it may take as much as 6 months for muscle atrophy to resolve and for maximal function to return. At this point, it is not necessary to impose any limitations on the dog's activity. Decisions about the advisability of a second procedure on the opposite hip should

be delayed until at least 6 months, since it is difficult to evaluate the unoperated leg until the operated leg achieves normal function. Should the nonoperated leg remain or become lame, the options are either another hip replacement or excision arthroplasty.

Prognosis. Most dogs return to full function by 8 weeks after THR. Satisfactory function occurred in 95% of 362 cases followed 3 months or more.[67] This was defined as full weight bearing, normal range of motion, normal gait, and normal level of activity with no signs of pain in the hip. Another study reported good to excellent function in 96% of patients.[71] The nature of reported complications varies in the published reports. One report indicates a 7.2% prevalence of aseptic loosening of the femoral component, but this report was made before specific changes were made in component design and cementing technique.[72] Another report indicates that aseptic loosening of the acetabular component was the most significant complication and developed in 3% of cases.[71] A third study reports that dorsal luxation of the femoral component was the most common complication and developed in 4.7% of cases.[73] Some complications, such as component luxation, are likely secondary to nuances of surgical technique that may be under the surgeon's control. Other complications may be related to canine physiology rather than surgical technique. Femoral medullary infarction has been reported to develop in 14% of canine total hip arthroplasties, with no described cause and little or rare clinical significance.[74] Osteosarcoma has been reported at the THR site in several dogs, with devastating effect.[75,76]

When complications such as aseptic loosening of the cement have developed, salvage of the limb is usually achieved by removing the prosthesis and bone cement and treating it as an excision arthroplasty, although revision by implanting a new prosthesis is possible. There seems to be no tendency for the prostheses to break down or loosen with time as in human patients, except as noted earlier. Thus, at this point, the procedure does not appear to be time limited, which indicates that the THR technique has established itself as a reliable clinical procedure for the treatment of a variety of abnormal conditions of the hip.

Femoral Head and Neck Excision

Femoral head and neck excision to allow formation of a fibrous false joint is also termed *excision arthroplasty* or *femoral head and neck ostectomy* (FHO). Pain is relieved by elimination of bony contact between the femur and the pelvis as scar tissue interposes. Because of slight limb shortening and some loss of range of motion, some gait abnormality persists. The procedure may be performed bilaterally, preferably with procedures separated by an interval of 8 to 10 weeks.

Patient Selection. Excision arthroplasty is a nonreversible procedure and must be considered a salvage operation. Nevertheless, it is a valuable method for improving the quality of life for many pets by elimination of pain. Indications will vary with the skill of the surgeon, internal fixation devices available, and financial considerations. There is some tendency to overuse the procedure for conditions that are reparable.

Degenerative joint disease resulting from dysplasia is the most common indication for excision arthroplasty. The procedure is often the first choice of treatment for a mature animal that is basically a house or yard pet only; it is also the treatment of choice for Legg-Calvé-Perthes disease. More pragmatically, it may be used when financial constraints preclude expensive orthopedic reconstruction. Other common indications include chronic osteoarthrosis from any cause, comminuted fractures of the acetabulum or femoral neck, fractures of the femoral head, and chronic luxation

of the hip with erosion of the femoral head. In summary, the procedure is suitable for any condition in which the integrity of the hip joint has been compromised and primary repair is not feasible or in which osteoarthrosis is well established.

Surgical Technique. A craniolateral approach to the hip is preferred (Figure 16-16, *A* and *B*) because it does not involve transection of the gluteal muscles, as do the dorsal approaches.[5] Some surgeons favor a ventral approach (Figure 16-16, *C* and *D*) because it is more cosmetic. In the craniolateral approach, it is important to incise and reflect the joint capsule and origin of the vastus lateralis muscle to expose the cranial aspect of the femoral neck adequately. The gluteal muscles are retracted dorsally by inserting a Hohmann retractor inside the joint capsule. Bone-holding forceps attached to the region of the trochanter may be used to subluxate the femur. This facilitates cutting of the round ligament with curved scissors and elevation of the rest of the joint capsule from the femoral head.

The neck may be cut with an osteotome or power saw with the limb externally rotated 90 degrees with a Hohman retractor, spay hook handle, or curved scissors (depending on animal size) prying between the acetabulum and the femoral head. In a large dog, this osteotome should be at least 1 inch wide (2.5 cm). If a wide osteotome is not available, the predetermined osteotomy line is prescored in steps.

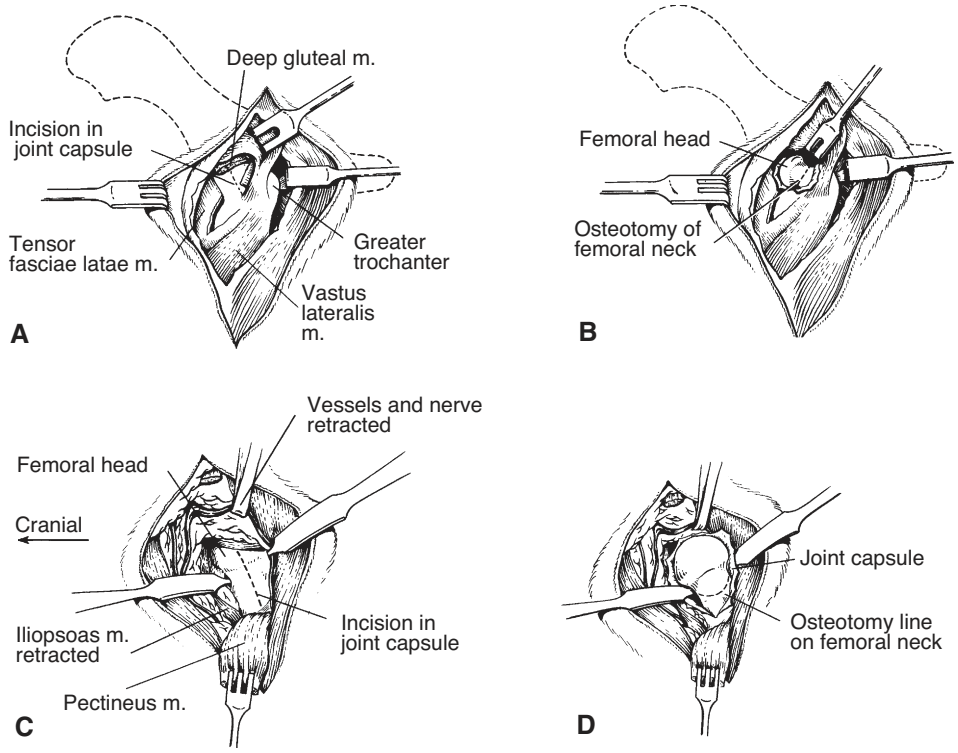


FIGURE 16-16. Approaches for femoral head and neck excision. **A,** Incision of the joint capsule in the craniolateral approach[5] in the left hip. The incision starts on the acetabulum and extends over the center of the femoral head and neck into the origin of the vastus lateralis muscle. **B,** The joint capsule has been retracted and the femoral head luxated by cutting the round ligament. The position of the femoral neck osteotomy can now be visualized. **C,** Incision of the joint capsule in the ventral approach[5] in the right hip. **D,** The joint capsule has been retracted and the femoral head luxated after cutting the round ligament. The position of the femoral neck osteotomy can now be visualized.

The cut should extend from the base of the trochanter major across the neck in a line that will intersect the medial cortex of the femur without leaving a sharp angle (Figure 16-17, *A*). The cut may include part of the trochanter minor in some cases, but care should be taken to minimize or eliminate this.

Once this line of cut has been established, the handle of the osteotome or saw is moved toward the animal's trunk until it is parallel to the sagittal plane of the thigh (Figure 16-17, *B*). This plane is best visualized by observing the position of the patella and tibial tubercle. The tendency is to align the osteotome or saw perpendicular to the femoral neck, as shown in Figure 16-17, *C*. Such a cut will result in a spur of the caudal neck being left on the femur, which then rubs on the acetabular rim and prevents fibrous tissue interposition between the bones. With the osteotome, the cut is made from a slightly distal-to-proximal direction to avoid splitting the medial cortex of the femur. Once the femoral head and neck are free, they can be grasped with bone-holding forceps or a towel clamp to allow cutting the remaining soft tissue attachments with curved scissors.

The femoral neck is palpated for irregularities, splinters, or a shelf of neck on the caudal surface. The stifle is grasped and pushed proximally and distally to mimic weight bearing in order to discover crepitus. Further neck debridement is accomplished with a rongeur, osteotome, or power saw. Leaving too long a neck that rubs on the dorsal acetabular rim is the most common reason for failure to achieve good function. Some recommend using a rasp, but it is awkward to use. Exposure of this area of the femoral neck is facilitated by externally rotating the limb until the lateral aspect of the hock can be placed against the thoracic or abdominal wall. In some animals, osteophyte production on the dorsal acetabular rim results in contact irritation and should also be debrided.

Some reports indicate better results are obtained by interposing soft tissue between the femoral neck and the acetabulum. Two methods have been proposed for soft tissue interposition. Berzon and colleagues[77] recommend detaching the cranial third of the deep gluteal muscle from the trochanter major and suturing its tendon to the insertion of the iliopsoas muscle on the trochanter minor (Figure 16-18). Lippincott[78] detached a pedicle of biceps femoris muscle, wrapping it around the

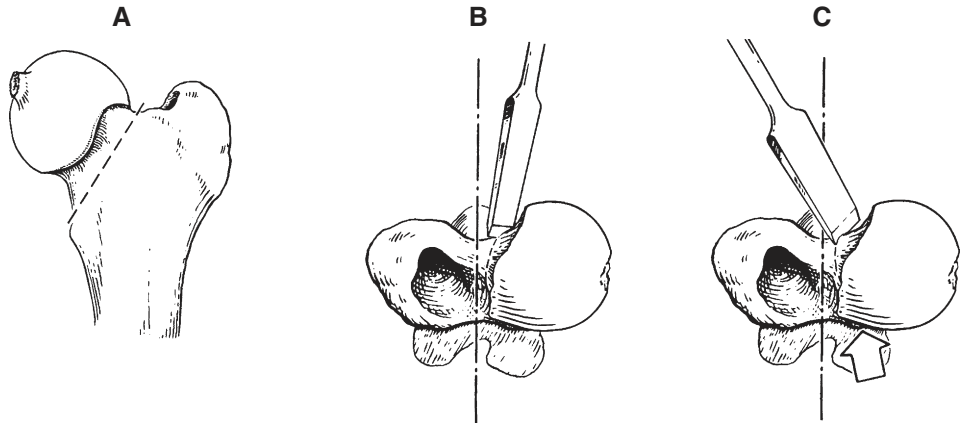


FIGURE 16-17. Femoral head and neck excision. **A,** The osteotomy lines as seen from the cranial aspect (frontal or transverse plane) of the femur. **B,** Once the proper angle of cut in the transverse plane is established, the osteotome is moved toward the animal's trunk until it is parallel to the sagittal plane of the femur. **C,** If the osteotome is directed perpendicular to the femoral neck, a spur of the caudal neck *(arrow)* will be left on the femur.

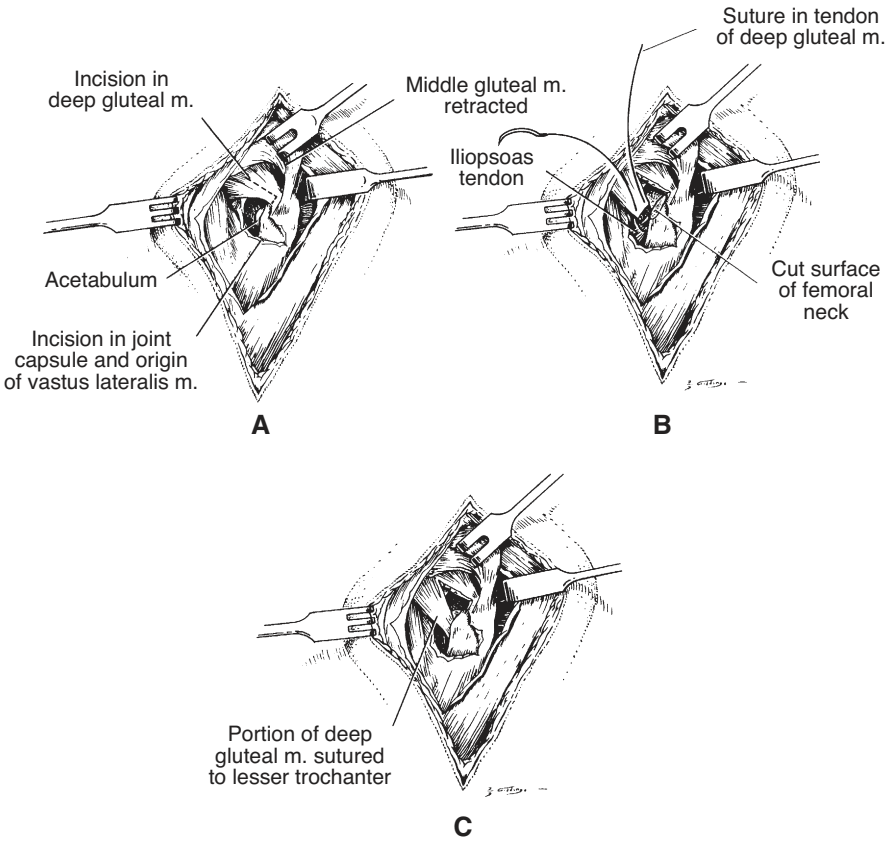


FIGURE 16-18. Provision for a soft tissue pad between the femoral neck and the pelvis. **A,** Following a craniolateral approach,[5] a pedicle of the deep gluteal muscle can be detached from the trochanter major, cutting close to the bone to leave as much tendon as possible on the muscle. **B,** With strong external rotation of the femur, the pedicle is sutured through its tendinous end to the tendon of the iliopsoas muscle near its insertion on the lesser trochanter. **C,** With the femur returned to a neutral position, the deep gluteal pedicle covers the cut surface of the femoral neck.

femoral neck and suturing it to the gluteal and vastus lateralis muscles (Figure 16-19). Experimental observations have not shown any objective difference when this method is compared with the conventional noninterpositional method,[79] but the study was done on normal dogs, so its application to clinical situations is open to question. The authors have observed a more rapid return to active use of the limb but generally no difference in long-term results when the deep gluteal muscle pedicle is used. The exception is when excision arthroplasty is done in the presence of irreparable acetabular fractures. In this case, deep gluteal interposition has been helpful. The joint capsule may also be closed over the acetabulum if possible, but this is contraindicated if it attaches to the femur because it would hinder range of motion.

Aftercare. Early, active use of the limb is necessary after excision arthroplasty. Passive range of motion exercises, prescribed 20 to 30 times four times per day, are started immediately and continued until the dog or cat can bear weight at a run, in which case it is doing its own physical therapy. Leash walking and freedom for the

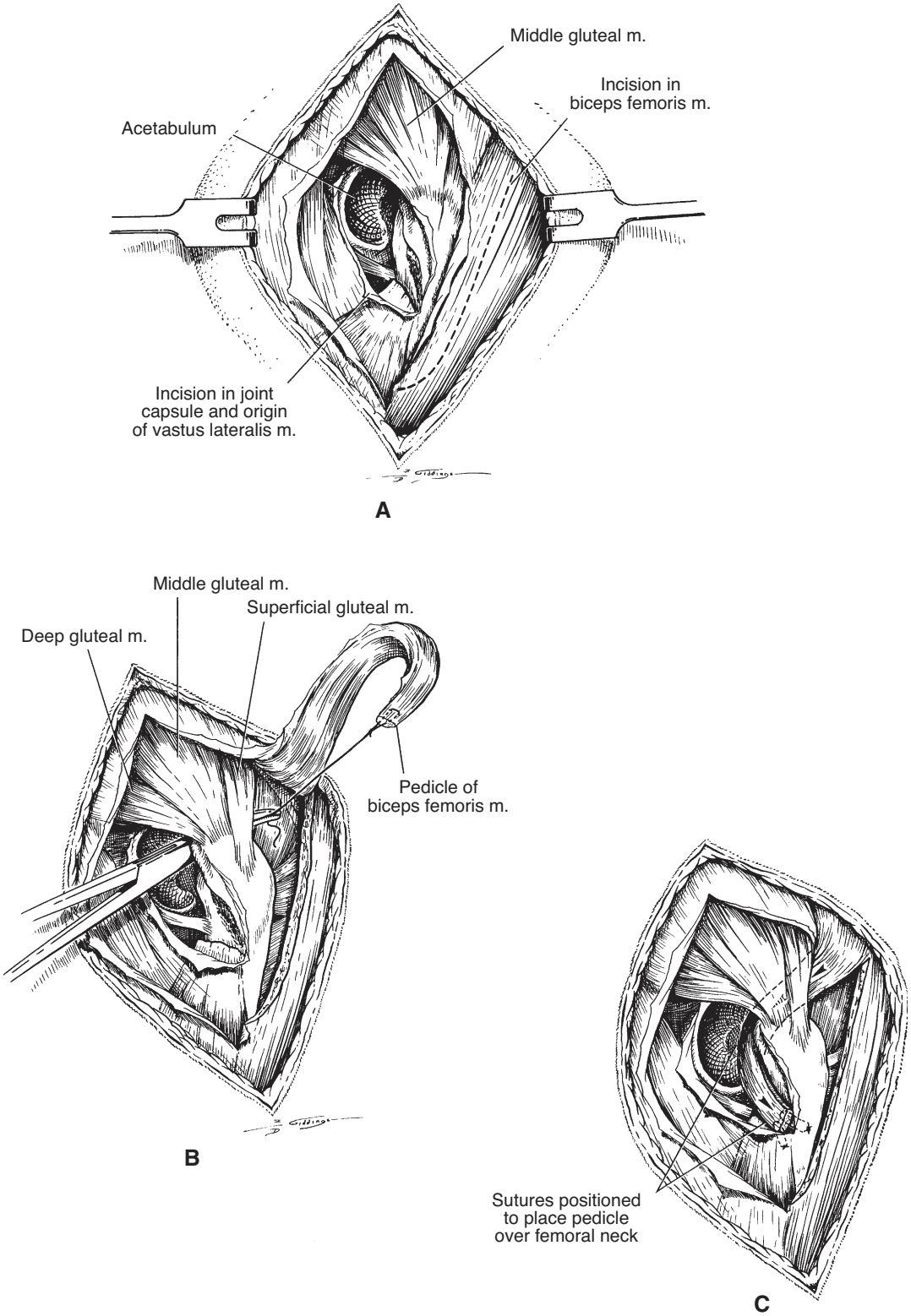


FIGURE 16-19. **A,** Another method of soft tissue interposition involves freeing a pedicle of biceps muscle *(dashed line)*. **B,** A suture is attached to the muscle pedicle and is pulled under the gluteal muscles from a caudal-to-cranial direction. **C,** The muscle pedicle is sutured to the elevated vastus lateralis in a position that holds it across the femoral neck ostectomy.

animal to move about a confined area are encouraged until suture removal. After 2 weeks postoperatively, active exercise such as running and swimming is encouraged. Animals usually will be toe touching in 10 to 14 days, partially weight bearing in 3 weeks, and actively using the leg by 4 weeks. When indicated, bilateral operations should be done 8 to 10 weeks apart. In some cases, it will be necessary to delay the second surgery even further until active use of the first limb has been achieved. In cases of severe pain from bilateral hip problems, bilateral excisions can be done simultaneously. Aftercare is difficult because it takes several days for such animals to become ambulatory. This care is much easier in smaller breeds (e.g., <25 kg body weight).

Prognosis. Return to active and pain-free use of the limb depends on surgical skill, length of time the hip pathology has been present, and severity of the pathology. Animals undergoing surgery for acute trauma, such as head and neck fractures, may be functional within 30 days. Those having chronic dysplasia with long-standing pain and muscle atrophy may require 6 months or more. These animals benefit particularly from swimming as an exercise. Patients with extremely displaced acetabular fractures and some with chronic dysplasia may never again regain good function.

Reported results vary considerably. Gendreau and Cawley's analysis of 32 cases indicated only 37% excellent results and 26% good results, with only three of seven dogs weighing over 25 kg experiencing excellent results.[80] Berzon and colleagues,[77] however, reported 90% to 100% use of the limb in 83% of all cases, with no significant difference in results between large and small breeds.[77] It is pointless to assess results in this surgery by evaluating the postoperative gait. Smaller breeds undoubtedly experience less change in gait, but femoral head and neck excision is usually successful in large breeds for relieving pain and restoring the animal's quality of life.

Pectineal Myectomy

A variety of procedures on the pectineus muscle have been proposed to treat hip dysplasia and to prevent it. These surgeries include *myectomy, myotomy, tenectomy,* and *tenotomy.* All are designed to relieve tension produced by the muscle and transmitted to the hip joint. It has been speculated that this dorsal force on the femoral head pushes it against the dorsal acetabular rim and thus contributes to development of hip dysplasia.[81] Subsequent studies have indicated no effect in preventing dysplasia as a result of pectineal tenotomy[82] or myotomy.[83] Nevertheless, symptomatic improvement does result in many mature dogs for a variable time after pectineal resection.

Pectineal resection does not affect the radiographic changes associated with hip dysplasia; the degenerative changes progress at least as fast after surgery as would be expected without surgery. It is possible that increased abduction of the femur results, with a more varus position of the femoral head relative to the pelvis, which places the head more deeply in the acetabulum (see previous discussion of intertrochanteric varus osteotomy). Relief of pain possibly results from increasing the load-bearing areas of the femoral head and neck, thus decreasing the load per unit area of articular cartilage. Stress on the joint capsule may also be lessened. Because the joint is still unstable, however, degenerative changes continue, and pain usually returns after a variable period, ranging from a few months to years.

There is no way of predicting how long the effects of surgery will be beneficial; therefore, pectineal surgery has only limited value in treating hip dysplasia. It is useful under conditions in which short-term effects are acceptable, such as completing a field trial campaign.

Surgical Technique. The pectineal muscles are exposed by means of the ventral approach to the hip joint. After the pectineus tendon is undermined and its origin cut, the abducted leg is adducted, thereby extruding the muscle through a proximal incision. The distal tendon is incised and the entire muscle removed. Subcutaneous tissues and skin are closed only after attaining perfect hemostasis in the field.

Aftercare. Moderate exercise should be started 2 to 3 days after surgery to minimize the possibility of fibrous bands forming in the excision site, which could restrict the femur. Such bands are minimized by total myectomy; however, they are not totally eliminated.

LEGG-CALVÉ-PERTHES DISEASE

Known by several other names, such as Legg-Perthes or Calvé-Perthes disease, osteochondritis juvenilis, avascular necrosis, and coxa plana, Legg-Calvé-Perthes disease is noninflammatory aseptic necrosis of the femoral head and neck in small-breed dogs (Figure 16-20). The cause of such necrosis is not known with certainty, but ischemia resulting from vascular compression[84] and precocious sex hormone activity[85] have been proposed. A genetic cause, homozygosity for an autosomal recessive gene, has been reported.[86] In our experience the prevalence of this condition is much less than that encountered 20 to 30 years ago.

In all cases the bone of the femoral head and neck undergoes necrosis and deformation, during which the animal manifests pain. The articular cartilage cracks as a result of the collapse of subchondral bone. Bone eventually returns to the necrotic area, but the femoral head and neck are deformed, with resulting joint incongruity and instability. This condition leads to severe degenerative changes within the entire hip joint and to development of marked osteoarthrosis.

Male and female animals are equally affected. Bilateral involvement has been reported as 16.5%[87] and 12%.[88] The toy breeds and terriers are most susceptible.

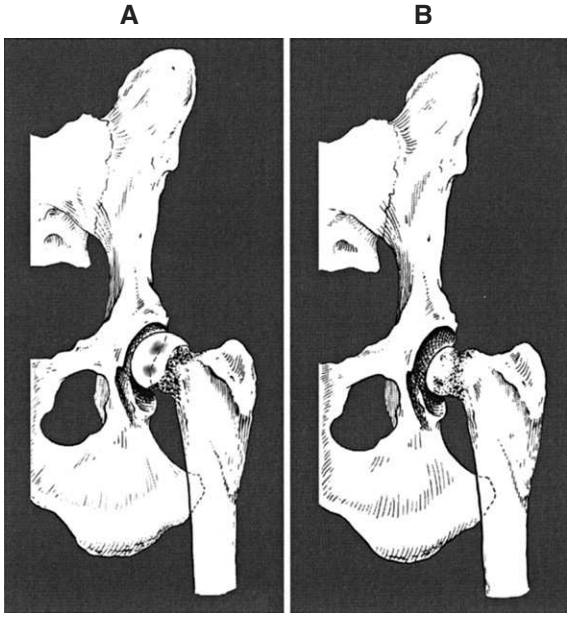


FIGURE 16-20. Legg-Calvé-Perthes disease. **A,** Bony destruction early in the disease causes both radiographic lucency and actual loss of substance in the femoral head *(gray circular spots)* and neck. The epiphysis seems unaffected in this early stage. **B,** At the end point of the process, the femoral head has collapsed and deformed. Occasionally, loss of bone will result in pathological avulsion fracture.

The peak incidence of onset is 5 to 8 months of age, with a range of 3 to 13 months.[86]

Clinical Signs

Often the first abnormality noted is irritability. The animal may chew at the flank and hip area. Pain can be elicited in the hip, especially on abduction. Later, crepitus may be present, with restricted range of motion and shortening of the limb. Atrophy of the gluteal and quadriceps muscles becomes apparent. Onset of lameness is usually gradual, and 6 to 8 weeks is required to progress to complete carriage of the limb,[87] although pain can be acute when there is fracture of the femoral head at lytic areas.

Radiographic signs include increased joint space and foci of decreased bone density in the head and neck (Figure 16-20, *A* and *B*). The femoral head flattens where it contacts the dorsal acetabular rim, then distorts further to a variable degree. Osteophytes, as well as subluxation and fracture of the femoral head and neck, may be seen occasionally.

Treatment

Once the femoral head becomes distorted in animals with Legg-Calvé-Perthes disease, femoral head and neck excision is warranted (see Figures 16-16 and 16-17). Excision of the femoral head and neck produces more favorable results than conservative treatment with rest and analgesics.[87,88] Results are better, and recovery time is much shorter. With the proper surgical technique, virtually 100% of these animals will become ambulatory and free of pain. A slight limp may remain because the leg is shortened by removal of the femoral head and neck, and the thigh and hip muscles remain somewhat atrophied. In rare instances where lucencies are seen without collapse of the femoral head, an Ehmer sling may be tried for 3 to 4 weeks. This allows the necrotic bone to remodel without weight bearing causing collapse of the head.

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17

Fractures of the Femur and Patella

The incidence for fractures of the femur is about 20% to 25% of all fractures in most veterinary practices; this rate is higher than for any of the long bones in the body. Additionally, femur fractures represent 45% of all long-bone fractures, a rate more than double that of other bones.[1] The femur also has the highest incidence of nonunion and osteomyelitis of all fractures. Open reduction and internal fixation are indicated in almost all femoral fractures.[2,3] Because of the eccentric loading of the femur during weight bearing (see Figure 2-70), it is in this bone that the surgeon must be most cognizant of the tension/compression cortices and their effect on implants. Defects in the medial (compression/buttress) cortex place enormous bending loads on the implant, and thus femoral fractures are the most severe test for an internal fixation device.

In this chapter we suggest methods of treating various types of fractures as classified in the AO Vet fracture classification scheme (see Table 2-1).[1] Patellar fractures are included with distal femoral fractures. Treatment recommendations are keyed to the fracture patient scoring system detailed in Table 2-6 when applicable.[4,5]

FIXATION TECHNIQUES

Coaptation

The coaptation form of fixation has almost no application in femoral fractures because of the difficulty of immobilizing the hip joint in the dog and cat. A spica-type cast is required, but problems preventing the routine practical application of such a cast in small animals have not been solved.

For about 20 years, starting in the early 1930s, use of the modified Thomas splint was the most common method of immobilizing femoral fractures[6,7] (see Figure 2-25). With the advent of internal fixation, this splint has rapidly faded from common use as the sole method of immobilizing femoral fractures. When used as the sole method of fixation, the modified Thomas splint must be confined to greenstick fractures, fissure fractures, and fractures with minimal displacement in the very young patient. The veterinarian must keep in mind that the ring, when properly applied, lies at the proximal third of the femur and may act as a fulcrum at the fracture site, resulting in displacement of the proximal fragment. The splint also adds significant mass and elongates the distal lever arm, which can add to displacement of the distal fragment.

The leg may be attached to the modified Thomas splint with the joints in various angles to exert the best mechanical advantage on the fracture. In most cases, however, the leg is splinted in the angulation of the normal standing position. Placing the leg in full extension over time may lead to a decrease in range of joint movement in the stifle and to some loss of function or total dysfunction if fibrous ankylosis occurs in the hyperextended position. The splint must be frequently checked for pressure points, readjusted, and repaired during the healing period. It must be protected against moisture, both inside and out. Exercise must be restricted to help protect the splint from becoming loose or damaged. The presumed economic advantages of coaptation over internal fixation are seldom realized in the treatment of femoral fractures.

A long lateral molded splint can also be applied to greenstick fractures, fissure fractures, and fractures with minimal displacement in the very young patient (see Figure 2-24). The advantage over the Thomas splint is the absence of the ring proximally.

Intramedullary Pins and Wires

There are numerous types of intramedullary (IM) pins available with various types of points (see Figure 2-54).[1,8] The round pins (Steinmann, Kirschner wire) are by far the IM pins most often used.

Steinmann Pin

When the Steinmann pin is used as the sole method of fixation of diaphyseal fractures, it should be reserved primarily for fractures that are inherently stable, such as type A1 and some type A3 (see Figure 17-20). More instability can be tolerated in skeletally immature animals because of the rapidity of callus formation. Steinmann pins may be used for unstable fractures only with supplemental fixation such as an external fixator, multiple pins, plate, cerclage wire, or lag screws.

Pin Insertion

The pin may be inserted from the proximal end (normograde) by entering at the trochanteric fossa (Figure 17-1) or by passing it retrograde from the fracture site proximally through the medullary canal (Figure 17-2).

Normograde pin insertion is applicable to both closed and open reductions and is preferred because it has the advantage over retrograde placement of positioning the pin more laterally in the trochanteric fossa and thus farther from the femoral head and sciatic nerve.[9] Additionally, less soft tissue is penetrated, facilitating cutting the pin shorter, which minimizes seroma formation and decreases patient discomfort. For midshaft and proximal femoral fractures, it is best simply to extend the approach incision proximally for insertion of the pin. Transection of the tendon of insertion of the superficial gluteal muscle and elevation of the muscle before inserting the pin will allow for cutting the pin quite short at the conclusion of surgery. In other cases a short skin incision is made just dorsomedial to the greater trochanter. The pin is inserted through the subcutaneous fat and the gluteal muscles until the trochanter is felt on the tip of the pin. During the insertion process, the proximal femur is held in the angulation and rotation of the normal standing position. Keeping the pin chuck and pin axially oriented to the femur, the pin is "walked" medially off the trochanter into the trochanteric fossa, where it will center itself with some pressure through the pin chuck. When performing an open reduction, the proximal femoral bone segment exposed in the open approach can be grasped with a bone-holding forceps to stabilize it. The pin is driven into the bone by quarter

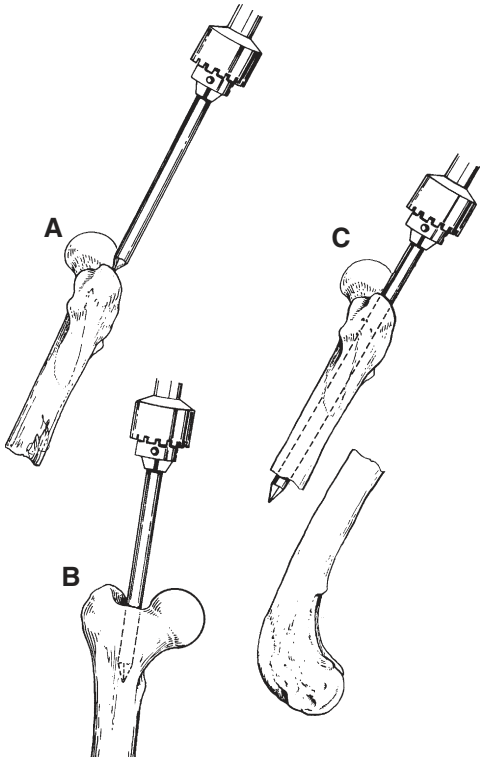


FIGURE 17-1. Normograde intramedullary pinning technique using Steinmann pin, with the proximal femur in the angulation and rotation of the normal standing posture. **A,** The pin is inserted through the skin and underlying soft tissue at the eminence of the trochanter major. **B,** The pin slides along the medial surface of the trochanter major into the trochanteric fossa, through the cortical bone, and down the medullary cavity. **C,** The pin is held in axial alignment, and the bone fragment is held with bone-holding forceps to prevent rotation during pin insertion.

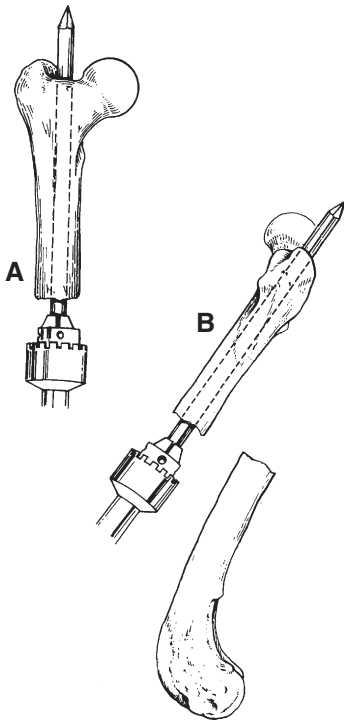


FIGURE 17-2. Retrograde intramedullary pinning technique using Steinmann pin, with the proximal femur in the angulation and rotation of the normal standing posture. Correct position of the proximal femur, particularly avoiding abduction, external rotation, and excessive flexion of the hip, is essential to avoid potential sciatic neuropraxia. **A,** The distal end of the proximal bone fragment is grasped with bone-holding forceps, and the pin is inserted proximally in the medullary canal. **B,** As the pin is driven proximally, an effort is made to direct it along the craniolateral surface of the medullary cavity. The proximal bone fragment is adducted until it is parallel to the surface of the table and held in the rotation and angulation of the normal standing position as the pin penetrates the proximal bone and soft tissues.

turns of the hand chuck in a back-and-forth motion, constantly applying firm pressure. Axial alignment is easily maintained by watching the proximal femoral segment, and the medullary cavity is quickly entered and the pin continued distally to the fracture site.

If the *retrograde* technique is used, care should be taken to have the proximal fracture fragment adducted (parallel to the table) and in the angulation and rotation of the normal standing position. On passing the pin proximally, it is directed along the craniolateral surface of the medullary cavity (see Figure 17-2). All these precautions help keep emergence of the pin away from the femoral head and sciatic nerve. (See later discussion on sciatic nerve injury associated with IM pinning.)

The method of seating the pin distally varies with the patient's bone type. Most dogs have pronounced cranial bowing of the femoral shaft (Figure 17-3, *A*). If the pin is allowed to follow its own course into the distal segment, it will often penetrate the cranial cortex just proximal to the femoral trochlea (Figure 17-3, *B*). In this case, simple pin retraction is not appropriate because postoperatively the pin often migrates distally through the pin track and reenters the joint. The pin should be retracted to the fracture site, the fracture reangulated as described later, and the pin driven distally into unpenetrated trabecular bone. Even if the pin does not penetrate the cortex, it is not stable fixation for fractures of the middle or distal segments. In these fractures, it is important that the pin be seated in the dense trabecular bone of the distal metaphysis and condyles.

After the fracture is reduced and as the pin is directed into the distal segment, it is best to angle both segments slightly caudally. This allows for deeper insertion of the pin in the cancellous bone of the distal metaphysis and also for more stable fixation (Figure 17-3, *C*). When the bone is relatively straight, as in the toy dog

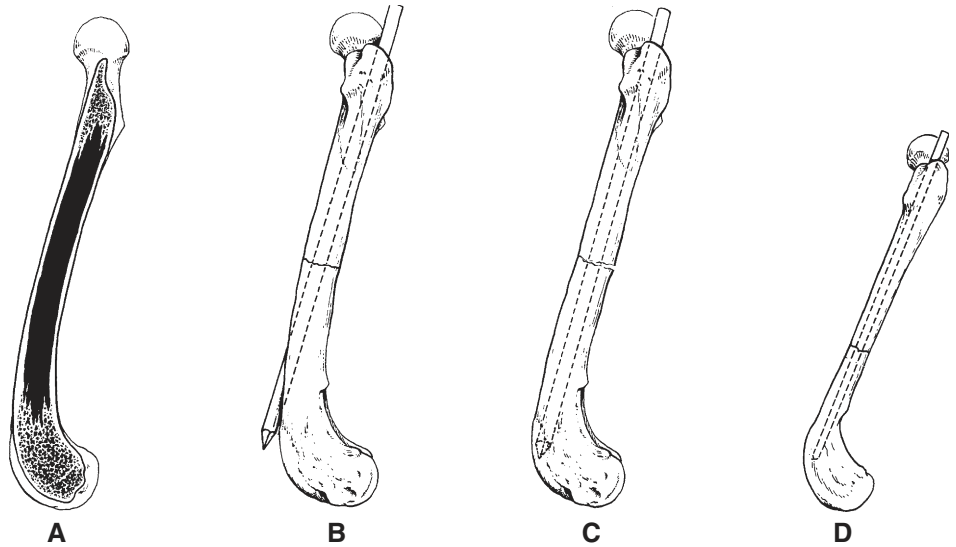


FIGURE 17-3. Effect of femoral shape on pin insertion. **A,** Sagittal section through a canine femur showing the cortical bone, cancellous bone, and marrow cavity. **B,** The canine femur has some cranial curvature, and the intramedullary pin cannot be inserted to a sufficient depth with the fracture reduced in perfect apposition. **C,** With the fracture segments bent caudally at the fracture site, the intramedullary pin can be passed along the caudal cortex into cancellous bone at the distal end. This anchorage in cancellous bone greatly improves stability. **D,** Anatomical reduction of a cat femur and insertion of a Steinmann pin for fixation. The diaphysis of a cat femur is straight.

breeds and in the cat, the pin naturally follows the medullary canal distally into the condyles (Figure 17-3, *D*). In any situation *the pin should penetrate distally at least to the proximal border of the patella* when the stifle is placed at the normal standing angle. With the pin chuck removed from the pin, another pin of the same length can be positioned external to the leg to verify the depth of insertion. Rotation of the distal femoral segment while seating the pin is neutralized by flexing the stifle and using the proximal tibia as a lever to control the femur. This also allows some compressive force to prevent distracting the fragments while driving the pin.

After the pin is inserted to the full depth with the point of the pin near, but not penetrating, the subchondral bone, it is cut as short as possible, or it may be retracted 1 cm, cut off, then driven back into position by means of a countersink and mallet. Do not allow the fracture to distract during this type of pin seating. A long pin in the gluteal area can lead to discomfort and seroma formation as well as to an increased possibility of sciatic nerve entrapment by the tissue reaction incited by the pin (see following discussion). Some prefer that the depth of insertion be checked by taking a radiograph before cutting the pin. The incision may be closed; taking precautions to maintain sterility of the protruding pin, a lateral radiograph is taken, and depth adjustments are made before cutting the pin.

Pin Diameter

Ideally, pin diameter should approximate 75% to 80% of the marrow cavity. This is possible throughout the medullary canal in the cat and toy dog breeds because the femur is straight (see Figure 17-3, *D*); however, it is not possible in most dogs because of the cranial bowing of the femur (see Figure 17-3, *A*) and the narrowing of the canal at the midshaft. In these dogs the pin should occupy about 75% to 80% of the marrow cavity diameter at the midshaft, which will give the pin 50% to 75% diameter relative to other areas of the medullary canal.

Complications

Horizontal shearing and rotary instability are the most common complications when a round pin is used. Any instability at the fracture site will invariably cause the pin to loosen because of bone resorption and to migrate proximally, sometimes completely out of the bone. Additional supplemental fixation should be added to guard against instability and movement at the fracture site. Supplemental fixation is described later in this chapter.

The *sciatic nerve* can become irritated or trapped over the top of the cut-off IM pin either at the time of insertion or, more often, during the convalescent period if the precautions previously stated are not observed. This is especially true in cats because of their limb positions during grooming. The incidence of such sciatic injury was 14.5% in one retrospective study.[10] This seems inappropriately high in our experience, especially if the pin is placed as close to the trochanter as possible and cut as short as possible. Most cases are the result of excessive fibroplasia caused by leg motion and an overly long and medially placed pin, rather than outright damage to the nerve during pin insertion. Clinical signs were delayed for 2 or 3 weeks postoperatively in 79% of cases, probably from contracture of maturing fibrous tissue. Usual clinical signs included pain in the hip region on palpation, carrying of the leg with the hip flexed, and the proprioceptive reflex of the foot being diminished or lost. Immediate surgical intervention is indicated in such a situation. After careful dissection down to the area, the pin is either cut shorter or removed if the fracture is healed. It is helpful to find the normal sciatic nerve several centimeters distal to the trochanter and trace it proximally to avoid accidental nerve damage in the rare circumstance in which the sciatic nerve has become displaced cranial to the trochanter.

Enveloping fibrous tissue is dissected away from the nerve. Injury to the sciatic nerve is usually temporary, with no cases of permanent neurological deficit in a series of 14 cases.[10]

Postoperative Management

Activity must be restricted until the stage of clinical union is reached. Union should be checked radiographically before removal of the pin. After clinical union is achieved, the pin may be removed by incising over its top and retracting it by pulling with quarter turns back and forth. This is usually done with the patient under a short-acting anesthetic, but in some cases it may be removed under sedation and local anesthesia. Aseptic procedures are used for removal of the pin. If the pin has been cut sufficiently short to preclude soft tissue irritation, it is sometimes left in place with no adverse effects. Occasionally, such a pin will loosen and migrate proximally, necessitating immediate removal.

Küntscher Nail

The Küntscher nail has the advantage of affording rigid stability to both bending and torsion or rotation; however, insertion requires attention to the details in its use. Frequent complications include the following: (1) the nail may jam in the medullary canal or may split the bone; (2) longitudinal fracture lines already present may be opened up; and (3) if too small in diameter, the nail may not provide sufficient stability. The Küntscher nail is rarely used in North America for small animals because of these complications and the availability of other fixation methods.

Interlocking Nail

The interlocking nail is an effective fixation method for diaphyseal femoral fractures of the dog and cat.[11-21] Whereas standard Steinmann IM pinning alone is of little value in unstable fractures, the interlocking nail can provide both rotational and compression (buttress) stability previously available only by bone plate fixation. The disadvantages are maintaining the equipment inventory necessary to handle an array of bone sizes and becoming adept at using the system.

Bone healing with the interlocking nail has been very good in early clinical reports. The main complication reported is that approximately 9% resulted in broken nails, attributed to selection of a smaller nail than indicated or positioning of a nail hole too close to the fracture site.[9] In vitro biomechanical studies of interlocking nails compared to bone plates or plate-rod combinations have described excellent material properties of bending and stiffness for interlocking nails, but significantly less rigidity when subjected to torsion.[17,21] Clinical experience and biomechanical testing have led to revision of the 6-mm and 8-mm nails and expansion of the system to 4.0-mm and 4.7-mm nails. The current system is now sized appropriately for femoral fractures of adult cats and dogs of most sizes, except perhaps for giant breeds.

Technique

Preoperative planning with a template onlay to the radiograph helps the surgeon to select the correct diameter and length of the implant. A choice of the standard interlocking nail, with two screw holes proximal and distal, or a nail with three holes is based on the proximity of the nail hole to the fracture. It is recommended to maintain a 2-cm distance from any nail hole to the fracture site to prevent nail breakage. A limited lateral surgical approach to the femur is completed for fracture reduction. IM pins of smaller diameter are used first in normograde fashion to open the medullary canal. The interlocking nail is driven into the intramedullary space

with standard "pin technique." The machined joint of the interlocking nail is attached to the extension and the drill guide jig (see Figure 2-54, *E*). Drill guide inserts and sleeves are used through the jig to place the locking screws.

Kirschner Wires

In reality only a small-diameter Steinmann pin, Kirschner wires are used as transfixation pins in a variety of femoral fractures, both as primary and supplemental fixation (see Figures 17-7, 17-10, 17-12 to 17-15, and 17-32).

Pins and Tension Band Wire

This method is widely applied for fractures and avulsions of the trochanter major (see Figure 17-7, *C*). The tendon of the superficial gluteal muscle is cut and the muscle elevated off the trochanter before placing the pins. The pins can be either anchored distally in the medial cortex distal to the lesser trochanter or driven straight down the medullary canal, in which case the pins should be slightly longer for greater stability. Proximally, the tension band wire is passed around the pins through the middle gluteal muscle close to the bone to prevent cutting of the muscle as the wire is tightened. The transverse hole for distal anchorage of the wire can be drilled through the distal end of the third trochanter without elevating the vastus lateralis muscle if the drilling proceeds from caudal to cranial, with internal rotation of the femur and strong retraction of the biceps femoris muscle. Careful bending of the protruding pins and seating them close to the bone are necessary to avoid soft tissue irritation, which can be a problem in thin dogs.

Cerclage Wires

Cerclage wires can provide very effective interfragmentary compression of larger fragments when a reconstructive approach is taken to the fracture repair (see Figures 17-21, 17-24, 17-25, and 17-27). Cerclage wires are always used as a supplemental fixation and never as primary stabilization in shaft fractures.

Because of the insertion of the adductor magnus muscle on the diaphysis, most fragments from the caudal half of the femur have a viable periosteal blood supply. Great care should be taken in reducing such fragments to preserve the muscle attachment and its blood supply. Proof of the usefulness of this blood supply is provided by the observation that the first callus seen in femoral fractures is always along the caudal side of the shaft. Considerable effort must also be expended to pass the wire around the femur in the most atraumatic manner possible in order to elevate a minimal amount of muscle from the bone. The use of a wire passer greatly assists in this maneuver (see Figure 2-61). The passer is used as if it were a large needle and is inserted into the adductor muscle as close as possible to the bone surface, then rotated around the bone to emerge cranially. The wire is inserted into the lumen in the tip of the passer and inserted until the tip of the wire is visible in the hole of the passer. The wire is grasped and the passer backed out through the same track.

Because the shaft of the femur is reasonably tubular, there is no problem of wire slippage in the central portion of the bone. As the subtrochanteric and supracondylar areas are approached, it may be necessary to notch the bone or otherwise prevent migration of the wires in these tapering areas (see discussion of cerclage wires in Chapter 2).

External Fixators

When an external fixator is applied on femoral fractures as the sole method of fixation, it is used primarily on small breeds of young dogs and cats. In general, these

repairs heal quite rapidly. When used on other femoral fractures, and especially in dogs, it is best to combine the fixator with the IM pin.

The surgeon is restricted to use of the unilateral type IA one-plane configuration on the femur. Double connecting bars are often indicated when using the Kirschner-Ehmer fixator system in medium to large dogs because of the bending load imposed in most unstable fractures. Another choice would be to use a stiffer external fixator system. One fixation system (IMEX SK, IMEX Veterinary, Inc., Longview, Texas) uses larger connecting rods of aluminum or carbon fiber for increased stiffness at the fracture site, which is better suited to the difficult mechanical environment of the canine femur. In general, the fixator is well tolerated by the patient, although dogs are sometimes reluctant to bear weight on the limb, apparently because of the penetration of both the quadriceps (stifle extensor) and the biceps femoris (stifle flexor) muscles. This temporarily limits the range of stifle joint movement, which with the formation of adhesions may become a permanent limitation. Passive range of motion exercises may help minimize this problem. Temporary loss of weight bearing can be tolerated as long as no other limb fractures are present. In such a situation it is usually necessary to achieve early, equalized load sharing between the limbs to minimize stress on the implants. This problem with function is not usually encountered in the cat.

The fixator may be applied with the fracture site closed or open. Open reduction is usually preferable because the reduction can be visualized during the insertion procedure. The muscle mass of the thigh makes closed reduction difficult in most animals. Because the splint is inserted on the lateral surface of the femur and penetrates large muscles, it is vulnerable to trauma, pin track drainage, and premature fixation-pin loosening. This loosening can be partially overcome by inserting six or eight pins; however, the more fixation pins used, the greater the muscular impingement problem. The use of enhanced threaded pins may also help with this concern, since fewer pins will be required to maintain fixator stability. Early pin loosening will be less likely with enhanced threaded pins. Postoperative use of bulky dressings to stabilize the soft tissues has been advocated to reduce pin loosening caused by muscular motion around the pins.[22]

External Fixator and Intramedullary Pin

The external fixator is added to the IM pin fixation to help increase stability by reducing movement and rotation at the fracture site and helping to maintain length.[2,23,24] The unilateral type IA two-pin fixator is used primarily for transverse and short oblique fractures (Figure 17-4), and a four-pin or six-pin type IA fixator is used on comminuted fractures. As a general rule, it is advisable to use a minimum of four fixation pins; only with a fracture patient score of 9 to 10 and a body weight of less than 15 pounds (6.8 kg) should two pins be considered.[24]

This combination of methods is used because the presence of the IM pin will allow the fixator to be removed as soon as stabilizing callus is radiographically visible, typically at 4 to 6 weeks. Early removal allows greater weight bearing on the limb, which favors fracture healing and minimizes chances of permanent loss of motion in the stifle joint.

If a complex, multifragment fracture is present, with a fracture patient score of 1 to 7, a more complex external fixator may be combined with the IM pin. A hybrid type I-II external fixator may be used with an IM pin (see Figure 17-33, *B*). The increased frame stiffness of the hybrid is needed for healing of the complex fracture; however, the pin and fixator combination can be applied through a very limited surgical approach. The limited surgical approach reduces damage to fragment blood supply, and a "biological osteosynthesis" with rapid healing is achieved. A maximum of five to seven fixator pins is used to reduce the amount of

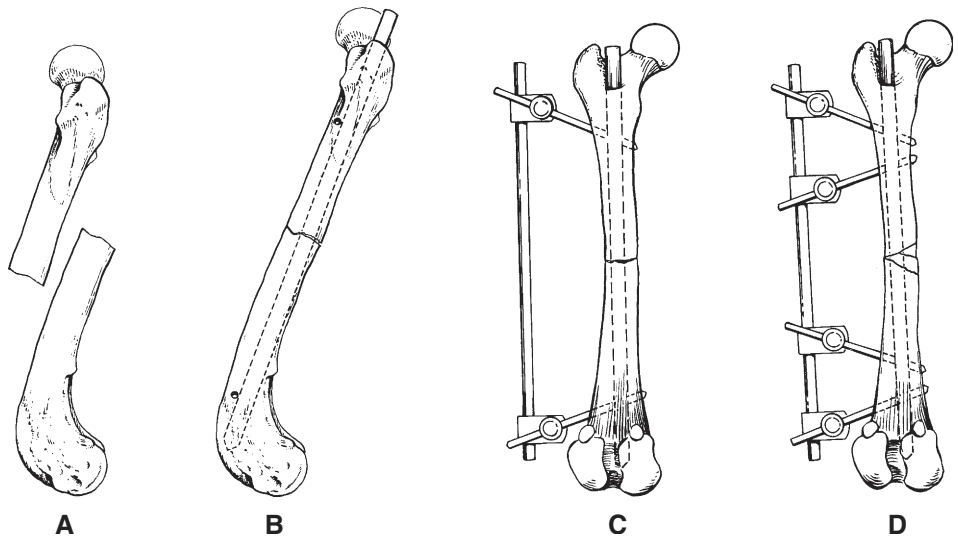


FIGURE 17-4. Insertion of an intramedullary pin and type IA external fixator, 1/1 pins for fixation. **A,** Transverse fracture of the femur. Fractures of this type have a tendency to rotate. **B,** Self-locking bone-holding forceps holds fracture reduced during insertion of the Steinmann pin into the distal segment. Holding both fracture segments so that they do not rotate during the insertion process makes for a tighter fitting pin. The two circles show approximate location of fixation pins. Fixation pins can also be placed caudal to the intramedullary pin. **C,** Caudocranial view of reduced and fixed fracture. **D,** Wedge fracture (caudocranial view) immobilized by use of an intramedullary pin and external fixator, 2/2 pins. Four pins are inserted for added stability.

muscular impingement. Also, the frame may be partially disassembled and the fixator pins removed as healing progresses, to restore weight-bearing stress to the bone and enhance muscular function of the limb.

Some circumstances warrant development of a more complex fixator frame, such as severe comminution or expected delayed healing. A type IB frame or a type IB fixator modified to "tie in" to the IM pin may be used as fixation for complex femoral fractures. Tie-in of the fixator to the IM pin is accomplished with the use of single or double clamps and an additional connecting bar (see Figure 11-15).

Technique

The procedure for inserting the IM pin (Figure 17-4, *A* and *B*) is the same as described earlier. When using this combined fixation, the IM pin can be reduced somewhat in diameter from the normal size to provide better clearance for the fixation pins that are inserted in the proximal and distal fragments. The following steps are used:

1. Start the fixation pin insertion with the soft tissue in its normal position. The pin should pierce intact skin and preferably not enter on the incision line.
2. Insert the pins near the proximal and distal ends to obtain the best mechanical advantage. Placement of these pins to avoid the IM pin is facilitated by utilizing the greater trochanter proximally and the condylar region of the femur distally (Figure 17-4, *B*).
3. Insert pins slightly off center to miss the IM pin.

4. If smooth fixation pins are to be used, place the fixation pins at approximately a 70-degree angle to the long axis of the bone, penetrate both cortices, and connect the pins with single clamps and a connecting bar (Figure 17-4, *C* and *D*).
5. When four or six fixation pins are used, the end pins are inserted first with two or four empty single clamps assembled on the connecting bar. The remaining pins are then inserted through the clamps into the bone. If the IM pin impedes insertion through the uniplanar configuration, double clamps and bars may be needed (see Figure 2-47, *B*).
6. Enhanced threaded fixation pins may be used if prolonged healing is anticipated with a difficult fracture. Threaded pins will prolong stability of the fixator pins and prevent early loosening and pullout. Enhanced threaded pins are most easily used in the end positions, if used with the Kirschner-Ehmer system, but can be used in any pin position if IMEX clamps (IMEX SK) are used.
7. If a complex fracture is present in a larger dog, there are benefits to using the IMEX SK external fixator system. The carbon fiber or aluminum connecting rods have greater stiffness than the rods used in the Kirschner-Ehmer system. As previously stated, the Imex clamps allow convenient use of enhanced threaded pins at any clamp position. The resulting fixator construct is stronger, more rigid, and more durable.

The wound may be closed before or after application of the external fixator. Closure after application has the advantage of enabling visualization of the fracture site until all fixation is in place.

Postoperative Management

Activity should be restricted during the healing period. The external fixator usually can be removed after a good primary callus is visible radiographically; this takes about 4 to 6 weeks. If a complex fracture is treated, the disassembly of the external fixator may be staged at several intervals, beginning at 4 to 6 weeks, to stimulate fracture healing by reintroduction of weight-bearing stress. The IM pin is removed when the fracture has reached the stage of clinical union.

Bone Plates

Bone plates are adaptable to practically all types of shaft fractures and have the distinct advantage of providing uninterrupted, rigid internal fixation. In most cases the bone plate is the fixation of choice in large dogs.[3] Depending on the fracture type, the plate may be used as a tension band compression plate in short oblique, transverse, and some segmental fractures; as a neutralization plate in long oblique and reducible wedge fractures; and as a buttress or bridging plate in nonreducible wedge fractures. These functions are sometimes combined according to the fracture type. Figure 2-75 lists applicable plate sizes according to body weight.

The plate is usually applied on the lateral surface and contoured to fit that surface. Usually, the curvature pattern for contouring is taken from a craniocaudal radiograph of the opposite femur for buttress (bridging) application, or the plate may be contoured at the time of application for reducible fractures. A considerable lateral twist is necessary in the caudodistal end of the plate if it is necessary to extend the plate onto the condyle. Failure to do so will result in the craniodistal corner of the plate being elevated from the bone. A liberal exposure is necessary for application of the bone plate. To extend the plate distally to the condyle, it is necessary to open the stifle joint as an extension of the approach to the shaft.

At least three or preferably four or more bone screws (penetrating six to eight or more cortices) should be placed in each of the proximal and distal bone segments. A simple transverse type A3 fracture can typically be stabilized with six cortices on each side of the fracture, whereas eight cortices is the minimum number needed in buttress (bridging) applications. Whenever possible, the plate and screws should be inserted to develop compression at the fracture site. This has the distinct advantage of providing a more rigid fixation and making conditions more nearly optimal for healing.

The choice of a buttress plate for multiple fractures has become more common with the recent emphasis on biological osteosynthesis. Bone healing of the femur associated with the use of the buttress plate has been faster than healing of femoral fractures treated with complete fragment reconstruction and application of a neutralization plate.[25] A buttress plate can be applied to a femoral fracture with minimal manipulation of bone fragments, therefore preserving the blood supply and healing potential of the soft tissue associated with the fracture. The disadvantage of using a buttress plate on the femur is that the lateral position of the plate subjects it to extreme bending stress during weight bearing. The combination of an IM pin with a buttress plate has been described to help overcome this disadvantage[25-28] (see Figure 2-80). The IM pin is placed first, which allows efficient alignment of the major fragments proximally and distally with minimal disruption of the fracture site. The plate is then contoured and applied to the lateral surface of the femur. Bicortical screws may often be used through the plate, with some adjustment to the angle of screw placement to avoid the IM pin. If interference with the pin is encountered, monocortical screws may be placed. A minimum of three monocortical and one bicortical screws above and below the fracture is recommended for plate/pin combinations.[26] The pin will function during healing to share loading and to protect the plate from the bending forces of weight bearing. A pin diameter that occupies approximately 35% to 40% of the diameter of the midshaft medullary space has been proposed to provide adequate stiffness at the fracture site for healing.[27] This diameter can be adjusted for the severity of the fracture, with slightly larger diameters chosen for the more complex fractures.

Lag Screws

The primary site of application of lag screws as primary fixation is in fractures of the proximal and distal zones, where they are invaluable in providing rigid fixation (see Figures 17-7, 17-10, 17-13, 17-17, 17-18, 17-34, and 17-35). Figure 2-75 lists applicable screw sizes according to body weight. Lag screws are never used as the sole method of fixation in immobilizing shaft fractures of the long bones. They can be used advantageously for interfragmentary compression in oblique, spiral, and butterfly segments and in certain types of multiple fractures when combined with a primary fixation method (see Figures 17-22, 17-23, 17-26, and 17-27). If diaphyseal bone segments are large enough for bone screws to be used, they are to be preferred over cerclage wire. When properly inserted, bone screws are superior for compression and rigid fixation and are less apt to disrupt periosteal blood supply during their insertion.

PROXIMAL FRACTURES

Fractures of the proximal zone account for approximately 25% of femoral fractures[1] and offer significant challenges to provide adequate internal fixation (Figure 17-5). Very few of these fractures will respond to nonsurgical treatment.

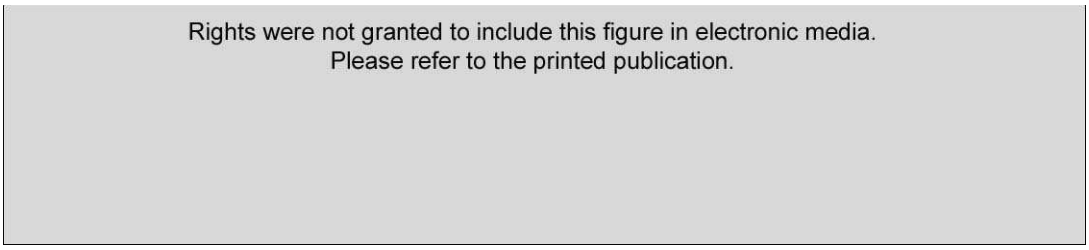


FIGURE 17-5. Proximal fractures of the femur. **A:** *A1,* Avulsion; *A2,* intertrochanteric simple; *A3,* multifragmentary. **B:** *B1,* Basicervical; *B2,* transcervical; *B3,* with trochanteric avulsion. **C:** *C1,* Articular simple; *C2,* articular multifragmentary; *C3,* multifragmentary cervical and trochanteric. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

Fracture Type 3-1-A; Proximal, Trochanteric Region

(Figure 17-5, *A*)

Open Approaches

Type A fractures of the trochanteric region are exposed by the approach to the greater trochanter and subtrochanteric region of the femur (Figure 17-6, *A*). Type B cervical and type C capital fractures are usually adequately exposed by the craniolateral approach to the hip (Figure 17-6, *B*), sometimes combined with the trochanteric approach.[29]

Type A1, Avulsion

In most cases the type A1 fracture is a physeal separation at the trochanter accompanied by dislocation of the femoral head[2] (Figure 17-7, *A*). With the animal under anesthesia, a closed reduction of the femoral head is usually attempted first. If this can be accomplished and the reduction feels stable, fixation of the fracture is indicated next. If the dislocation cannot be reduced or is unstable on reduction, the open approach should include the coxofemoral joint.

Reduction and Internal Fixation

The following steps are observed:

1. If closed reduction of the hip was successful, or if there is no luxation, make the approach to the trochanteric region and proceed with fixation of the trochanter major. The trochanter major may be fixed by using two small pins or Kirschner wires (K-wires), and this is sufficient for most animals under 4 months of age (Figure 17-7, *B*). These pins must be anchored in the medial cortex of the cervical region to provide good stability. Fixation by use of a tension band wire is usually the procedure of choice, particularly in larger dogs (Figure 17-7, *C*). Fixation with a cancellous bone screw is used only for animals approximately 4 1/2 months of age or older (Figure 17-7, *D*). In our experience, this procedure has not significantly altered anatomical growth of the femur (length or shape) in dogs over 4 1/2 months of age.
2. When open reduction and repair of the coxofemoral joint capsule are indicated, proceed directly with the approach to the hip joint.
3. Some of the origin of the vastus lateralis muscle is usually still attached to the lateral surface of the fractured trochanter major. This muscle is gently elevated,

just sufficiently to reduce the fracture, with tag ends remaining attached to the trochanter major, to be sutured on closure.
4. After replacing the femoral head, obtain stability by closing the joint capsule. Abduction of the leg allows for easier and tighter closure of the joint capsule. Other measures for stabilizing the hip joint are discussed in Chapter 16.
5. Apply fixation of the trochanter major.

Aftercare. If the coxofemoral joint was luxated, place the leg in an Ehmer sling or off-weight-bearing sling for 5 to 7 days (see Figures 2-31 and 2-32), and limit exercise during the healing period of 4 to 6 weeks. No external support is needed for simple trochanter fracture.

Type A2, Intertrochanteric Simple

Reduction and Internal Fixation

After exposure by the approach to the trochanter and subtrochanteric region of the femur, the pin and tension band wire method can be used for fixation in animals with a relatively high fracture patient score (e.g., 8-10). Although similar in principle to the method previously described for the trochanter (Figure 17-7, *C*), some modification of pin size is needed. Rather than small, flexible K-wire, larger Steinmann pins are used, and they are driven distally, as usual for Steinmann

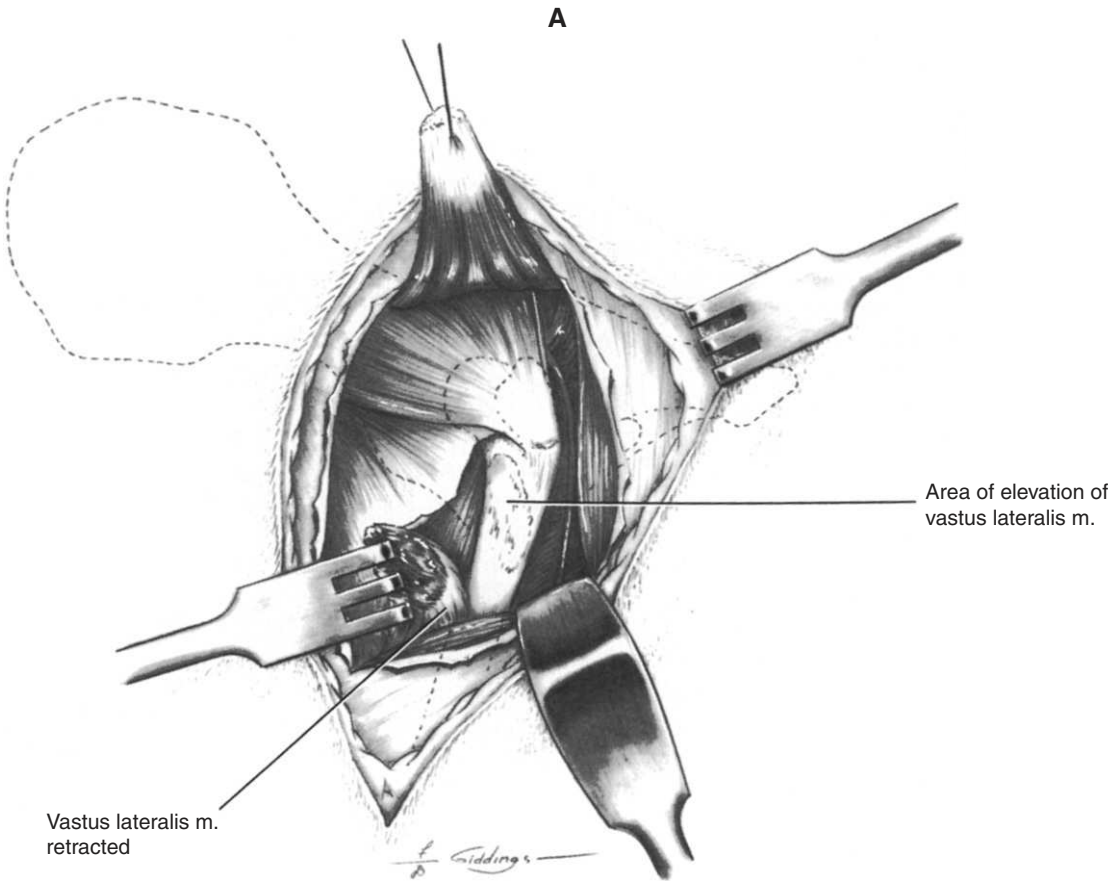


FIGURE 17-6. **A,** Approach to the greater trochanter and subtrochanteric region of the femur.

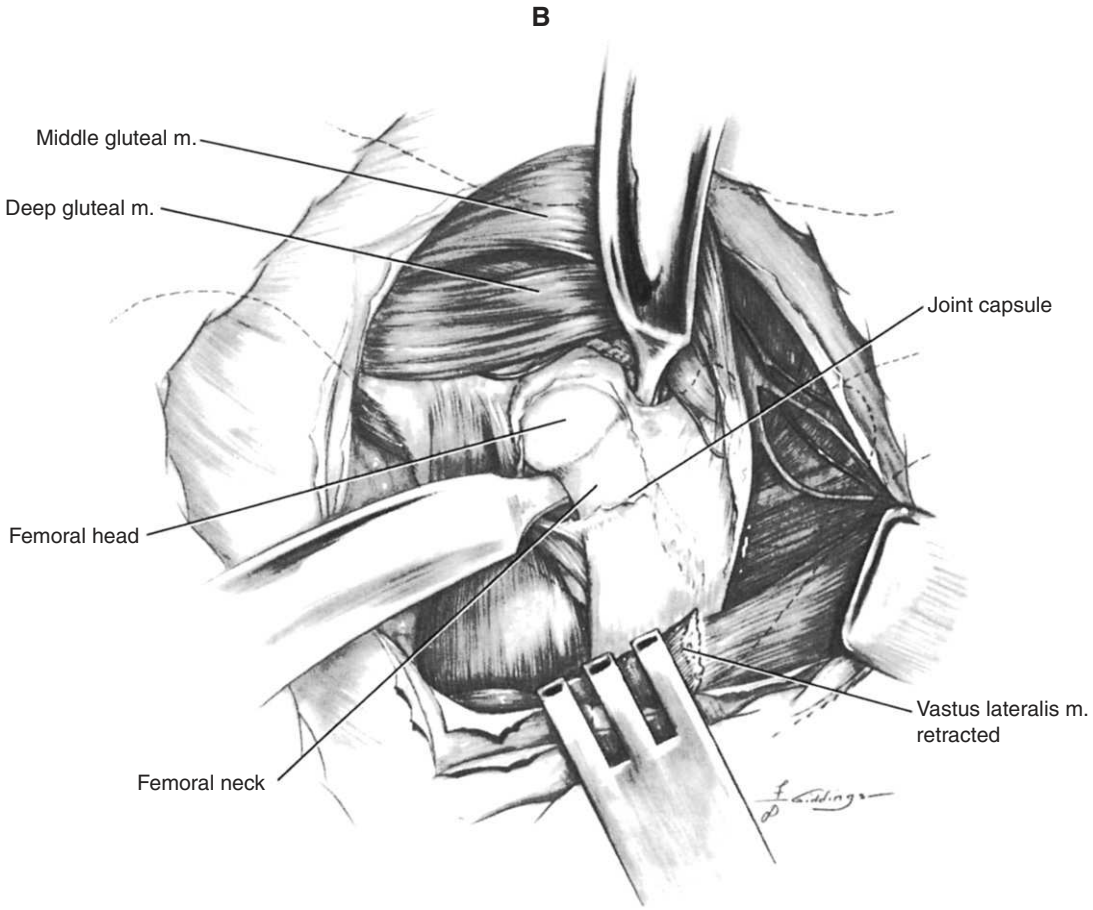


FIGURE 17-6. *Continued* **B,** Approach to the craniodorsal aspect of the hip joint through a craniolateral incision. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

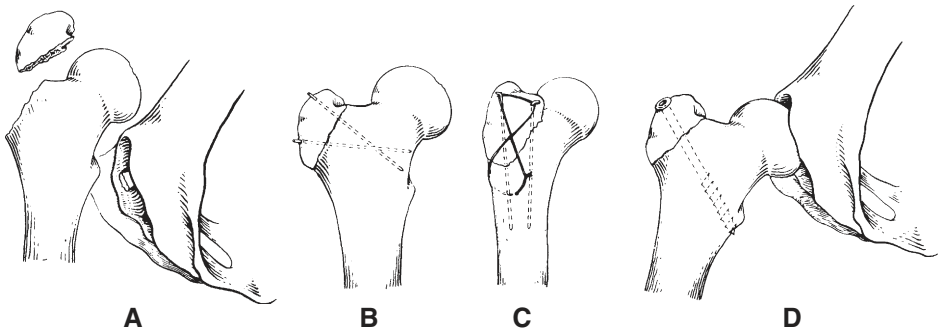


FIGURE 17-7. **A,** Type A1 fracture of the trochanter major with dislocation of the femoral head. **B,** Fixation by two small pins. **C,** Fixation by tension band wire; this is usually the method of choice. **D,** Fixation of the trochanter major with a cancellous bone screw.

pins (Figure 17-8). Because of their diameter, it may not be possible to bend the proximal end of these pins; in this situation they are driven as closely as possible to the bone surface without the wires slipping over the end. Carefully passing the wire through the middle gluteal muscle close to the bone will help prevent slipping over the pins. Rush pins can also be used in place of Steinmann pins, and their hooked end eliminates the problems just described. Drilling of the distal hole for the tension wire will require elevation of the vastus lateralis muscle. The position of the hole is adjusted so that the wire crosses close to the fracture line.

Other possible fixation methods for lower fracture patient scores (<8) involve external fixators or bone plates, as described next for type A3 fractures.

Aftercare. No external support is required, only restriction of exercise for the healing period. Removal of the implants after clinical union may be necessary if soft tissue irritation is noted.

Type A3, Multifragmentary

Reduction and Fixation

Although somewhat formidable in appearance, these fractures heal surprisingly well, probably because of the highly vascularized trabecular bone in the area and the relatively short proximal lever arm of the fracture. Movement of the hip joint partially neutralizes disruptive forces at the fracture line.

Fracture patient scores may be at the bottom of the scale (see Table 2-6), especially if concurrent injuries are present. The key consideration relative to fixation is the degree of fragmentation of the *calcar region,* that portion of the medial cortex between the femoral head and lesser trochanter. Weight-bearing forces create considerable bending strain in this bone, and if it is fragmented, the fixation device must be capable of withstanding both bending and compression loads (Figure 17-9). If this area of bone is intact (see Figure 17-5, *A*), the fixation can function primarily as a tension band to neutralize bending forces.

Both external fixators and bone plates offer suitable fixation. The external fixator is a type IA, single plane, with at least two but preferably three pins in each major bone segment (see Figure 17-9). One pin can be inserted deeply into the femoral head, but with care not to penetrate the articular surface. The remaining proximal pins

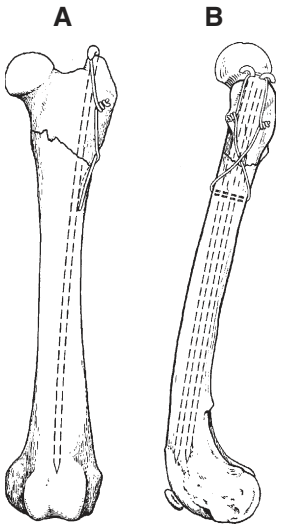


FIGURE 17-8. Fixation of a type A2 intertrochanteric simple fracture of the proximal femur. **A** and **B,** The fracture is pinned with two small Rush or Steinmann pins from the eminence of the greater trochanter. A tension band wire is then applied, anchored around the protruding ends of the pins and through a drill hole distally. The drill hole is positioned to cause the figure-of-8 wire to cross close to the fracture line.

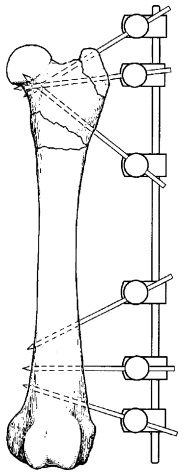


FIGURE 17-9. Fixation of a type A3 multifragmentary fracture of the proximal femur by means of a type IA external fixator. A double connecting bar is used for very large breeds or when significant fracture gaps remain.

penetrate the calcar region medially. Bone plate fixation is similar to that shown for type C3 fractures (see Figure 17-18), with some of the plate screws probably acting as lag screws to stabilize fragments. Double hook plates, as used for intertrochanteric osteotomy (see Chapter 16), have also been applied to these subtrochanteric fractures.[30] Autogenous cancellous bone graft should be used in any unreduced fracture gaps.

Aftercare. No external support is required, only restriction of exercise for the healing period. The external fixator is removed when clinical union is verified. Removal of the bone plate after clinical union may be necessary if soft tissue irritation or loosening of the implant is noted. An additional reason to remove the plate is that because the plate ends in the diaphysis and creates a stress raiser, there is an increased risk of accidental fracture at the end of the plate.

Fracture Type 3-1-B; Proximal, Simple Cervical (Figure 17-5, *B*)

In these femoral neck fractures, the fracture line varies and is usually simple; however, it may be multiple in nature. Various degrees of compromised blood supply to the head and neck may occur in association with the original injury.[3,31,32] Considerable mechanical damage from abrasion can be done to the fracture surfaces if the animal starts actively walking on the limb before fixation is accomplished. This abrasion can destroy the irregular surfaces of the fracture and make accurate reduction very difficult. The incidence of unfavorable complications can be greatly reduced by (1) early surgery, (2) accurate reduction, (3) rigid uninterrupted fixation with compression at the fracture site, and (4) careful supervision of the postoperative care. In general, if these issues are successfully addressed, the prognosis is favorable. Because of this, excision of the femoral head and neck or total hip replacement is usually considered a second choice in most fresh fractures of the femoral neck in larger breeds. Technical difficulties arise in repairing neck and head fractures in small breeds, and because of their excellent function with femoral head and neck excision, many consider this the best treatment in cats, toy breeds, and miniature breeds.

Note: Repair of a fractured femoral neck or of a fracture of the proximal femoral epiphysis in a young growing animal may result in shortening of the femoral neck and instability of the hip joint, which may give rise to alterations of the hip joint characteristic of hip dysplasia.

Open Approaches

The craniolateral approach to the hip joint is preferred for open reduction (Figure 17-6, *B*), since it is generally more sparing of blood supply to the bone than the dorsal approaches.[32]

Type B1, Basicervical; Type B2, Transcervical

Both these fracture types are handled in a similar manner. An impacted fracture with no displacement may heal with external immobilization and restricted exercise. The safer and preferred procedure is to apply fixation using a bone screw or multiple pins without further disturbing the position. Fractures showing various degrees of displacement respond best to an open approach with reduction and fixation. Mechanical studies indicate that a lag screw or three parallel 2.0-mm (5/64-inch) K-wires were able to resist a force of three times body weight, equivalent to the forces placed on a normal hip during walking exercise. Two K-wires, either parallel or divergent, were not as strong.[33] (See Figure 2-75 for appropriate screw sizes.)

Reduction and Fixation

After making the approach, temporary reduction is usually carried out to see if reduction and fixation are feasible. This usually can be accomplished by grasping the trochanter major with vulsellum or pointed reduction forceps and manually maneuvering the fracture segments back into position (see Figure 2-15). Abduction of the femoral shaft is usually necessary to accomplish reduction.

Lag Screw Fixation. A cortical lag screw is preferred over partially threaded screws for fixation because it eliminates the necessity for ensuring that all the threads are in the neck/head fragment.

1. The gliding hole is first drilled through the femoral neck (Figure 17-10, *A* and *B*). Note carefully the angle of the drill relative to the femoral shaft. The hole is started at the distal end of the third trochanter to keep the screw entirely within the femoral neck. The screw is often started too high on the trochanter, with the result that the screw is too acutely angled to the shaft. This results in high bending loads on the screw, with subsequent failure or loosening. Another common error is to aim the drill too caudally, which results in a screw that exits the neck or head caudally and is therefore of insufficient length. The surgeon must focus on positioning the screw immediately beneath the cranial cortex of the femoral neck, which will result in perfect screw position central and deep within the femoral head.
2. With the fracture segments reduced and compressed either by a pointed reduction forceps or by medial pressure on the trochanter, one or more K-wires (0.045-0.062 inch; 1.2-1.6 mm) are inserted through the trochanter, femoral neck, and head. Unlike the screw, the K-wire should traverse the dorsal bridge of bone between the trochanter major and femoral head, not the trochanteric fossa, for maximum holding power (Figure 17-10, *C* and *D*). The pin is positioned proximally so that it does not interfere with insertion of the bone screw. It will assist in maintaining reduction and will help keep the femoral head from turning during the drilling, tapping, and insertion of the bone screw. Maintenance of reduction is assisted by applying pressure at the fracture site using bone forceps attached to the trochanter major.
3. An appropriate-size drill sleeve is inserted through the gliding hole; this serves as a guide for centering and drilling the appropriate-size tap hole in the femoral head.

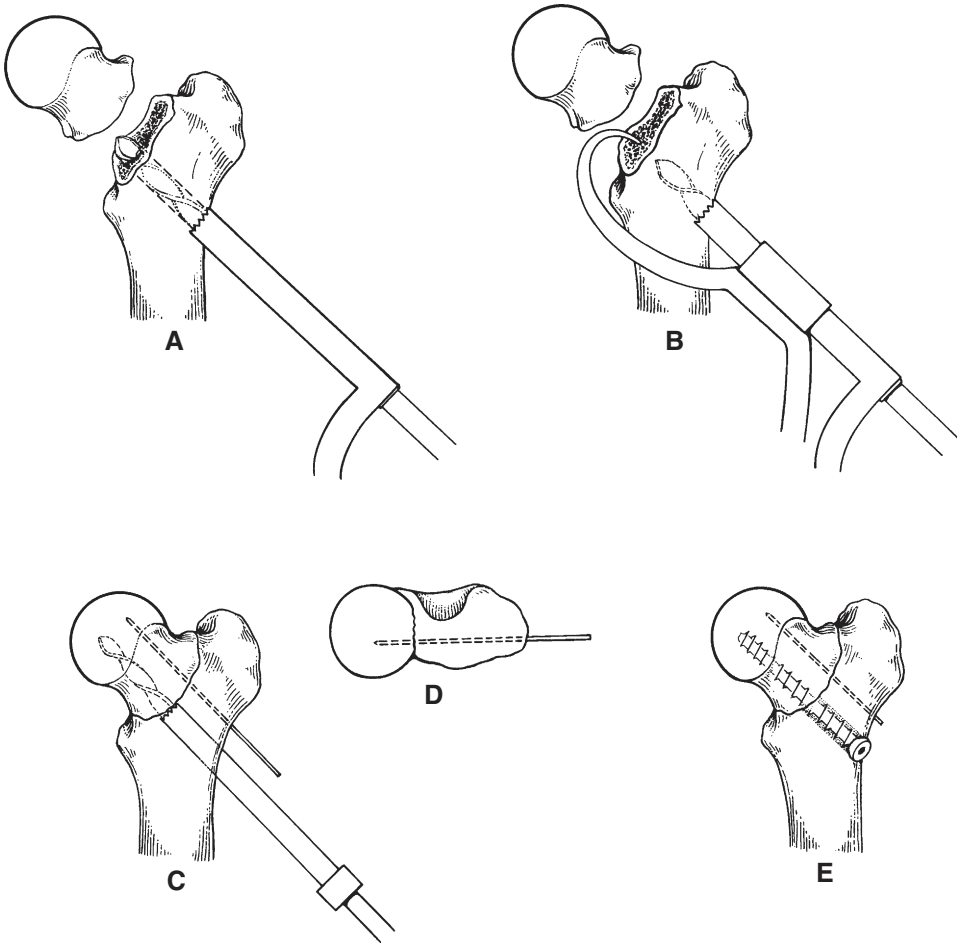


FIGURE 17-10. When a cortex screw is used for cervical fracture fixation, the gliding hole is drilled up through the femoral neck before reduction so that the hole is properly placed. **A,** Drilling the hole using regular drill guide. **B,** Drilling the hole using a pointed drill guide. This is advantageous in placing the hole properly. **C** and **D,** The fracture is next reduced, and small Kirschner wire is inserted to aid in stabilizing the fragments. The appropriate drill sleeve is inserted into the femoral gliding hole. This functions as a guide for drilling the appropriate-size hole in the femoral head. **E,** After the hole is measured and tapped (unless a self-tapping screw is used), the appropriate size and length of screw is inserted. This serves as a lag screw in compressing the fragments. A cancellous screw could be used to accomplish the same objective if all the threads are on the far side of the fracture line.

Ideally, the depth of the hole should be to the subchondral bone; this depth can be estimated by visualizing and measuring the head and neck segment before reduction and by measurement from the radiograph. Before the drill bit is removed, penetration of articular cartilage should be checked by rotation and flexion-extension of the hip joint to check for crepitus. A curved hemostat can also be passed along the surface of the femoral head through a small joint capsule incision. The depth of the hole is measured, tapped, and the appropriate-size cortical screw is inserted (Figure 17-10, *E*). Compression of the fracture line should be confirmed visually during tightening of the screw. The K-wire is usually left in place. When the basicervical fracture line is quite oblique, as in Figure 17-11, special attention must be paid to reduction because

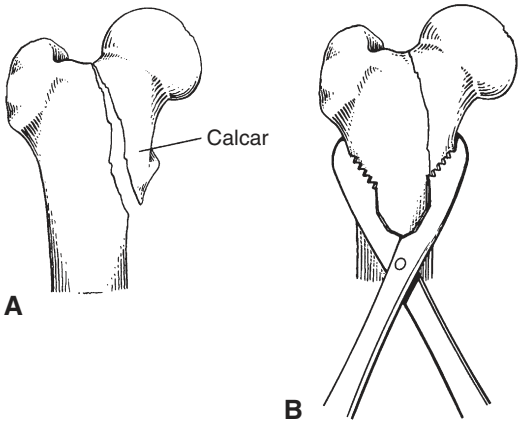


FIGURE 17-11. **A,** Oblique type B1 fractures of the femoral neck require care, **B,** to reduce and compress the calcar region before bone screw fixation.

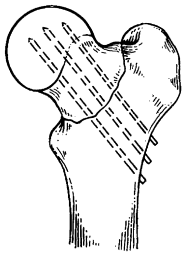


FIGURE 17-12. Fixation of a type B1 femoral neck fracture using Kirschner wires. This method is used primarily for small dogs and cats.

contact may not be good at the distal part. Elevation of a portion of the vastus lateralis off the fractured neck allows visualization of the reduction. Application of reduction forceps during fixation in the distal calcar area is essential in most cases of this type. It may be possible to insert a second lag screw from the midpoint of the third trochanter into the calcar.

Kirschner Wire Fixation. After reduction as just described, the K-wires are best placed with a low-speed power drill; they are difficult to drill accurately with a hand chuck. The angle of insertion is as described for the screw (Figure 17-12). The outer wires are placed as proximally and distally in the neck as possible, and the central pin is then placed between the wires.

Aftercare. At the completion of surgery, radiographs should be taken from two ventrodorsal views; one view should show the legs flexed at the hips ("frog-leg" position), and another should show the rear legs extended. The frog-leg position is particularly useful to visualize the depth of the screw in the head and neck. The leg is usually placed in an off-weight-bearing or Ehmer sling for 7 to 10 days (see Figures 2-31 and 2-32). Exercise is restricted for the next month or until the stage of clinical union is reached, as evaluated radiographically; then activity is slowly returned to normal over the next month. The bone screw and pin usually are not removed.

Type B3, Cervical with Trochanteric Avulsion

A combination of the methods described for A1 and B1 and B2 fractures is applied to type B3 fractures.

Fracture Type 3-1-C; Proximal, Capital or Multifragmentary Cervical (Figure 17-5, *C*)

Type C1, Articular Simple

This group of fractures includes both fractures through the articular surface (Figure 17-13) and those involving the physis only (Figure 17-14).

Avulsion Fracture of Femoral Head

With this fracture, a small portion of the femoral head remains attached to the round ligament, and the femoral head is dislocated in the craniodorsal position (Figure 17-13, *A*). The fracture segment remaining attached to the round ligament varies in size and is usually visible on a radiograph. Treatment varies with the individual case, depending primarily on the size of the fragment and the exact location of the fracture line. This discussion presents several suggested courses that may be followed.

Closed Reduction. An Ehmer sling is applied for approximately 2 weeks (see Figure 2-31), and activity is restricted for an additional 2 to 4 weeks. Success of

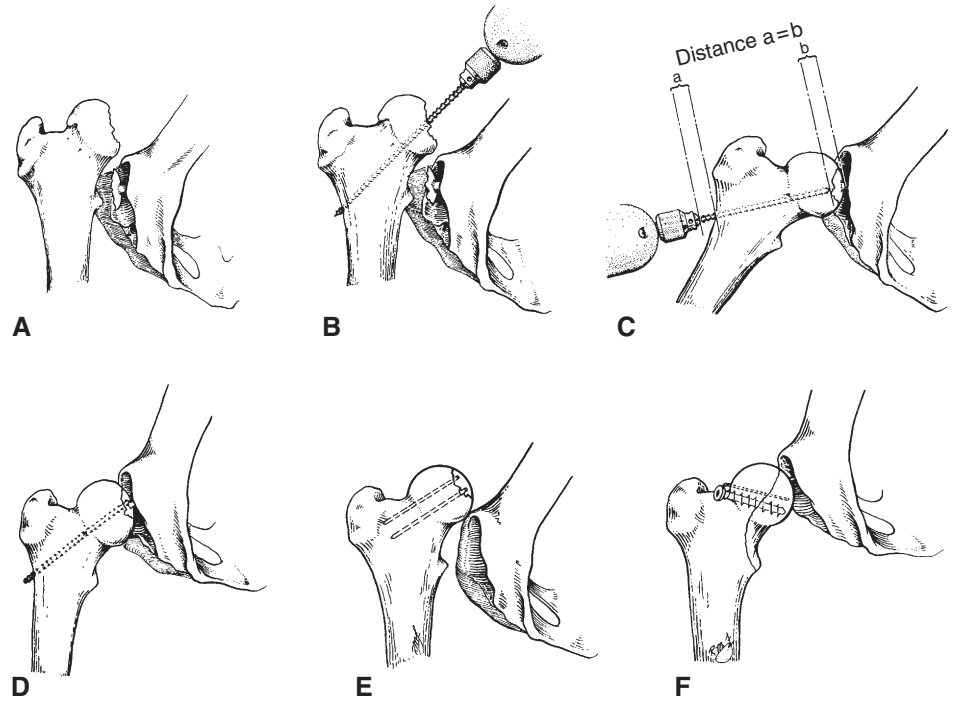


FIGURE 17-13. Fixation of a type C1 avulsion fracture of the femoral head. **A,** Avulsion fracture with dislocation of the femoral head. **B,** Small, double-pointed thread pin is inserted in the center of the fracture surface and passed retrograde through the head and neck, emerging at the base of the trochanter major. **C,** Pin chuck is attached at a distance from the bone *(a)* corresponding to thickness of avulsed segment *(b)*; fracture segments are reduced and compression is applied during insertion of the pin. **D,** About 1/8 inch of the pin is left protruding so that removal is possible. **E,** Alternate method is to cut the round ligament, reduce the fracture, and stabilize by inserting two or more countersunk Kirschner wires. **F,** Occasionally a portion of the femoral head and neck is fractured off in an oblique fashion. If the fragment is large enough, it may be fixed using a small screw and Kirschner wire.

this procedure depends on perfect reduction at the fracture site and maintenance of the reduction until the fracture segments have healed. Both these conditions must be met if this procedure is to be successful, but this is difficult to accomplish unless the fragment is very small.

Surgical Excision of Bone Fragment and Reduction of Femoral Head. The avulsed segment is permanently removed through a craniolateral approach to expose the hip joint. The femoral head is replaced and stabilized by one of the methods discussed in Chapter 16; after closure, the leg is immobilized for approximately 7 to 14 days (e.g., with an Ehmer sling). If the removed avulsed segment is too large, the remaining portion of the femoral head may not remain stable in the acetabulum, and dislocation will occur. Development of significant degenerative joint disease is to be anticipated if the fragment is large.

Open Reduction and Fixation.[2,3] A dorsal open approach with osteotomy of the trochanter major is necessary to expose the hip joint fully (see Figure 15-14).[29] A small, threaded K-wire is started in the center of the fracture surface of the femoral head and passed retrograde through the head and neck, emerging at the base of the trochanter major (Figure 17-13, *B*). The retrograde pin may need to be inserted through the retracted gluteal muscles first in order to start the pin at the proper angle. The pin is inserted until it is flush with the fracture surface, and the chuck is attached on the opposite end at a distance from the bone corresponding to the thickness of the avulsed fragment (Figure 17-13, *C*). The fracture is held in reduction and compressed during insertion of the threaded pin. The pin is then bent to minimize migration and cut off 1/8 inch beyond the trochanter major (Figure 17-13, *D*). If the fracture segment is large enough, two pins are inserted. After closure, the leg is immobilized in a non-weight-bearing or Ehmer sling for about 10 to 14 days (see Figures 2-31 and 2-32). Exercise is restricted until healing is complete.

Another method of fixation worth consideration, especially if reduction cannot be visualized in the dorsal approach, is to cut the round ligament, reduce the fracture fragments, and stabilize by use of two or more small, countersunk K-wires (Figure 17-13, *E*). Miniscrews (1.5-2.0 mm) can also be used from the articular surface, as illustrated in Figure 17-16. In some cases the ventral portion of the head and neck is fractured obliquely and may be reduced and fixed in place using a miniscrew and K-wire placed from the edge of the articular surface (Figure 17-13, *F*).

A third method of fixation also uses miniscrews and K-wire but uses a ventral approach to the hip joint.[34] Although only a limited number of cases have been described, advantages to this technique are that it is not necessary to cut the round ligament and the fragment can be directly visualized.

Total Hip Replacement. When the femoral head cannot be reconstructed and saved, total hip replacement should be considered as an option (see Chapter 16).

Excision of Femoral Head and Neck. Excision arthroplasty is usually considered a last resort in large dogs because the intact joint should be maintained if possible (see Chapter 16).

Fracture of Femoral Capital Physis

This condition is limited to young animals in which the capital physis is still present (Figure 17-14, *A*). It usually occurs between ages 4 and 11 months in dogs. Capital femoral injury in cats, regardless of apparent previous physeal closure, may

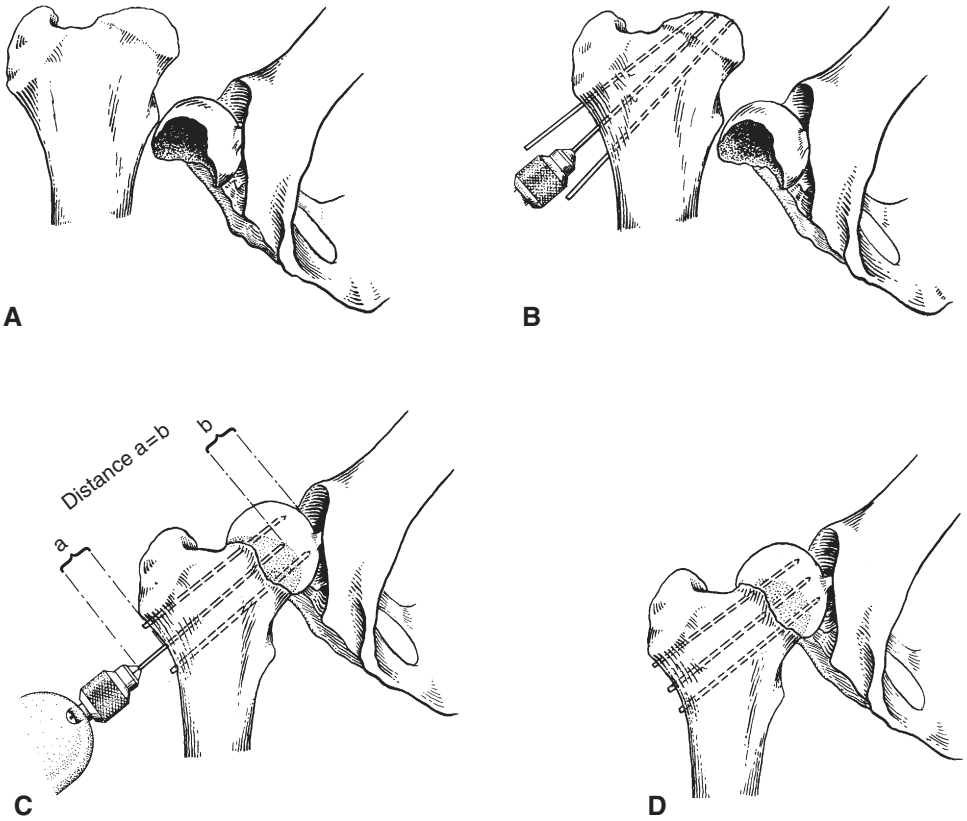


FIGURE 17-14. Normograde fixation of a proximal femoral type C1 physeal fracture with multiple Kirschner wires. **A,** Physeal fracture. **B,** Two to four Kirschner wires are driven from the base of the trochanter major up through the femoral neck to the fracture surface. **C,** After reduction, a pin chuck is set at a distance from the bone corresponding to the thickness of the epiphysis; pins are driven into the epiphysis. **D,** All pins are deeply seated into the epiphysis but do not penetrate the articular cartilage.

occasionally be seen as late as 12 to 16 months of age. In most cases this fracture is primarily a separation at the epiphyseal line (usually Salter-Harris I, occasionally II; see Table 22-1). The joint capsule can be attached to the epiphysis, partially detached, or completely stripped off, which undoubtedly affects healing. Fortunately, in most cases there is some attachment. Occasionally, breeds prone to Legg-Perthes disease develop fractures of the femoral head that mimic physeal separation. Lameness may be acute, however, without a history of significant trauma.

If open reduction and internal fixation are to be done, they should be performed as soon as possible, preferably within the first 24 hours, to avoid the danger of thrombosis occurring in the kinked capsular vessels at the junction of the femoral head and neck, and to avoid further injury to the surface of the neck caused by abrasion from the epiphysis. The femoral neck also undergoes demineralization quite rapidly, and this change is usually evident on the radiograph within 7 to 10 days. Internal fixation is indicated in large-breed dogs. Small dogs and cats have excellent and predictable function with excision arthroplasty (femoral head and neck excision). However, internal fixation in small dogs and cats also results in excellent function and in most cases can be readily accomplished with the pin techniques described here.[35]

Prognosis. The prognosis with internal fixation depends on (1) the age of the patient, (2) concurrent injuries of the hip joint, (3) early accomplishment of surgery, (4) preservation of blood supply in the procedure, (5) accurate reduction at the fracture site, (6) rigid uninterrupted fixation, and (7) restriction of early weight bearing. The percentage of successful outcomes decreases with each day's delay in surgery. A good healing response is possible for patients treated within 4 days. Success has been achieved in patients treated within 10 days; after this period, however, rigid fixation is difficult to obtain because of demineralization and abrasion of the femoral neck. All dogs will show evidence of degenerative joint disease at some point postoperatively.[36] Arthritic changes are more pronounced in animals that are 4 months of age or younger at the time of injury and in those that have concurrent ipsilateral injury to the coxofemoral joint.[37] Although radiographic narrowing of the femoral neck occurs in about 70% of cases after internal fixation, this seldom results in collapse of the neck.[37]

Kirschner Wire or Pin Fixation. The pin techniques described here are preferable to use of a lag screw in most cases and particularly in younger animals (<7 months of age) because these methods are less likely to result in premature closure of the physeal plate and resultant femoral neck shortening. Figure 17-14 shows the surgical procedure for fixation of a proximal femoral physeal fracture.[2,3] The exposure of the area should be conservative to minimize destruction of blood supply. Reduction of the fracture is best accomplished by grasping the trochanter major with vulsellum or pointed reduction forceps and moving the femur distally and medially into position (see Figure 2-15). The capitus is usually rotated in relation to the neck because of the round ligament and may cause some difficulty in reduction. Medial pressure on the trochanter while flexing and extending the hip joint with the femur abducted will usually cause the epiphysis to derotate and lock into the femoral neck in the reduced position. Small, pointed reduction forceps applied with finger pressure only can be attached to the periphery of the capitus to assist in the derotation. Pressure must be applied in a medial direction while driving pins across the fracture site to prevent distraction.

Note: A review of the contour of the epiphysis and epiphyseal line is most helpful before undertaking anatomical reduction.

Two to four small, smooth pins are inserted for immobilization. Pin size corresponds with the size of bone and may range from a 0.035-inch K-wire to a 5/64-inch Steinmann pin (1-2 mm). The pins may be inserted in antegrade (see Figure 17-14) or retrograde (Figure 17-15) fashion; antegrade is preferred in most cases. The pins may be inserted parallel or in a converging-diverging manner; mechanical studies indicate superior strength of parallel placement over diverging pins.[33] The main objective is to have the pins well distributed at the fracture surface. Three-pin fixation techniques are stronger and stiffer than one- or two-pin fixation techniques.[38] The pin chuck is set on the pin so that the distance from the chuck to the lateral femoral cortex corresponds with the thickness of the epiphysis (Figures 17-14, *C,* and 17-15, *C*). With the fracture compressed in the reduced position, the pins are inserted into the epiphysis one at a time (Figures 17-14, *C* and *D,* and 17-15, *C* and *D*). The pins should not penetrate the articular cartilage. Pin penetration can be checked by careful movement of the femoral head in the acetabulum after each pin is inserted and by palpation of the femoral head using a small, curved hemostat.

Aftercare. At the completion of surgery, radiographs should be taken from two ventrodorsal views; one view should show the legs flexed at the hip (frog-leg view), and the second should show the rear legs extended. The frog-leg view is superior for judging depth of penetration of the pins. An Ehmer or non-weight-bearing sling is

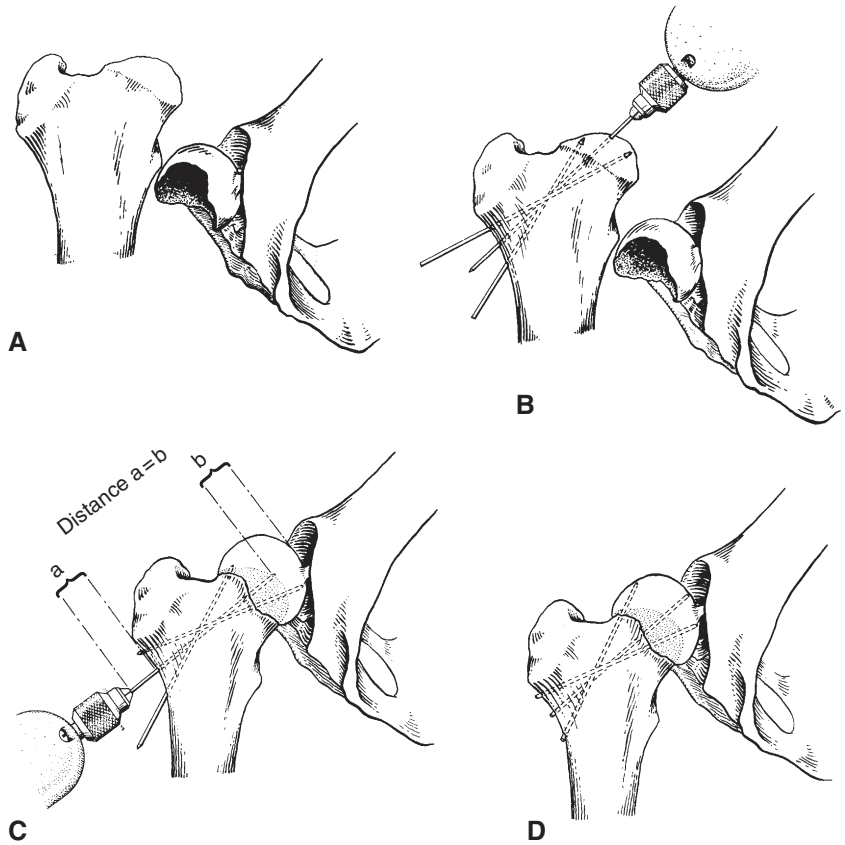


FIGURE 17-15. Retrograde fixation of a proximal femoral physeal fracture with multiple Kirschner wires. **A,** Physeal fracture of the proximal femur. **B,** Two to four double-pointed Kirschner wires are driven retrograde from the fracture to exit distal to the trochanter major on the lateral femoral surface. **C,** After reduction, a pin chuck is set at a distance from the bone corresponding to the thickness of the epiphysis; pins are driven into the epiphysis. **D,** All pins are deeply seated in the epiphysis but do not penetrate the articular cartilage. The converging/diverging pins may not be as strong as parallel pins.[33]

applied to the leg for about 7 to 10 days (see Figures 2-31 and 2-32). Exercise should be limited for the next 5 weeks. The pins are usually left in place unless indicated otherwise.

Follow-up radiographs should be taken at about 6 weeks. At this time, they should reveal healing or any complications.

Lag Screw Fixation. Lag screw fixation through the articular surface has been advocated by some[39] (Figure 17-16). However, severing the round ligament further compromises the blood supply. In dogs older than 7 months of age, the epiphysis may be reattached by lag screw fixation through the femoral neck (Figure 17-17). There is no mechanical advantage over pin fixation,[33] and we do not find either of these screw techniques necessary in rapidly healing physeal injuries. In addition, the technique is more technically difficult to perform properly because of the thin cross section of the epiphysis and the large distance between screw threads and screw tip.

If lag screw placement through the articular surface is chosen, the epiphysis must be freed of soft tissue attachments and removed from the acetabulum. After reduction

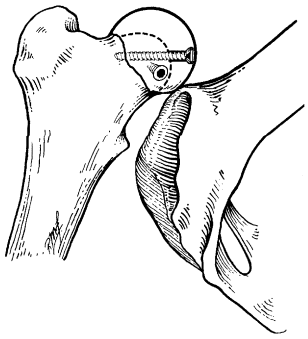


FIGURE 17-16. Fixation of a proximal femoral physeal fracture with lag screws from the articular surface. Two 1.5- to 2.0-mm screws are used, with the screw heads countersunk below the cartilage surface. One screw is in the fovea capitus, and the second is near the cranial border of the epiphysis.

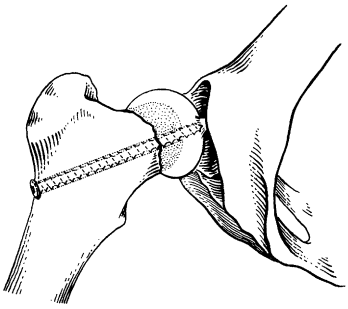


FIGURE 17-17. Lag screw fixation of a physeal fracture of the femoral head. Care must be taken in tightening the screw because the threads in the epiphyseal end are in cancellous bone.

onto the metaphysis, a K-wire is inserted through the fovea capitus for temporary stabilization while a 1.5- to 2.0-mm screw is inserted in lag fashion cranial to the fovea. The head of the screw must be countersunk below the articular surface. The K-wire is removed and replaced with a second screw.

Fracture of Femoral Physis and Trochanter Major

Combined fracture separation of both the femoral capital physis and the trochanter major physis occasionally occurs (see Figure 17-5, *B*). Radiographs must be studied carefully to detect both fractures preoperatively because the trochanter is frequently obscured by the femur. Often the trochanter is in the proper location, but the shaft of the femur is displaced proximally and cranially.

The open approach is made difficult by the gluteal muscles and vastus lateralis muscles remaining on the large trochanter major. The vastus attachment at the distal end of the trochanter major should be incised to gain exposure for reduction. The femoral capital physis is pinned as described in Figure 17-14 and the trochanter is wired as in Figure 2-65, *A*.

Type C2, Articular Multifragmentary

Successful internal fixation of these fractures is very unlikely, and degenerative joint disease is the almost inevitable consequence of such attempts. Most of these animals are candidates for either total hip replacement or excision arthroplasty, which are covered in Chapter 16.

Type C3, Multifragmentary Cervical and Trochanteric

Reduction can only be accomplished by performing an open approach. The exposure of choice is usually a combination of the craniolateral approach to the hip

joint (Figure 17-6, *B*) and the lateral approach to the femur (see Figure 17-19). Fixation can usually best be accomplished using a bone plate and bone screws.[2,3] Fractures of this type in some of the larger dogs are amenable to the use of a hook plate. [30] Depending on the degree of fragmentation, the pin or external fixator techniques such as shown in Figures 17-8 and 17-9 may be applicable, since a screw for the femoral neck can be accommodated in both instances.

Bone Plate and Lag Screws

In Figure 17-18, a craniolateral approach to the hip joint and a lateral approach to the femur are performed to expose the fracture site. The approach procedure is modified to fit the individual fracture. Reduction is usually accomplished by starting at the proximal end and working toward the distal end. Bone-holding forceps, K-wires, lag screws, and cerclage wire help hold the fragments in the reduced position. The bone plate is contoured. An easy and helpful procedure is to prebend the plate to the curvature of the lateral surface of the opposite femur, as shown from a craniocaudal view on the radiograph. The use of a dynamic compression plate (DCP) has the added advantage of allowing oblique insertion of the bone screw proximally into the femoral neck and head along with affording compression of the various fracture segments. Usually, the first bone screw is inserted through the base of the trochanter major and neck and into the femoral head. Judicious effort must be used to ensure proper deep insertion of this very important screw into the larger part of the femoral head. The trochanter major is then reduced and fixed in position (Figure 17-18, *A* and *B*). The remaining bone screws are inserted as indicated (Figure 17-18, *C* and *D*). In some cases, additional bone screws that produce a lag effect may be used advantageously to assist in compressing at the fracture site.

Aftercare. Following closure, an off-weight-bearing sling may be indicated for 3 to 7 days (see Figure 2-32). Exercise is severely restricted for 6 to 8 weeks. Radiographs taken at 6 to 8 weeks are used to evaluate the healing, and if satisfactory, a gradual resumption of normal activity is started.

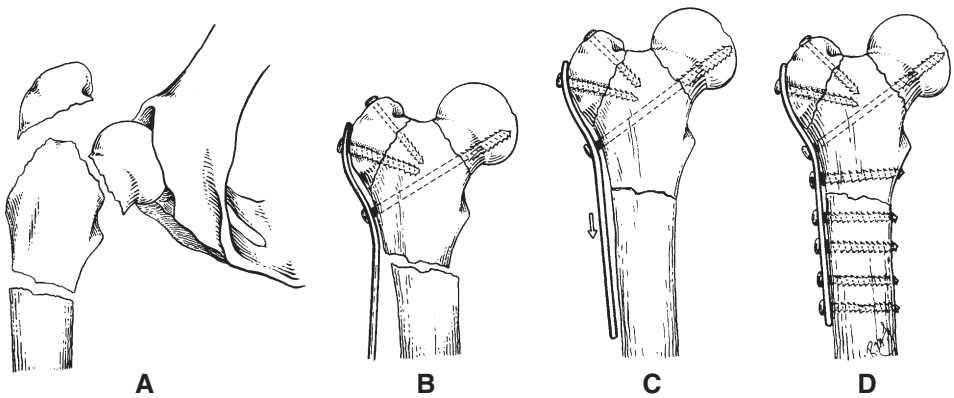


FIGURE 17-18. Fixation of type C3 fractures of the femoral neck, trochanter major, and femoral shaft. **A,** Fracture as seen in a craniocaudal radiograph. **B,** The plate is contoured, and a long lag screw is placed in the femoral neck. The trochanter major is reduced and fixed. **C,** The subtrochanteric fracture is reduced. A tension device or dynamic compression plate (DCP) is used to obtain compression. **D,** Fixation plate in place.

Complications in Proximal Femoral Fractures

Most complications in femoral head and neck fractures are caused by the following:

1. Compromised blood supply to the femoral head and neck that occurs at the time of the initial injury or during the surgical procedure.
2. Poor bone reduction.
3. Inadequate fixation.
4. Premature weight bearing.

The most frequently occurring complications are as follows:

1. Delayed union or nonunion.
2. Avascular necrosis.
3. Secondary osteoarthritis.
4. Cessation of neck growth in young animals as a result of premature closure of the physis, leading to subluxation of the hip.

Radiographic Signs

Radiographic evidence of a complication may appear as a loss of density in the femoral neck or along the fracture line in contrast to the surrounding bony tissue. Such a sign indicates a disturbance in blood supply, demineralization, and possible movement at the fracture site. In long-standing cases, a mottled appearance of the femoral head indicates replacement of some areas of necrotic bone by new bone. In some patients, the femoral neck may disappear partially or completely in 3 to 6 weeks, leading to varying degrees of segmental collapse of the neck. In most cases, clinical and radiographic evidence of complications is evident within 6 weeks. However, about 6 months should elapse before the clinician attempts to determine the ultimate fate of the femoral head and neck, even in those patients that appear to be healing initially. Most animals with coxofemoral dislocation, physeal separation, or femoral neck fracture that made a good recovery show some temporary demineralization and slight narrowing of the femoral neck.

Treatment

If reduction and fixation are satisfactory, restricted activity and more healing time are indicated. In some cases, a more rigid internal fixation with restriction of activity is indicated. Those beyond salvaging with a functional hip joint are subjects for excision arthroplasty of the femoral head and neck or for total hip replacement, as discussed in Chapter 16.

DIAPHYSEAL FRACTURES

Diaphyseal fractures are usually the result of direct trauma and are accompanied by various degrees of soft tissue damage and hematoma.[2,3] The fracture pattern may be quite variable: transverse, oblique, spiral, multiple, fragmented, or occasionally, greenstick in the young animal. Diaphyseal fractures account for 56% of femoral fractures.[40] As discussed earlier, external fixation is rarely adequate. Treatment recommendations are keyed to the fracture patient scoring system detailed in Table 2-6 when applicable.[4,5] The internal methods of fixation include use of the following:

1. Intramedullary Steinmann pin alone.
2. Intramedullary Steinmann pin plus auxiliary fixation (unilateral external fixator, cerclage wires, lag screws).

3. Interlocking intramedullary nail. Although still in the early stages of clinical use, the interlocking nail holds promise of being as useful in femoral fractures as bone plates have been in the past.
4. Unilateral external fixator with an IM pin and other auxiliary fixation as indicated. The caveats applicable to external fixators used on canine femoral fractures are discussed earlier under Fixation Techniques.
5. Plate with or without lag screws or cerclage wires. In general, the multiple and very unstable fractures respond best to bone plate and screw fixation. In large dogs, almost all femoral shaft fractures make a better functional response and are accompanied by fewer complications with bone plate and screw fixation.
6. Plate with IM pin for *bridging osteosynthesis*. The most complex diaphyseal fractures are often treated with a plate using buttress function. This configuration is subjected to considerable bending stress during weight bearing, attributable to the mechanical environment of the canine femur. The addition of an IM pin shields the buttress plate from bending stress to prevent fatigue failure from weight bearing.

Open Approach and Reduction

With few exceptions, a lateral approach is used to expose the femoral shaft for reduction and internal fixation (Figure 17-19).[29] In middle to proximal femoral fractures, the proximal fragment rotates caudally, allowing excessive anteversion of the femoral head. The surgeon must remember this when applying fixation, especially in comminuted fractures (see Figure 17-25). Oblique or multiple wedge fractures develop considerable overriding and can be very difficult to reduce, especially in large breeds or when several days have elapsed since the injury. The use of fracture distractors or reduction by means of an IM pin is helpful (see Figures 2-18 and 2-19).

Fracture Type 3-2-A; Diaphyseal Simple or Incomplete

(Figure 17-20, *A*)

Type A1, Incomplete

The temptation to treat these fractures by external splintage should be resisted, for the reasons mentioned earlier in the discussion of fixation techniques.

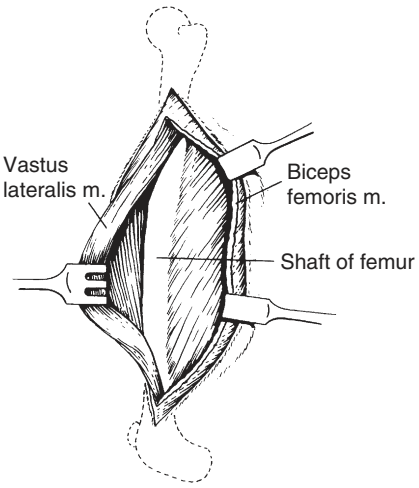


FIGURE 17-19. Open approach to expose the femoral shaft.[29] The belly of the biceps femoris muscle is reflected caudally, and the vastus lateralis muscle and fascia lata are reflected cranially, exposing most of the femoral shaft.

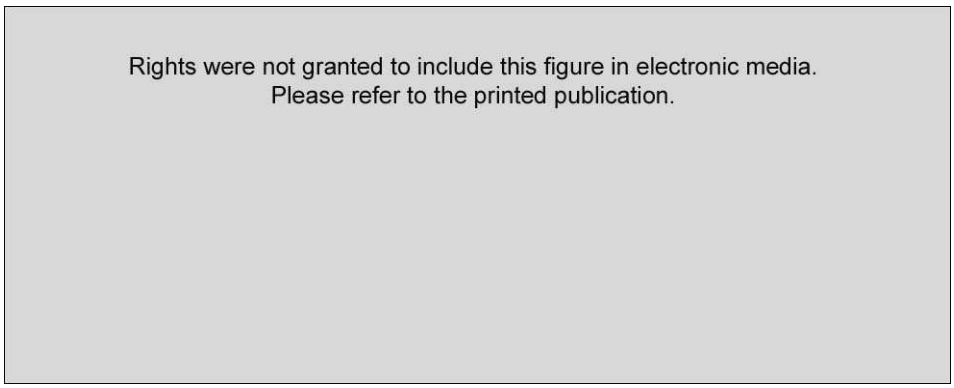


FIGURE 17-20. Diaphyseal fractures of the femur. **A:** *A1,* Incomplete; *A2,* oblique; *A3,* transverse. **B:** *B1,* One reducible wedge; *B2,* reducible wedges; *B3,* nonreducible wedges. **C:** *C1,* Reducible wedges; *C2,* segmental; *C3,* nonreducible wedges. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

Additionally, these fractures occur primarily in growing animals, and immobilization of the limb in these animals often leads to development of coxa valga with resulting instability of the coxofemoral joint. Fracture patient scores typically are in the 9 to 10 range (see Table 2-6). It is very simple to insert a Steinmann pin in a normograde manner, often without an open approach (see Figures 17-1 and 17-3). The pin adequately stabilizes the fracture against the bending forces of the hamstring muscles and allows early weight bearing. The pin can be a smaller diameter than usual and should be seated close to the bone in the trochanteric fossa to minimize compromise of hip joint function. Because of bone growth, it may not be possible to remove the pin after healing.

Type A2, Oblique

Reduction and Fixation

A long oblique fracture of the femur is shown in Figure 17-21. A fracture patient score of 8 to 9 would be expected. After a lateral open approach, the Steinmann pin is inserted in the proximal segment, the fracture is reduced and maintained by using self-retaining bone forceps, and the pin is then inserted into the distal segment. In long oblique fractures with a fracture line length equal to twice the bone diameter, cerclage wires are inserted at about 1-cm intervals (Figure 17-21, *B* and *C*). After clinical union, the IM pin is removed, and the cerclage wires are left in place.

Figure 17-22 presents another case of a long oblique femoral fracture, with a fracture patient score of 8 to 9, in a large-breed or giant-breed dog. After reduction and insertion of the Steinmann pin, one or more lag screws may be inserted to bring about interfragmentary compression. In this case an IM pin slightly smaller in diameter is used. The lag screws are inserted off center to avoid the IM pin. After clinical union, the IM pin is removed, and the lag screws are left in place.

Type A3, Transverse

Providing rotational stability is the primary concern in these fractures, and in large breeds this could easily drive the fracture patient score down to 7 to 8. Although considered a "simple" fracture, type A3 is one of the most common types to result in nonunion, no doubt because of underestimating the biomechanical forces involved. Age and size of the patient are important determinants as to type of fixation.

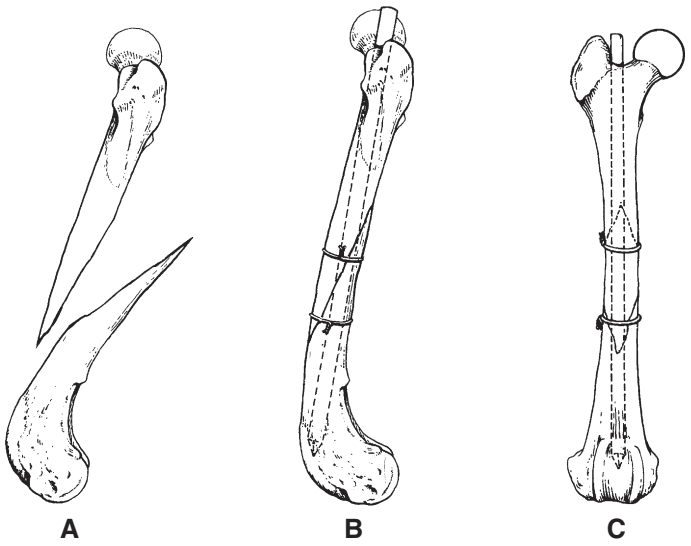


FIGURE 17-21. **A,** Type A2 long oblique fracture of the femur. **B,** Following a lateral open approach, an intramedullary pin is inserted into the proximal segment. The fracture is reduced and maintained by self-retaining bone forceps; the pin is inserted into the distal segment. **C,** In long oblique fractures, cerclage wires are inserted at 1- to 2-cm intervals; after clinical union, the intramedullary pin is removed and cerclage wires are left in place. If there is any doubt in regard to stability after applying the above, an external fixator may be added at surgery.

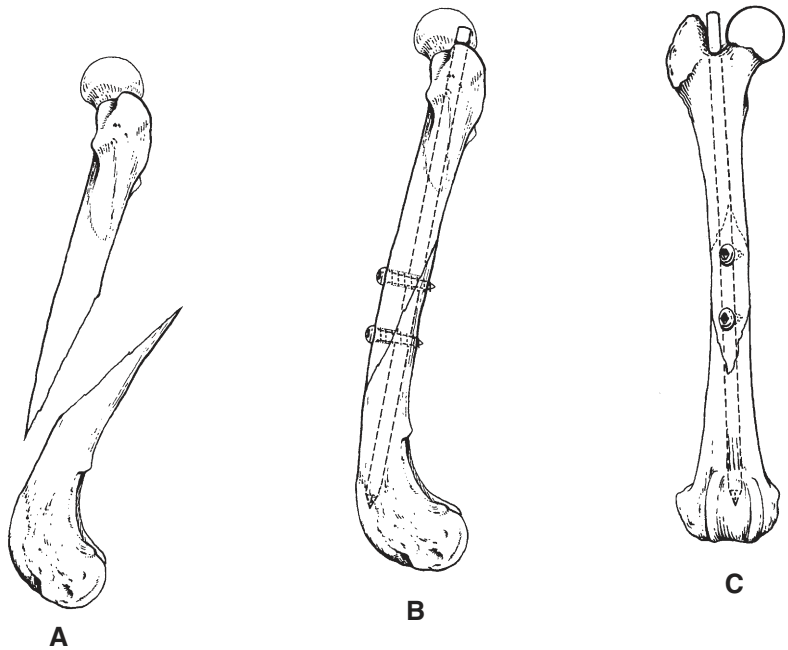


FIGURE 17-22. **A,** Type A2 long oblique fracture of the femur. **B,** After reduction and insertion of an intramedullary pin, lag screws may be inserted to bring about interfragmentary compression. **C,** Lag screws may be inserted off center to avoid the intramedullary pin. After clinical union, the intramedullary pin is removed and the lag screws are left in place.

Internal Fixation

Steinmann Pin. If the patient is less than approximately 6 months of age, the exuberant callus expected will compensate considerably for the lack of rotational stability, and simple Steinmann pin fixation would be adequate (see Figures 17-1 to 17-3). In mature dogs, however, some additional auxiliary fixation is needed. If the patient is less than 15 to 20 pounds (7-9 kg), interfragmentary wire fixation is often adequate. These patterns are described in Chapter 2 (see Figure 2-63). Such wire fixation must be very carefully applied to ensure that the wire is truly tight, and this author is very conservative in recommending them.

Steinmann Pin and External Fixator. In larger breeds, a type IA fixator combined with the pin is much more secure than pin and wire fixation (see Figure 17-4). The technique is described earlier under Fixation Techniques.

Interlocking Nail. Expansion of the interlocking medullary nail fixation system (Figure 2-54, E) to smaller sizes has improved its versatility of application to large cats and dogs of most sizes.[14,18,19]

Bone Plate. Compression bone plate fixation is a very simple and highly effective method of treatment in animals of all sizes, especially in large and giant breeds. Six to eight cortices should be captured by the plate screws (see Figure 2-75 for choice of plate size).

Aftercare. See aftercare suggestions at the end of this section.

Fracture Type 3-2-B; Diaphyseal Wedge (Figure 17-20, *B*)

Increasing degrees of instability characterize these fractures; therefore, simple intramedullary Steinmann pinning is less applicable. Fracture patient scores range from 3 to 7.

Type B1, One Reducible Wedge

Reduction and stabilization of the wedge by means of cerclage wires or lag screws convert these fractures to type A3 transverse fractures, so primary fixation is as described for those fractures. Fracture patient scores typically are 6 to 7.

Internal Fixation

Bone Plate and Lag Screws. Figure 17-23 illustrates the combination of lag screw and compression plate fixation.

Steinmann Pin, Cerclage Wires, and External Fixator. After reduction and cerclage wire stabilization of the wedge, this fixation can be completed as shown in Figure 17-4.

Interlocking Nail and Cerclage Wires. After reduction and cerclage wire stabilization of the wedge, the interlocking nail would be appropriate fixation in large cats and dogs of most sizes.

Type B2, Several Reducible Wedges

Increasing instability and complexity cause fracture patient scores to drop to 4 to 6.

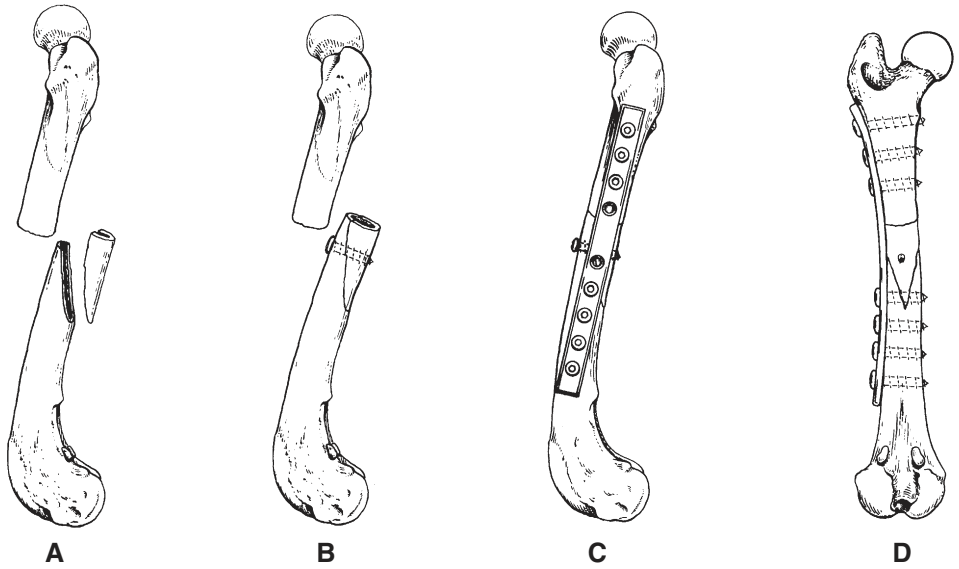


FIGURE 17-23. **A,** Type B1 femoral shaft fracture with butterfly fragment. **B,** Reduction of fracture and fixation in place using a lag screw for interfragmentary compression. **C** and **D,** Contoured bone plate applied on lateral surface of the femur.

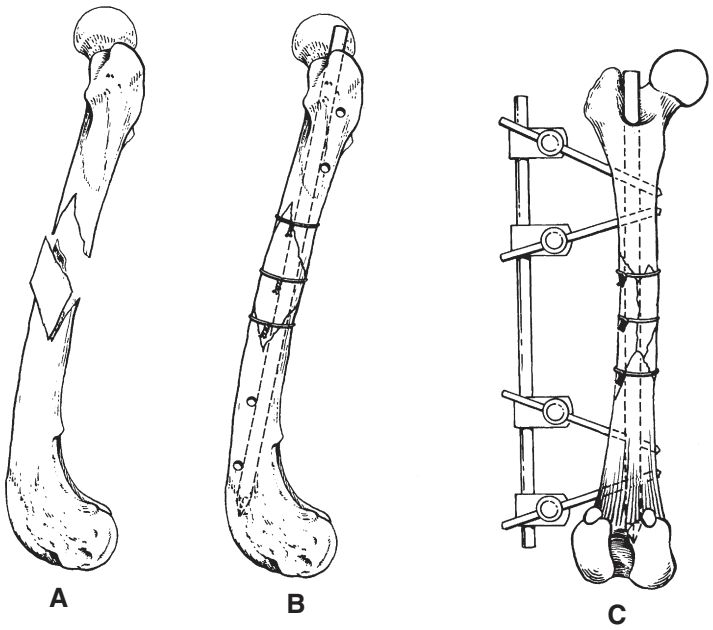


FIGURE 17-24. **A,** Type B2 fracture of the femur. **B** and **C,** Rigid fixation by use of an intramedullary pin, three cerclage wires, and an external fixator.

Internal Fixation

The methods of fixation are an extension of those for type B1 fractures. Figure 17-24 illustrates stabilization by multiple cerclage wires, Steinmann pin, and type IA external fixator. Bone plates are typically applied to function as neutralization plates rather than compression plates. A minimum of six cortices must be captured by plate

screws in each of the proximal and distal segments. Either cerclage wires under the plate or lag screws are used to secure the wedges.

Type B3, Nonreducible Wedge

Although not all the fragments can be reduced and stabilized, the bone is still able to assume some buttress function, and shortening of the bone is not the major problem as long as the major diaphyseal sections are held in alignment. It is best to take a biological fixation approach to these fractures, since total reduction is not possible; on the other hand, a bridging or buttress fixation is not needed.

Reduction and Internal Fixation

Bone Plate. The principles of biological fixation can be respected during plate fixation only if the temptation to attempt reduction of the fragments is resisted. The fracture hematoma and fragments should be disturbed as little as possible, consistent with reduction of the major diaphyseal fragments. It is usually possible to place the fracture under compression with the plate, and this will add stability. Six to eight cortices must be captured by plate screws in each major segment.

The major problem with plate fixation occurs when the nonreducible fragments are on the medial cortex, which is the natural buttress cortex of the femur. Failure to bone graft this area (see Chapter 3) can lead to plate failure because of repetitive bending stresses applied to the plate over a very short segment of the plate. If the fragmented area of the medial cortex is relatively small, autogenous cancellous bone graft will stimulate early callus formation and relieve the bone plate of bending stress. Larger, nonreduced areas on the medial cortex can be physically reinforced by onlay or inlay grafts supplemented with autogenous cancellous graft (see Figure 3-3, *E*). Fragmentation of the caudal cortex usually does not need grafting, since the fragments have intact periosteal blood supply from the adductor magnus muscle if they are not stripped away from the muscle.

Interlocking Nail. Because bending stresses are more evenly distributed over the length of the interlocking nail than in the bone plate, loss of the medial cortex is not as critical. Autogenous cancellous bone grafting is still a useful procedure to ensure early callus formation. Minimal exposure of the fracture site may be necessary to ensure passage of the pin into the distal segment. Interlocking nails are available with diameters appropriate for the medullary canal of large cats and dogs of most sizes.

Steinmann Pin and Type IA External Fixator. As with the interlocking nail, bending stresses resulting from loss of the medial cortex are less critical with this fixation than with plates. This is a very useful alternative to plate fixation in the cat, although slightly less satisfactory in the dog because of the problems with function mentioned earlier (see Fixation Techniques). Minimal exposure of the fracture site may be necessary to ensure passage of the pin into the distal segment. A minimum of six fixation pins is advisable, and a double-bar configuration (see Figure 2-43, *E*) is used in animals larger than approximately 45 pounds (20 kg).

Aftercare. See aftercare suggestions at the end of this section.

Fracture Type 3-2-C; Diaphyseal Complex (Figure 17-20, *C*)

These segmental fractures represent the most challenging fixation problems of all long-bone fractures because of the magnitude of the mechanical forces acting at the fracture site. Fracture patient scores are very low, in the 1 to 3 range.

Type C1, Reducible Wedges

Reduction and Internal Fixation

As may be anticipated, fixation is a combination of methods previously described. The fracture is intermediate in fracture patient score relative to the other two fractures in this group. Either cerclage wires (Figure 17-25) or lag screws (Figure 17-26) are used to join the wedges, followed by a primary fixation. The surgeon's experience will determine whether a reconstructive technique should be used to reduce the fragments without compromise to healing, or whether the fragments should be left unreduced for a more "biological" approach, regardless of fixation method.

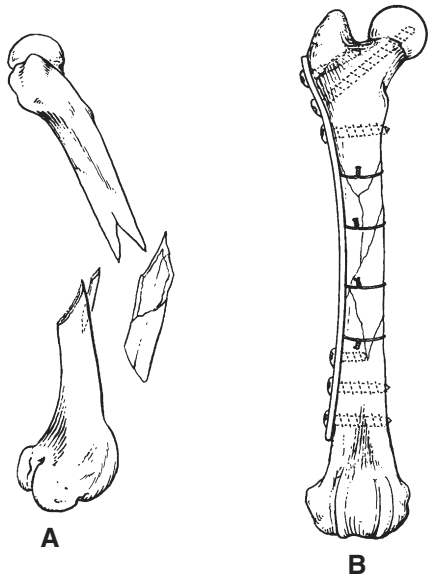


FIGURE 17-25. **A,** Type C1 fracture of the femoral shaft with numerous fissure fractures present. **B,** Reduction of fracture segments, one by one. Cerclage wires immobilize fragments and reconstruct femur. Neutralization plate applied; screw holes in plate directly overlying fracture lines are left vacant.

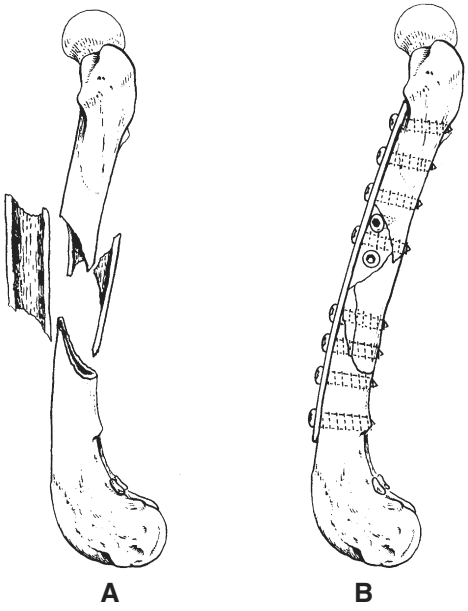


FIGURE 17-26. **A,** Type C1 fracture of the femur. **B,** Fracture reduced; interfragmentary compression achieved by use of lag screws through the bone alone and through the plate. A neutralization plate is applied to overcome rotary, bending, and compressive forces. In this case, it was more advantageous to apply the plate on the cranial surface.

Bone Plate. This is probably the most widely used form of fixation in this situation. The function of the plate will vary, depending on the obliquity of the proximal and distal fracture lines. If all the fracture lines can be compressed by cerclage wires or lag screws, the plate functions as a pure neutralization plate (see Figures 17-25 and 17-26). If the proximal and/or distal fracture line is greater than 45 degrees relative to the long axis, the plate can be placed in some degree of compression, typically with one screw placed in the load position in the plate hole.

Steinmann Pin and Type IA External Fixator. If the wedges can be stabilized with cerclage wires, a type IA external fixator and Steinmann pin can be used as primary fixation. Because of the instability inherent to these fractures, a minimum of six fixation pins along with an IM pin is advisable, and a double-bar configuration (see Figure 2-43, *E*) is used in animals larger than approximately 45 pounds (20 kg).

Interlocking Nail. If the wedges can be stabilized with cerclage wires, the interlocking nail can be used as primary fixation.

Type C2, Segmental

Type C2 is the most stable fracture within this group, consisting of only two fracture lines (Figure 17-27).

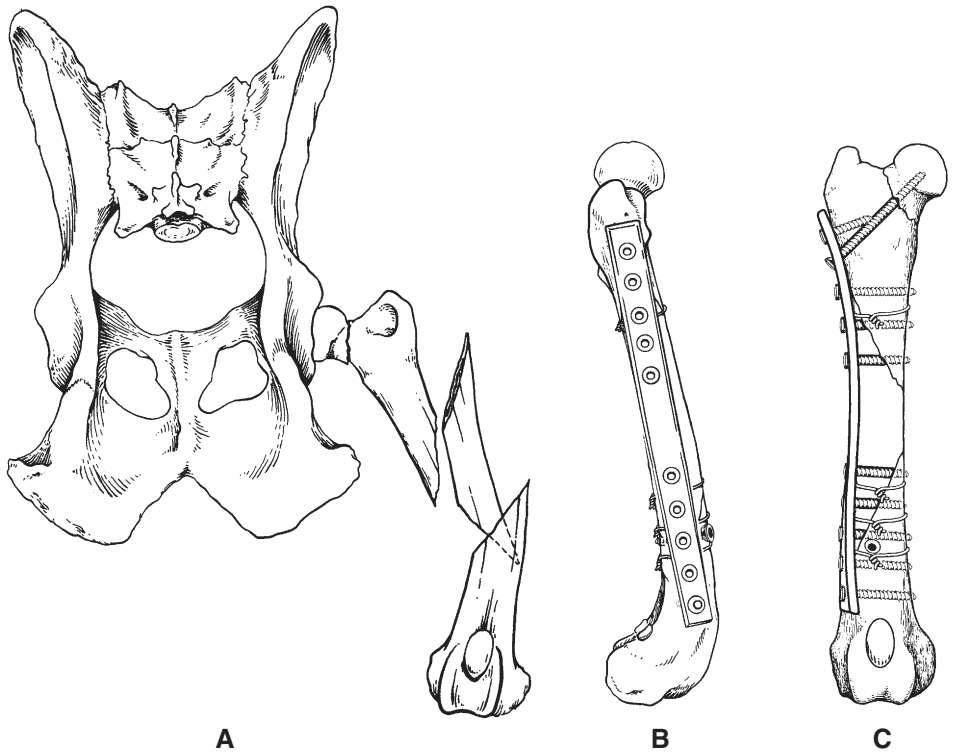


FIGURE 17-27. Type C2 multiple fracture of the femoral shaft and neck in 1-year-old Border collie. **A,** On open approach, numerous fissures were noted in the various fracture segments. **B** and **C,** The femoral shaft was first reconstructed and fixed together with one lag screw and four cerclage wires. A neutralization plate was applied with a 4.5-mm lag screw to immobilize the femoral neck fracture. Note the twist in the distal plate necessary in the supracondylar region. The plate was removed at 7 months; shaft lag screw and cerclage wires were left in place.

Reduction and Internal Fixation

Bone Plate. Depending on the obliquity of the fracture line, the plate can function in compression or neutralization mode. If both fracture lines are transverse, the plate is applied with compression at both ends (see Figure 2-72, *D, E,* and *F*). If the fractures are oblique, they can be compressed with either cerclage wires or lag screws and the plate applied in the neutralization mode. In some cases the plate is applied in compression at one end of the intermediate segment and in neutralization at the other end. At least six cortices must be captured by plate screws in each of the proximal and distal segments.

Steinmann Pin and Type IA External Fixator. Because of the instability inherent to these fractures, a minimum of six fixation pins is advisable, and a double-bar configuration (see Figure 2-43, *E*) is used in animals larger than approximately 45 pounds (20 kg). If the fracture lines are oblique enough, cerclage wires or lag screws can be used to compress these fractures before the fixator is applied.

Interlocking Nail. If the fracture lines are oblique enough, cerclage wires can be used to compress these fractures before the interlocking nail is applied.

Type C3, Nonreducible Wedges

Bridging osteosynthesis is applicable to type C3 fractures, with fracture patient scores ranging from 1 to 3.

Reduction and Internal Fixation

Maximal advantage of bridging osteosynthesis is taken when the fracture is reduced either in a closed manner or with a minimal open approach and no manipulation of fragments. Reduction attempts may ruin soft tissue attachments and hinder early callus formation. Care must be taken to ensure rotational alignment when using closed or minimal open reduction.

Bone Plate. Although a much larger exposure is needed to apply the plate in buttress or bridging function, bone plates still work well in this application if proper care is taken. Application of a bridging plate is illustrated in Figure 17-28. The temptation to disrupt and manipulate the wedges must be overcome. "Neat freaks" have a distinct disadvantage here! The plate is contoured from a craniocaudal radiograph of the normal femur and applied to the proximal segment, ideally ensuring that at least eight cortices are captured by plate screws. Proximal screws placed deeply in the femoral neck are counted as two cortices; six cortices can be accepted in the proximal segment if necessary. The distal segment is attached to the plate with bone-holding clamps, and the best possible length is attained by traction, the fracture distractor (see Figure 2-18), or IM pin distraction (see Figure 2-19). The proximal segment must be rotated cranially to eliminate excessive anteversion before the plate is clamped to the distal segment. The distal screws are then applied through the plate, with at least eight cortices captured. Autogenous cancellous bone graft is applied to the fracture area (see Chapter 3), taking care to not disturb the wedges. If a large gap is observed at the fracture site because of severe displacement of large fragments, either the gap must be filled with autogenous cancellous bone graft or one or two loops of absorbable suture must be used to gently move the displaced fragment closer to the fracture gap.

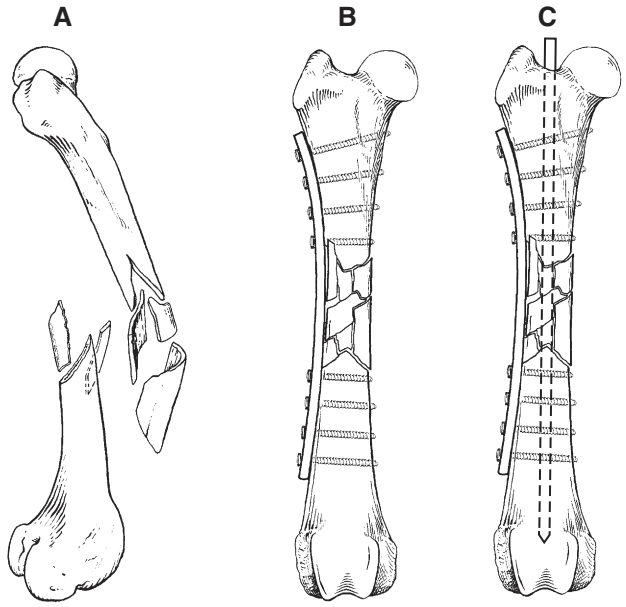


FIGURE 17-28. Biological osteosynthesis with a bone plate. **A,** Complex type C diaphyseal fracture of the femur. **B,** The plate is contoured from the radiograph of the opposite femur and attached proximally and distally without any handling or reduction of the fragments, which will tend to be pulled into the fracture gap by muscular forces. It is important to restore bone length as accurately as possible to allow the fragments to drift into position. Eight cortices proximally and distally should be engaged by plate screws for this type fixation of the femur. **C,** An intramedullary pin has been placed into the femur before application of the plate to aid in alignment of the bone and to protect the plate from bending stress during weight bearing.

Plate and Intramedullary Pin. Plates applied with bridging or buttress function are subjected to considerable bending stress during weight bearing, which can cause fatigue failure of the implant. The combination of buttress plate with an IM pin helps to shield the plate from bending stress[26,27] (Figure 17-28, *C*). An IM pin with a diameter 35% to 40% that of the intramedullary space is placed first, with care taken to prevent disruption of the fracture hematoma.[27] Placement of the pin also helps to align the major proximal and distal fracture fragments. The plate is then contoured and applied with bone screws. Screws are placed to avoid the IM pin if possible. If the pin interferes with screw placement, a unicortical screw may be used in place of bicortical screws. Often, bicortical screws are successfully placed. A minimum of one bicortical and three monocortical screws is placed above and below the fracture.

Steinmann Pin and Type IA or IB External Fixator. The goals of bridging osteosynthesis are respected by the use of the pin and type IA fixator, applied as previously described. This is a very useful alternative to plate fixation in the cat, although slightly less satisfactory in the dog because of the problems with function mentioned earlier (see Fixation Techniques). Because there will be no load sharing of the bone with the fixator, a minimum of six fixation pins is advisable, and a double-connecting-bar configuration (see Figure 2-43, *E*) is used in animals larger than approximately 45 pounds (20 kg) if the Kirschner-Ehmer fixation system is used.

Another fixation configuration useful in complex fractures is the combination of an IM pin with the type IB fixator (Figure 2-45, *B*). Whether used with the Kirschner-Ehmer system or with the more rigid IMEX SK external fixation system, the type IB fixator adds increased strength and stiffness for use in a difficult fracture. The type IB external fixator may be attached to the IM pin with a "tie-in" configuration.[41] The IM pin is not cut short but is attached to the fixator with a double clamp.

Interlocking Nail. Because of its ability to act as a buttress, the interlocking nail is a good choice for type C3 diaphyseal fractures with nonreducible wedges. Minimal exposure of the fracture site may be necessary to ensure passage of the pin into the distal segment. This system is now available with nails 4.0, 4.7, 6.0, and 8.0 mm in diameter for use in femoral fractures in dogs of most sizes and in cats.

Aftercare of Diaphyseal Fractures

Ideally, the animal would be allowed early, limited active use of the limb. This requires totally stable internal fixation, good owner compliance with confinement and exercise restrictions, and a patient that will not overstress the repair with hyperactivity. If any of these elements are less than optimal, an off-weight-bearing sling is advisable for 2 to 3 weeks (see Figure 2-32). Exercise should be severely restricted for 4 to 6 weeks, with a gradual return to unrestricted activity at 8 to 12 weeks. Radiographs should be taken at 4 to 8 weeks for IM pins and external fixators and 8 to 10 weeks for plates to confirm clinical union before any significant increase in exercise is allowed.

DISTAL FRACTURES

Fractures of the distal segment represent about 20% to 25% of all femoral fractures and 11% of all diaphyseal fractures[1,40] (Figure 17-29). Fractures involving the distal femoral physis are relatively common in young animals between ages 4 and 11 months. Salter type I and II fractures are seen most frequently.[2,3,42] Supracondylar fractures are seen most often in the mature animal. Both fracture types present similar biomechanical problems relative to reduction and fixation and are discussed together. (See Chapter 22 for further discussion of physeal injuries.) Articular fractures are relatively uncommon, accounting for about 17% percent of all distal segment fractures.[1,40]

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FIGURE 17-29. Distal fractures of the femur. **A:** *A1,* Simple; *A2,* wedge; *A3,* complex. **B:** *B1,* Lateral condyle sagittal; *B2,* medial condyle sagittal; *B3,* frontal unicondylar. **C:** *C1,* Simple, metaphyseal simple or wedge; *C2,* simple, metaphyseal complex; *C3,* multifragmentary. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

Open Approaches

Arthrotomy of the stifle joint is necessary to expose all these distal fractures. The exact approach varies with the extent of the pathology, but the lateral approach is most common because it is suitable for all the nonarticular fractures (Figure 17-30).[29] Medial and bilateral approaches are used for articular fractures, and osteotomy of the tibial tuberosity is sometimes useful for type C fractures.

Fracture Type 3-3-A; Distal, Extraarticular (Figure 17-29, *A*)

The distal segment is usually displaced caudally and accompanied by a sizable hematoma (Figure 17-31, *A*). The objectives of treatment should include (1) anatomical reduction and (2) rigid uninterrupted fixation so that the animal is free to move the stifle joint during the healing period. Suggested methods of treatment include Rush pins and small transfixation pins/K-wires inserted across the fracture line in a crossing or parallel pattern. In type A2 (Salter II) fractures in which a portion of the metaphysis is attached to the distal epiphysis, it may be advantageous to insert a lag screw transversely to attach the metaphyseal wedge.

Type A1, Simple; Type A2, Wedge

Closed Reduction and Fixation

In early cases with minimal displacement, especially in cats and small dogs, closed reduction is sometimes possible if the patient is seen within the first 24 hours. The fracture is reduced by flexing the stifle joint with the tarsus extended and applying distal traction on the caudal surface of the proximal part of the tibia. With the femur stabilized, flexion of the stifle with proximal pressure on the tibia usually maintains the reduction. Immobilization is applied, holding the stifle in flexion by means of a modified Thomas splint or Ehmer sling (see Figures 2-25 and 2-31).

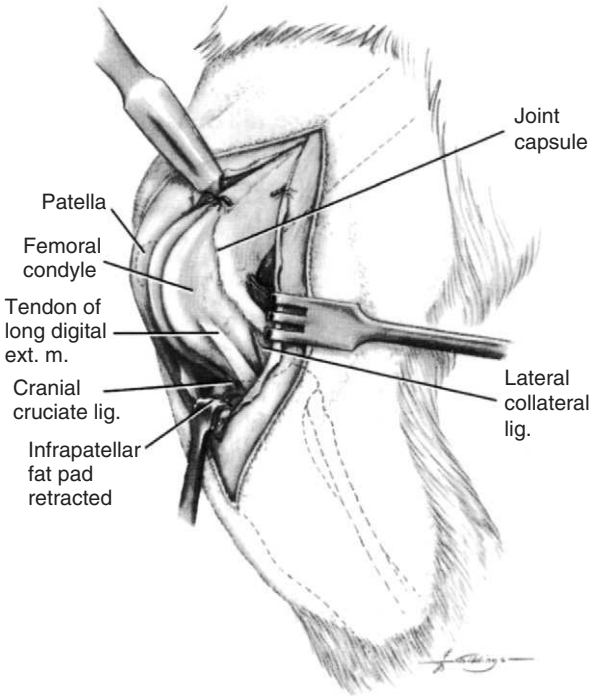


FIGURE 17-30. Approach to the distal femur and stifle joint through a lateral incision. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat*, ed 4, Philadelphia, 2004, Saunders.)

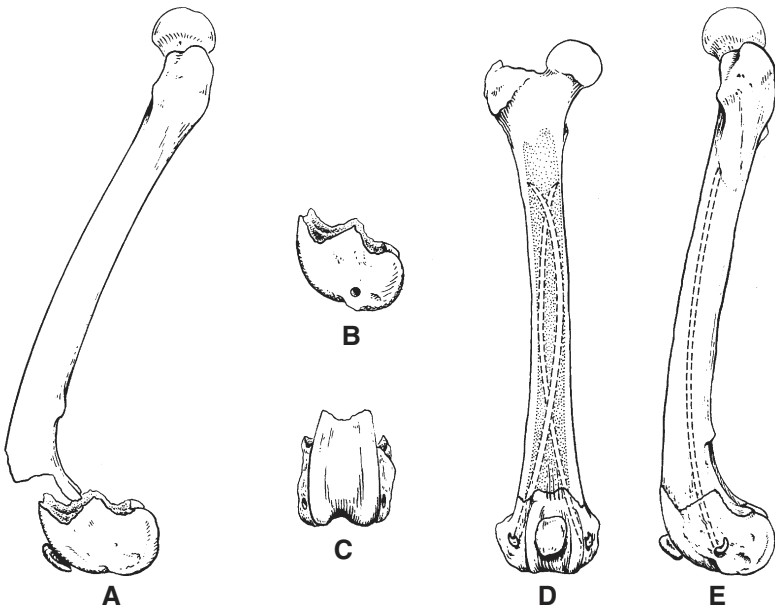


FIGURE 17-31. Rush pin fixation of type A1 distal femoral physeal fractures. **A,** Salter-Harris type I fracture of the distal femoral physis. **B** and **C,** Position on femoral condyles of entry holes for Rush pins. These holes should be the same diameter as Rush pins and placed in the caudal half of the physis (condylar area). **D** and **E,** After reduction of the fracture, double Rush pins are driven into the femoral medullary canal. Pins should be two thirds to three fourths of the length of the femur. The pins bend in two planes as they are driven, thus storing energy that is transferred to the bone as compression.

With splint fixation, padding, gauze, and adhesive tape are applied to maintain caudal traction on the femur and cranial traction on the tibia. Reduction should be confirmed radiographically. This treatment may result in some stiffness of the stifle because the joint is not free to move during the healing period, and intraarticular and extraarticular adhesions are more likely to form during immobilization of the joint. Removing the fixation at 2 weeks will minimize this problem.

Open Reduction

The patient is placed in the dorsal recumbent position. A lateral approach to the stifle joint is made, and the fascia lata incision is extended proximally to allow separation of the biceps femoris muscle from the quadriceps muscles, exposing the fracture site.

The same basic maneuvers just described for closed reduction are used, but reduction can be aided by levering the epiphysis back into position. A flat bone skid or scalpel handle can be used to assist in this approach. The most proximal edge of the epiphysis containing the trochlear groove is quite fragile and must be protected from secondary fracture. Grasping the epiphyseal segment with a bone-holding forceps should be avoided if possible. If necessary, a pointed reduction forceps or vulsellum forceps can be applied to the medial and lateral nonarticular surfaces of the condyles. If a week or more has elapsed since the fracture occurred, it may be necessary to remove a small amount of bone from the distal end of the proximal segment. Perfect reduction is ideal; if this is not possible, however, the distal segment should be overreduced cranially to avoid patellar impingement during extension of the stifle. Failure to reduce the epiphysis adequately was the main cause of poor results in a study of 47 distal femoral fractures.[43]

Internal Fixation

Although retrograde insertion of small Steinmann pins has been an accepted fixation in the past, this method was more likely to be associated with sciatic nerve impingement, as discussed earlier under Fixation Techniques.[10] Other methods are suggested here for this reason.

Rush Pins. Two Rush pins are inserted by first drilling diagonal holes (20 degrees to the sagittal plane of the femur) into the medial and lateral surfaces of the condyles just proximal to the gliding surfaces (Figure 17-31, *B* and *C*). The two pins are then inserted and driven into the femoral shaft simultaneously (Figure 17-31, *D* and *E*). Note that the pins are also aimed cranially so that they curve in both the frontal and the sagittal planes. This requires that the holes be drilled as far caudally on the condyles as possible, near the collateral ligaments. Care must be taken so that the holes in the distal segment are not "split out" in the drilling and insertion process. In most cases, no additional fixation is necessary. Healing is rapid, and the pins are removed in 3 to 5 weeks if they are used in a young growing animal. Alternatively, in young animals the hook end is cut off after pin placement, which lessens the chance of causing premature closure of the growth plate. If the animal is close to skeletal maturity, the pins are routinely left in situ because they have minimal tendency to loosen and migrate. Using true Rush pins, this method is most applicable to large breeds of dogs, where 3/32- or 1/8-inch (2.4- to 3.2-mm) pins are most common. In cats and toy breeds of dogs, 0.045- to 0.062-inch (1.2- to 1.5-mm) K-wires can be used in a manner similar to that for Rush pins. The hook end can be bent before setting the pin against the condyle.

Transfixation Pins or Kirschner Wires. For this simple nailing fixation, the pins can be applied in a crossed or parallel position (Figure 17-32). Pin size varies from

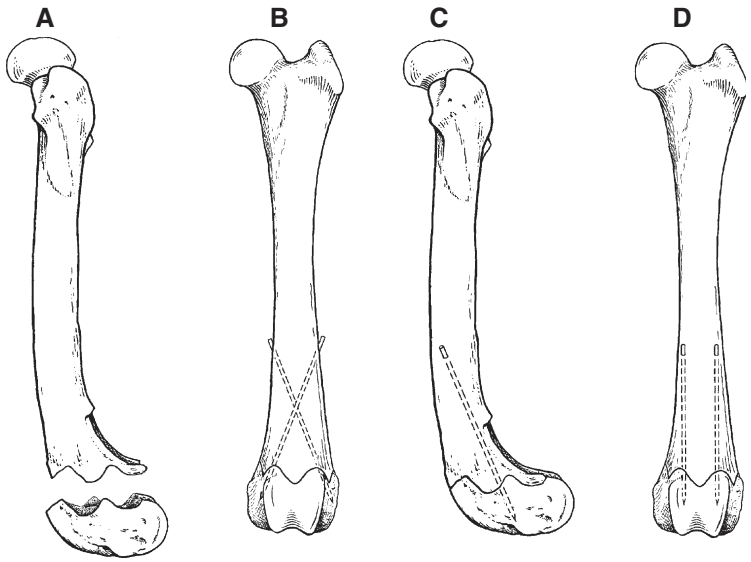


FIGURE 17-32. **A,** Distal femoral type A1 physeal fracture. **B** and **C,** After reduction, fixation may be accomplished by the use of two transfixation cross pins. These may be inserted from proximal to distal without penetration of the articular cartilage, or from the condyle into the opposite cortex with the pin cut and seated flush with the cartilage. Note the caudal angulation of the pins to ensure their being seated well into the condyle. **D,** An alternative method of pinning is placing the pins parallel to each other.

0.045-inch (1.2-mm) K-wires to 3/32-inch (2.4-mm) Steinmann pins. This method is particularly advantageous in chondrodystrophic breeds, where the extreme curvature of the distal femur and condyles makes other methods difficult. When using cross pins, they are usually started in the metaphyseal area and extend distally into the opposite condyles (Figure 17-32, *B* and *C*). Parallel pins are similar, except that they are driven into the ipsilateral condyle (Figure 17-32, *D*). Note that the pins must be started far enough medially and laterally in the femur to avoid the quadriceps muscle, which must be free to glide. A common error is failure to angle the pins sufficiently caudal to enter the large part of the condyles. Both methods avoid penetration of the articular cartilage, and thus no pin ends are in the joint. Crossing-pin fixations caused more complications than single Steinmann pin or modified Rush pin fixation in one study, primarily because the fracture could be more easily fixed while still underreduced than with the other fixations.[43]

Crossing pins are driven from the articular surface by some surgeons, but this method has the disadvantages of the pins protruding into the joint and often less stable fixation. The latter disadvantage is caused by the flare of the condyles relative to the shaft; starting the pin into the condyle at an angle sufficient to cause the pin to "bite" in the bone creates a more acute pin angle relative to the shaft than is desirable. The result is that the pin exits the metaphyseal cortex too close to the fracture line to provide optimal stability.

Lag Screws. Bone screws can be substituted for the transfixation pins just described and can provide additional stability, especially in large breeds and chondrodystrophic breeds. Care must be taken to ensure a lag effect for maximum stability. Insertion from proximal to distal is advisable.

Aftercare

Activity should be restricted, and no additional fixation is usually indicated. Healing is rapid in physeal fractures, usually being clinically united in 2 to 3 weeks. Nonphyseal fractures take 3 or 4 more weeks for clinical union. If there is considerable trauma in the area, it may be advisable to have the owner apply 20 to 30 gentle passive flexion-extension movements of the stifle joint two or three times daily.

Prognosis

The younger the animal sustaining physeal fractures, the greater is the potential for growth abnormalities. Functional problems were seen in 18% of young animals because of femoral shortening.[44] In another study of 48 physeal fractures, good to excellent clinical function was obtained in 88% of cases.[24]

Type A3, Complex

There is no possibility for closed reduction of these fractures; they must be handled by open approach and internal fixation.

Reduction and Fixation

Bone Plate. Neutralization plate fixation can be considered if the fragments are large enough to reduce and fix by any method. The reconstruction plate (Synthes, Ltd., Paoli, Pa) is adaptable to this location because it can be contoured to curve from the shaft onto the condyle[45] (Figure 17-33, *A*). It is important that the fragments be reduced and that the plate is truly a neutralization plate because this plate is not stiff enough to function as a buttress plate. Conventional straight plates are rarely useful, since it is difficult to insert sufficient screws into the distal segment because

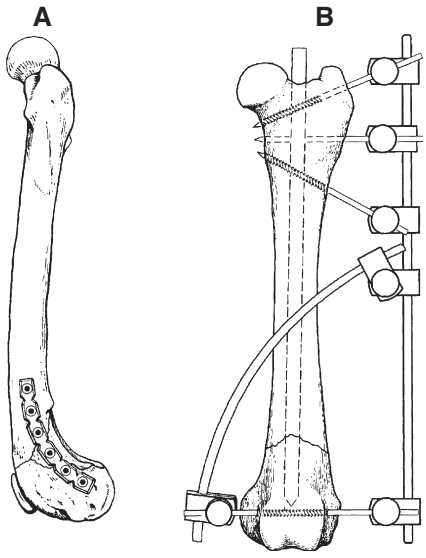


FIGURE 17-33. Fixation of type A3 complex distal femoral fractures. **A,** Reconstruction plate (Synthes, Ltd., Paoli, Pa) contoured on edge to closely fit the femoral condyle. **B,** Hybrid type I-II external fixator with a curved connecting bar controls rotation and length while the intramedullary pin provides axial stability. The double clamp on the connecting bar can be avoided by attaching it to the third fixation pin with a single clamp.

of the curvature of the bone. The hook plate used for intertrochanteric osteotomy (see Chapter 16) can be made to function as a buttress plate in large dogs by placing the two hooks and one screw in the distal segment.

A problem with plate fixation of any type is that the plate is intraarticular or periarticular at its distal end. This can lead to irritation of the joint and varying degrees of lameness; therefore, these plates are usually removed after several months. Additionally, a very secure closure of the lateral parapatellar retinaculum is needed to prevent dehiscence and medial patellar luxation. Gentle passive flexion/extension movements at the stifle are helpful in reducing a decreased stifle range of motion.

External Fixator. A hybrid fixator can be used when the fragments are irreducible and buttress or bridging fixation is needed (Figure 17-33, *B*). The Steinmann pin is placed in conventional manner, with care taken to seat it as deeply as possible in the condyle, and a center-threaded, positive-thread-profile fixation pin is placed transversely through the condyle. This pin is attached to the straight lateral connecting bar, and a curved connecting bar is used to attach the medial end of the pin to the lateral bar. The Steinmann pin and fixation pin provide stability in both axes of the condyle.

Fracture Type 3-3-B; Distal, Partial Articular (Figure 17-29, *B*)

Type B1, Lateral Condyle, Sagittal; Type B2, Medial Condyle, Sagittal

Condylar fractures are quite rare (Figure 17-34). When they occur, the medial condyle is the one most frequently involved. In most cases the caudal cruciate ligament and the medial collateral ligament are attached to the fractured segment. In some cases the fractured condyle is a single segment; in others it is multiple in nature. The latter may be difficult to treat and restore to good function. A good functional recovery depends on anatomical reduction, rigid fixation, and movement of the joint during the healing period.

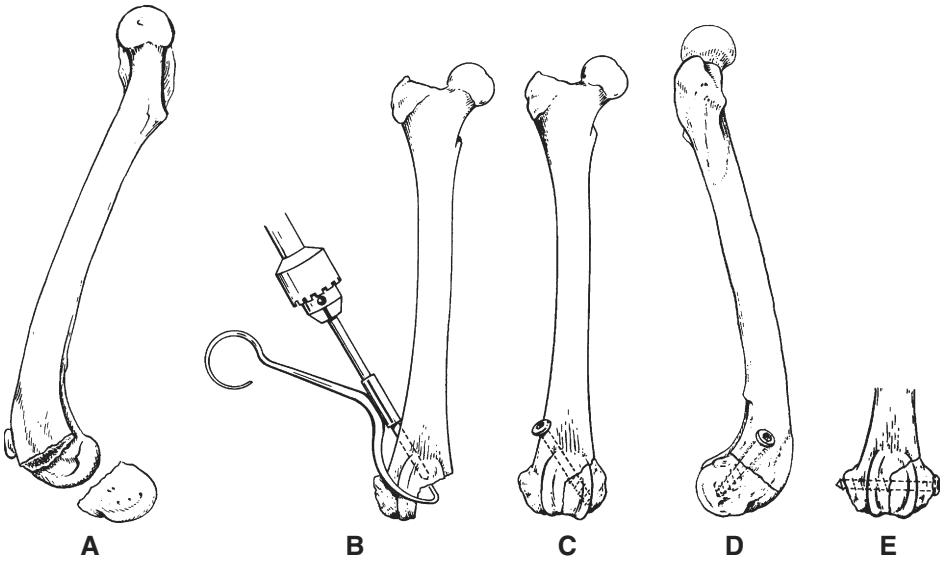


FIGURE 17-34. **A,** Type B1 condylar fracture of the femur. **B,** Fixation by drilling and inserting a cancellous bone screw diagonally from proximally into the fractured segment. **C** and **D,** Craniocaudal and lateral views of the fracture reduced and cancellous bone screw in place. **E,** If the fractured condylar segment is large enough, it may be immobilized by a transcondylar bone screw (cancellous or cortical screw with lag effect).

Reduction and Fixation

An open approach is performed as already described. If the fracture is primarily in one piece, and particularly if it includes attachments of the cruciate and collateral ligaments, reduction and fixation should be attempted. Reduction is usually accomplished by use of a hook to pull the segment cranially, and levering is used for final reduction. If reduction is impossible, especially if the injury is several days old, a partial horizontal capsulotomy in addition to the standard vertical parapatellar incision allows room for maneuvering the caudally displaced condyle (approach to the caudomedial or caudolateral parts of the stifle joint[29]). Exposure can also be improved in some large dogs by osteotomy of the origin of the collateral ligament.

Lag screw fixation may be accomplished by two general methods, depending on the exact location and direction of the fracture line. In many cases it is necessary to drill and insert a bone screw diagonally from proximally in the opposite metaphyseal cortex into the fractured condyle (Figure 17-34, *B*, *C*, and *D*). In larger dogs it is advantageous to insert two bone screws. If the intercondylar fracture surface is large enough, the screw may be inserted in a transcondylar manner (Figure 17-34, *E*). Before closure, the joint should be inspected for small fragments of loose bone and cartilage, which should be removed.

Aftercare. Every effort should be made to keep the joint moving. Passive range of motion exercises, 20 to 30 cycles, two or three times a day, should be started as soon as the animal will tolerate them. If external support is needed, an off-weight-bearing sling is preferred to any immobilization because some limited motion will be possible (see Figure 2-32).

Type B3, Frontal Unicondylar

As in the sagittal fracture, the medial condyle is most often involved. Open approaches are similar to those described above for type B1 and B2 fractures.

Reduction and Fixation

Lag screw fixation is indicated, but it is difficult to place the screws so that the head of the screw does not interfere with joint function. It is preferable to direct the screw from cranial to caudal by starting the screw just outside the trochlear ridge, then across the fracture line. The other possibility is lag screw or K-wire fixation directed from the condyle surface cranially into the metaphysis. The head of the screw or end of the K-wire must be countersunk below the articular cartilage, unless it is possible to place the screw or pin outside the gliding surface. The miniscrews in 1.5-mm or 2.0-mm sizes are easiest to countersink.

Aftercare. The postoperative considerations are similar to those for type B1 and B2 fractures.

Fracture Type 3-3-C; Distal, Complex Articular (Figure 17-29, *C*)

Type C1, Simple, Metaphyseal Simple or Wedge

This is a supracondylar and bicondylar fracture in combination, commonly called a T or Y fracture. In addition to the condyles being fractured at their junction with the shaft, there is a sagittal fracture between the condyles (Figure 17-35, *A*). This fracture is relatively rare and is usually accompanied by displacement, extensive soft tissue damage, and hemarthrosis. The joint should be checked for ligament and meniscal damage. Anatomical reduction, rigid fixation of the fracture segments, and early postoperative movement of the stifle joint are essential to ensure good return of function.

Reduction and Fixation

An open approach is performed as previously described. The fractured condyles are reduced and held together by vulsellum or pointed reduction forceps. Because the fracture involves an articular surface, anatomical reduction is essential. A hole is

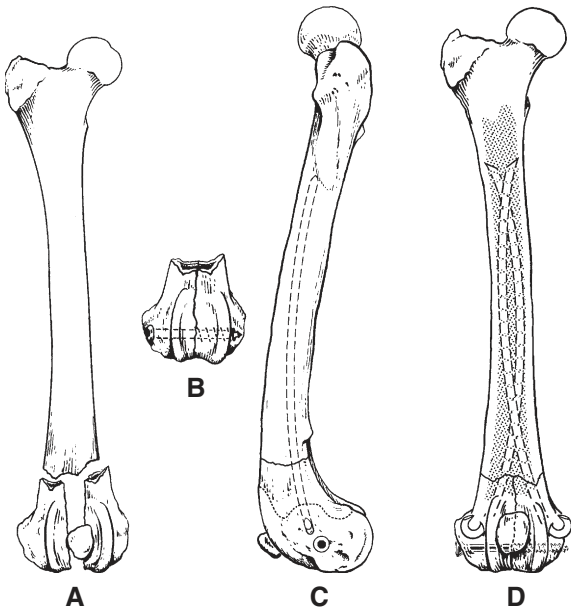


FIGURE 17-35. Fixation of a type C1 bicondylar fracture (T or Y) of the distal femur. **A,** Fracture. **B,** Transcondylar lag screw is applied first. **C** and **D,** The supracondylar fracture is fixed with two Rush pins.

drilled transversely through the condyles, and a cancellous or cortical screw inserted with a lag effect will compress the fracture site (Figure 17-35, *B*). Essentially, the fracture has now been converted into a supracondylar type A1 or A2 fracture. The condyles are attached to the femoral shaft using two Rush pins (Figure 17-35, *C* and *D*), two crossing or parallel transfixation pins (see Figure 17-32, *B*, *C*, and *D*), or a curved reconstruction plate (see Figure 17-33, *A*).

Aftercare. Every effort should be made to keep the joint moving. Passive range of motion exercises, 20 to 30 cycles, two or three times a day, should be started as soon as the animal will tolerate them. If external support is needed, an off-weight-bearing sling is preferred to total immobilization because some limited motion will be possible (see Figure 2-32).

Type C2, Simple, Metaphyseal Complex; Type C3, Multifragmentary

Surgical exposure, reduction, and fixation of this group involve a combination of methods described earlier. A transcondylar lag screw is always the first step (Figure 17-35, *B*), converting the remaining fracture to a type A3 fracture, which is treated as in Figure 17-33. Multiple lag screw and K-wire fixation of small articular fragments is accomplished as the situation demands. If multiple fragments are present above the condyle that cannot be reduced, a reconstruction plate is used with buttress function. However, the plate will be subjected to considerable bending stress and should be combined with an IM pin for additional support. Aftercare is as previously described.

PATELLAR FRACTURES

Fractures of the patella are rarely encountered in small animals. Being a sesamoid bone located between the tendon of the quadriceps femoris muscle and the patellar ligament, the bone fragments are subjected to strong distracting forces. Internal fixation is indicated in simple two-piece fractures when the fragments are of approximately equal size. Because of the strong tension forces over the cranial cortex, tension band wire fixation is indicated. Monofilament stainless steel wire of sufficient strength is used for immobilization. Wire of 22 gauge (0.025 inch, 0.635 mm) is suitable for toy breeds and cats, 20 gauge (0.032 inch, 0.812 mm) for average dogs, and 18 gauge (0.040 inch, 1.02 mm) for large breeds. It is always safest to err on the side of wires that are too large rather than too small.

Apical fragments of less than one third of the patella are difficult to stabilize and are best treated by excision and reattachment of the tendon or ligament to the remaining fragment. Some multifragmentary fractures may require total patellectomy (see Chapter 18), but an attempt should be made to salvage at least one large fragment because this will often provide better function than a total patellectomy.

Undisplaced Fissure Fracture

Figure 17-36 shows a fissure fracture of the patella immobilized by use of two tension band wires. The first wire is inserted through the quadriceps tendon and patellar ligament close to the patella. Passage of the wire through the tissue can be facilitated by first passing a bent hypodermic needle and then inserting a wire through it. The second wire is inserted in a similar or figure-of-8 fashion, but in a more cranial position. The wires are then tightened.

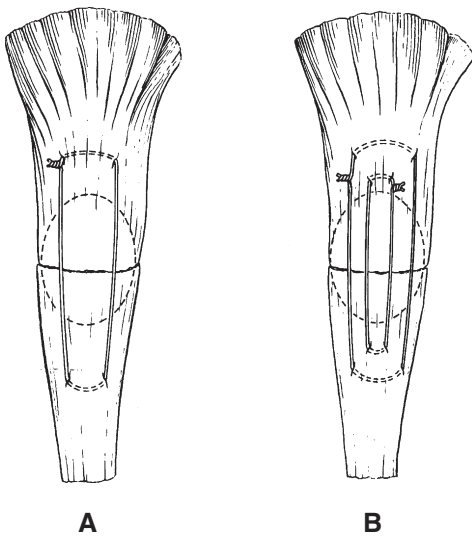


FIGURE 17-36. Fissure fracture of the patella immobilized by two tension wires. **A**, One wire is inserted through the quadriceps tendon and patellar ligament close to the patella. Passage of the wire through the tissue can be facilitated by first passing a bent hypodermic needle and then inserting a wire through it. **B**, The second wire is inserted in a similar or figure-of-8 fashion, but in a more cranial position. The wires are then tightened.

Transverse Fracture

Figure 17-37 illustrates a transverse fracture fixed with one Kirschner wire and a tension band wire in a small or medium-size dog; in large breeds a second wire is used (see Figure 17-38). A medial or lateral parapatellar incision is made for examination of the fracture line and articular surface. A retrograde hole is drilled with a 1.5-mm drill bit in the proximal patellar segment (Figure 17-37, *B*). This is helpful because patellar bone is very dense, and predrilling will allow easy passage of a K-wire. The fracture is reduced and held in position by pointed reduction forceps. The hole is extended into the distal segment by reversing the drill, and a K-wire is inserted (Figure 17-37, *C* and *D*). The K-wire must be somewhat larger than the hole drilled or a loose pin will result. The tension band wire is inserted and tightened, and the pin is cut distally (Figure 17-37, *E*). The joint capsule, retinaculum of the quadriceps, and skin are sutured.

Multifragmentary Fracture

Figure 17-38 shows a multifragmentary fracture of the patella fixed with one K-wire and two tension band wires. If too small to be reduced and fixed, the small chips are removed. A K-wire is inserted after drilling a 1.5-mm hole. A tension band wire is applied and tightened (Figure 17-38, *B*). In larger dogs, an additional tension band wire is inserted through the tendon of the quadriceps and patellar ligament for increased stability (Figure 17-38, *C*).

Postoperative Care

Additional auxiliary fixation, such as a modified Thomas splint (see Figure 2-25), reinforced padded bandage, or off-weight-bearing sling (see Figure 2-32), may be indicated in some cases to relieve the surgical area of excessive tension during the early healing period (1-2 weeks). Activity should be restricted until clinical union at 4 to 6 weeks. The K-wires and tension wires may need to be removed at this time if there is any migration of implants or soft tissue irritation.

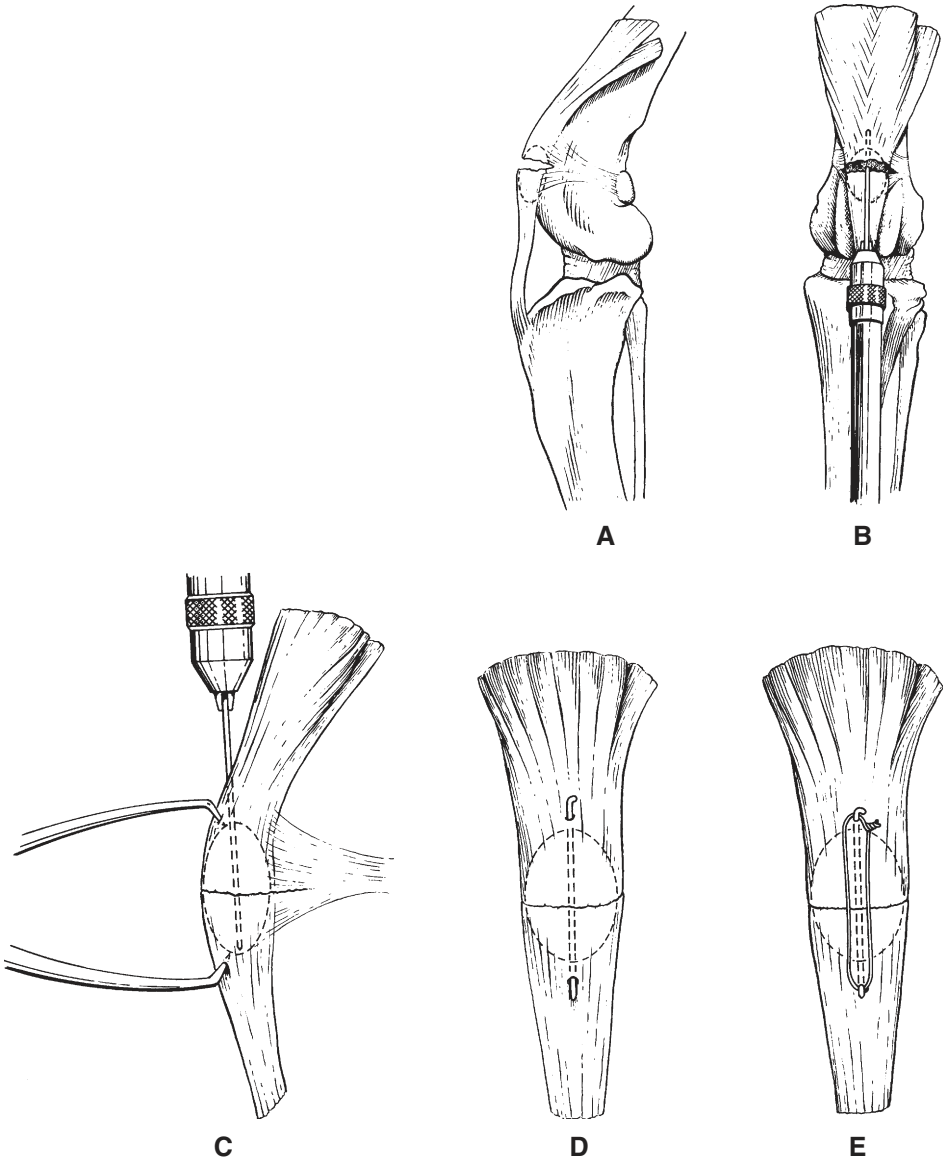


FIGURE 17-37. Transverse fracture fixed with one Kirschner wire and a tension band wire. **A,** Medial or lateral parapatellar incision is made to enable examination of the fracture line and articular surface. **B,** With a 1.5-mm drill bit, a retrograde hole in the proximal patellar segment is drilled. **C,** The fracture is reduced and held in position by compression forceps. The hole is extended into the distal segment by drilling, and a Kirschner wire is inserted. **D** and **E,** The tension wire is inserted and tightened, and the pin is cut distally. The joint capsule, retinaculum of the quadriceps, and skin are sutured.

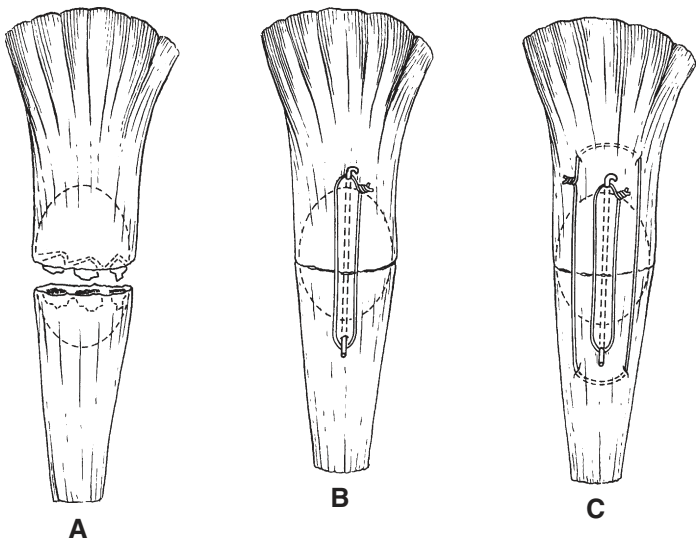


FIGURE 17-38. Multifragmentary fracture of the patella fixed with one Kirschner wire and two tension wires. **A** and **B,** If indicated, the small chips are removed. Kirschner wire is inserted after drilling 1.5-mm hole. Tension wire is applied and tightened. **C,** In many cases, an additional tension wire is inserted through the tendon of the quadriceps and patellar ligament for more stability.

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18
The Stifle Joint

PATELLAR LUXATION

Patellar luxations occur frequently in dogs and occasionally in cats and are often seen in most small animal practices. These luxations fall into the following classes:

1. Medial luxation: toy, miniature, and large breeds.
2. Lateral luxation: toy and miniature breeds.
3. Medial luxation resulting from trauma: various breeds (rare).
4. Lateral luxation: large and giant breeds (genu valgum).

Categories 3 and 4 are discussed separately in later sections.

The *extensor* (or *quadriceps*) *mechanism* of the stifle consists of the quadriceps, patellar tendon, patella, patellar ligament, and tibial tubercle. This mechanism should lie in a straight line from the proximal femur to the middle of the hock (Figure 18-1, *A*). Most often in animals with patellar luxation, even after patellar reduction, there is malalignment of the extensor mechanism (Figure 18-1, *B*). This malalignment contributes to the luxation.

Medial Luxation in Toy, Miniature, and Large Breeds

Most luxations are termed "congenital" because they occur early in life and are not associated with trauma. Although the luxation may not be present at birth, the anatomical deformities that cause these luxations are present at that time and are responsible for subsequent recurrent patellar luxation. The only well-researched investigation into the cause of these luxations concluded that the occurrence of medial patellar luxation is characterized by *coxa vara* (decreased angle of inclination of femoral neck) and a decrease in femoral neck *anteversion* (relative retroversion).[1] These basic skeletal changes were considered to be the cause of the complex series of derangements of the pelvic limb that characterize medial patellar luxations in the small breeds. The changes are depicted in Figure 18-1, *A* and *B*. Patellar luxation in these breeds should be considered an inherited disease. Breeding of affected animals is not advisable.[2]

Medial luxation is much more common than lateral luxation in all breeds, representing 75% to 80% of cases, with bilateral involvement seen 20% to 25% of the time. We have noted a dramatic increase in medial luxation in large and giant breeds in recent years, especially in the Akita, Labrador, husky, and malamute. Concurrent rupture of the cranial cruciate ligament is present in 15% to 20% of the stifles of middle-aged and older dogs with chronic patellar luxation. In this situation, the cruciate ligament is placed under increased stress because the quadriceps mechanism

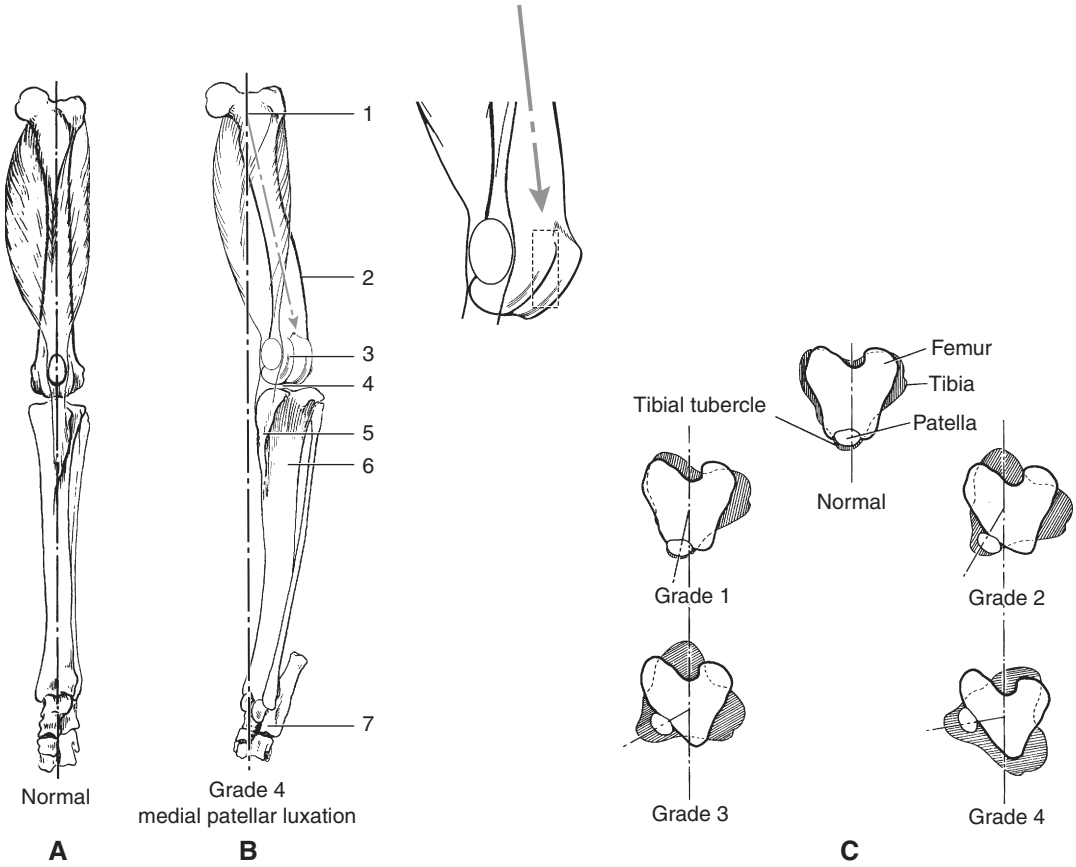


FIGURE 18-1. Skeletal abnormalities with severe congenital medial patellar luxation. **A,** Normal left hindlimb, cranial view. Note that the quadriceps mechanism is centered over the femur and that the dashed line through the proximal femur and distal tibia also runs through the patella. **B,** Deformities typical of medial patellar luxation. Note the position of the quadriceps mechanism and patella; the dashed line from proximal femur to distal tibia lies well medial to the stifle joint. *Inset,* The straight arrow represents the corrected extensor mechanism after tubercle rotation and the line of patellar movement. The dotted rectangle represents the location and angle of the newly created trochlea, which is necessary to have the patella track properly. This illustrates the inadequacy of some trocleoplasty techniques. *1,* Coxa vara. *2,* Distal third of femur bowed medially (genu varum). *3,* Shallow trochlear sulcus with poorly developed or absent medial ridge. *4,* Medial condyle hypoplastic; joint tilted. *5,* Medial torsion of the tibial tubercle, associated with medial rotation of the entire tibia. *6,* Medial bowing of the proximal tibia. *7,* Internal rotation of foot despite lateral torsion of distal tibia. **C,** Position of the tibia relative to the femur and shape of femoral trochlea in grades 1 through 4 of medial patellar luxation. The femoral cross section in the region of trochlear sulcus is shown in dark outline, and the proximal tibial cross section is shaded. Progressive medial rotation of the tibia and deformity of the medial trochlear ridge are noted. (See the text for a complete explanation of grades 1 through 4, according to Singleton.[4])

is ineffective in stabilizing the joint. The leg is also internally rotated, which stretches the cruciate ligament. In the cat, medial luxation is also more common than lateral luxation. One series of 21 cases included 52.4% bilateral medial, 33.3% unilateral medial, and 14.3% unilateral lateral luxations.[3]

A method of classifying the degree of luxation and body deformity is useful for diagnosis and for deciding on the method of surgical repair. Such a classification

was devised by Putnam[1] and adapted by Singleton.[4] The following classification is adapted from Singleton (Figure 18-1, *C*):

Grade 1

- Intermittent patellar luxation causes the limb to be carried occasionally. The patella easily luxates manually at full extension of the stifle joint, but it returns to the trochlea when released. No crepitation is apparent.
- When the patella is reduced, deviation of the tibial tubercle from the midline is minimal. After the patella is reduced, flexion-extension of the stifle is in a straight line with no abduction of the hock.

Grade 2

- Luxation occurs more frequently than in grade 1. Lameness signs are usually intermittent and mild. The patella luxates easily, especially when the foot is rotated (internally for medial luxation, externally for lateral luxation) while the patella is pushed. Reduction occurs with opposite maneuvers.
- The proximal tibial tuberosity may be rotated up to 30 degrees with medial luxations and less so with lateral luxations. With the patella luxated medially, the hock is slightly abducted with the toes pointing medially ("pigeon-toed"). With lateral luxation, the hock may be adducted with the toes pointing laterally ("seal-like").
- Many cases in grade 2 "live" with the condition reasonably well for many years, but the constant luxation of the patella over the medial lip of the trochlea can cause erosion of the articulating surface of the patella and also the proximal area of the medial lip. This results in crepitation becoming apparent when the patella is luxated manually. Increased discomfort may result in the dog throwing its weight to the forelimbs on ambulation.

Grade 3

- The *patella is permanently luxated* (ectopic), with torsion of the tibia and deviation of the tibial crest between 30 and 60 degrees from the cranial/caudal plane. Although the luxation is not intermittent, many animals use the limb with the stifle held in a semiflexed position.
- Flexion-extension of the joint causes abduction and adduction of the hock.
- The trochlea is very shallow or even flattened.

Grade 4

- The tibia is medially twisted, and the tibial crest may show further deviation, with the result that it lies 60 to 90 degrees from the cranial/caudal plane.
- The *patella is permanently luxated* (ectopic).
- The patella lies just above the medial condyle (if medial luxation), and a "space" can be palpated between the patellar ligament and the distal end of the femur.
- The limb may be carried if unilateral, or the animal moves in a crouched position, with the limbs partly flexed.
- The trochlea is shallow, absent, or even convex. The trochlea often is twisted, necessitating placement of the newly made trochlea (chondroplasty) at an angle different from that of the original trochlear region in order to track vertically after tubercle transposition (see Figure 18-1, *B, inset*).

Clinical Signs

Four classes of patients with patellar luxation are identifiable, as follows:

1. Neonates and older puppies often show clinical signs of abnormal hindleg carriage and function from the time they start walking; these generally represent grades 3 and 4.

2. Young to mature animals with grade 2 to 3 luxations usually have exhibited abnormal or intermittently abnormal gaits all their lives but are presented when the symptoms worsen.
3. Older animals with grade 1 and 2 luxations may exhibit sudden signs of lameness because of further breakdown of soft tissues (e.g., cruciate rupture) as a result of minor trauma or worsening of pain from degenerative joint disease.
4. Dogs that are asymptomatic.

Signs of lameness vary from animal to animal. Lameness may be intermittent or continuous. Usually it is a mild to moderate weight-bearing lameness with occasional carrying of the limb. A few dogs will carry their leg most of the time. Dogs with lateral luxations in general have more ambulation problems than those with medial luxations. The owner may see the dog stretch its leg backward in its effort to reduce the patella. Reluctance to jump may be noted.

Signs may worsen as the animal gains weight, articular cartilage erosion occurs, the luxation becomes permanent, the cruciate ligament ruptures, or the hip becomes luxated.

Examination of the limb for patellar luxation is best performed in lateral recumbency. Gentle palpation usually does not cause pain. In small animals or in severely deformed legs, the patella is best located by starting at the tibial tuberosity and working proximally along the patellar ligament. The foot should be internally/externally rotated while trying to push the patella medially/laterally.

Observations should include the following:

1. Instability in both directions.
2. Presence of crepitus.
3. Degree of tibial tuberosity rotation.
4. Limb torsion or angulation.
5. Inability to reduce the patella.
6. Location of the reduced patella within the trochlea. In straight-legged dogs such as the Akita or Shar-pei, the patella occasionally rides proximal in the trochlea ("patella alta"), whereas chondrodystrophied dogs' patellas ride distal in the trochlea ("patella baja").
7. Inability to extend the limb to a normal standing angle (in puppies with severe contracture accompanying patellar ectopia).
8. Presence/absence of drawer movement.

Each of these features affects the types of steps needed for surgical repair.

Surgical Repair of Patellar Luxation

Asymptomatic patellar luxation often is found during routine physical examination. We do not recommend immediate surgery, but instead counsel owners on subtle signs indicative of problems, such as kicking the leg out behind, reluctance to jump, and reluctance to exercise vigorously. These dogs still respond well to late surgical repair, even if cruciate ligament rupture subsequently occurs. However, there are two exceptions in which we recommend surgery on the "asymptomatic" animal. In young puppies with patellar ectopia, it is advisable to consider repair early (3-4 months) before irreparable contracture. In medium to large breeds, surgery is recommended early before erosion and deformity to the trochlea. Surgical choices are then more restricted and the prognosis more guarded.

Arthroplastic techniques applicable to stabilization of patellar luxations can be divided into two classes: soft tissue reconstruction and bone reconstruction.

Considerable judgment and experience are necessary to decide the best procedure or combination of procedures for a given case. After the descriptions of various surgical techniques, we provide an algorithmic approach of progressive surgical procedures to be used to achieve patellar stability (the treatment plan). The animal should not leave the surgery table with a loose patella in the hopes that fibrosis will later tighten it. This often fails. In addition, the patella should be evaluated for luxation in the opposite direction to ensure that overcorrection has not occurred.

A cardinal principle is that skeletal deformity, such as deviation of the tibial tuberosity and shallow trochlear sulcus, must be corrected by bone reconstruction techniques. Attempting to overcome such skeletal malformation by soft tissue reconstruction alone is the most frequent cause of failure. Soft tissue procedures, by themselves, *must be limited* to obvious grade 1 cases. Failure to transpose the tibial tubercle may be the most common cause of failure. The surgeon must be aggressive in deciding to move the tubercle without moving it too great a distance. In some cases, 2 to 3 mm is a sufficient amount to realign the quadriceps mechanism with the femoral trochlea and thus stabilize the patella. Both stifles are routinely repaired at the same time in small dogs and cats, regardless of the type of procedures done. With practice, the surgeon will not find these to be lengthy procedures, and the extra costs and dangers of a second surgery outweigh the slightly more difficult postoperative course with bilateral surgery.

Large mature dogs with grade 3 or 4 medial luxation present a special problem with the trochlear groove. If the distal femur has become twisted, the location of the trochlea is at an angle to the straight, vertical extensor mechanism (see Figure 18-1, *B, inset*).

Soft Tissue Reconstruction Procedures

Overlap of Lateral or Medial Retinaculum

The retinacular overlap procedure can be used on either the lateral side for a medial luxation or the medial side for a lateral luxation. The retinacular fascia and joint capsule are incised 3 to 5 mm from and parallel to the patella. This incision extends from the tibia proximally to a point 1 to 2 cm above the patella. An incision of the fascia lata continues to the midfemur level (Figure 18-2, *A*). With size 2-0 or 3-0 nonabsorbable suture, the cut edge of the fascia attached to the patella is sutured beneath the more lateral fascia, with several mattress sutures placed through the fornix of the capsule (Figure 18-2, *A* and *B*). The superficial layers of fascia and capsule then are sutured to the fascia that remains attached to the patella. In some cases, this fascia will extend beyond the cranial midline of the joint and will be sutured to fascia on the opposite side of the patella (Figure 18-2, *B*). Suturing continues the length of the fascial incision (Figure 18-2, *C*).

This technique can be combined with patellar and tibial antirotational suture ligaments (see Figure 18-4). For lateral luxation, a similar procedure is performed on the medial side. The fascial incision is made through fascia between the caudal belly of the sartorius muscle and the vastus medialis muscle and the cranial belly of the sartorius.

Fascia Lata Overlap

The fascia lata overlap technique[5] is applicable only to medial luxations; when used alone, the procedure is indicated only in the limb that has normal conformation (grade 1 luxation). This overlap is opposite that of the retinacular overlap. Fascia lata overlap can be combined with patellar and tibial antirotational sutures (see Figure 18-4).

Subcutaneous tissues are reflected to expose the lateral retinaculum and fascia lata to the midpoint of the femur. The fascia lata is incised at its junction with the

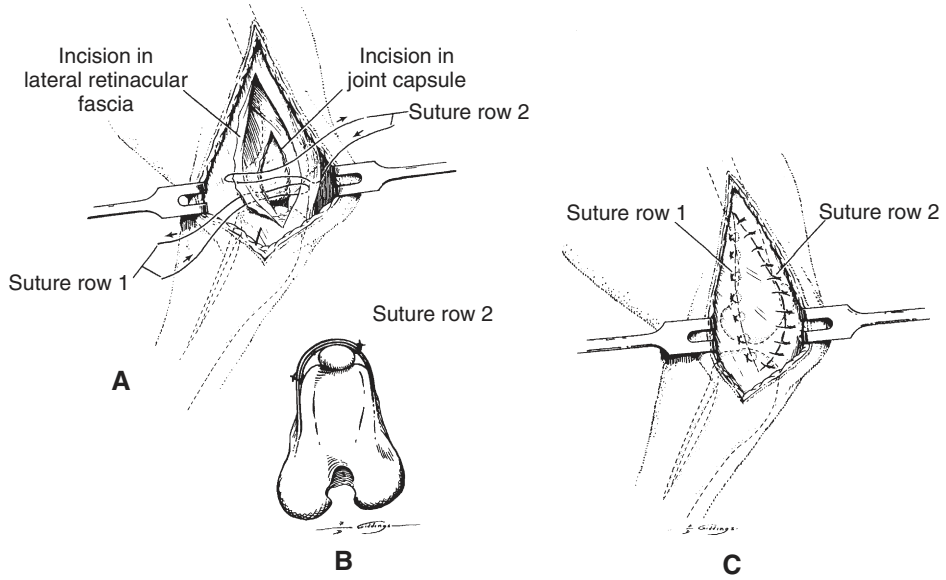


FIGURE 18-2. Lateral retinacular overlap. **A,** Lateral parapatellar incision has been made through lateral fascia and joint capsule. The superficial fascia (fascia lata) has been incised from the tibia to the midfemoral level. Suture row 1 is started well back from the edge of the fascia caudally; it passes through the fornix of the joint capsule, through the cranial fascia close to the incision, and back through the caudal fascia like a mattress suture. All these sutures are placed before row 2 is placed. Size 2-0 or 3-0 nonabsorbable suture is preferred. **B,** Cross-sectional view shows the two suture rows. Note that row 2 may actually be medial to the midline, depending on the looseness of the caudal fascia. **C,** Row 1 and 2 sutures are complete. The biceps creates increased tension on the patellar ligament, the patella, and the distal half of the quadriceps.

biceps femoris muscle from the level of the patella proximally as far as possible. Distal to the patella, the incision runs parallel to the patellar ligament over the tendon of the long digital extensor (Figure 18-3, *A*). The fascia lata proximal to the patella is reflected cranially and bluntly elevated off the underlying vastus lateralis muscle until the white aponeurosis between the vastus lateralis and rectus femoris muscles is visualized. Nonabsorbable size 2-0 and 3-0 sutures are placed between the cranial edge of the biceps muscle and the exposed aponeurosis. The first suture is in the patellar tendon at the proximal end of the patella, with three or four more sutures placed proximally (Figure 18-3, *A* and *B*). If the patella can still be luxated, one or two more sutures are placed just proximal to the patella to further tighten the biceps muscle. Distal sutures are placed in the patellar ligament. The cranial fascia lata is pulled caudally over the surface of the biceps muscle and sutured in place with a combined simple pattern and a Lembert pattern (Figure 18-3, *B* and *C*).

Patellar and Tibial Antirotational Suture Ligaments

An adaptation of Rudy's technique[6] creates a synthetic lateral patellar ligament by anchoring the lateral fabella toward the patella with nonabsorbable suture (Figure 18-4, *A* and *B*). Medial tibial rotation can be prevented by another suture passing from the lateral fabella to the tibial tubercle or distal patellar ligament (Figure 18-4, *B*). The two sutures can also be combined (Figure 18-4, *C*). Similar placement of sutures around the medial fabella is used for lateral patellar luxations. Such sutures are most often used in conjunction with trochleoplasty in older dogs

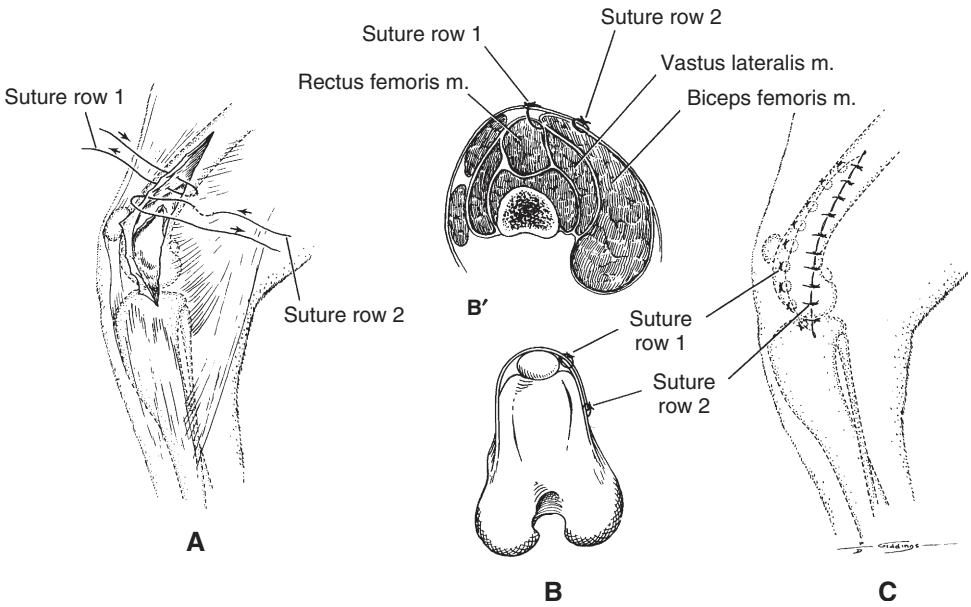


FIGURE 18-3. Fascia lata overlap. **A,** Lateral parapatellar incision has been made through the fascia lata and joint capsule. This incision follows the cranial edge of the biceps muscle proximally, and distally it ends over the long digital extensor tendon. The cranial fascia is reflected and elevated to identify the white aponeurosis between the rectus femoris and vastus lateralis muscles. Row 1 sutures are placed to pull the biceps to this aponeurosis proximal to the patella and to the lateral border of the patella and patellar ligament distally. Row 2 sutures complete the overlap. **B** and **B′,** Two cross-sectional views show the relationship of the biceps muscle and fascia lata to the rectus femoris muscle and patella. The biceps has been pulled cranially to exert lateral tension on the quadriceps and patella. **C,** Suture rows 1 and 2 are completed.

with grade 2 luxation and also work well as primary treatment in neonates as young as 5 days.[6]

The fabella is the center of the arc of rotation of the patella; thus the suture remains relatively taut during both flexion and extension of the stifle. By adjusting the point of insertion on the distal patellar ligament or tibial tubercle (Figure 18-4, *B*), the surgeon can make the suture taut at whatever degree of flexion produces the most medial tibial rotation. In many cases, particularly in dogs that are several years old before patellar luxation occurs, the tibial tubercle is not truly displaced or rotated relative to the rest of the tibia and foot (grades 1 and 2). In this situation the surgeon will note that when the patella luxates medially, the whole tibia rotates medially. This phenomenon is particularly noticeable in lateral luxation, a condition in which the tibia rotates laterally. Prevention of tibial rotation will greatly reduce the tendency of the patella to luxate. These sutures will probably break or loosen eventually in most cases; however, the fibrous tissue formed around the suture, plus realignment of soft tissues, will maintain the new position of the tibia or patella.

Fascia lata is incised along the cranial edge of the biceps muscle to allow retraction of the biceps caudally (Figure 18-4, *A*). Braided polyester (suture size 2-0 to 0 for small breeds, 0 to 2 for large breeds) is placed around the fabella on a half-circle Mayo catgut or Martin's uterine suture needle (see Figure 18-12 for details on technique for needle placement). The needle passes around the fabella in a distal-to-proximal or cranial-to-caudal direction most easily. The joint capsule can be opened

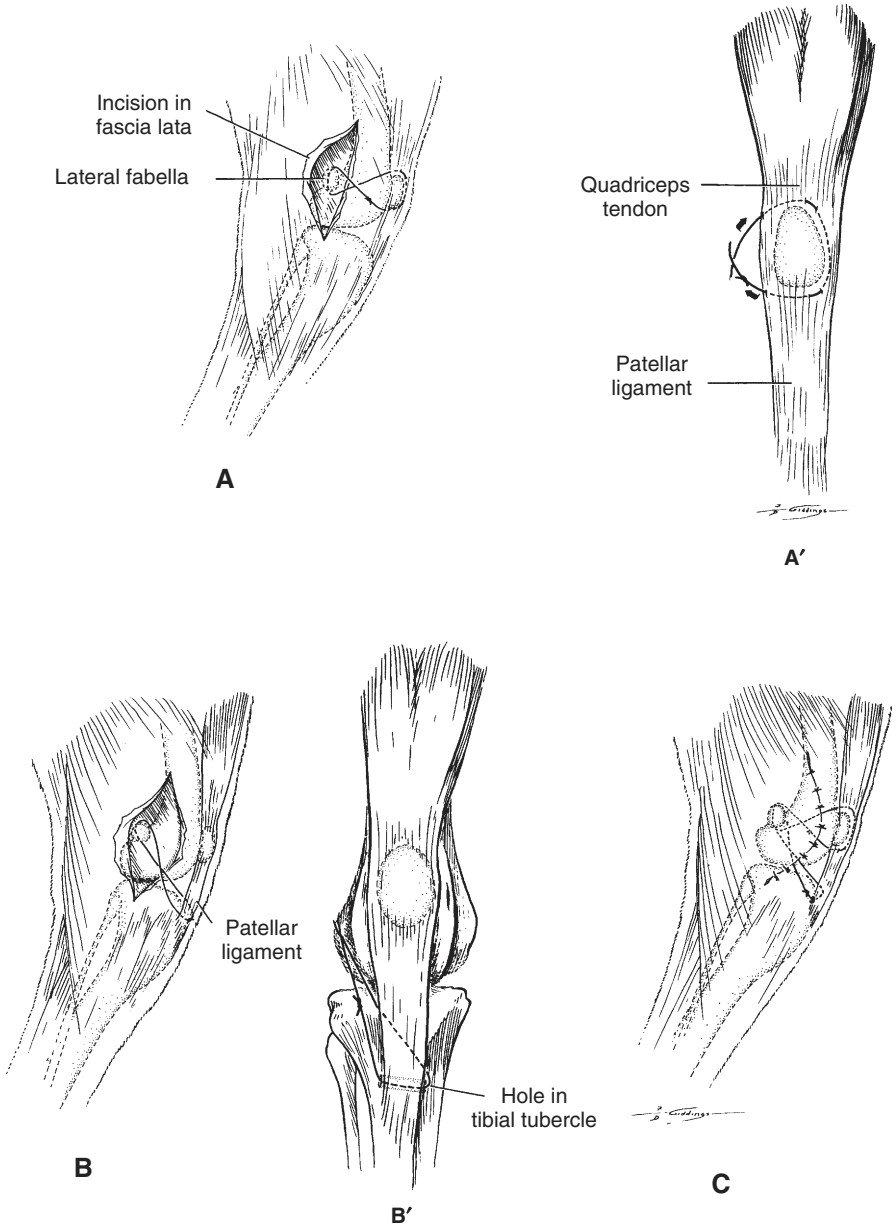


FIGURE 18-4. Patellar and tibial antirotational suture "ligaments."[6] **A,** The fascia lata is opened along the cranial border of the biceps muscle to expose the lateral fabella by caudal retraction and elevation of the biceps. Braided polyester suture material (size 2-0 in toy breeds to size 2 in large breeds) is passed behind the lateral fabella and around the patella, as shown in **A′.** The suture is tied just tight enough to stabilize the patella. **B,** To prevent medial tibial rotation, a suture can be passed around the fabella as in *A*, then placed either in the distal patellar ligament or in the tibial tuberosity. **B′,** Various locations are tried to find one that results in the suture being tightest when the stifle is flexed to the degree that causes greatest internal tibial rotation. The suture is tied tightly enough to prevent rotation. **C,** The two sutures can be combined. The caudal fascia lata has been overlapped in closing.

on the lateral side to allow inspection of the joint and to perform trochlear arthroplasty if indicated. The suture is attached around the patella in semi–purse-string fashion by a "bite" taken into the quadriceps tendon from lateral to medial at the proximal end of the patella. The suture is then passed distally along the medial border of the patella and laterally along the distal end of the patella (Figure 18-4, *A*).

All "bites" are placed deeply and as close to the patella as possible. With the suture passing medial to the patella, it cannot pull out. The lateral joint capsule is closed and sometimes imbricated if there is redundant tissue. The patellar suture must not lie on exposed articular cartilage. With the patella in place, the suture is tied with enough tension to prevent patellar dislocation.

The same method can be used on the medial side for lateral luxation. An incision is made along the cranial border to the caudal belly of the sartorius muscle, which is retracted caudally to expose the medial fabella. Suture placement is similar to that described for medial luxation.

The tibial antirotational suture is placed around either the medial or the lateral fabella. The suture can be attached to the distal patellar ligament or through a hole in the tibial tuberosity (Figure 18-4, *B*). The leg is positioned in various degrees of flexion to find the angle of maximal tibial rotation. The suture material is then tied tightly enough to prevent tibial rotation. In addition, lateral or medial retinacular overlap can be performed to imbricate the joint (Figures 18-2 and 18-4, *C*), or the fascia lata overlap method can be used (Figure 18-5).

Desmotomy and Partial Capsulectomy

Rarely used alone, these steps are frequently used in combination with other steps. *Desmotomy* refers to a simple release of the contracted medial or lateral retinaculum on the side toward which the patella is luxated (see Figure 18-7, *B*). The dynamics

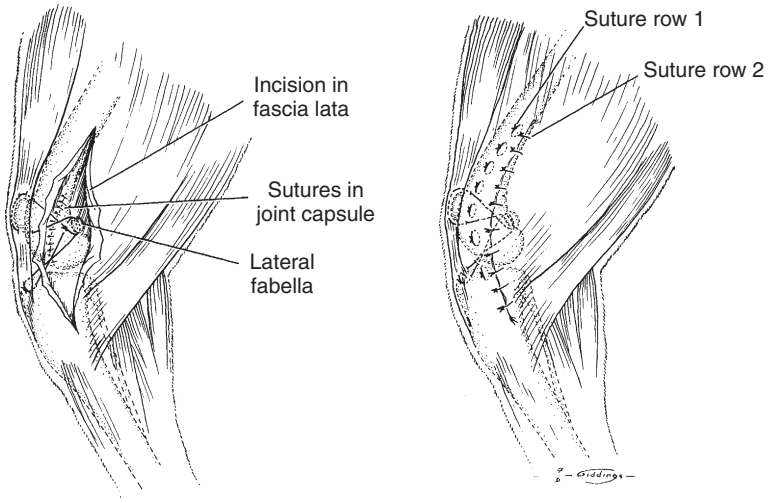


FIGURE 18-5. Combining patellar and tibial suture "ligaments" with fascia lata overlap. **A,** The lateral fascia has been incised (see Figure 18-3). The joint capsule has been sutured before the suture "ligaments" are placed to prevent suture material from rubbing on articular cartilage. **B,** After the fascia lata overlap, the suture "ligaments" are almost completely covered by fascia, emerging only for a short distance before being inserted around the patella or in the patellar ligament.

of this contraction are visualized during flexion and extension. The patella normally glides proximally and distally, paralleling the trochlea. With joint capsule contracture, the patellar excursion runs obliquely to that plane even after tubercle rotation. Desmotomy may eliminate this oblique movement. The incision begins at the tibial plateau and continues proximally through both layers of the joint capsule and retinacular tissues proximal enough to relieve all tension on the patella. The incision is usually left open to prevent tension from redeveloping. Synovium will quickly seal the joint to prevent synovial fluid leakage. Sutures connecting the edge of the patella with the deep fascia help prevent rocking of the patella. *Partial capsulectomy* refers to removing an elliptical piece of stretched joint capsule and retinaculum on the side opposite the direction of the patellar luxation. Suturing the edges together results in imbrication or tightening of the joint capsule.

Quadriceps Release

In some grade 3 and most grade 4 luxations, the quadriceps is so misaligned that it causes displacing tension on the patella after reduction of the luxation. In this situation, the entire quadriceps mechanism must be dissected free to the midfemoral level.

Bilateral parapatellar incisions are made through the joint capsule and retinaculum, as in the bilateral approach to the stifle joint.[7] These indications are continued proximally along the borders of the quadriceps muscle groups. Laterally, the separation is made between the vastus lateralis and biceps muscles; medially, it is made between the vastus medialis and caudal belly of the sartorius. The entire quadriceps is then elevated from the femur, freeing the insertion of the joint capsule proximal to the trochlea. The superficial fascial incisions are sutured after the rest of the reconstructive procedures are completed.

Bone Reconstruction Procedures

Trochleoplasty

Trochleoplasties are techniques that deepen a shallow, absent, or convex trochlea. There are several ways to achieve this, each involving injury to the articular cartilage, and this should be avoided if possible, especially in the larger dog. Small dogs and cats tolerate these procedures well, although return to full function may be somewhat delayed. Trochleas that are flat or convex often accompany a twisted distal femur. With medial luxation, the area of the medial ridge is twisted caudally, causing a further lack of ridge height. The region of the deficient trochlear groove is oblique to a surgically corrected, straight extensor mechanism (see Figure 18-1, *B*). In cats, small dogs, and many large dogs, this can be overcome by trochleoplasties. However, some large-breed and giant-breed dogs require a derotational and angular osteotomy to obtain a heightening of the medial ridge needed to achieve patellar stability.

To assess sufficiency of trochlear depth, the patella is reduced. On reluxating the patella, there should be an obvious "catch" or impedance to luxation, especially at the level of the trochlea where luxation occurs. If this is not the case, more aggressive deepening is performed.

Trochlear Chondroplasty.[8,9] This "cartilage flap" technique is useful only in puppies up to 10 months of age. As an animal matures, the cartilage becomes thinner and more adherent to the subchondral bone, making flap dissection difficult. A cartilage flap is elevated from the sulcus (Figure 18-6, *A*), the subchondral bone removed from beneath it (Figure 18-6, *B*), and the flap pressed back into the deepened sulcus (Figure 18-6, *C*). If not deep enough, the process is repeated. This results in a deepened trochlea, with maintenance of articular cartilage in the sulcus and with fibrocartilage or fibrous tissue at the incisional gaps.

The cartilage flap survives, and experimental dogs have shown no adverse effects from the procedure.[8]

Wedge Recession Sulcoplasty.[10] A V-shaped wedge, including the sulcus, is removed from the trochlea with a saw (Figure 18-6, *D*). The resulting defect in the trochlea is widened by another saw cut on one edge to remove a second piece of bone (Figure 18-6, *E*). When the original bone wedge is replaced, it is recessed into the defect, creating a new sulcus composed of hyaline cartilage[11] (Figure 18-6, *F*). The sides of the defect become lined with fibrocartilage. This method is preferred in mature animals.

Trochlear Block Recession.[12] Instead of a V-shaped wedge as in the recession sulcoplasty, the sides of the piece removed are parallel rather than angled (Figure 18-6, *G, H,* and *I*). This allows the trochlea to be deepened somewhat more proximally than with the recession sulcoplasty. Using a power saw, two parallel incisions in cartilage and bone along the widest part of the trochlear ridges are made from the top of the trochlea to a level almost at the origin of the caudal cruciate ligament (Figure 18-6, *G*). A wide osteotome or power saw is used to make the cut above the caudal cruciate origin connecting the previously made cuts; this cut is angled toward

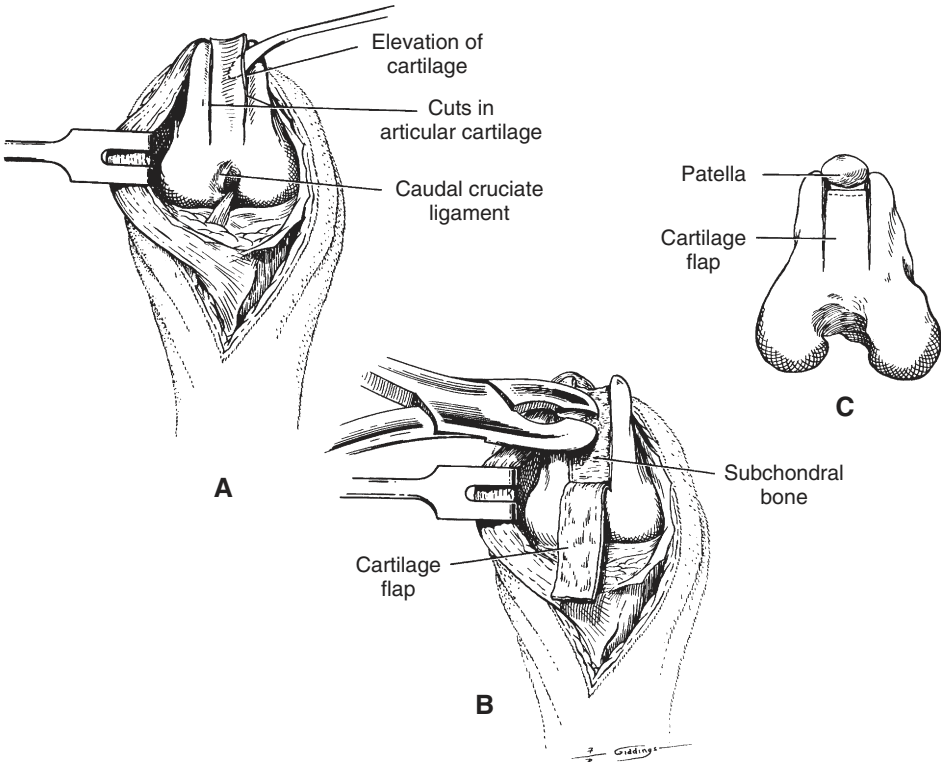


FIGURE 18-6. Trochleoplasty techniques. **A** to **C,** Trochlear chondroplasty. For this technique, the animal must be less than 10 months old. **A,** The new sulcus is outlined by cuts through the thick adolescent cartilage. The proximal transverse cut is at the level of the proximal trochlear ridges. A sharp periosteal elevator is used to raise cartilage from subchondral bone. **B,** The cartilage flap is hinged distally to allow removal of subchondral bone with rongeurs. **C,** When the cartilage flap is replaced, the sulcus is deep enough to retain the patella. Fixation of the cartilage is not required.

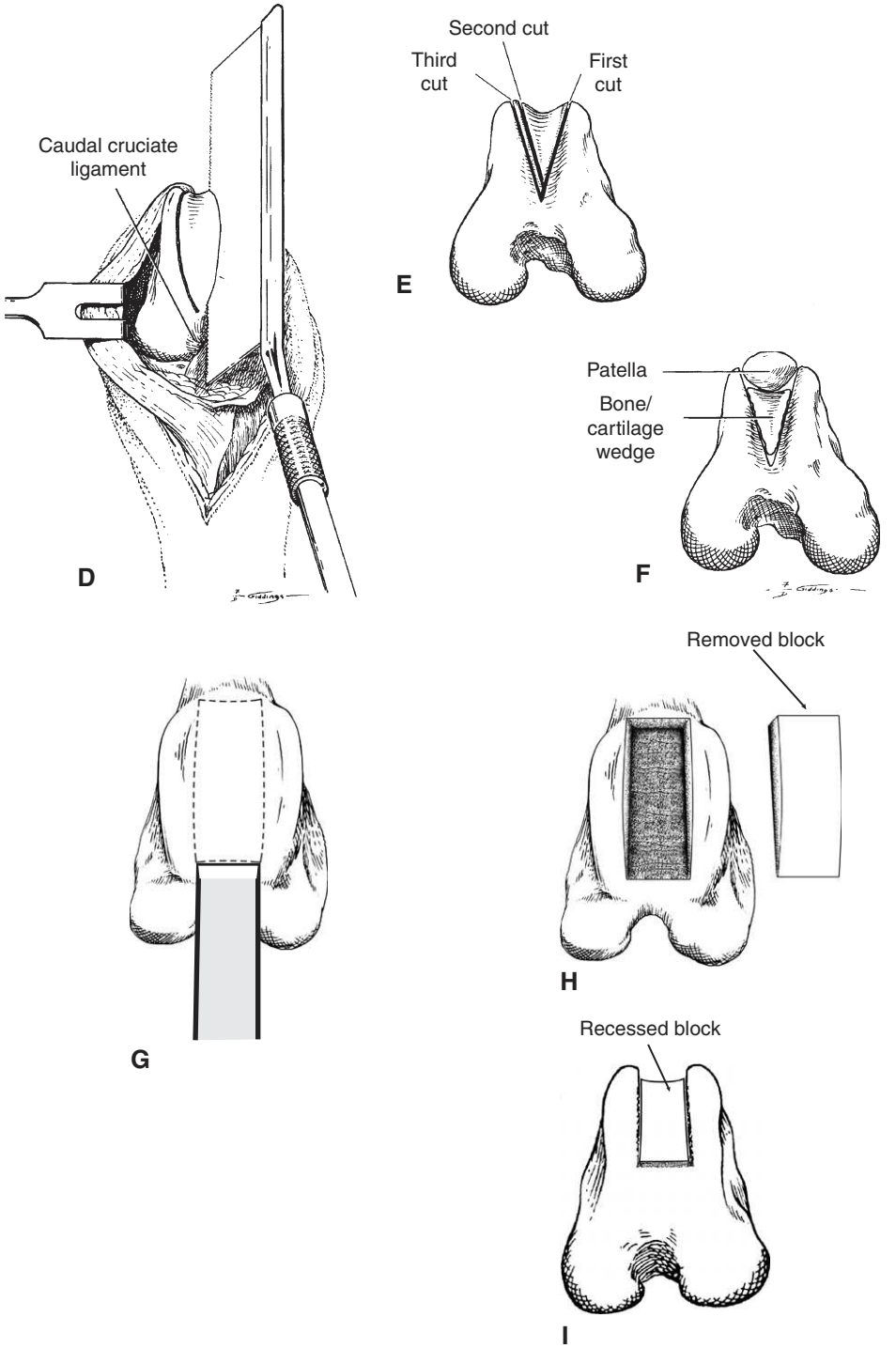


FIGURE 18-6. *Continued* **D** to **F,** Modified recession sulcoplasty.[10] **D,** A thin-blade hobby saw (X-Acto, Long Island City, NY), ethylene oxide or chemically sterilized, is used to cut a V-shaped wedge from the trochlea, extending from the caudal cruciate origin to the proximal trochlear ridges. **E,** Cuts made in the indicated order create a V-shaped defect and slightly smaller wedge. **F,** When the original bone and cartilage wedge is replaced in the defect, it is recessed and thus creates a deeper sulcus. No fixation of the wedge is required. **G** to **J,** Trochlear block recession. *Continued*

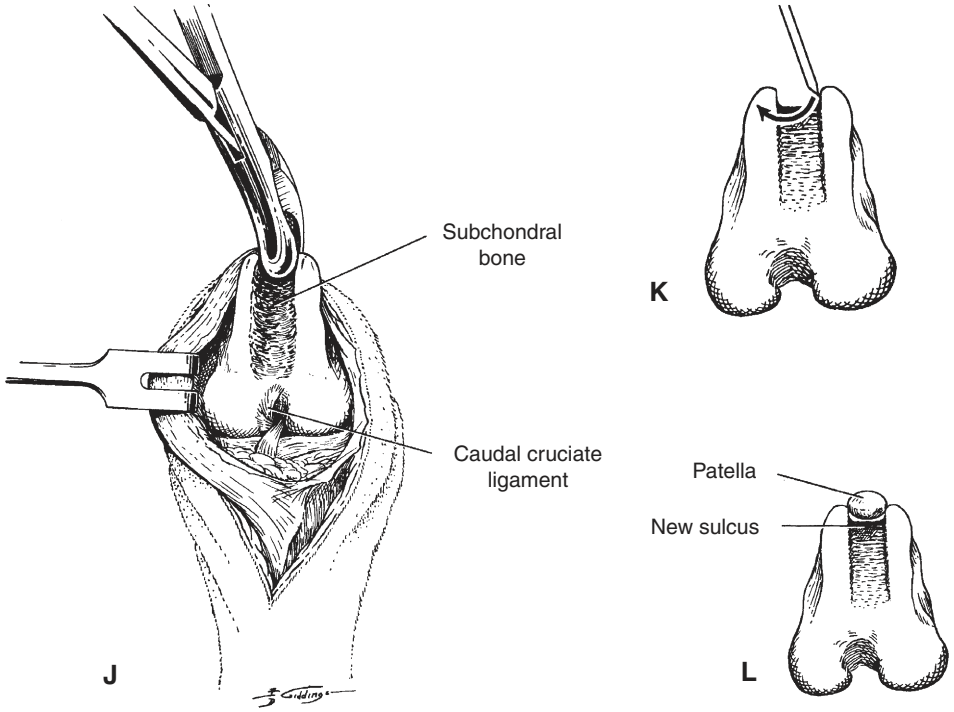


FIGURE 18-6. *Continued* **G,** An osteotome or thin blade power saw is used to outline the troclear block to be removed. **H,** The distal end of the block is cut just above the origin of the caudal cruciate ligament and angled to meet the proximal trochlear incision. The proximal trochlear deepening is important because the patella usually luxates adjacent to the shallow proximal trochlea. The recession sulcoplasty (*D-F*) does not deepen the proximal trochlea as far as the block resection does. **I,** After deepening the subchondral cancellous bone, the block is replaced without fixation, and cancellous bone is packed along the sides of the block. **J** to **L,** Trochlear sulcoplasty ("curettage"). An outline of the proposed sulcus is made in the cartilage with a scalpel along the condylar ridges. **J,** Articular cartilage and bone are then removed within the outlined area to create a straight-sided, curved-bottomed trough, as shown in **K.** After removal of cancellous bone, the bed is made smooth by scraping across the groove with an osteotome. Others prefer a rasp or power bur. The distal end of the trough is near the origin of the caudal cruciate ligament, and it extends to the proximal trochlear ridges. **L,** The trough should be deep enough so that the patella does not touch bone in the bottom of the trough and wide enough so that the patella rides deeply in the new sulcus. Done in this manner, articular cartilage of the patella is not damaged by abrasion on subchondral bone, and fibrocartilage can fill in the gap and conform to the excursions of the patella.

the proximal aspect of the trochlea. Great care must be taken to prevent dropping and contaminating the loosened block (Figure 18-6, *H*). The block is removed and wrapped in a bloody sponge while trabecular bone is removed from the femur to recess the block. The wedge is then pressed back into this recessed femur and cancellous graft packed into the gaps at the side of the block (Figure 18-6, *I*). The advantage of this technique is that the proximal trochlea can be made deeper than with the V–shaped wedge recession.

Trochlear Sulcoplasty.[13] In the curettage technique, articular cartilage is removed to the level of subchondral bone to create a sulcus deep enough to prevent patellar luxation (Figure 18-6, *J, K,* and *L*). By cutting completely through articular

cartilage to subchondral bone, fibroplasia will result in a sulcus lined with fibrocartilage, which is an acceptable substitute for hyaline cartilage in non–weight-bearing areas. The width of this new groove must accommodate the width of the patella and must be smooth. This can be accomplished by scraping the convex surface perpendicularly with an osteotome (Figure 18-6, *K*) or by using a rasp. Others prefer to use high-speed burs. Although destructive to the entire cartilaginous trochlear sulcus, this sulcoplasty still results in good function in small dogs and cats.

Because of the relatively wide patella in the cat, it does not fit into the trochlea well. The patella can be narrowed by removing bone from the medial and lateral sides.

Transposition of Tibial Tuberosity[14,15]

When the tuberosity is deviated, relocation to a more cranial position on the leg helps patellar stability. Degree of deviation can best be assessed by placing the animal in dorsal recumbency with the surgeon standing at the end of the table near the animal's feet (Figure 18-7, *A*).

A medial skin incision is made for lateral or medial luxations.[7] For medial luxations, a lateral arthrotomy with or without a capsulectomy is used. For lateral luxations, a medial arthrotomy with or without capsulectomy is performed. An incision is made in the periosteum medially along the tibial tuberosity and crest, including the distal attachment. The exact distal insertion of the patellar ligament is found by nicking the joint capsule along the medial aspect of the patellar ligament (the beginning of the desmotomy). To osteotomize the tuberosity, an osteotome as wide as the tuberosity should be used to avoid splitting it. The bone is cut starting 3 to 4 mm proximal to the insertion of the patellar ligament, which leaves a flange of bone that will be shaped similar to the notch of bone that will be cut on the tibia (Figure 18-7, *B* and *D*). The osteotome should not be twisted (keep flat side parallel with the patellar tendon) in order to avoid an asymmetric osteotomy. The attachment of the tibialis cranialis is *not* detached from the lateral aspect of the tubercle and crest, thus saving blood supply to the small, osteotomized bone. The periosteum and fascia distal to the tubercle osteotomy *are* incised, allowing the entire tubercle to be moved laterally and distally (Figure 18-7, *D, E,* and *F*). Another procedure involves leaving this periosteum intact; however, the tubercle then can only be swiveled, not moved in other planes (Figure 18-7, *G*).

After the tuberosity crest is loosened medially and distally, it is pushed laterally while the tibialis cranialis muscle is dissected away from the lateral aspect of the tibia. The soft tissues are *not* removed from the lateral aspect of the osteotomized tuberosity crest. To expose the area for the notch to be made along the lateral side of the tibia, a curved hemostat is levered between the tuberosity and caudal tibia (Figure 18-7, *C*). A triangular notch is usually made 5 to 8 mm distal from the proximal end of the osteotomy. In large dogs with "patella alta," the notch should be moved more distally (1.0 -1.5 cm) to pull the patella distally into a more competent, deeper trochlear groove. If the tuberosity is extremely deviated, this notch is placed farther caudal and lateral on the tibia. For lateral luxations, the tubercle is osteotomized the same way, but the bed for the tubercle to relocate medially is made larger than the lateral notch.

To relocate the tuberosity, the knee is hyperextended to relax the extensor mechanism, and the top of the tuberosity is placed in the notch and held tightly (Figure 18-7, *D*, *inset*) while drilling 0.035- to 0.062-inch Kirschner wires (depending on animal size). The pin is driven through the thickest part of the tubercle in a slightly proximal and caudomedial direction (Figure 18-7, *E*). The pin should engage the opposite tibial cortex to avoid pin migration and should not penetrate

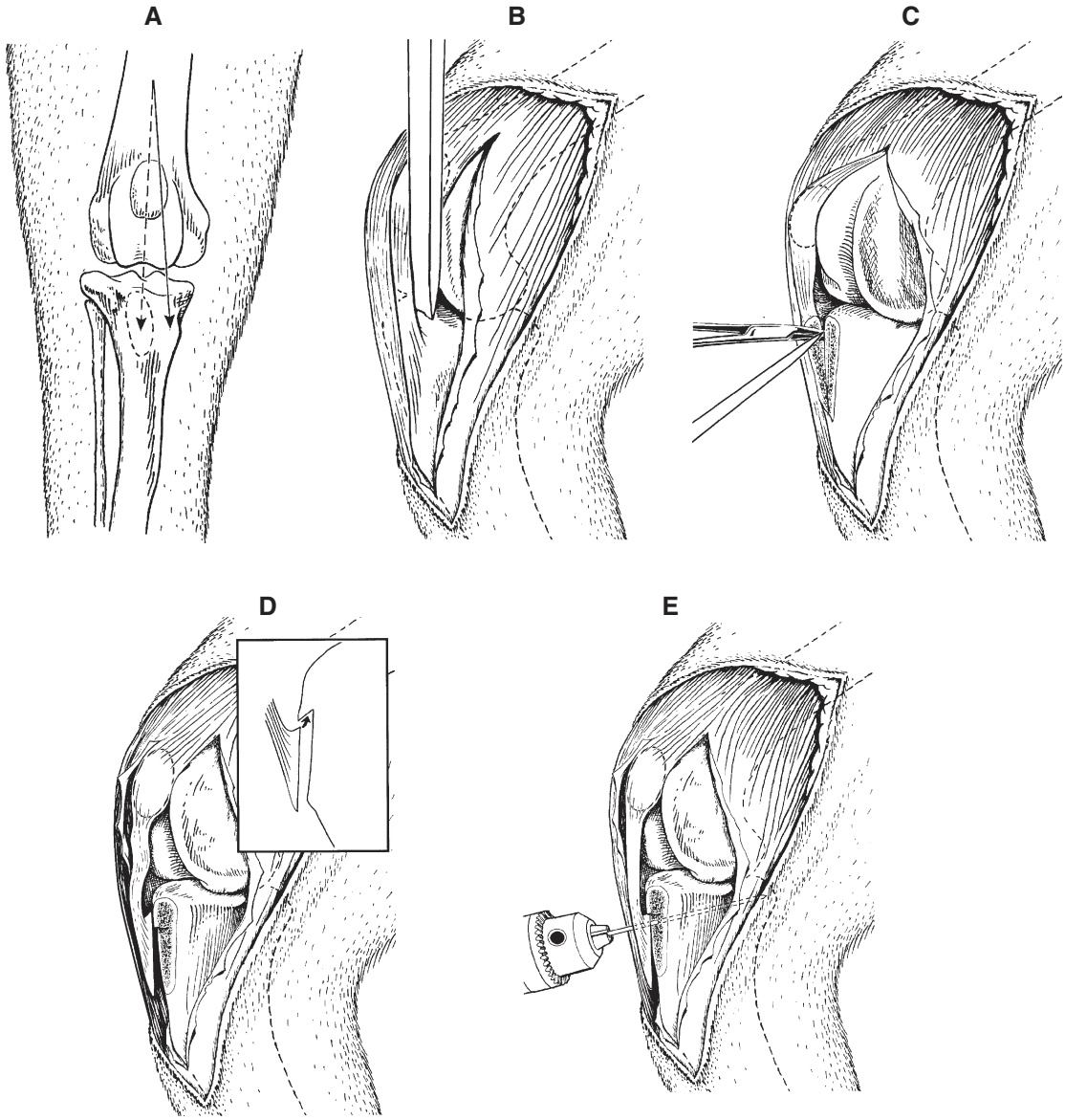


FIGURE 18-7. Tibial tuberosity transposition.[14] **A,** Evaluating the amount of transposition needed. The dotted line demonstrates the correct relocation of the deviated tuberosity *(solid line)*. **B,** The medial fibrous joint capsule is "released," correcting medial capsular contraction. The attachments lateral to the tubercle and crest are *not* incised. The tuberosity and crest osteotomy is started 3 to 4 mm from the insertion of the patellar ligament. **C,** With the tuberosity and crest retracted with a hemostat, a triangular piece of tibia is removed from the lateral aspect of the tibial crest (assuming medial luxation). **D,** The notch made on the side of the tibia is similar in shape to the flange of bone left proximal to the patellar ligament insertion (see *inset*). With the knee hyperextended, the tuberosity is placed into the notch. **E,** With the tuberosity held in place with thumb forceps (omitted for clarity), a pin is driven toward the caudal medial tibial condyle, with great care taken not to drive it proximally into the joint.

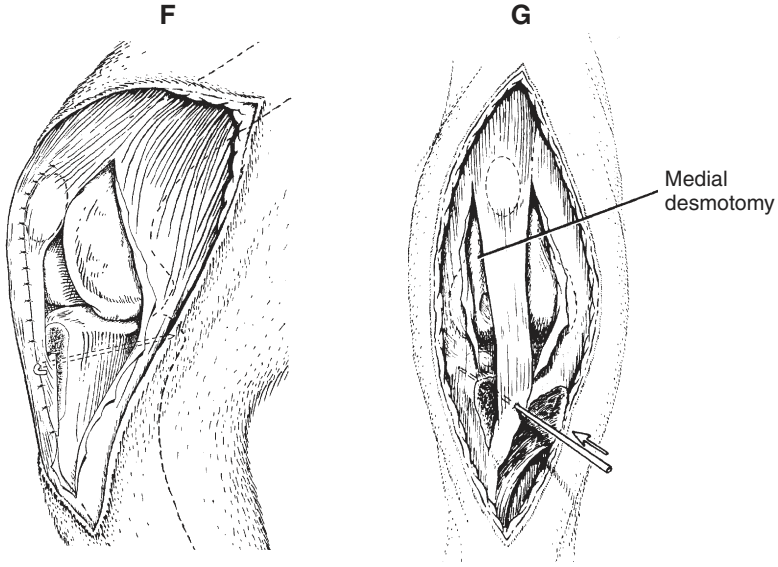


FIGURE 18-7. *Continued* **F,** The pin is cut so that there is 1/8 inch of pin protrusion to prevent the bone from slipping off the pin. Alternatively, the pin may be bent before being cut if the tuberosity is thick enough. **G,** An alternative method for transposing the tuberosity involves incising lateral and medial attachments to the tuberosity but leaving the distal bone and periosteum intact. The tuberosity is swiveled and pinned.[15] (*Note:* This is the opposite leg from the rest of this series.)

joint surfaces. The tuberosity has now been transposed distally (thereby tightening the patellar ligament), laterally, and twisted so that the flat side of the tuberosity is flush with the side of the tibia. Realignment is checked, and if satisfactory, the pin is cut 2 to 3 mm from the tuberosity (Figure 18-7, *F*). In large dogs, two pins may be used. Some surgeons bend the pins before cutting them, but this should be avoided in small tuberosities to prevent splitting.

Closure commences by suturing the external fascia of the tibialis cranialis to the periosteum on the medial aspect of the tibia. The lateral joint is closed and the patella checked for stability. If still unstable, the groove may need to be deepened or the tuberosity rotated farther.

In dogs with severe deformity, the lateral and medial attachments to the tuberosity may need to be incised to move the tuberosity to the area of the fibula. In cases of "patella alta," the tuberosity may have to be moved more distally after freeing more of the soft tissues proximal to the patella.

Another technique for osteotomizing the tuberosity is to incise the periosteum medially and tibialis cranialis laterally, freeing up both sides of the tuberosity. However, the tuberosity is left attached distally. The tuberosity is then swiveled laterally and pinned to a newly made notch[15] (Figure 18-7, *G*).

Patellectomy

Patellectomy should be used only in very rare occasions when erosion is severe and the dog has not improved clinically with successful realignment procedures. It is accomplished by incising vertically over the midline of the patella. With a sharp scalpel blade, the quadriceps tendon, retinaculum, and joint capsule and patellar ligament are peeled off the patella in quadrants, leaving as much soft tissue as possible. After the patella is removed, the large defect over the femoral trochlea

(Figure 18-8, *A*) is closed by simple interrupted or purse-string sutures using nonabsorbable suture. If there is a large void of soft tissue and a concern of tissue breakdown, a vertically placed, locking loop suture pattern may be used (Figure 18-8, *B*).

Osteotomy

In rare cases with severe deformity, after the extensor mechanism has been relocated to a more normal cranial position, the osteotomized tibial tuberosity lies above the proximal end of the tibia due to muscle contracture and cannot be pinned. In a few instances the femur has been osteotomized, 1 or more cm of bone removed, and then repaired with intramedullary pins (or plated if trochleoplasty interferes with proper seating of the pins). This relaxes the extensor mechanism and allows the tibial tuberosity to be moved distally for pinning to the tibia. In cases of severe torsion of the tibia and femur, realignment osteotomies have been reported, but these are complex, and we have not used them. In such cases, arthrodesis is probably a more feasible procedure.

With the increase in patellar luxations seen in large dogs, aggressive osteotomy techniques may need to be performed more often than previously.

Femoral Osteotomy for Medial Luxation. After realigning the tubercle and deepening the groove in large and giant dogs with grade 3 or 4 medial luxations, the patella may still not be stable. Distal torsion of the femur moves the medial side of the distal femur more caudal from a frontal plane (see Figure 18-1, *C*), thereby lowering the location of the medial ridge. A distal derotational femoral osteotomy with bone plate fixation brings the medial side of the trochlea more cranially. If the trochlea is angled relative to the straight extensor mechanism, a closing wedge component of the osteotomy is performed as well. The osteotomy is planned so that at least three plate screws can be placed distal to the osteotomy. Other reconstructive procedures may be needed to achieve stability of the patella.

Femoral Osteotomy for Lateral Luxation. In the large and giant breeds, lateral luxation (see later discussion) may be associated with valgus deformity and distal torsion of the femur (Figure 18-9, *A* and *B*). If these deformities are severe enough, bone corrective procedures as previously described may not be sufficient to stabilize the patella. In such patients, a midshaft opening wedge osteotomy is done, the femur

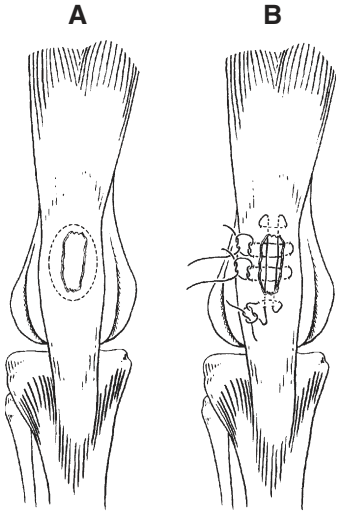


FIGURE 18-8. Patellectomy. **A,** After exposure with a medial parapatellar skin incision, a vertical incision has been made on the midline of the patella. The patella is "shelled" out in quadrants with a sharp scalpel, leaving an oval hole (the dotted line represents the previous location of the patella). **B,** Closure of the hole in the soft tissue can be accomplished by two horizontal mattress or interrupted sutures with nonabsorbable suture. If there is concern of dehiscence, a vertical locking loop suture pattern may be added.

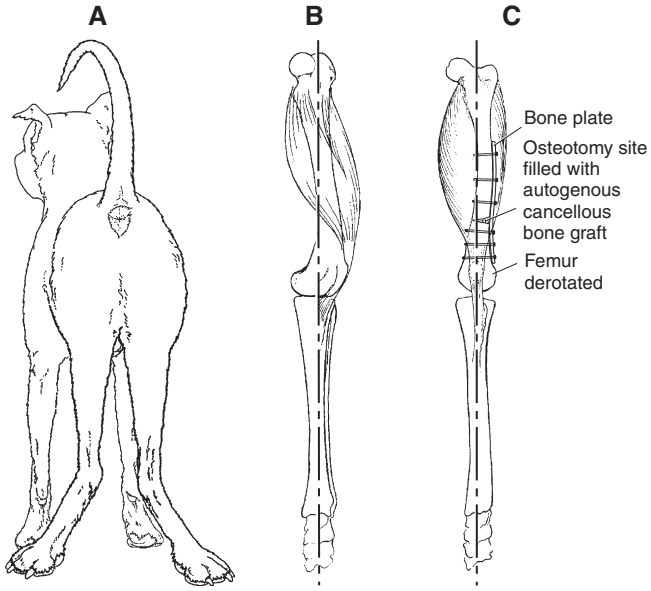


FIGURE 18-9. A, Large Great Dane puppy with genu valgum. Note the wide hips, narrow stifles and hocks, with the toes pointing outward. **B,** Femur and tibia from a large Great Dane with genu valgum showing valgus angulation and torsion of the femoral condyles. **C,** Surgical correction involves a midshaft transverse osteotomy; internal rotation of the distal femur, creating a varus bowing of the femur sufficient to realign the quadriceps mechanism; and stabilization with a bone plate. The osteotomy gap is filled with autogenous cancellous bone graft.

is derotated and placed in sufficient varus position to allow the patella to center in the trochlear sulcus, and a bone plate is used for fixation (Figure 18-9, *C*). The defect created in the lateral cortex is filled with autogenous cancellous bone graft (see Chapter 3). Lateral desmotomy, various soft tissue reconstructions, and recession trochleoplasty may be necessary in addition to the osteotomy.

Aftercare for All Surgical Techniques

Because many of these breeds are "jumpers," padded bandage support for 10 to 14 days may be useful in the active patient. If bilateral surgery has been performed, postoperative pain may seriously inhibit attempts to use the limbs. Aspirin or other pain medications may be used for 5 to 7 days (see Chapter 6).

Because toy and miniature breeds are not very tolerant of pain, some difficulties are occasionally encountered. If the dog is not starting to bear weight by 4 weeks, active physiotherapy must be started. Swimming is best but often is not possible. In small dogs, bathtub hydrotherapy may be substituted. Passive flexion-extension, 20 to 30 times four times a day, may be helpful. Leash walking, ball throwing, and other activities to tempt the animal into a running gait are also useful. Taping a small, plastic syringe cap or glass marble between the toes and metatarsal pad of the opposite limb for a few hours at a time also works well on some dogs. Placing the opposite leg in an Ehmer sling for several days may be done as a last resort.

Prognosis

Willauer and Vasseur[16] have reported on the follow-up evaluation of medial patellar luxation repair in 52 stifles. No lameness was observed in 92% of the stifles, although 48% had persistent, palpable patellar luxation. The recurrent luxations were always of a lesser grade than the preoperative grade, with 17 of the 25 being grade 1. Regardless of the degree of lameness or stability of the patella, most dogs had radiographic signs of degenerative joint disease. It must be inferred from these findings that stability of the femoropatellar joint is not essential to good function in the small breeds, which supports the common clinical observation that some small-breed dogs with medial patellar luxations never show clinical signs. Early correction of severe deformities will undoubtedly play a major role in ensuring good function.

Medial Luxation Treatment Plan

Although not all cases can be fitted into rigid categories, we have attempted to outline procedures that may be useful for each grade of luxation. Treatment is aimed at reducing the anatomical defects. The procedures are done in the following order until patellar stability is achieved.

Grade 1

1. If the extensor mechanism is straight:
   a. Lateral fascia lata overlap (see Figure 18-3).
   b. Tibial antirotational suture (see Figures 18-4, *B,* and 18-5).
2. If the tubercle is deviated:
   Tibial tubercle transposition (see Figure 18-7), with or without partial capsulectomy, retinacular overlap, or fascia lata overlap (see Figures 18-2 and 18-3).

Grade 2

1. Medial desmotomy if the medial retinaculum prevents easy patellar reduction (see Figure 18-7, *B*).
2. Tibial tubercle transposition (see Figure 18-7) and partial lateral retinacular capsulectomy or fascia lata overlap (see Figures 18-2 and 18-3).
3. If the patella is still unstable, add:
   Trochleoplasty (see Figure 18-6).

Grade 3

1. Medial desmotomy (see Figure 18-7, *F*).
2. Tibial tubercle transposition (see Figure 18-7).
3. Trochleoplasty (see Figure 18-6).
4. Partial capsulectomy, lateral retinacular or fascia overlap (see Figures 18-2 and 18-3).
5. Lateral patellar and tibial antirotational sutures (see Figures 18-4 and 18-5) if the patella is still unstable.

Grade 4

1. Procedures for grade 3.
2. Release of quadriceps.
3. If still unstable, consider:
   a. Femoral (see Figure 18-9, *B* and *C*) derotation and shortening and possibly tibial osteotomy.
   b. Arthrodesis (see Figures 18-31 and 18-32).

The limiting factor in grade 4 luxation repair is flexure contraction at the stifle. If the shortening is severe, the osteotomized tubercle may not reach the tibia in the rotated position, necessitating femoral shortening or quadriceps lengthening. If the joint cannot be extended to a near-normal angle, arthrodesis may be the only viable option.

Lateral Luxation Treatment Plan

Surgical treatment is as follows:

Grade 1

1. Medial retinacular overlap or capsulectomy (see Figure 18-2) in all cases.
2. Medial tibial antirotational suture (see Figure 18-4, *B*) if the patella is still unstable after 1.

Grades 2 and 3

1. Lateral desmotomy if the lateral retinaculum prevents easy patellar reduction (see Figure 18-7, *F*).
2. Medial tibial tubercle transposition (see Figure 18-7).
3. Medial retinacular overlap (see Figure 18-2).
4. If the patella is still unstable, add:
   a. Trochleoplasty (see Figure 18-6).
   b. Medial patellar and tibial antirotational sutures (see Figures 18-4, *B,* and 18-5).

Combined Medial and Lateral Luxation Treatment Plan

Surgical procedures are as follows:

The tubercle is usually in straight alignment:

1. Trochleoplasty (see Figure 18-6).
2. Combined medial and lateral retinacular overlap (see Figure 18-2) or capsulectomies.

Medial Luxation Resulting from Trauma

All breeds are subject to this relatively rare injury, although minor skeletal changes and mild patellar instability predispose to the problem. Traumatic luxation of the hip can be accompanied by medial patellar luxation. In our experience, we have not seen traumatic lateral luxation. Rarely, with tibial fractures of young dogs, the patella may become luxated. If undetected, and the fracture stabilized with coaptation, an ectopic patella results. The patella should be checked on all tibial fractures and replaced before coaptation. Another case of "traumatic" patellar luxation occurs as an iatrogenic complication after failure to close the fascia lata adequately during distal femoral fracture repair.

Clinical Signs

Mechanically, the situation is similar to that of a grade 1 luxation, with signs of acute inflammation superimposed. Pain is severe, and anesthesia or deep sedation is usually required for palpation. The limb is carried in flexion and internal rotation. Joint effusion and swelling of soft tissue are evident.

Radiographic examination to rule out hip luxation, patellar fracture, and avulsion or tearing of the patellar ligament is indicated. (See Chapter 16 for a discussion of these injuries.)

Treatment

Closed reduction and immobilization in a sling or Schroeder-Thomas splint may be indicated if the patella is reasonably stable after reduction. If the patella is extremely unstable or if luxation recurs after immobilization, surgical treatment should be undertaken.

1. Fascia lata overlap.
2. Lateral patellar suture (see Figures 18-4 and 18-5) if stability is not achieved by 1.

Lateral Luxation (Genu Valgum) in Young Large and Giant Breeds

Also called *genu valgum,* this condition is seen in the same breeds that are affected by hip dysplasia. The distal femoral trochlea becomes twisted externally, with the

lateral aspect of the femur shortened relative to the medial side. We have noted an unusual incidence in certain strains of flat-coated retrievers. Rudy[6] postulated a genetic pattern of occurrence and noted Great Danes, Saint Bernards, and Irish wolfhounds as being affected most often. Olsson[17] proposed that genu valgum of large and giant breeds of dogs is caused by osteochondrosis of the distal femur.

Components of hip dysplasia, such as *coxa valga* (increased angle of inclination of the femoral neck) and increased anteversion of the femoral neck,[18] are related to lateral patellar luxation. These deformities cause internal rotation of the femur with lateral torsion and valgus deformity of the distal femur, which displaces the quadriceps mechanism and patella laterally (see Figure 18-9, *A* and *B*). Early treatment consists of slowing the puppies' growth rate by dietary means. If patellar luxation occurs, surgical correction is necessary.

Clinical Signs

Bilateral involvement is most common. Animals appear to be affected by the time they are 5 to 6 months of age. The most notable finding is a "knock-knee" (genu valgum) stance. The patella is usually reducible, and laxity of the medial collateral ligament may be evident. The medial retinacular tissues of the stifle joint are often thickened, and the foot can often be seen to twist laterally as weight is placed on the limb.

Treatment

The following procedures are used:

1. Mildly affected: lateral luxation without marked rotational deformity of the femur.
   a. Trochleoplasty (see Figure 18-6).
   b. Tibial tubercle transposition, although rotated medially (similar to Figure 18-7).
   c. Retinacular overlap medially (see similar to Figure 18-2).
   d. Periosteal incision and stripping to stimulate growth on lateral (concave) aspect of the physeal plate to stimulate growth.[19]
2. Greatly affected: lateral luxation with marked valgus deformity of femur.
   Corrective osteotomy of the femur (see Figure 18-9, *C*).

RUPTURE OF CRANIAL CRUCIATE LIGAMENT

Cranial cruciate ligament ruptures are one of the most common injuries in the dog and the major cause of degenerative joint disease (DJD) in the stifle joint. The ligamentous injury may be a complete rupture with gross instability or a partial rupture with minor instability. In either case, untreated animals show degenerative joint changes within a few weeks and severe changes within a few months. The severity of degeneration seems to be directly proportional to body size, with animals weighing more than 15 kg showing the most changes. Vasseur and colleagues[20] have consistently demonstrated degenerative changes and decline in material properties (strength) of the ligament in dogs over 5 years of age. The intensity of the changes became worse with age, but animals less than 15 kg had significantly less change in material properties than larger dogs. This confirms the earlier observations of Paatsama[21] and Rudy.[6] Systemic inflammatory joint diseases (e.g., rheumatoid arthritis) in humans and dogs have long been known to be associated with rupture of the cranial cruciate ligament.[22]

Synovial fluid analysis of partial cruciate tears demonstrated increased nucleated white cells, suggesting a moderate inflammation compared with the typical noninflammatory changes seen with complete tears and DJD.[23,24] There was no historical evidence of systemic (i.e., multiple joints or limbs) joint disease.

The function of the cranial cruciate ligament is to constrain the stifle joint so as to limit internal rotation and cranial displacement of the tibia relative to the femur and to prevent hyperextension.[25] The ligament is composed of two functional parts: the small *craniomedial band* (CMB) and the larger *caudolateral band* (CLB). Mechanisms of injury can be related to these normal functions: most often the ligament is injured when the stifle is rotated rapidly with the joint in 20 to 50 degrees of flexion or when the joint is forcefully hyperextended.[26] The former occurs when the animal suddenly turns toward the limb with the foot firmly planted. This causes extreme internal rotation of the tibia with stress on the cranial cruciate ligament. Hyperextension probably occurs most frequently by stepping into a hole or depression at a fast gait.

From 30% to 40% of dogs sustaining a cruciate ligament rupture will rupture the opposite ligament within 2 years. Young, straight-legged breeds (mastiffs, chow chows, Labrador retrievers) seem to have an increased prevalence of this problem in the last 15 to 20 years. Bilateral problems are even more common in these young dogs. Straight-leggedness, angle of the tibial plateau, and narrowing of the intercondylar notch may be contributing factors.

The medial meniscus may be torn acutely at injury but is more often damaged as a result of chronic instability of the joint, producing crushing and eventual shredding of the caudal horn of the medial meniscus. Some type of meniscal injury is present in about 50% of the animals we have seen. These injuries are discussed later in this chapter. Concurrent patellar luxation is seen fairly often in toy breeds of dogs. In these cases the patellar luxation is probably the initial condition and the cruciate ligament ruptures most likely caused by the tibial instability produced by the luxated patella and subsequent stretching of the crucial ligament. Partial cruciate ligament disease is becoming more frequently diagnosed and is seen especially in straight-legged dogs (see later discussion).

Clinical Signs and Diagnosis

Although pain is noted early with non–weight bearing, most animals will start to use the limb within 2 to 3 weeks and apparently improve for several months until a gradual or sudden decline in the use of the limb is noted, often as a result of secondary meniscal damage. At this time, the degenerative changes of osteoarthrosis are present, and functional decline is continuous. Diagnosis is based on demonstration of cranial *drawer motion* using direct and indirect palpation techniques (see Chapter 1). Drawer motion should be tested in flexion, normal standing angle, and extension. With acute injuries and gross instability, drawer motion may be evident. Joint effusion may be noted for several days after injury. With chronic injuries and with partial tears, drawer motion is much less evident and requires very careful examination. With chronic cruciate ligament instability, periarticular tissues become thickened and fibrotic, with only limited stretching possible. Drawer motion in these patients may be almost imperceptible, but any drawer motion is abnormal. In skeletally immature dogs, slight drawer motion ("puppy drawer") may be possible, but such motion stops abruptly as the ligament is stretched taut. This abrupt stoppage of cranial drawer motion is also noted in cases of isolated caudal cruciate rupture.

With partial cruciate ruptures, a small amount of drawer motion will be appreciated only in flexion, emphasizing the need to check drawer in extension, neutral, and flexion. Testing the joint for increased internal rotation of the tibia is also helpful in animals with chronic conditions and in those with partial rupture. The amount of torsion of the tibia can be compared with the opposite limb.

Fibrosis of the joint capsule and associated structures partially stabilizes the joint, but not sufficiently to prevent its continual deterioration. Animals of all ages often

have firm swelling of tissues on the medial surface of the joint between the medial collateral ligament and the proximal tibial ("buttress sign"). The significance of this swelling is uncertain, but we believe it is associated with chronic meniscal injury.

Radiographs are of little value in the typical unstable cruciate ligament rupture other than to document the amount of osteoarthrosis present. These are better appreciated on arthrotomy. Radiographs are helpful in animals in which drawer motion is subtle or absent. If radiographs are taken, observations should include the following:

1. *Osteophytes.* These are seen especially around the distal patella, the supratrochlear region, the tibial and femoral margins, and fabellae.
2. *Fat pad sign.* On the lateral projection a normal triangle of radiolucent fat is present from the distal patella to the femur and tibia (Figure 18-10). The cruciates and menisci account for the normal radiodensity just caudal to this triangle. With synovial effusion or fibrosis of the fat pad region, the area cranial to the femur becomes whiter (Figure 18-10, *B*). Good-quality soft tissue technique films are necessary to define this change.
3. *Cranial drawer.* Normally with cruciate rupture, the unstressed leg lies in a neutral drawer position (Figure 18-11, *A*). If cranial drawer is detected on the radiograph (Figure 18-11, *B*), it may indicate the presence of a torn meniscus wedging the tibia forward.
4. *Avulsions.* These seen rarely and usually occur in the young animal.



A B

FIGURE 18-10. **A,** On a lateral projection of a normal stifle, the fat pad is represented by a triangle of dark lucency *(arrows)* that reaches the femoral condyle. **B,** On a lateral projection of a swollen stifle, the "fat pad sign" is represented by a smaller triangle *(arrows)* of dark lucency that does not reach the femoral condyle. The increased soft tissue density caudal to the lucency is caused by fluid or by fibrosis of the fat pad.

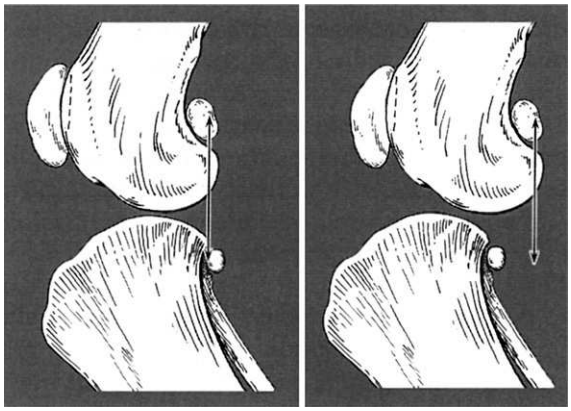


FIGURE 18-11. Tibial position in neutral and cranial drawer positions. **A,** In a neutral position, a straight line made from the fabella, end of the femoral condyle, and tibia/fibula will touch the head of the fibula/tibia. **B,** With significant cranial drawer, this line will not touch the fibula. *Note*: Unless a meniscus is wedging the tibia forward, it is rare to find cranial drawer on radiography of the unstressed stifle.

Modes of Therapy

It is well agreed that once instability resulting from cranial cruciate insufficiency occurs, progressive degenerative changes, such as periarticular osteophytes, articular erosions, and meniscal damage, begin within a few weeks. Controversy exists, however, regarding the best treatment for a ruptured cranial cruciate ligament.

Conservative treatment by splintage has been advocated. Close confinement for 4 to 8 weeks was reported to yield satisfactory function in the majority of small dogs (body weight <20 kg).[27] Vasseur[28] reported similar results. He found that dogs of 15 kg or less had satisfactory function several months after injury, whereas larger breeds uniformly functioned poorly. All animals had evidence of DJD, and one must speculate how well they would function several years later. Despite this evidence to the contrary, if owners want the best treatment for their pet, our clinical experience leads us to recommend surgical treatment of all dogs and cats with this injury.

No surgical technique consistently stops the development or progression of DJD. It is hoped that less DJD develops as a result of the surgical stabilization than if no surgery is performed. Clinically, most authors cite an 85% to 90% clinical "success" rate after surgery, even after dogs have been lame for months.

Most stifle joints should be opened, explored, and "cleaned up" regardless of the stabilization technique. A medial arthrotomy is most helpful for examining and removing the commonly ruptured medial meniscus. It may be accomplished through a lateral arthrotomy if the stabilization technique dictates a lateral approach. The synovium should be inspected; rough or voluminous periarticular osteophytes are removed to prevent physical irritation to the synovium; and menisci are inspected carefully (meniscectomy is discussed later). The stump of the cruciate ligament, as well as the remainder of a 20% or more partial cruciate tear, is debrided to prevent degenerative inflammatory products from irritating the synovial lining. The joint is then closed (unless contraindicated because of the type of stabilization technique used) with nonabsorbable interrupted sutures and the stabilization procedure performed.

Extracapsular methods embrace a wide variety of stabilization techniques for the cruciate-deficient stifle joint. Most of these involve use of heavy-gauge suture to decrease joint instability, although some rely instead on transposition of soft or bony tissues. The indication for these approaches as opposed to the reconstructive intraarticular methods has been debated constantly over the last 40 years. Regardless of the type of repair done, most published reports indicate between 85%

and 90% good to excellent function at follow-up. Intracapsular methods usually involve anatomical (or near-anatomical) replacement of the cruciate ligament with autogenous or autologous grafts or synthetic materials. An in vitro examination of various methods of repair indicated that intraarticular methods of repair result in more normal joint motion than extraarticular methods.[29] This seems to be particularly important in dogs weighing more than 17 to 20 kg and most especially in the acute injury to the athletic animal. Extraarticular methods work well in smaller breeds but often have been considered not to be as satisfactory in the larger, athletic animal with an acute cruciate rupture. In a study of dogs undergoing experimental cranial cruciate ligament repair, there was essentially no functional difference in peak vertical forces measured by force plate analysis (see Chapter 1) between the dogs' preoperative and 20-week postoperative evaluations after an extracapsular technique (modified retinacular imbrication technique).[30] Dogs undergoing an under-and-over intracapsular technique still had significantly decreased vertical peak forces 20 weeks postoperatively. Stability with extracapsular suture techniques is attributed to thickening of the joint capsule and retinaculum because of inflammation from the surgical procedure and implanted sutures. The experience of one of us (DLP), however, suggests that the fibular transposition method discussed later in this chapter is highly satisfactory for large dogs. On the other hand, one of us (GLF) uses the suture technique exclusively, including performance dogs, varying the number of sutures used depending on animal size, amount of drawer movement, and function of the contralateral limb. A high percentage of patients with cruciate injuries, however, are household pets. Experience also indicates that extraarticular techniques are more appropriate than intraarticular techniques when the cruciate injury is chronic. In this situation the inflammatory response and chronic changes within the joint create an adverse environment for transposed autologous tissue. Synthetic replacements for the cranial cruciate ligament have had some success in humans, but none of the available protheses is economically feasible for widespread veterinary use.

A question arises as to the advisability of surgery for a symptomatic animal with chronic instability and severe DJD. Simply providing stability will not cause the DJD to disappear, but the animal usually improves dramatically in function after surgery. In addition, most patients undergo torn menisci and severe osteophytosis; their removal, along with stabilization, usually improves the animal's function. In animals with chronic conditions that have no instability even after a partial cruciate injury is debrided, stabilization procedures are unnecessary. The veterinarian also must address medical management of the joint disease, as discussed in Chapter 6.

The following surgical section reviews extracapsular techniques (imbrication, retinacular, modified retinacular imbrication, three-in-one, fibular head transposition, tibial plateau leveling), intracapsular techniques (Paatsama, over-the-top, under-and-over), and a combination (four-in-one over-the-top technique).

Postoperative care may or may not include a soft bandage for 2 weeks (surgeon's preference), followed by 6 weeks of strict leash walks of only 5 to 10 minutes' duration. After this, the animal's activity is slowly increased over the next 4 to 8 weeks depending on physical demands. Weight reduction (usually indicated) is attempted by lowering caloric intake, and clients are warned that there is a 30% or more chance that the opposite cranial cruciate ligament will rupture in the next 2 years.

Extracapsular Techniques

Imbrication Techniques

A long-standing technique for stabilizing drawer movement involves the placement of Lembert sutures on the medial and lateral aspects of the joint capsule.[31] In our

experience, this repair, by itself, stretches and becomes lax. However, it is the basis for combination techniques that we perform.

Retinacular Technique

The retinacular technique, as first described by DeAngelis and Lau,[32] involves placing one or two large, nonabsorbable sutures around the lateral fabella and anchoring to the distal patellar ligament (see Figure 18-13, *B*). This becomes a restraint to drawer movement.

Modified Retinacular Imbrication Technique

The modified retinacular imbrication technique (MRIT)[33] borrows from the techniques just described. Instead of one or two sutures around the lateral fabella that are anchored to the patellar ligament, mattress sutures are passed around both the lateral fabella and the medial fabella and anchored to a hole in the tibial tuberosity. Another suture is passed from the lateral fabella to the retinaculum along the side of the lateral aspect of the patella and acts as an imbrication suture (Figure 18-12, *A*). Currently, this imbrication suture is used only on small dogs. Dogs over 20 kg instead have a second lateral suture placed at the tibial tubercle region. A landmark for finding the fabella is directly caudal to the distal third of the patella. The suture material we presently use for both the MRIT and the three-in-one procedure is monofilament nylon fishing leader material (20- to 80-pound test available); the material size approximates the weight of the animal (Hard Nylon leader, Mason Tackle Co., Otisville, Mich). Very few reactions have been encountered compared with other suture materials used. Breakage occasionally occurs, usually on the caudal side of the fabellae. This material is carefully rinsed and sterilized with ethylene oxide or a "cold cycle" of steam. Large, braided polyester suture (size 0 for small breeds and 2 to 4 for larger breeds) can be substituted and is recommended if sutures are placed in the patellar ligament rather than the tibial tuberosity (see Figure 18-13, *B*), which may be more suitable for toy and miniature breeds of dogs and cats. Soaking braided imbrication sutures in chlorhexidine solution a few minutes before implantation reduces the number of infections and draining tracts associated with burying large-gauge, braided nonabsorbable sutures, which has been reported as high as 21%.[34]

Surgical Technique. A medial arthrotomy is performed to remove remnants of the cruciate ligament, as well as large rough osteophytes, and to inspect the menisci. Inspection and removal of damaged medial menisci are more difficult through a lateral arthrotomy (see later discussion). The arthrotomy is closed with interrupted nonabsorbable or synthetic absorbable simple interrupted sutures before the stabilization technique. To gain easier access to the fabella, a cutdown is made. The distal biceps femoris insertion on the fascia lata is incised just enough (approximately 5 cm) so that a large needle may be retrieved around the back of the fabella (Figure 18-12, *B*). Another advantage of a cutdown is that the sutures are not lying on top of muscle, which may undergo pressure atrophy, leading to suture looseness. In techniques using advancement of muscle for active countertraction to drawer movement (see three-in-one procedure), the biceps femoris distal insertion is incised more proximally and distally. The fabella is identified by passing a curved mosquito forceps around and under the fabella. The forceps is quickly elevated several times so that the junction of the femur-fabella is delineated. A stout half-curved needle (Martin's uterine needle) is passed from cranial to caudal at the level of the proximal fabella (Figure 18-12, *C*). To achieve needle passage, the needle tip must be inserted perpendicular to the tight fabellar-femoral junction, and once it is inserted

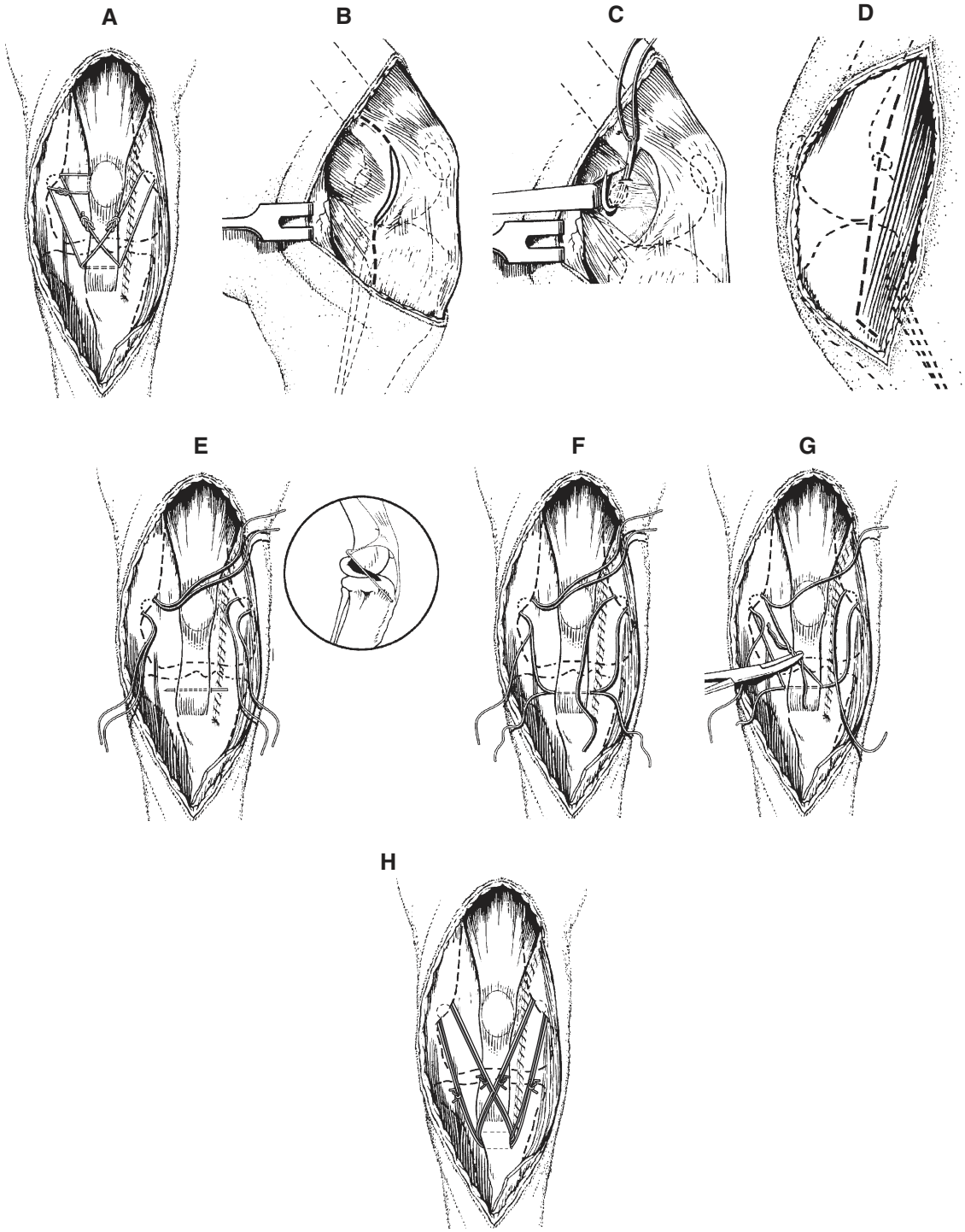


FIGURE 18-12. Modified retinacular imbrication technique (MRIT).[33] A medial approach[7] to the stifle joint has been performed, remnants of the cruciate ligament and torn menisci removed, and the joint closed. Stabilization is accomplished with variations of the placement, size, and numbers of heavy-gauge monofilament nylon sutures (see text). **A,** Final placement of three sutures: one lateral fabellar/tuberosity, one medial fabellar/tuberosity, and one imbrication suture adjacent to the patella (sometimes omitted or rerouted to the tuberosity in large dogs).

FIGURE 18-12. *Continued* **B,** Slightly curved incision at the biceps insertion is made to identify the fabella, allow identification of the peroneal nerve, and allow tightening of the suture without trapping muscle. This would have caused necrosis and relative loosening of the suture. The dotted line indicates extension of the fascial incisions if biceps muscle advancement is desired at closure. **C,** Half the length of suture material is threaded through a heavy half-curved needle and passed around the proximal third of the lateral fabella. It is then cut close to the needle, which then forms two strands. **D,** The medial fabella is exposed by incising along the cranial edge of the caudal belly of the sartorius muscle and partially detached at its insertion if later muscle advancement is desired. The medial suture is placed similar to *C*. **E,** Horizontal hole is made with a 3/32-inch or 5/64-inch pin in the tuberosity, 1 cm caudal and distal to the patellar ligament insertion (see *A*). *Inset,* Relationship of the mattress sutures with the plane of the cranial cruciate ligament when the hole in the tubercle is properly placed. **F,** The caudal strand of the medial suture is passed from medial to lateral. The caudal strand of the lateral suture is passed through the same hole. **G,** With all drawer movement removed by an assistant (see text), the first throw of the lateral suture is tightly tied and grasped with a smooth-tipped forceps (ground-down needle holder works well). If drawer is eliminated, the knot is completed. If not, the forceps is released, and the suture is retightened and tied. The medial suture is similarly tied. An additional support suture is placed adjacent to the patella, being careful not to create a lateral luxating patella (see *A*). ***H,*** Alternatively, four sutures are placed from the fabella to the tubercle in large dogs with moderate or marked (grade 3 or 4) drawer. Closure of the deep fascia, subcuticular layers, and skin layers is routine.

5 to 6 mm, the needle arcs around and hugs the fabella to avoid injury to the fibular nerve, which lies about 2 to 3 cm caudally. Just after the needle emerges, the suture is cut behind the eye of the needle. Now there are two sutures around the fabella with one pass. The medial fabellar area is approached by longitudinally incising the cranial fascial insertion of the caudal belly of the sartorius (Figure 18-12, *D*). With the muscle reflected caudally, the needle and suture are similarly passed around the medial fabella. In dogs over 45 kg with grade 3 or 4 drawer, the suture is doubled so that four sutures are attached to the tibial tubercle region (Figure 18-12, *H*). The hole on the tibial tuberosity is made with a 5/64- or 3/32-inch Steinmann pin 1 cm distal and 1 cm caudal to the proximal and cranial surface of the tibial tubercle in a 40-pound (20-kg) dog (Figure 18-12, *E*). This ensures that the mattress suture is in the same plane as the cruciate ligament. The sutures are threaded through these holes by first bringing the medial suture from a medial-to-lateral direction (Figure 18-12, *F*). It is then taken back toward the medial fabella either under or over the patellar tendon. Likewise, the lateral suture is passed from the lateral to the medial side and then passed under or over the patellar tendon. Placing the sutures under the tendon avoids pressure on it. The knots may be placed near the hole on the tibial tuberosity or near the patellar ligament, depending on how the sutures are brought through the tuberosity (i.e., the top proximal part of the medial suture is brought through from lateral to medial, or the bottom distal part of the suture is brought through from medial to lateral). The surgeon should be consistent so that the knots can be located if removal is necessary.

To make the sutures effective, all slack and drawer movement must be removed from the joint as the sutures are tied tightly. To do this, an assistant finds the stifle angle of most drawer movement, and while keeping this angle, externally rotates the tibia and pushes it in "caudal" drawer. The first throw of the lateral suture is held gently with a smooth forceps (a filed-down needle holder works well) (Figure 18-12, *G*), and drawer motion is checked. If drawer remains, the suture is released, retightened,

and regrasped with the forceps and checked again for drawer, then tied completely. The medial fabellar suture is similarly tied, with the assistant holding the leg in the same overreduced position. Alternatively, some use a slipknot, thereby eliminating the need to grasp and potentially weaken the suture material. In our hands, suture breakage occurs behind the fabella, not at the knot. The fabellar sutures lie on top of the patellar ligament and should not be tied so tightly that the ligament is appreciably indented. The lateral imbrication suture, which passes from the lateral fabella to the retinacular fascia adjacent to the lateral aspect of the patella, is tied last (Figure 18-12, *A*), with care not to overtighten and cause patellar luxation. In larger dogs this suture is instead placed as a second suture at the tibial tubercle. The number, placement, and size of these sutures are modified depending on the degree of drawer movement, size and function of animal, and the existence of concurrent patellar luxation. For example, a 120-pound dog may have two lateral and two medial fabellar sutures placed without the imbrication suture (Figure 18-12, *H*). Dogs with minimal drawer may receive only one lateral fabellar-to-tibial tubercle suture and one imbrication suture.

Three-in-One Technique

The technique shown here is a slight modification of the MRIT procedure previously described. The major differences are (1) the addition of advancement of the caudal sartorius muscle medially and the biceps femoris laterally to add some immediate postoperative support to the repair and (2) the position of the knots on the fabellar sutures. In small breeds (<30 pounds, or 15 kg) the medial fabellar suture is eliminated (see earlier comments in MRIT section relative to suture material considerations).

Surgical Technique. A medial arthrotomy is performed.[7] Fragments of the cruciate ligament are removed, and menisci are inspected and removed only if severely torn or fragmented (see later discussion of meniscus). The medial joint capsule is closed with synthetic absorbable suture material (Figure 18-13, *A*). To expose the medial fabella, an incision is made through the fascia on the cranial edge of the caudal belly of the sartorius muscle and extended distally into the proximal portion of this muscle's insertion on the tibial crest (Figure 18-12, *D*). A monofilament nylon suture is passed around the medial fabella with a half-circle Mayo catgut or Martin's uterine suture needle, as shown in Figure 18-12, *C*.

The skin is next undermined and reflected laterally to expose the lateral side of the joint (Figure 18-13, *B*). The fascia lata is incised on a line from the cranial edge of the biceps femoris muscle toward the patella, where the incision is angled toward the proximal tibia, paralleling the patellar ligament. The fascia lata is reflected caudally to expose the lateral fabella and collateral ligaments without incising the synovial capsule. Two sutures are placed around the lateral fabella, as in Figure 18-12, *E,* if the patellar ligament imbricating suture is to be used (see later); if not, only one suture is placed. A small hole is drilled transversely through the tibial tuberosity near the insertion of the patellar ligament (Figure 18-12, *E*). The more proximal end of the medial suture is brought through the bone tunnel from a medial-to-lateral direction, and the distal part is passed under the patellar ligament to emerge laterally near the hole in the tuberosity, resulting in a figure-of-8 pattern (see Figure 18-13, *A*). A similar but opposite maneuver is performed with one of the two lateral sutures. With the stifle held at a standing angle and all drawer motion removed (i.e., the tibia externally rotated and forced caudally), these sutures are then tied snugly, thus eliminating drawer movement. Having the sutures placed so that the knots are tied as if a horizontal mattress suture helps maintain tension within the knot while placing

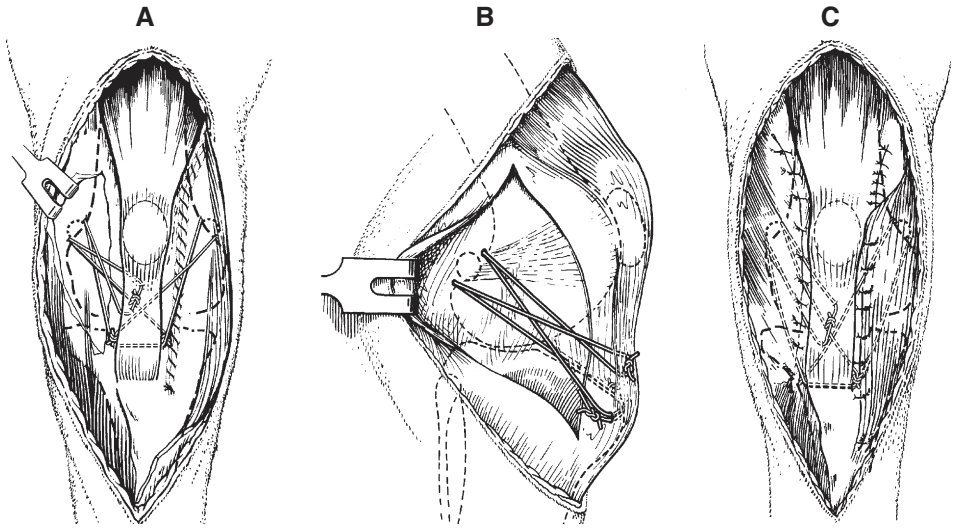


FIGURE 18-13. Three-in-one technique, a modification of MRIT method of Figure 18-12. The changes include advancement of the biceps femoris and caudal sartorius muscles for additional muscle traction to combat drawer motion, method of suture placement, and position of the knots. **A** and **B,** After closure of the medial arthrotomy, part of the distal insertion of the caudal belly of the sartorius muscle is detached from the tibia for later advancement (see also Figure 18-12, *D*). A medial fabellar suture is placed as in Figure 18-12, *C*. Laterally, an incision is made in the fascia lata starting proximal to the fabella and ending distally at the tibia, paralleling the patellar ligament. A transverse hole has been placed in the tibial tuberosity (see Figure 18-12, *E*) and a lateral fabellar suture placed as in Figure 18-12, *C*. The proximal end of the suture is placed from lateral to medial through the drill hole, and the distal end of the suture is brought under the patellar ligament. A similar but opposite maneuver is used on the medial suture. The knots are tied distally, with the lateral suture tied first. The second lateral suture, placed in the distal patellar ligament and tied under tension to produce slight caudal displacement of the ligament, is optional. **C,** The detached portion of the caudal sartorius is sutured to the patellar ligament proximally to the level of the patella. The fascia of insertion of the biceps femoris muscle is overlapped over the patellar ligament distally to place the muscle under increased tension.

the second throw, thus more easily being done by surgeon without an assistant. The lateral suture is tied first. The second lateral suture may be used, if desired, to imbricate the joint further by placing it in the lateral third of the distal end of the patellar ligament (Figure 18-13, *B*). The fascia lata is closed by overlapping it onto the patellar ligament and quadriceps fascia to increase tension on the muscle. The previously detached portion of the caudal belly of the sartorius and medial fascia are sutured to the patellar ligament medially. The proximal portion of the medial fascial incision is closed conventionally. The final closure has the fabellar sutures completely covered, except for the knots, by muscle and fascia (Figure 18-13, *C*). This may help prevent seroma formation and contamination of these large sutures from partial disruption of the skin incision during the first few days postoperatively.

Postoperative Care. The limb may or may not be bandaged postoperatively (surgeon's preference). Very restricted exercise is allowed for the first 8 weeks, with a gradual return to normal activity over the next several weeks. The muscle force across the knee joint is four to five times body weight, and "abuse" of the limb may cause implant failure before the development of strong fibrous tissue.

Clinical experience indicates that if the lameness does not improve over the next 8 to 12 weeks, or if it improves but then worsens, there is either a torn meniscus or a suture break or reaction. It is therefore important for the surgeon to know exactly where the knots were placed in order to expedite suture removal. Such removal of the imbricating sutures after 3 months postoperatively does not increase drawer motion because the fibrosis created by surgery provides long-term stability.

Fibular Head Transposition

An alternative extraarticular technique that has gained increasing acceptance is the fibular head transposition (FHT) of Smith and Torg.[35] By freeing the fibular head and attached lateral collateral ligament (LCL), the fibula can be moved cranially and attached to the tibia. The LCL is placed under tension and functions similarly to the sutures in the MRIT or three-in-one method. Drawer motion and internal tibial rotation are resisted by the transposed ligament. Biomechanical studies have confirmed that the stiffness of the LCL is sufficient to stabilize the stifle joint.[36] Further mechanical studies after transposition of the LCL indicated a gradual increase in structural qualities, reaching approximately 135% of their original values 10 months postoperatively.[37]

Smith and Torg[35] found the method produced good to excellent clinical grades in 90% of patients, and the experience of one of us (DLP) with the FHT over a 7-year period is similar. The clinical results are similar to intraarticular methods, but there is the major advantage of significantly decreased recovery time (see following discussion). The effectiveness of the technique has been questioned in one experimental study, which concluded that this method did not control drawer motion or rotational stability, did not prevent progression of DJD, and was associated with meniscal damage in 25% to 50% of the dogs in the study.[38] Objectively, these are not impressive results, but they are more an indication of the "state of the art" at that time in stabilizing the cruciate-deficient stifle than a condemnation of the technique. If all the then current used methods were subject to such a rigorous evaluation, it seems certain that they would all show similar results. In fact, relative to the incidence of postsurgical meniscal injuries requiring second surgeries in 665 stifles stabilized with three methods (lateral retinacular imbrication, intraarticular over-the top, and FHT), significantly fewer dogs with FHT returned with meniscal injuries (8.6%) than with the other two methods (16.5% and 19%).[39]

Surgical Technique. This surgery for FHT is more demanding than will be appreciated from the following description, and it should be thoroughly practiced on cadavers before attempting it in a patient. Once familiarity is gained, the level of difficulty, operating time required, and incidence of postsurgical complications are similar to the over-the-top procedures. Potential intraoperative problems include fracture of the fibular head or neck, accidental transection or avulsion of the collateral ligament, and injury of the peroneal (fibular) nerve. Wire breakage and pin migration are the most common late complications but are minimal with good technique.

The technique described is slightly modified from the original description.[35] The anatomical relationships of the LCL and the fibular head are illustrated in Figure 18-14, *A*. After a lateral skin incision, a medial parapatellar approach (to allow better exposure if meniscectomy is required) to the joint is made. After inspection of the joint, with removal of the remnants of the cranial cruciate ligament and inspection of the meniscus (see later discussion), the medial capsule and retinaculum are closed, including the caudal belly of the sartorius muscle in the closure, as in Figure 18-13, *C*. The fascia lata is incised next so that the incision continues distally along the lateral edge of the tibial tuberosity for 2 to 3 cm, avoiding the underlying

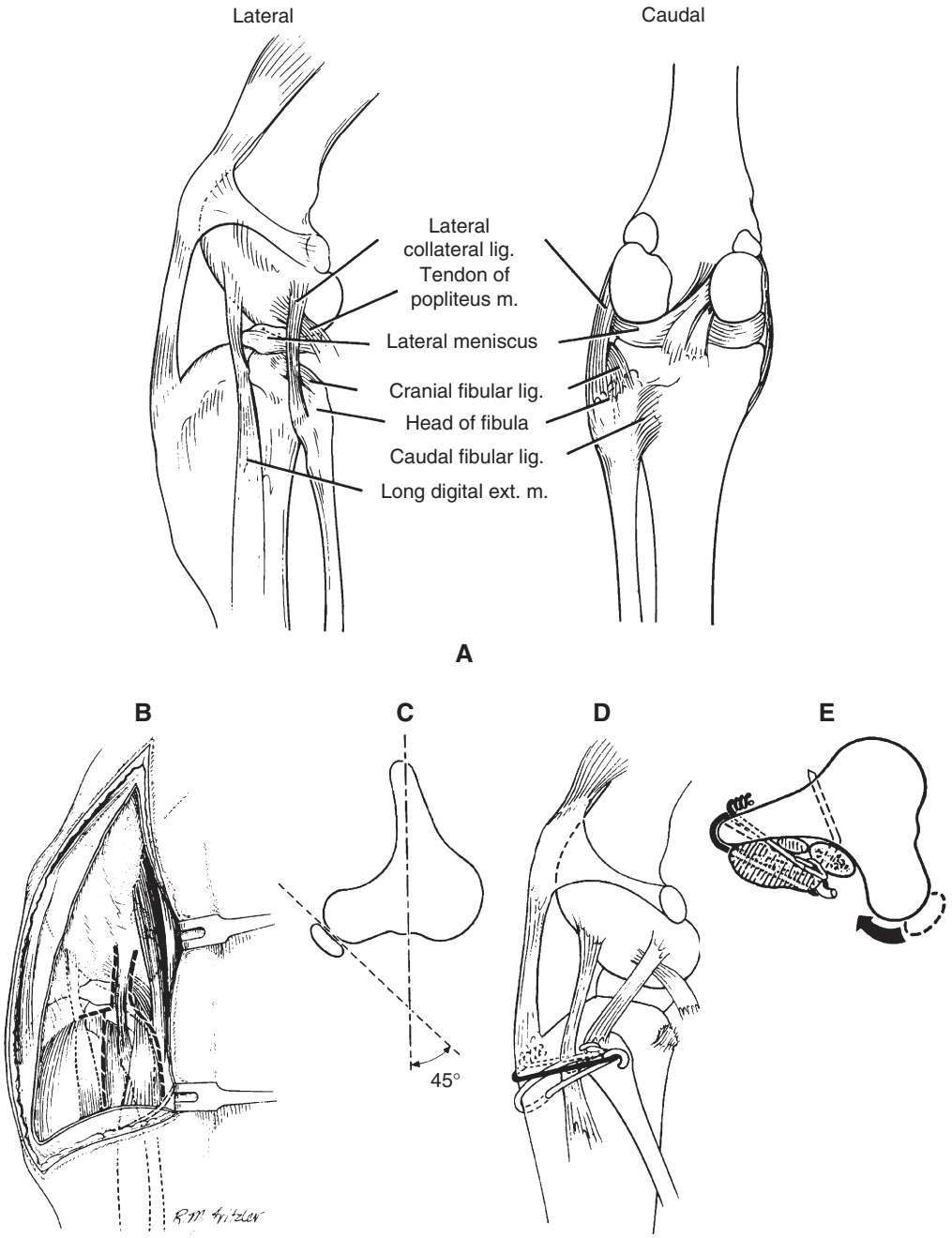


FIGURE 18-14. Fibular transposition technique, modified from method of Smith and Torg.[35] **A,** Lateral collateral ligament and tibial ligaments of the fibular head. The collateral ligament will be dissected free from the joint capsule and the ligaments of the fibula incised to free it from the tibia. **B,** Lateral skin incision and medial parapatellar approach to the joint. The medial capsule and retinaculum have been closed as in the three-in-one technique, but without a suture around the medial fabella (see Figure 18-13, *C*). The fascia lata is incised as in Figure 18-13, *B,* except that the incision continues distally along the lateral edge of the tibial tuberosity for 2 to 3 cm. After sharp elevation from the tibia, caudal retraction of the fascia lata exposes the fibular head, collateral ligament, and the underlying muscles. The peroneal (fibular) nerve must be identified and protected. (See text for further description of the incisions depicted.)

FIGURE 18-14. *Continued* **C,** The dissection plane for incising the tibiofibular ligaments is 45 degrees to the sagittal plane of the tibia. **D** and **E,** A 0.62-inch (1.5-mm) Kirschner wire is driven into the center of the head of the fibula and is then used to move the fibula cranially under the caudal edge of the tibialis cranialis muscle. When the collateral ligament is taut and most drawer motion abolished, the Kirschner wire is driven into the tibia to penetrate the transcortex. A hole is drilled in the tibial tuberosity for a 16- or 18-gauge (1.2- to 1.0-mm) eyelet cerclage wire, which is passed cranially through the tibialis cranialis muscle, around the tuberosity, and back through the muscle (see text for details). As the wire is tightened, the pin will bend and produce more tension on the collateral ligament; when cranial drawer motion is abolished, the wire is cut and the end buried in the muscle. A twisted wire is then placed around the pin through a second bone tunnel and is tightened on the craniomedial aspect of the tibial tuberosity.

fascia of the tibialis cranialis muscle. Caudal retraction of the fascia lata and biceps femoris muscle, after sharp elevation of the fascia from the tibia, exposes the fibular head, LCL, and underlying muscles (Figure 18-14, *B*). The peroneal (fibular) nerve *must* be identified and protected. The nerve is most readily seen if all fat and areolar tissue is elevated from the fascia of the peroneus longus muscle; the nerve and an accompanying vessel enter the muscle caudally 1 to 2 cm distal to the fibular head.

The first incision is into the fibularis longus muscle along the caudal side of the fibula, starting just proximal to the peroneal nerve, and continuing proximally along the caudal border of the collateral ligament. The muscle is elevated from the fibular head. Sharp dissection is used to free the cranial border of the collateral ligament from underlying joint capsule. Undermining and freeing of the ligament from the joint capsule is done from the caudal side of the ligament by blunt dissection using a curved forceps or scissors and a spreading action. The incision made to free the cranial border of the ligament is continued distally into the intermuscular fascia between the peroneus longus and tibialis cranialis muscles, then cranially through the origin of the tibialis cranialis until the tendon of the long digital extensor muscle is exposed. The tibialis cranialis muscle and the tibial origin of the peroneus longus muscle are elevated from the tibia.

The ligaments of the fibular head are incised to free it from the tibia by working from the cranial aspect of the fibular head while retracting the peroneus longus muscle. The dissection plane between the tibia and fibular head is approximately 45 degrees caudal from the sagittal plane of the tibia (Figure 18-14, *C*). Incision of the ligaments can be done with a variety of instruments, such as a scalpel, a sharp periosteal elevator, or osteotome, but the most useful instrument has been a canine meniscus knife (Veterinary Instrumentation, Sheffield, England; Jorgensen Laboratories Inc., Loveland, Colo; see Figure 18-22, *E*). This instrument follows the plane between the bones without cutting bone and greatly reduces the chance of accidental fracture of the fibular head. This dissection is difficult only in more chronic cases because osteophytes may protrude into the interosseous plane.

After the proximal fibula is freely movable, a 0.62-inch (1.5-mm) Kirschner wire (K-wire) is driven into the center of the head of the fibula and is then used to help move the fibula laterally and then cranially under the caudal edge of the tibialis cranialis muscle. A 5/64-inch (2-mm) pin is used in very large breeds (>80 pounds, or 35 kg). Use of larger pins will not allow them to bend easily, which is essential to the technique as described here. The tibia is externally rotated, and the stifle is held at a standing angle, with drawer movement removed during the transposition maneuver.

A Schroeder vulsellum forceps or an AO/ASIF pointed reduction forceps (Synthes, Ltd., Paoli, Pa) is useful to maneuver and hold the fibula in the desired position. One jaw of the forceps is placed caudal to the fibular head, and the other jaw is engaged on the tibial tuberosity. Be certain that the jaw of the forceps does not trap the peroneal nerve or penetrate the insertion of the collateral ligament because this will tear the ligament. The forceps fixes the fibular head and collateral ligament and allows testing of drawer motion before drilling the K-wire into the tibia. Most, but not all, of the motion will be neutralized at this time.

The K-wire is then driven into the tibia to penetrate the transcortex (Figure 18-14, *D* and *E*). The K-wire should not be cut short yet. A 3/32-inch (2.5-mm) hole is drilled in the tibial tuberosity by laying the pin on the surface of the fibula and penetrating the tibialis cranialis muscle. A 16-gauge hypodermic needle is passed caudally through the bone hole and the tibialis cranialis muscle toward the surface of the fibula where the K-wire penetrates it. A 16- to 18-gauge (1.2- to 1.0-mm) eyelet wire is inserted into the needle, which is then withdrawn, leaving the wire in place. The larger wire, 16 gauge or 1.2 mm, is used for dogs over 80 pounds (35 kg). The cranial end of the wire is looped laterally around the tuberosity and then passed back through the tibialis cranialis muscle toward the K-wire.

The free end of the wire is passed through the eyelet, which is positioned to face cranially by bending the wire around the pin. As the wire is tightened, the pin will bend cranially and produce more tension on the collateral ligament, thus the need for a small-diameter bendable pin. When cranial drawer motion is abolished, the wire is bent over and cut, the cut end being buried in the tibialis cranialis muscle. Substituting a twisted wire for the eyelet wire is possible but is slightly more difficult to tighten without breaking the wire because of the large number of turns required to move the fibula. A second wire is placed in a similar manner through a second hole in the tibial tuberosity, except that this wire is secured by twisting on the craniomedial aspect of the tuberosity and bent flat against the bone. Overtightening of this wire should be avoided because it will loosen the first wire. This could also be an eyelet-type wire if desired. We have seen some wire breakage when a single wire is used, thus the addition of the second wire. A hook is now bent in the K-wire, which is then driven flush with the fibula, taking care not to entrap the fibular nerve. The end of the K-wire protruding from the medial side of the tuberosity is cut flush with the bone. For very large dogs, over 100 pounds (45 kg), a second pin is used, placed caudal to the fibular head and driven into the tibia. The second wire is placed around this pin as previously described.

Addition of a large, monofilament nylon lateral fabella–to–tibial tuberosity suture, as described earlier in the MRIT and three-in-one sections, has clinically proved to be a useful addition to this procedure. Based on the work of Dupuis and colleagues,[37] the transposed collateral ligament undergoes elongation after transposition, but this all occurs in the first 3 weeks postoperatively. If the lateral suture can serve as a protector of the ligament during this period, there should be better long-term stability of the joint, and this has been borne out in practice, with very minimal long-term drawer motion observed. After placement of the imbrication suture, the fascia lata is sutured by advancing it as far craniomedially as possible, thereby placing the biceps femoris muscle under tension (see Figure 18-12, *C*).

Aftercare. The limb is not splinted postoperatively. Only very restricted exercise is allowed for 4 weeks, followed by a gradual increase of activity and full resumption of activity at 8 weeks. Most animals will be partially weight bearing within the first week and walking comfortably with only a slight limp at 3 to 4 weeks.

Tibial Plateau Leveling Osteotomy

A technique that has gained popularity over the last several years is the tibial plateau leveling osteotomy (TPLO), as proposed by Slocum.[40] This entails cutting the proximal tibia, rotating the plateau caudally and distally, and plating to stabilize the osteotomy. The theory is that the correct plateau angle will counteract cranial tibial thrust during weight bearing (see Chapter 1 and following discussion). It does not stop direct drawer movement. This technique had been patented (Slocum Enterprises, Eugene, Ore), but the patent has expired, allowing more widespread teaching and use of TPLO. Specialized saw blades and jigs are available from Slocum Enterprises. A variety of alternative bone plates and saws for this procedure are now available from several manufacturers.

Although those who perform this surgery are enthusiastic about it, long-term objective data on efficacy are minimal. A consistent subjective impression by many surgeons is that limb function recovers more quickly than with other cruciate ligament procedures.[41,42] In a prospective clinical trial comparing TPLO with imbrication techniques, subjective evaluation of parameters such as time to recovery, range of motion (ROM), owner satisfaction and willingness to recommend the procedure, ability to sit normally, and postoperative complications were judged to be better for TPLO than for imbrication techniques.[43] Another study compared intracapsular, TPLO, lateral retinacular imbrication, and FHT techniques using force plate evaluations and found no clear superiority of any method, although the author admitted accurate conclusions could not be made because of the variability between 206 dogs and the statistical power of the study.[44]

However, another study comparing a postoperative progression of osteoarthritis in 40 dogs showed 16 dogs to have a statistically significant progression of mean osteophyte score 6 months postoperatively, whereas 57.5% showed no progression of osteophytosis.[45] Another study showed zero to minimal changes in the radiographic score of 30 stifle joints at least 1 year after TPLO.[46] Lazar's group evaluated the long-term results of cranial cruciate ligament injury in large dogs treated by either TPLO or extracapsular repair (ECR).[47] With a minimal 12-month follow-up, there was a statistically significant increase in progression of osteoarthritis within the ECR group compared with the TPLO group. When standardized for time, the mean percent change in osteoarthritis score for each month after surgery was an increase of 9.8% per month for ECR and 3.0% per month for TPLO, a significantly slower rate of progression for TPLO. Thus, although TPLO does not totally prevent the progression of osteoarthritis, such progression is noted in all techniques.

Long-term objective studies regarding function and pathological changes after TPLO have not been well documented. Questions regarding long-term clinical impact on caudal cruciate ligament stress, ROM, and further documentation of progression of osteoarthritis are of importance.[48]

Cranial Tibial Thrust. During weight bearing in the normal dog, forces across the knee joint consist of body weight and muscle forces (quadriceps, hamstrings). As force is transmitted proximally, the femur and tibia are compressed together, causing a cranial thrust of the proximal tibia resulting from the caudodistal slope of the tibial plateau (see Figure 18-15, *A*). This places passive restraints (e.g. cranial cruciate ligament) under great tension. If hamstrings are weak or forces too great (leaping, twisting, turning), the degenerate ligament tears, allowing cranial drawer and a positive cranial tibial thrust sign *(tibial compression test)*. In theory, if the caudodistal slope of the tibia is reoriented to a more neutral position (research has shown the proper angle to be 6.5 degrees, with a clinical recommendation of 5 degrees) (Figure 18-15, *B*), a caudal tibial thrust is produced.

However, excessive correction of the slope places the caudal cruciate ligament at risk.[49]

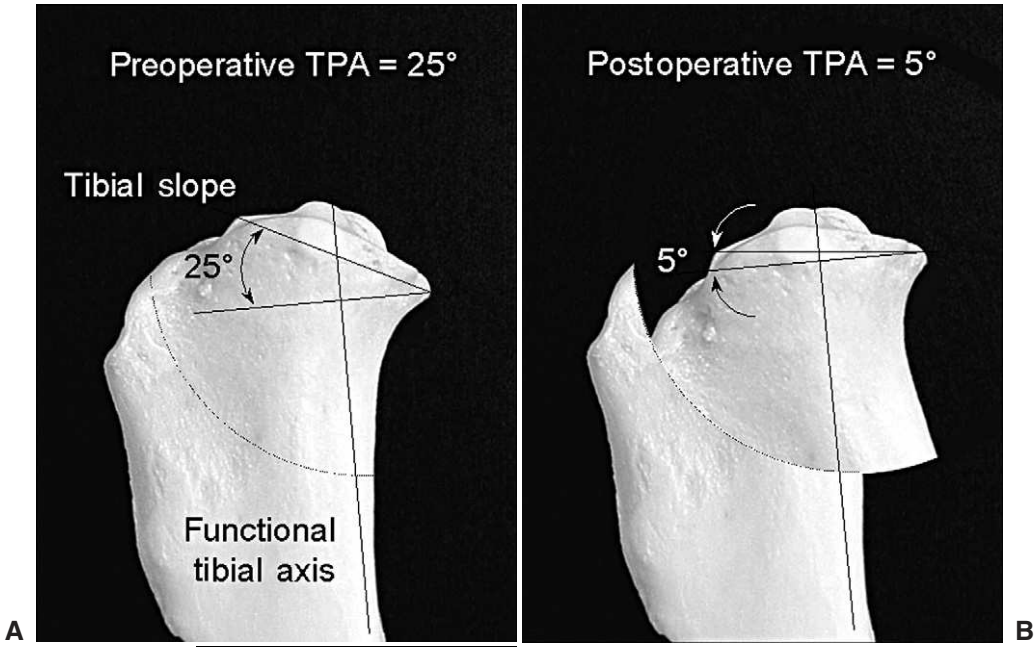
Surgical Technique.[40] Each patient's tibial plateau angle and the rotation needed to achieve an end point of 5 to 6.5 degrees are calculated using preoperative radiographs (Figure 18-15, *A* and *B*). A craniomedial parapatellar skin incision is made, followed by medial parapatellar arthrotomy. The frayed tags of the ligament are removed as well as torn menisci. If the meniscus is intact, a meniscal release is performed to prevent subsequent meniscal injury (see following discussion). This is followed by an approach to the proximal tibia through a medial incision.[7] Muscle insertions of the proximal medial tibia are incised (gracilis, semitendinosus, caudal belly of sartorius), leaving the medial collateral ligament intact. A jig (Slocum Enterprises) is applied to the medial tibia and guides a curved osteotomy, which will allow reorientation of the plateau to the desired angle. The curved osteotomy is performed using a biradial saw blade (Slocum Enterprises), and the proximal tibia is rotated to the proper 5-degree angle (Figure 18-15, *B*) and stabilized with a TPLO bone plate (Figure 18-15, *C*). This should eliminate cranial tibial thrust, as evidenced by elimination of the indirect drawer.

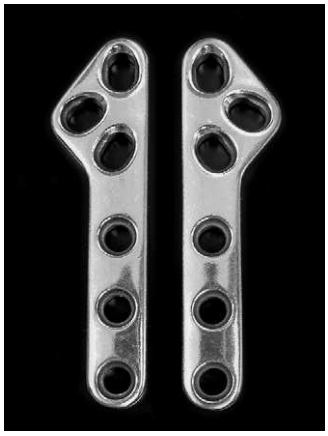
Aftercare.[50] Activity level is restricted to leash walking for 3 months or more, with gradual increase in the frequency and duration of walks. ROM exercises (25-50 repetitions of flexion-extension) are performed two or three times per day by the owner. Analgesics are given as needed. Massage, cold therapy, and other modalities (e.g., ultrasound, neuromuscular stimulation) have been advocated.

Reevaluation and radiographs are performed 6 to 8 weeks postoperatively, at which time clinical union of the osteotomy is usually achieved. Swimming may then be permitted, but without vigorous entry and exit.[40] Return to limb function occurs in 6 to 8 weeks, with full function expected by 4 to 6 months.

Complications. Complications after TPLO include infection, inflammation of the patellar tendon, fracture of the tibial tubercle, breaking of the plate or loosening of the screws, delayed healing of the osteotomy, rupture of the caudal cruciate ligament, meniscal injury, improper placement of the proximal screw into the stifle joint,[41] and inadequate tibial plateau correction. Also, with a "pivot shift," there is increased internal rotation of the tibia during weight bearing, probably caused by the relative relaxation of the lateral collateral ligament, which results from the increased femoral-tibial flexion angle.[48] Internal rotation of the distal tibia and femoral varus predispose to this problem. Although TPLO was associated in one study with more complications than other cranial cruciate ligament stabilization methods, the incidence of major complications was similar.[51] As in all technically demanding procedures, complications decrease with experience. The learning curve is steeper for TPLO than for other techniques, and the procedure is probably best limited to experienced orthopedic surgeons. Publications aimed at honing surgeon skills are needed.

Meniscal Release. During drawer movement, the medial meniscus moves forward with the tibia (see later section on meniscal injuries), and the caudal horn is subjected to crushing by the femoral condyle. After TPLO, passive drawer remains and active drawer is possible under some loading scenarios, potentially subjecting the meniscus to shear and crushing forces. Slocum and Slocum-Devine[52] proposed a release of the medial meniscus that relatively elongates the meniscus, keeping the caudal pole caudal to the condylar crush during drawer movement. Some orthopedists are





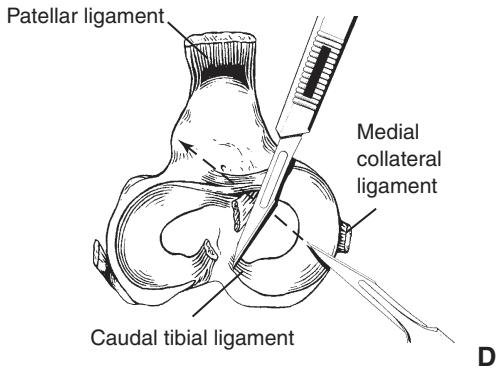


FIGURE 18-15. Tibial plateau leveling osteotomy (TPLO). **A,** Line is drawn on a true lateral radiograph of the stifle and talocrural joint from the intercondylar tubercles of the proximal tibia to the center of the talocrural joint (functional tibial axis). Another line is drawn along the tibial plateau slope from the cranial-to-caudal limits of the medial tibial condyle. The angle created between these two lines is called the "tibial plateau angle" *(TPA)* and in this illustration is 25 degrees. **B,** After a curvilinear osteotomy has been performed, the proximal tibia is rotated distally and caudally to achieve a desired TPA of 5 degrees. **C,** Specially designed plates (Slocum Enterprises) for right and left limbs are used to stabilize the fracture. **D,** Meniscal release. Through a craniomedial arthrotomy, the caudal tibial ligament of the medial meniscus is incised with a #11 scalpel blade. Alternatively, the meniscus is released by a midbody transection. After a limited caudomedial approach, a #11 scalpel is used to incise the meniscus at an angle 30 degrees to the frontal plane. The blade is aimed toward a point slightly caudal to the lateral edge of the patellar ligament insertion. (Photos courtesy Dr. Loic DeJardin, Michigan State University, College of Veterinary Medicine).

performing meniscal release in conjunction with other stabilization techniques as well. No original research was performed on this recommended technique as to what fills the "void," how long it takes, and whether it will last. Research studies using dog models and clinical studies are needed to prove the efficacy of this technique, which is controversial at this time.

Techniques for release. As proposed by Slocum, if drawer movement is considerable, as in a fresh, complete cruciate rupture, the caudal horn can be accessed by levering the tibia and meniscus forward by placing a Hohmann retractor between the front of the caudal cruciate ligament and the back of the caudal tibial plateau. A #11 scalpel blade is used to incise the tibial ligament of the caudal medial meniscus (Figure 18-15, *D*). With minimal drawer from a partial cruciate ligament rupture, Slocum recommends performing a caudomedial arthrotomy[7] just caudal to the medial collateral ligament and cutting the meniscus 30 degrees cranial to a frontal plane, aiming at a point just lateral to the insertion of the patellar ligament on the tibial tuberosity (Figure 18-15, *D*). If the cut is complete, the caudal horn can be retracted caudally with a small, sharp skin hook. With an adequate arthrotomy (1.0-1.5 cm proximal to the tibial plateau) and some experience, the condition of the meniscus can be evaluated and damaged areas excised with a small, curved meniscus knife. Most early partial cruciate ligament tears do not have meniscal injuries. Evidence indicates that the caudomedial approach to evaluate the meniscus may have some advantage over the conventional craniomedial approach, even though the cranial cruciate ligament cannot be debrided.[53]

There was significantly less postoperative progression of osteoarthritis in dogs that had the caudomedial arthrotomy than in those that had a craniomedial arthrotomy with excision of the remnants of the cranial cruciate ligament.[53]

Intracapsular Techniques

Paatsama Technique

One of the first intracapsular techniques was developed by Saki Paatsama[21] in the 1950s, and practitioners still perform this popular cruciate surgery. The technique involves harvesting a 1- to 2-cm-wide strip of fascia lata from the thigh and leaving it attached distally. Holes are drilled in the femur and tibia at the anatomical origin and insertion of the ruptured anterior cruciate ligament. Care must be taken to avoid injury to the caudal cruciate ligament. The end of the fascia lata strip is threaded through each of these two holes using looped wire. The graft is then pulled tightly and anchored with sutures along the patellar ligament.

Over-the-Top Technique

The over-the-top procedure, developed by Arnoczky and co-workers,[54] involves harvesting a cruciate replacement composed of the medial third of the patellar ligament, part of the patella, and the quadriceps tendon. It should be considered only in acute injuries of athletic dogs over 25 to 30 kg. Harvesting this graft is technically demanding because significant injury to the patella can occur. The graft is brought through the joint and then over the top of the lateral condyle and sutured. This avoids improper hole placement and possible fraying of the graft from bony edges, as can occur with the Paatsama technique.

Following a medial arthrotomy, the medial third of the patellar ligament is split away from the rest of the ligament but is left attached to the tibia and patella. Incisions in the patellar tendon and fascia lata continue proximally (Figure 18-16, *A*). A portion of the medial edge of the patella is split away from the patella with a small osteotome. Care should be taken not to penetrate the articular cartilage of the patella. The attachments of the patellar tendon proximally and patellar ligament

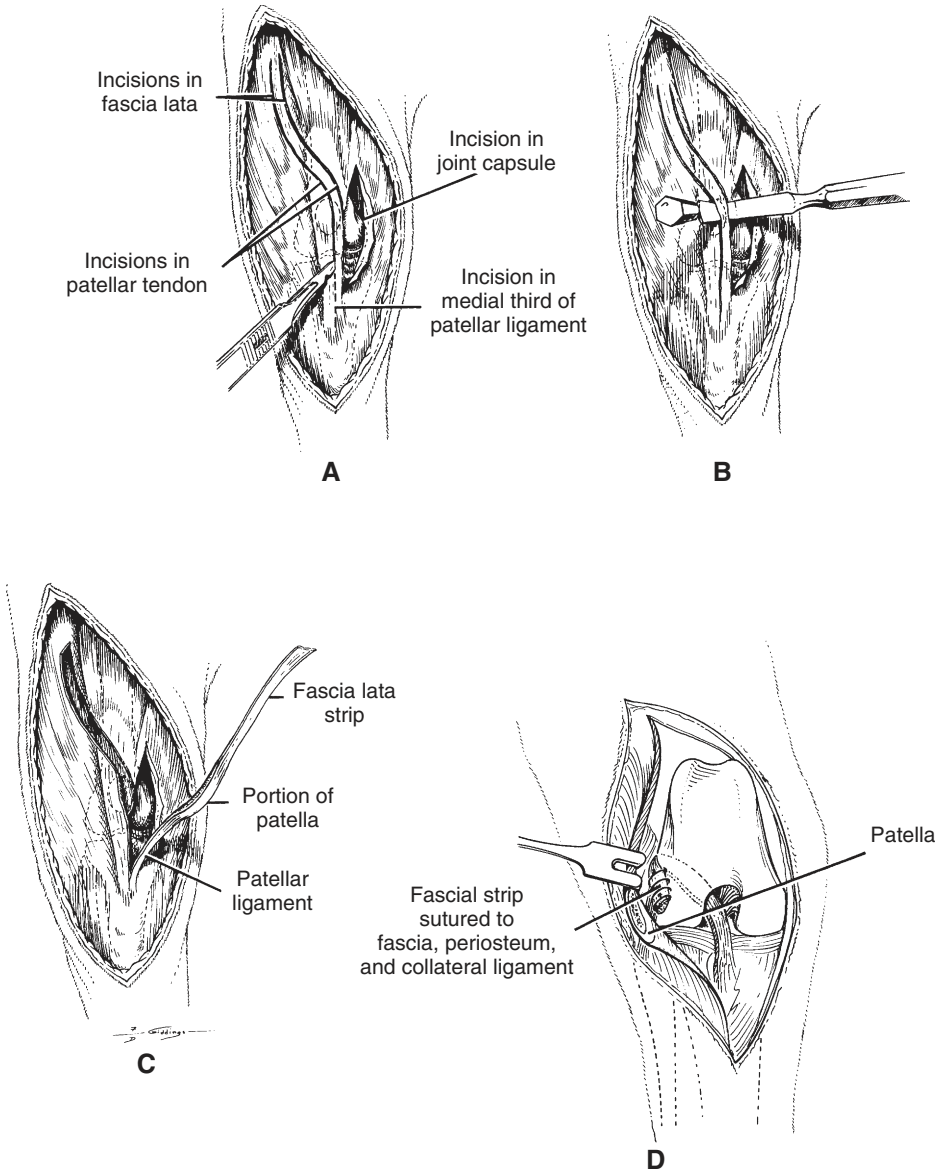


FIGURE 18-16. Intraarticular cranial cruciate stabilization: over-the-top technique.[54] **A,** Medial approach[7] with a lateral skin incision has been made to the right stifle. The medial arthrotomy is made on the medial edge of the patellar ligament and patella and continues proximally into the cranial sartorius and vastus medialis muscles. The medial third of the patellar ligaments is split away from the remainder of the ligament. Incisions in the patellar tendon and fascia lata define the fascial strip proximal to the patella. **B,** Part of the patella is removed with an osteotome, and care is taken not to cut into the articular surface. The patellar ligament attachment distally and the patellar tendon proximally must be preserved. **C,** The patellar ligament–patella–fascia lata strip is freed. **D,** The medial incision is continued as far proximally as necessary to allow lateral luxation and retraction of the patella and exposure of the lateral condyle. The fascial strip is pulled through the joint as in Figure 18-17, *D* and *E*, except that the forceps are passed from inside the joint capsule. After fixation of the fascial strip to the periosteum, fascia, and the lateral collateral ligament (see Figure 18-17, *H* and *I*), the joint is closed as in Figure 18-17, *F*.

distally must be preserved (Figure 18-16, *B*). When the bone fragment is free, dissection is continued proximally into the fascia lata, where the strip is prepared (Figure 18-16, *C*), as described later for the four-in-one over-the-top technique. The fascia-bone-ligament strip needs to be only two times as long as the tibial tubercle–patella distance. The medial capsule incision is continued as far proximally as necessary to allow lateral luxation and retraction of the patella and exposure of the lateral condyle. The fascial strip is pulled through the joint similar to Figure 18-17, *D* and *E,* except that the forceps is passed from inside the joint capsule. After fixation of the fascial strip to periosteum, fascia, and the lateral collateral ligament (Figure 18-17, *H* and *I*), the joint is closed (Figure 18-17, *F*).

Aftercare. No postoperative splinting is used with the over-the-top technique, but very restricted exercise (confinement to house, leash walking) is ordered for 12 weeks, followed by gradual return to activity and freedom for moderate exercise after 18 weeks. Intensive training of working dogs should not start until 6 months postoperatively.

Under-and-Over Technique

The under-and-over technique uses a fascia lata strip harvested as in the Paatsama technique. However, the strip goes all the way to the tibia. A tunnel is made under the intermeniscal ligament, and the graft is passed under the intermeniscal ligament into the interior of the joint. It is then pulled through the joint and over the top of the lateral condyle–fabellar region. After it is pulled tight enough to eliminate drawer, the graft is attached to the lateral femoral condyle with a spiked washer and screw.[55]

Intracapsular and Extracapsular Technique

Four-in-One Over-the-Top Technique

This technique involves using the three-in-one procedure plus a fascia strip used in over-the-top fashion. Four separate procedures have served to stabilize the joint: advancement of the caudal sartorius and biceps muscles creates caudal traction on the tibia; fabellar–distal patellar ligament sutures prevent drawer motion immediately and serve as an internal splint for the fascial strip; and the fascial strip replaces the cruciate ligament.

This technique[56] is indicated for animals weighing over 15 kg and can be used for smaller breeds if they are athletic, such as hunting beagles. The procedure is a modification of the over-the-top technique of Arnoczky and associates.[54] Although the original technique (see Figure 18-16) results in excellent stabilization, some surgeons have experienced technical difficulties in collecting the patellar ligament–fascia strip used for cruciate ligament replacement. An attempt has been made to simplify the procedure by using a fascia strip collected entirely from the fascia lata. Additionally, lateral stabilizing sutures (as in the three-in-one technique) provide immediate stability and protection for the fascial strip. The following procedure is described as done in dogs weighing more than 20 kg. The next-smaller suture sizes can be used in dogs between 15 and 20 kg.

Surgical Technique. A medial arthrotomy following a lateral skin incision is made to allow inspection of the joint, removal of ligament fragments, and meniscectomy (see Figure 18-22) when needed. A strip of fascia 1.5 to 2 cm wide at the base is isolated from the lateral aspect of the joint and remains attached at the junction of the patellar ligament with the tibial tubercle distally (Figure 18-17, *A*). The strip is fashioned by cutting its cranial edge from the lateral border of the patellar ligament

and is continued proximally a few millimeters lateral to the patella. This incision, which is made with a scalpel, is ended just proximal to the patella, and the caudal edge of the strip is formed by incising 1.5 to 2 cm caudal and parallel to the first incision. Care is taken to avoid incising the underlying synovial membrane. Proximal to the patella, the fascia lata is easily elevated from the quadriceps, and

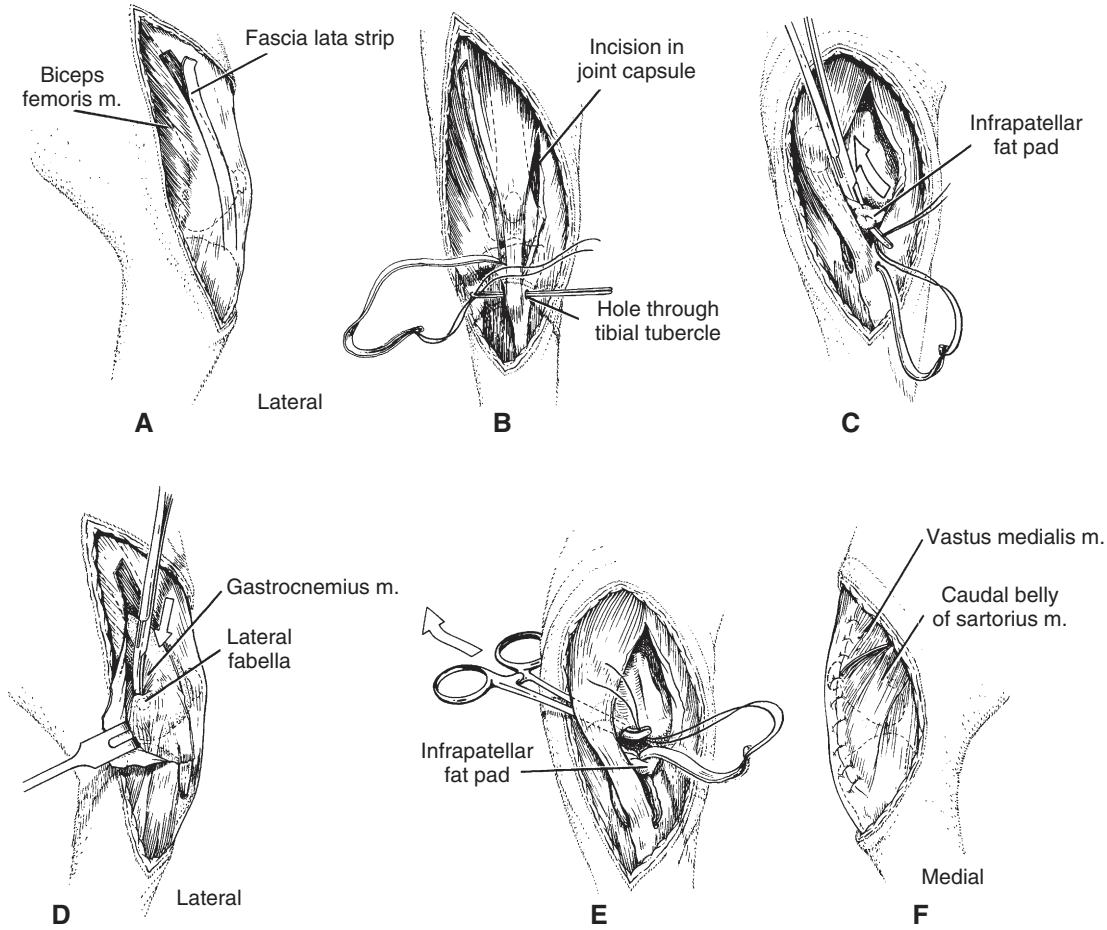


FIGURE 18-17. Intracapsular and extracapsular cranial cruciate ligament stabilization: four-in-one over-the-top technique.[56] **A,** Lateral view of right stifle. A medial arthrotomy has already been performed, the ligament remnants removed, and the joint explored. A fascia lata strip is developed, based on the tibial-patellar ligament junction. The strip is 1 to 1.5 cm wide at the base and slightly wider proximally. Its total length is 2.5 to 3 times the distance from the tibial tubercle to midpatella. **B,** A 5/32- to 3/16-inch hole has been drilled transversely through the tibial tubercle, close to the tibial plateau. A heavy monofilament suture has been attached to the fascial strip, which is then reflected distally and pulled through the hole from lateral to medial. **C,** The fascial strip is pulled into the joint by tunneling it through the fat pad. **D,** The lateral edge of the fascia lata incision is dissected and retracted to expose the lateral fabella. The portion of the gastrocnemius muscle originating proximal to the fabella is elevated, and a curved forceps is passed medial to the fabella, through the caudal joint capsule, and into the intercondylar notch of the femur. **E,** The curved forceps must emerge in the intercondylar space lateral to the caudal cruciate ligament. One end of the monofilament suture attached to the fascial strip is grasped so that the strip can be pulled proximally through the joint. **F,** The medial arthrotomy is closed in one layer. The caudal sartorius muscle is partially detached from the tibia, then sutured with the joint capsule and medial fascia to the patellar ligament, creating increased tension in the muscle (see also Figure 18-13, *C*).

dissection is continued with scissors. The caudal cut is continued proximally first and follows the cranial border of the biceps femoris muscle. The cranial border from the proximal patella is cut next, taking care to maintain or slightly increase the strip's width at the proximal end. The length of this strip is equal to 2.5 to 3 times the distance from the tibial tubercle to the midpatella.

A 5/32- to 3/16-inch (4- to 4.8-mm) hole is drilled transversely through the tibial tubercle close to the tibial plateau, and the proximal end of the fascial strip is drawn through the hole, thus transferring the strip to the medial side of the

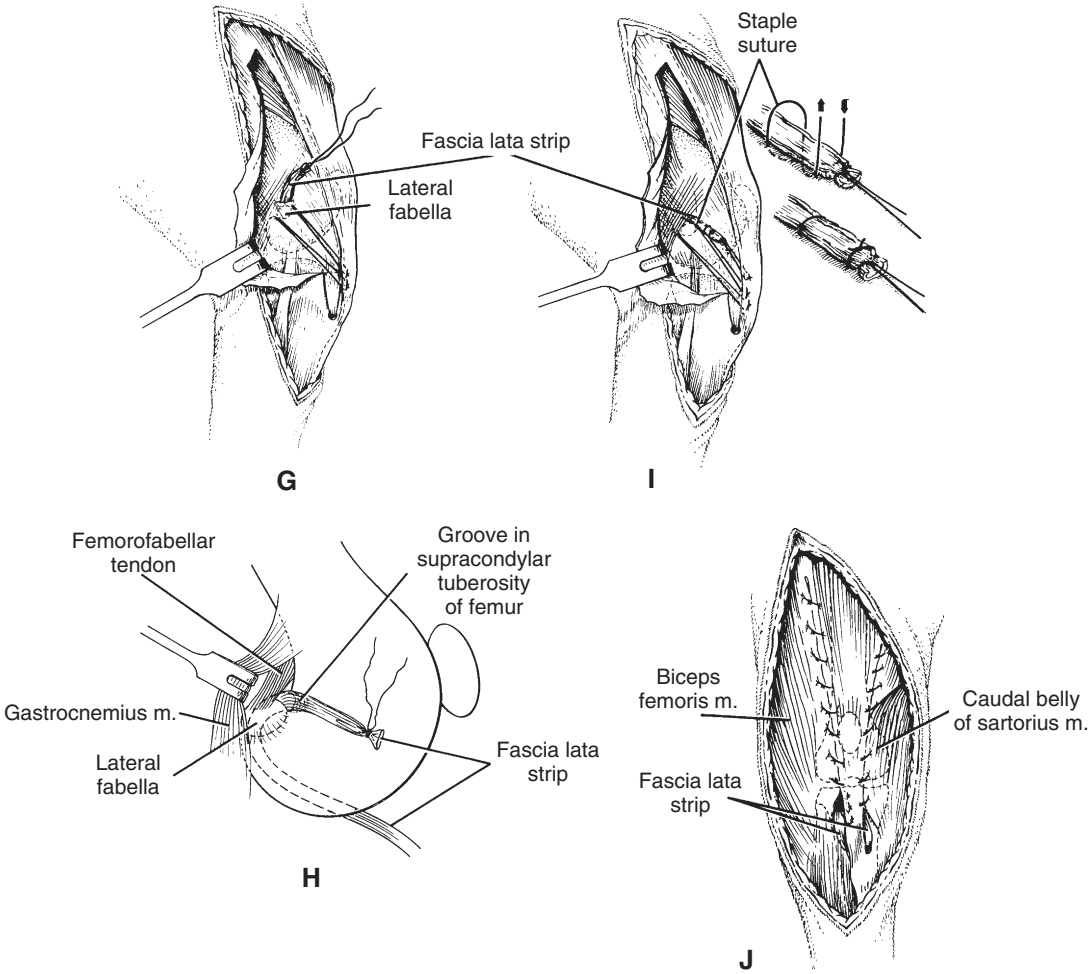


FIGURE 18-17. *Continued* **G,** Two sutures of size 2-4 nonabsorbable material are placed from the lateral fabella to the distal patellar ligament or tibial tuberosity and tied under tension with drawer motion reduced (see Figure 18-13). **H,** The femorofabellar ligament is elevated from the supracondylar tuberosity of the femur to allow a groove to be produced in the cortical bone of the tuberosity by rongeur, rasp, or osteotome. A wire loop can then be used to "fish" the suture attached to the fascia strip through this opening. **I,** The fascial strip is pulled tight and attached to joint capsule or patellar ligament with the suture attached to its end. The strip is then sutured to the femorofabellar tendon, fascia, and joint capsule with 3-4 cruciate "staple" sutures (see *inset*). **J,** This cranial view shows the bilateral closure that places caudal traction on the tibia as a result of increased tension from the biceps femoris and caudal sartorius muscles. Because of the removal of the fascial strip, the lateral closure places the biceps femoris muscle under tension.

tibia (Figure 18-17, *B*). Size 0 to 1 monofilament suture is attached to the fascia strip to aid in pulling it through the bone. The graft is pulled into the medial arthrotomy through the fat pad into the joint, medial to the patellar ligament (Figure 18-17, *C*).

On the lateral side of the joint, the lateral edge of the fascia lata incision is dissected and retracted to expose the lateral fabella. The portion of the gastrocnemius muscle originating proximal to the fabella is elevated from the femur, and a 7-inch curved Crile or Kelly hemostatic forceps is passed through this opening medial to the fabella with the curve facing cranially, through the caudal joint capsule, and into the intercondylar notch of the femur (Figure 18-17, *D*). The tips of the forceps are positioned lateral to the caudal cruciate ligament, where one end of the suture attached to the fascial strip is grasped with the jaws of the forceps (Figure 18-17, *E*). The forceps is pulled proximally, and the suture is used to pull the graft over the top of the lateral fabella.

The medial arthrotomy is then closed in one layer. The insertion of the caudal belly of the sartorius is partially detached from the tibia and sutured to the patellar ligament along with the joint capsule and medial fascia as far proximally as the patella. From that point proximal, the sartorius is not included in the remainder of the medial closure (Figure 18-17, *F*).

Two sutures of size 2 to 4 braided polyester or monofilament suture material are placed from the lateral fabella to the distal portion of the patellar ligament and tied tightly to eliminate drawer movement and to act as internal splints (Figure 18-17, *G*). The femorofabellar ligament is elevated from the supracondylar tuberosity of the femur to allow a groove to be produced in the cortical bone of the tuberosity by rongeur, rasp, or osteotome (Figure 18-17, *H*). A wire loop can then be used to "fish" the suture attached to the fascia strip through this opening. The fascial strip is pulled taut and then sutured to the femorofabellar fascia and joint capsule with a "staple" suture (Figure 18-17, *I*). The lateral fascial incision is closed. Because of the strip of fascia removed, this closure results in tightening of the lateral retinaculum (Figure 18-17, *J*).

Evaluation of Over-the-Top Procedures

These techniques generally provide a more anatomically placed pseudoligament than does Paatsama's original method involving the fascia lata.[17] Although in theory Paatsama's technique should result in anatomical placement of the fascial strip, in fact it has proved difficult for most surgeons to drill accurately from the lateral surface of the condyle to the point of the ligament's femoral origin. Additionally, the fascia usually made a sharp bend as it emerged from the bone tunnel and then turned distally, thus subjecting it to shearing forces. Arnoczky and colleagues[54] demonstrated that the fascial strip placed "over the top" almost perfectly mimics the normal ligament, remaining taut during the complete range of motion of the stifle. Because the pseudoligament is subjected only to tension and not shearing stress, it is not as likely to break. The fascial strip becomes vascularized, then undergoes fibroplasia and reorganization of collagen to resemble a normal ligament. This process appears to take 5 to 6 months; however, the animal is at risk until the tissue transfer regains strength, which is the reason for using the lateral support sutures in the four-in-one procedure. Occasionally an animal will stretch the "ligament" between 3 and 6 months postoperatively and will redevelop drawer motion. Such cases have undergone reoperation using extraarticular stabilization because the remaining fascia was unfit for use again. Previously these cases underwent repeat surgery by replacing the lateral sutures and adding a medial suture, as in the three-in-one technique. More recently, reoperation has been done with the fibular transposition method.

PARTIAL RUPTURE OF CRANIAL CRUCIATE LIGAMENT

A surprising number of cases of stifle lameness are caused by partial rupture of the cranial cruciate ligament. The veterinarian needs only to explore joints in the face of minimal physical findings to verify this. An increasing number of dogs (especially Labrador retrievers and Rottweilers) sustain partial tears at a young age (6-24 months). Often, it is bilateral and mimics hip dysplasia clinically, which may also be a concurrent problem. It is our experience that cruciate problems cause more clinical signs than hip dysplasia and should be addressed first before it is deemed necessary to perform any surgical procedure on the hips.

Clinical signs and history mimic those of complete rupture but are not as dramatic, and secondary arthrosis is much slower in developing, probably because the meniscus is not damaged as often as in complete ligament rupture. Degenerative changes can be extensive given enough time.

The cranial cruciate ligament functionally is composed of two parts: the small *craniomedial band* (CrMB) and the larger *caudolateral band* (CLB). The CrMB is taut in both flexion and extension, whereas the CLB is taut only in extension. The ability to diagnose these injuries by examination for drawer motion depends on which part of the ligament is damaged. If the injury is caused by hyperextension, it is most likely to damage the CLB, and no drawer motion will be present because the CrMB is intact. An injury caused by rotation or twisting with flexion is more likely to injure the CrMB. Under these circumstances, there is a small amount of drawer motion in flexion (the CLB is relaxed) but no motion in extension (the CLB is taut). Partial rupture of the CrMB in a single case was first reported by Tarvin and Arnoczky,[57] and another series was described later by Scavelli and associates.[58] In this later series, partial ruptures accounted for 8% of 320 cases of isolated cranial cruciate rupture. Drawer motion was detected in 52% of the cases and was found in flexion in only 69% of cases when detected. At surgery, 80% of the injuries were to the CrMB, 4% to the CLB, and 16% were interstitial tears (grade 2 sprain), in which the ligament was grossly intact but had undergone damage sufficient to render it functionally incompetent. Medial meniscus damage requiring surgical treatment was present in only 20% of these cases.

As can be seen from these figures, the incidence of partial tears of the cranial cruciate ligament is not insignificant and should be carefully considered as a cause of lameness in midsize to large breeds with pain in the stifle region and minimal or no drawer motion. Radiographs demonstrating the "fat pad sign" (see Figure 18-10) or osteophytes are truly significant. When repairing these injuries, the surgeon should approach them as if they were complete ruptures, since the ligament is no longer functional.[26]

Recently, we have seen dogs with chronic lameness, fat pad sign on radiographs, some presence of osteophytosis, and minimal or zero drawer movement. At surgical exploration the cruciate ligament may have a dull appearance, with or without the synovial covering that keeps the two bands of the cruciate together. Cutting the intact ligament reveals either cavitation within or separation of the craniomedial or caudolateral bands of the ligament or extreme friability of the ligament. This action is not taken without much trepidation. Subsequent stabilization of the drawer movement with a modified lateral imbrication technique resolved the chronic lameness in all cases. Therefore, if there is osteoarthrosis (and no indication of inflammatory joint disease) of the stifle without overt causes, such as osteochondritis dissecans, luxating patella, the rare instance of isolated meniscal damage, or synovial cell sarcoma, then the cruciate ligament is suspect. Careful probing to detect tears

of the caudal side of the ligament and observing the color and reflectivity of the ligament are warranted. Arthroscopic evaluation, magnetic resonance imaging (MRI), or ultrasound may have identified these unusual cases preoperatively.

AVULSION OF CRANIAL CRUCIATE LIGAMENT

As with most avulsions, cranial cruciate avulsion is a condition of skeletally immature dogs. Ligamentous attachments to bone by Sharpey's fibers are stronger than the bone in some cases; thus an avulsion rather than a tear of the ligament results (Figure 18-18). Usually seen as an avulsion of the insertion, this lesion is rare in the dog.

Physical examination findings are similar to those described for rupture of the cranial cruciate ligament, except that drawer motion is obvious and joint effusion is marked. Radiographs demonstrate the avulsed bone fragment in the intercondylar space.

Surgical Technique

The joint is exposed by a medial approach.[7] Hematoma and granulation tissue are removed from the bone fragment so that it can be identified (Figure 18-18, *A*). Two small holes are drilled from the medial and lateral sides of the tibial defect toward the medial tibial cortex (Figure 18-18, *B*). Stainless steel wire (size 20-22 gauge; 0.8-0.6 mm) is placed through the ligament close to the bone. Each end is then passed through the bone tunnels and twisted tightly on the medial tibial cortex. Alternatively, three diverging K-wires can be used (Figure 18-18, *C*). In rare instances the bone fragment is large enough to allow lag screw fixation (see Figure 18-20, *B*). If the fragment is comminuted, or if stretching of the ligament has also occurred, it may be advisable to pursue standard stabilization techniques, especially after 5 to 6 months of age.

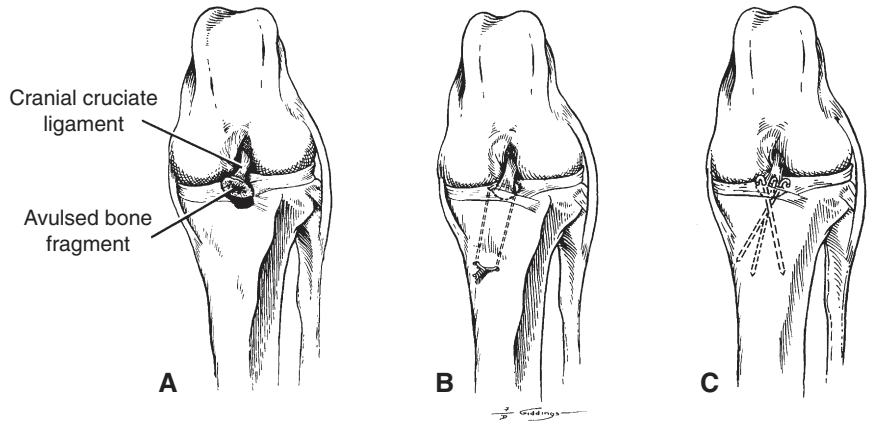


FIGURE 18-18. Avulsion of the tibial insertion of the cranial cruciate ligament. **A,** A bone fragment with the cranial cruciate attached has been elevated from the tibial plateau of the left tibia. A medial approach to the stifle is used for exposure.[7] Lag screw fixation is ideal if the bone fragment is large enough (see Figure 18-20, *B*). For smaller fragments: **B,** stainless steel wire, 20 to 22 gauge, is placed through the ligament insertion and through two drill holes that exit through the medial tibial cortex where the wire is twisted. **C,** Three Kirschner wires, inserted at diverging angles, provide good fixation.

Aftercare

The limb must be immobilized for 4 weeks to allow healing of the fracture. A Thomas splint or a long lateral splint is suitable (see Figures 2-24 and 2-25). The stifle must be fixed at the standing angle to minimize complications of immobilization, such as periarticular fibrosis and quadriceps contracture. Full exercise should not be allowed until 4 weeks after splint removal.

RUPTURE OF CAUDAL CRUCIATE LIGAMENT

The caudal cruciate ligament is slightly larger than the cranial ligament and is an important stabilizer of the joint. It is the primary stabilizer against tibial caudal subluxation (drawer movement) and combines with the cranial ligament to limit internal tibial rotation and hyperextension.[25]

Little is known about the handling of ruptures of the caudal cruciate ligament because it is a relatively uncommon injury. Most cases are caused by severe trauma and are accompanied by rupture of the medial collateral and cranial cruciate ligaments. Medial meniscal injury is also common in this situation. However, isolated caudal cruciate ruptures do occur. It has been suggested that the caudal cruciate is not functionally significant because the normal standing angle of the dog's stifle tends to work against caudal drawer motion.[59] Also, experimental severing of the ligament by Harari and co-workers[60] did not create any functional or pathological changes in seven dogs observed postoperatively for 6 months. In the absence of any reports on clinical series, it is difficult for the clinician to decide on the best method of handling a case. We have seen cases of chronic lameness caused by chronic caudal cruciate ligament tears. Our approach is to attempt surgical stabilization of an isolated injury only in working and sporting dogs or when the injury occurs with other ligament injuries of the stifle.

Clinical Signs

Demonstration of caudal drawer motion is fundamental to diagnosing caudal cruciate ligament injury. This can be complicated by the concomitant injuries mentioned. Testing for caudal drawer motion can produce confusing results because the tibia seems always to be subluxated caudally at rest from the pull of the hamstring muscles. Therefore, what may appear to be cranial drawer motion is actually the reduction of tibial subluxation. From this reduced position, we can then demonstrate caudal motion. Therefore, unlike testing for cranial motion, it is more important to note the relative position of the thumbs as they grasp the femur and tibia *before* motion is applied to the tibia (see Chapter 1). With isolated caudal cruciate ligament tears, drawer movement is less than that with full cranial cruciate rupture. Often a definitive end point ("thud") may be detected on drawering cranially, as the cranial cruciate tightens, especially with the leg in flexion. Drawer may disappear when the leg is tested in a neutral position. With both cranial cruciate and caudal cruciate rupture, there is a severe amount of instability, unless the menisci are torn so badly that they impede adequate palpation.

Diagnosis

Radiographs are important in caudal cruciate injuries because of these injuries' frequent association with other traumatic injuries and because of a higher percentage

of avulsion injuries than with the cranial cruciate ligament. This probably results from the caudal ligament being larger and stronger than the cranial cruciate ligament and therefore resisting rupture but predisposing to avulsion. The definitive diagnosis is made on arthrotomy. The caudal cruciate stump is evident in the intercondylar notch of the femur. Often it is covered by a proliferative mass that must be debrided before the rest of the joint can be inspected.

Surgical Treatment

Little has been documented concerning clinical management of caudal cruciate injuries. No really satisfactory technique exists for large, active dogs. The technique shown here (Figure 18-19) is satisfactory for small breeds and cats but is not always as useful in large breeds. Avulsion injuries are well stabilized by wire or screw fixation (see Figure 18-20). Repair of collateral injuries is described next.

Technique for Ruptured Ligament

A medial or lateral arthrotomy is combined with approaches to the medial and lateral caudal compartments of the stifle joint.[7] Fragments of ligament are excised, and meniscectomy is performed when indicated. The joint capsule is then sutured, and collateral ligament repairs are made if needed. Stabilization is initiated on the medial side, with placement of mattress sutures (size 2-0 to 0 nonabsorbable material) to imbricate the caudomedial joint capsule (Figure 18-19, *A*). A large, imbricating suture of size 0 to 3 braided polyester material or heavy monofilament nylon

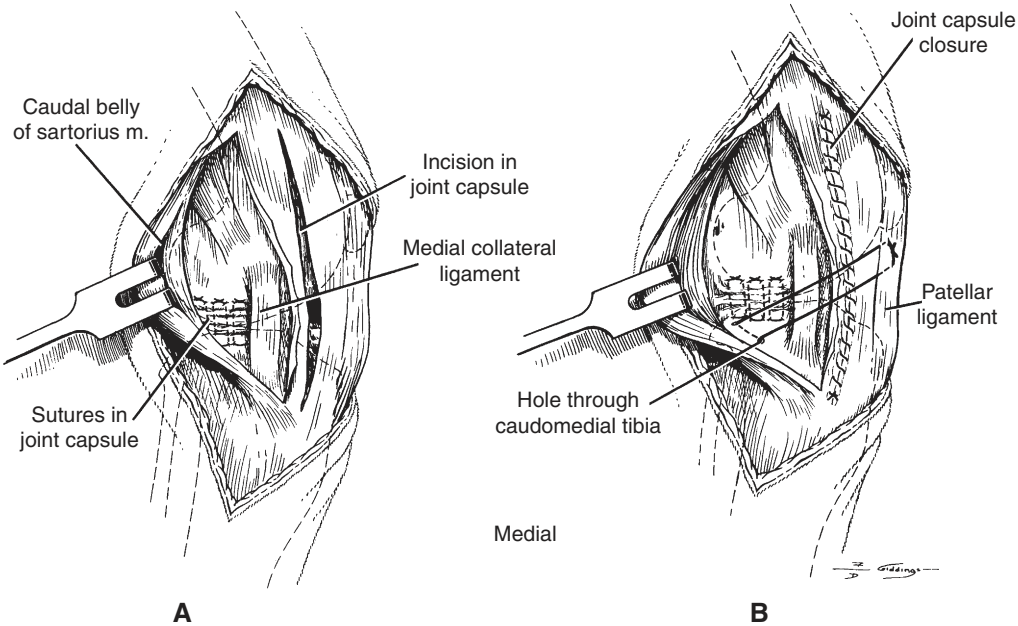


FIGURE 18-19. Rupture of the caudal cruciate ligament. **A,** The left stifle has been exposed by a medial approach to the stifle joint combined with an approach to the medial collateral ligament and caudomedial compartment of the joint.[7] The caudomedial joint capsule has been imbricated with mattress sutures of nonabsorbable material (size 3/0-0) placed vertically to the joint caudal to the medial collateral ligament. **B,** After closure of the joint capsule, a heavy-gauge (size 0-4) braided polyester suture is placed between the proximal patellar ligament and a drill hole in the caudomedial corner of the proximal tibia. This suture is tightened with the stifle at a normal standing angle and with drawer motion reduced.

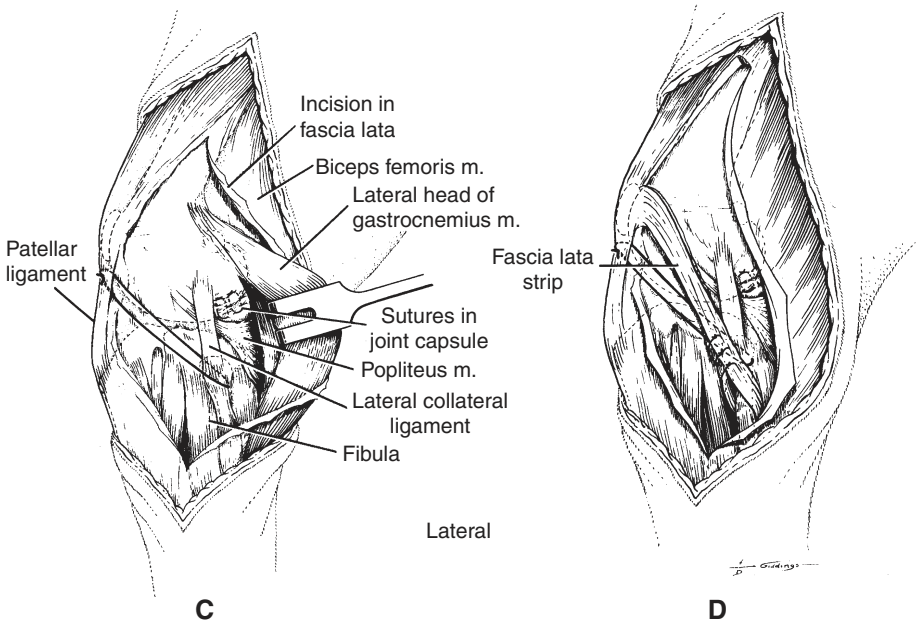


FIGURE 18-19. *Continued* **C,** The skin is retracted laterally to allow incision of the fascia lata and retraction of the biceps femoris. This reveals the lateral collateral ligament and caudolateral joint capsule.[7] The joint capsule is imbricated caudal to the lateral collateral ligament, and a heavy-gauge braided polyester suture is placed around the head of the fibula to the proximal patellar ligament. This suture is tied tightly with the stifle in a normal standing angle. **D,** For further augmentation, a strip of fascia lata may be dissected free proximally and left attached to the lateral border of the patella distally. This strip is passed around the fibular head, pulled taut, and then sutured to itself and to the surrounding fascia.

(see MRIT) is then placed from the medial half of the proximal patellar ligament to a hole drilled through the caudomedial corner of the tibia (Figure 18-19, *B*). This suture is tied tightly, with drawer motion reduced and the stifle positioned at the standing angle.

Similar sutures are placed on the lateral aspect of the joint (Figure 18-19, *C*), but the large suture is anchored around the fibular head. The fibular nerve should be protected during suture placement. A fascia lata transfer is also used on the lateral side. The strip is based on the lateral side of the patella and is long enough to be pulled around the head of the fibula and sutured to itself (Figure 18-19, *D*).

The fascia strip and large imbricating sutures are similar to those used in the technique of DeAngelis and Betts.[61] However, they are positioned more distally at the patellar end to more closely approximate the angle of caudal ligament. Imbrication of the caudomedial and lateral joint capsule is based on the technique of Hohn and Newton[59] for cranial cruciate rupture.

Aftercare

No splint is used unless the medial collateral ligament was repaired. Exercise is severely restricted for 4 weeks, then gradually increased through the eighth week.

Technique for Avulsion

Most avulsions occur at the *femoral origin* of the caudal cruciate ligament and are easily accessible for lag screw or wire fixation (Figure 18-20, *A*). If the fragment is large enough, fixation with a lag screw is preferred (Figure 18-20, *B*). Wire fixation

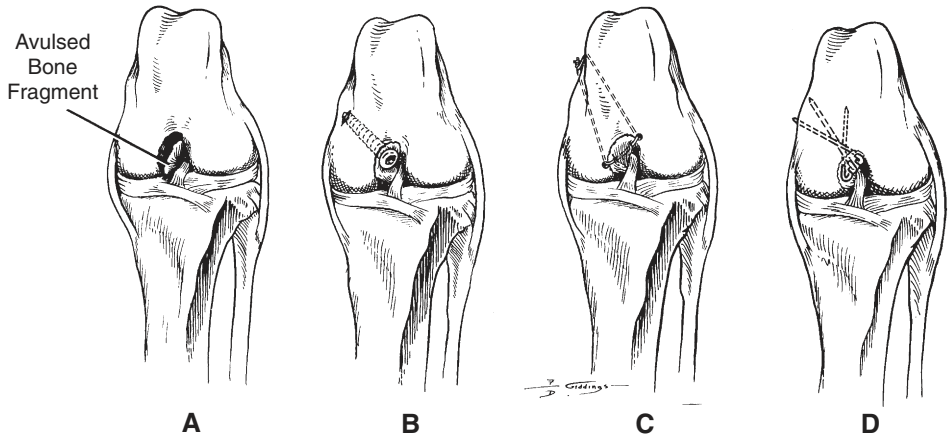


FIGURE 18-20. Avulsion of the femoral origin of the caudal cruciate ligament. **A,** Fragment of bone with the attached ligament has been avulsed from the medial femoral condyle. **B,** Lag screw has been used to fix the fragment. A lateral approach to the stifle provides the best exposure.[7] **C,** Stainless steel wire (20-22 gauge) is threaded through the ligament close to the bone fragment. Two parallel holes are drilled at opposite points on the edge of the femoral defect; the wire is passed through these holes, then twisted on the medial surface of the condyle. **D,** Three Kirschner wires can be inserted at diverging angles to stabilize the fragment.

can also be used if the bone fragment is small. The wire should pass through the ligament close to the fragment and then pass through bone tunnels to the medial condylar cortex, where it is twisted tightly (Figure 18-20, *C*). Another fixation method involves placing two or three K-wires through the fragment at diverging angles. These pins should penetrate the opposite condylar cortex.

Avulsion of the *tibial insertion* is treated similarly, although the fragment is much more difficult to expose. Best exposure is probably afforded by the approach to the caudomedial compartment of the joint.[7] The medial head of the gastrocnemius muscle and popliteal vessels must be strongly retracted.

Aftercare

A Thomas splint or long lateral splint is maintained for 4 weeks (see Figures 2-24 and 2-25), and exercise is severely restricted. After splint removal, activity is slowly increased through the eighth week.

MENISCAL INJURIES

In mammalian stifle joints there are two menisci, which are fibrocartilaginous structures interposed between the femur and tibia. The inner two thirds of the meniscus is avascular, and when the meniscus is injured, healing is poor.

Unlike the situation in humans, damage to the meniscal cartilages of the dog and cat rarely occurs as a primary injury; in almost all cases, one or more stifle ligaments are torn or stretched. Most often, the caudal horn of the medial meniscus is damaged as a result of the cranial tibial drawer motion that results from rupture of the cranial cruciate ligaments. Because the medial meniscus is firmly attached to the tibia by the caudal tibial ligament and to the medial collateral ligament, it moves with the tibia. Cranial drawer motion displaces the caudal horn cranial to the femoral condyle and

subjects the caudal horn to injury as a result of crushing and shear forces. Cranial drawer motion in extension is much more injurious to the meniscus and joint capsule than is drawer motion in flexion.[62] Isolated tears of the lateral meniscus have been seen by us, but rarely. A chronic, lateral femoral condylar osteochondritis dissecans lesion may cause a "kiss lesion" injury to the lateral meniscus.

The two most common injuries to the canine and feline meniscus are (1) the *caudal longitudinal tear* (so-called bucket-handle tear in human patients) (Figure 18-21, *A* and *E*), which separates the circumferential fibers completely from the tibial to the femoral surfaces, and (2) the "crush" of the caudal horn or limb of the meniscus, which is just an incomplete longitudinal tear (Figure 18-21, *C* and *D*). Other abnormalities include the double or triple "bucket-handle" tear (Figure 18-21, *F*), degenerative "fringe" tears (Figure 18-21, *G*) seen in the degenerate knee below an old femoral osteochondritic lesion, a rare transverse tear, and congenital lateral discoid menisci (Figure 18-21, *I*). Occasionally, we as well as others have seen calcified menisci. Peripheral detachments (Figure 18-21, *H*) or avulsions are usually seen in

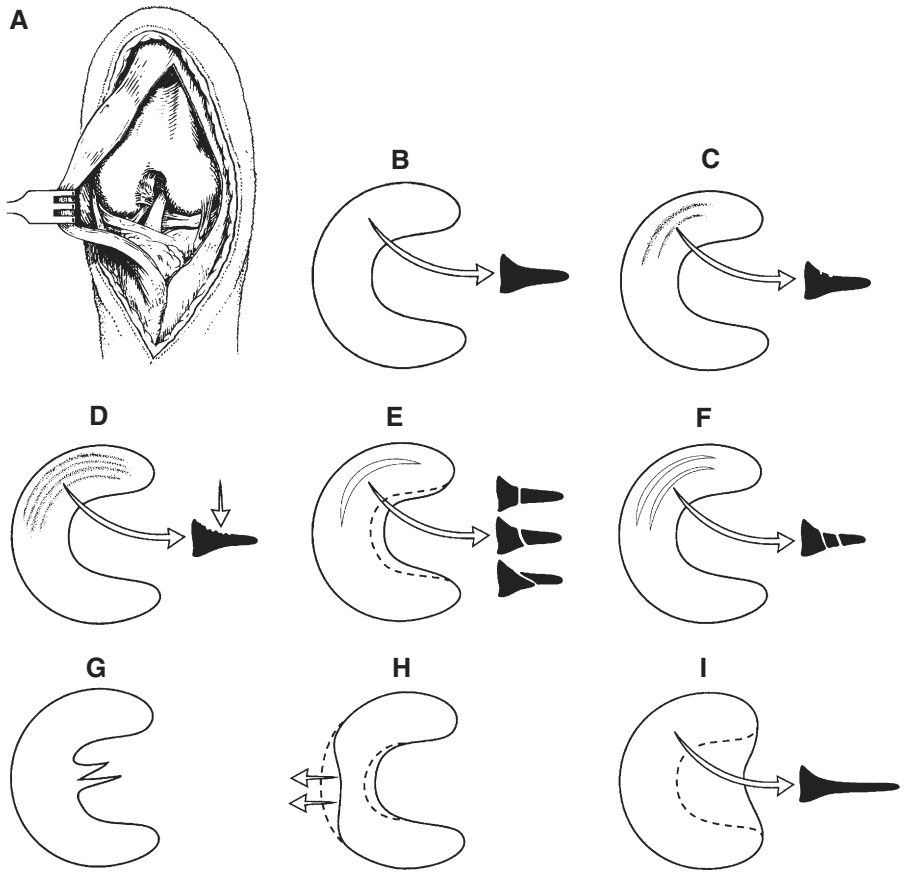


FIGURE 18-21. **A,** With the joint opened, a medial "bucket-handle" tear can be seen between the cranial horn of the meniscus and the femoral condyle. Vision and displacement of the torn part are assisted by levering a protected hemostat between the intermeniscal ligaments and femoral condyle (see Figure 18-22, *B*). **B,** Dorsal and cross-sectional view of a normal meniscus. **C,** Early fraying of the superficial layers of the meniscus. **D,** Crushed caudal horn. **E,** Longitudinal tear, or "bucket-handle" tear. **F,** Double "bucket-handle" tear. **G,** Degenerate fringe tear. **H,** Peripherally detached meniscus seen with traumatic stifles. **I,** Congenital lateral discoid meniscus. Dotted lines represent normal boundaries of the meniscus.

the significantly traumatized knee with multiligament derangement (e.g., automobile injury).[63,64] The incidence of meniscal injuries after rupture of the cranial cruciate ligament can be as high as 53%.[64,65] This incidence reflects a predominance of chronic cases as seen in a referral practice. Early surgical repair of the cruciate injury results in a much lower incidence of meniscal injury.

Clinical Signs and Diagnosis

Usually, dogs and cats with meniscal injury along with cruciate tears have more pain and lameness in the subacute or chronic stages than with cruciate rupture alone. Often there is a history of improving lameness after the cruciate rupture, followed by worsening as the meniscus subsequently is injured by the instability. An owner or observer may hear a "click" in 10% to 15% of dogs with meniscal injury. This click or grating sensation is often "felt" (and sometimes heard) when flexing, extending, performing the drawer test, or performing the cranial tibial thrust. Often there is a firm swelling at the medial joint line (medial buttress sign).

The definitive diagnosis is made on observing the abnormally displaced meniscus or portion of it. If, on arthrotomy, the caudal horn is reduced and injury unobservable, the tibia is levered forward by placing a curved mosquito hemostat forceps, guarded with a 1-inch piece of discarded sterilized suction tubing or urinary catheter, under the cranial intermeniscal ligament. As the knee is brought into more extension (45 degrees of flexion), the curved hemostat is levered against the femoral condyle. If the caudal horn becomes visible or luxates forward of the femoral condyle (normally the caudal horn of the medial meniscus, unlike the lateral meniscus, is not visible when drawer motion is produced in this way), it is deemed abnormal and removed. When the caudal horn becomes visible during the drawering maneuver and is slightly elevated off the tibia, it usually means the fibers of the caudal horn are becoming crushed and separated. If not removed, this may subsequently become a significant full meniscal tear. Excessive force should not be used because it will cause a normal meniscus to be displaced forward. Other surgeons use a Hohmann retractor placed through the interior of the joint to the back of the tibia and similarly lever the tibia forward. Often with this maneuver, a normal caudal horn of the meniscus will be pushed forward toward the front of the femoral condyle. Only if the meniscus (or parts of it) luxates totally in front of the condyle should it be considered abnormal when using this technique.

If drawer motion is slight because of chronicity or partial tears, observation of the caudal horn may be difficult.

Radiography has not been a reliable diagnostic method for this condition. MRI is the "gold standard" for diagnosing soft tissue knee injuries but is expensive and rarely available to our small animal patients. Arthroscopy may become important in the future, but at present, it is not widely available for routine examination of the canine stifle joint. Surgical exploration remains the most common and useful method of definitive diagnosis.

Treatment

Meniscectomy

Indications

The outer 25% to 30% of the meniscus is avascular, and tears do not heal for all practical purposes.

Removal of a normal medial meniscus in otherwise intact stifles results in regenerative material (consisting of fibrocartilage) filling the defect but does create

some DJD.[66-68] Although meniscectomy in small animals does *not* result in devastating DJD as can occur in humans, meniscectomy should not be performed unless pathological changes are seen. However, leaving a pathological meniscus in place often results in persistent lameness.

In human patients, total or partial meniscectomy was performed depending on surgeon preference. As long-term clinical follow-ups became available, it was apparent that some patients developed severe DJD on the side of the joint where the meniscus was removed. With the development of arthroscopic surgery, the meniscal damage can be totally assessed. The top and bottom surfaces may be visualized and the meniscus probed for stability. The abnormal tissue can selectively be removed, resulting in fewer long-term clinical problems. In the last decade, with further refinement of arthroscopic techniques, tears in the outer vascular areas may be healed if sutured. This is usually considered only in the young (<40 years of age), athletic patient. It is a much more involved surgical procedure and has a more extensive rehabilitation program than with simple meniscectomy.

In dogs and cats, arthroscopy is not readily available, and thorough evaluation of the entire meniscus is impossible by open surgery. However, close inspection is usually sufficient. A *partial* meniscectomy means removing that strip of pathological meniscus that has flipped forward of the femoral condyle. A *total* or *subtotal* meniscectomy means removing the meniscus at its perimeter, more peripheral than the actual tear in the parenchyma.

Some surgeons prefer total to partial meniscectomy for the following reasons:

1. Total meniscectomy is easier to perform, without iatrogenic articular cartilage damage during the surgical procedure.
2. It does not leave an unseen double or multiple bucket-handle tear (seen in about 10% of meniscal tears).
3. More precise removal of the "crushed" meniscus is possible.
4. Better regeneration is possible (debatable because the vascular portion is violated).
5. In our experience, dogs returning years later with debilitating DJD is not a clinical problem. The difference in life span between dogs and humans may be the reason.

Technique

A medial arthrotomy[7] is preferred for medial meniscectomy because it provides better exposure. Visualization of the caudal meniscal horns is aided by joint instability.

Total medial meniscectomy begins by cutting of the intermeniscal and cranial tibial ligaments[65] (Figure 18-22, *B*). All cutting is done with great care to avoid injury to articular cartilage of the tibia and femur. Number 11 and 15 blades or #64 Beaver miniblades (R. Beaver, Inc., Belmont, Mass) are the most useful sizes for the procedure. A Kocher forceps or meniscus clamp (Ascott Enterprises, Missassauga, Ontario) is attached to the freed cranial horn. It is pulled axially while the medial joint capsule is retracted abaxially. The meniscus is dissected away from the joint capsule with the blade in a vertical position to avoid cutting the medial collateral ligament and joint capsule (Figure 18-22, *C*). When beginning the dissection, it is well to keep in mind the abaxial edge of the medial femoral condyle. Incising more abaxially may lacerate the medial collateral ligament and fibrous joint capsule. Dissection continues using a small scalpel blade caudal to the medial collateral as strong traction is applied to the clamped meniscus in a cranial and axial direction. Cutting the caudal synovial attachment is the most difficult part of the procedure and may require additional exposure, as discussed later. Fortunately, with traction most pathological

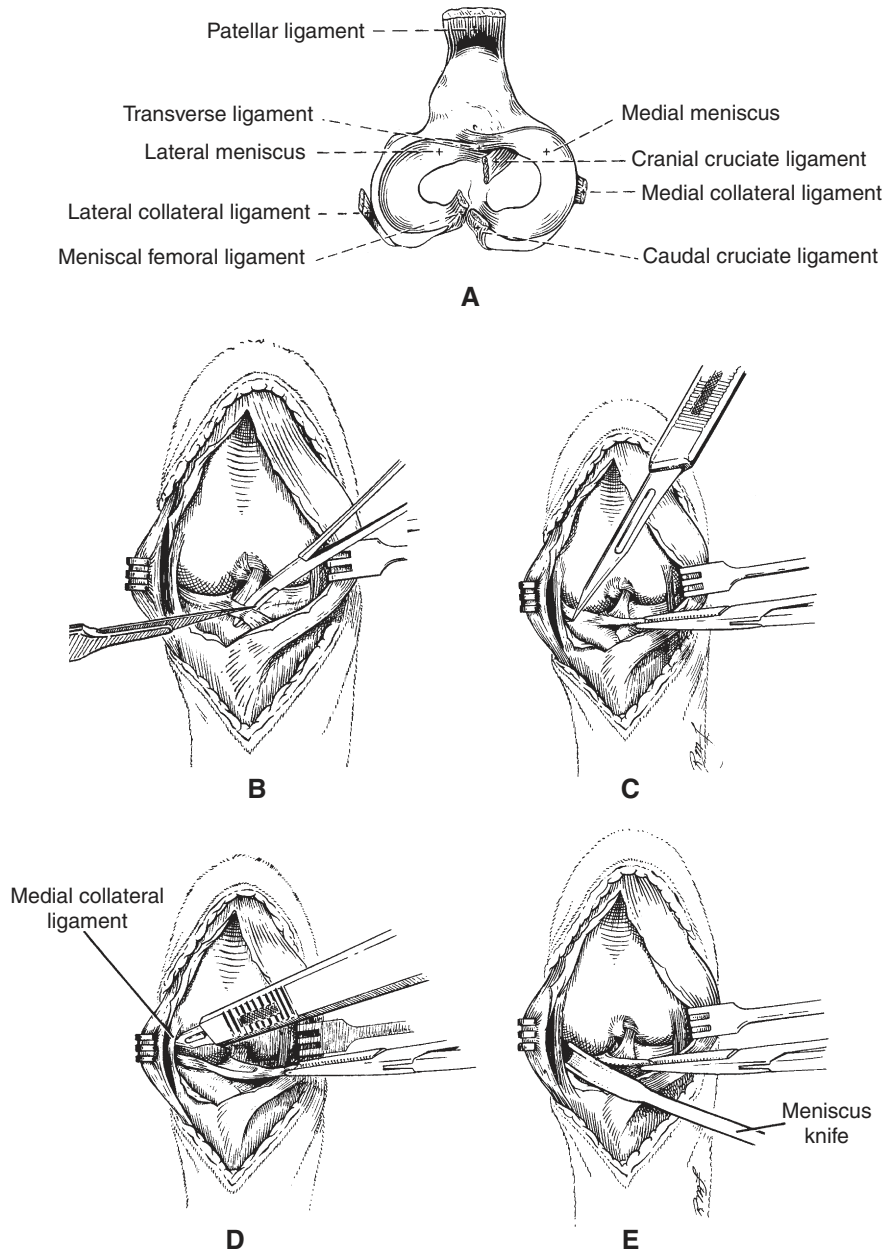


FIGURE 18-22. Medial meniscectomy.[65] **A,** Menisci and meniscal ligaments of the left stifle joint, dorsal aspect. **B,** The left stifle has been exposed by a medial parapatellar approach.[7] The cranial tibial and intermeniscal ligaments are severed, with a hemostat inserted to protect the underlying cartilage. **C,** Strong craniolateral traction is applied to the meniscus, and the medial joint capsule is retracted to allow dissection of the cranial horn free from the joint capsule. The scalpel blade is oriented vertically and aimed at the abaxial edge of the femoral condyle to avoid cutting the medial collateral ligament. The medial collateral ligament is normally not visualized but is inserted here for orientation. **D,** Continued traction allows the caudal joint capsule attachments to be cut. **E,** A small, curved meniscus knife (Veterinary Instrumentation, Sheffield, England; Jorgensen Laboratories, Inc., Loveland, Colo) simplifies freeing the meniscus caudal to the collateral ligament.

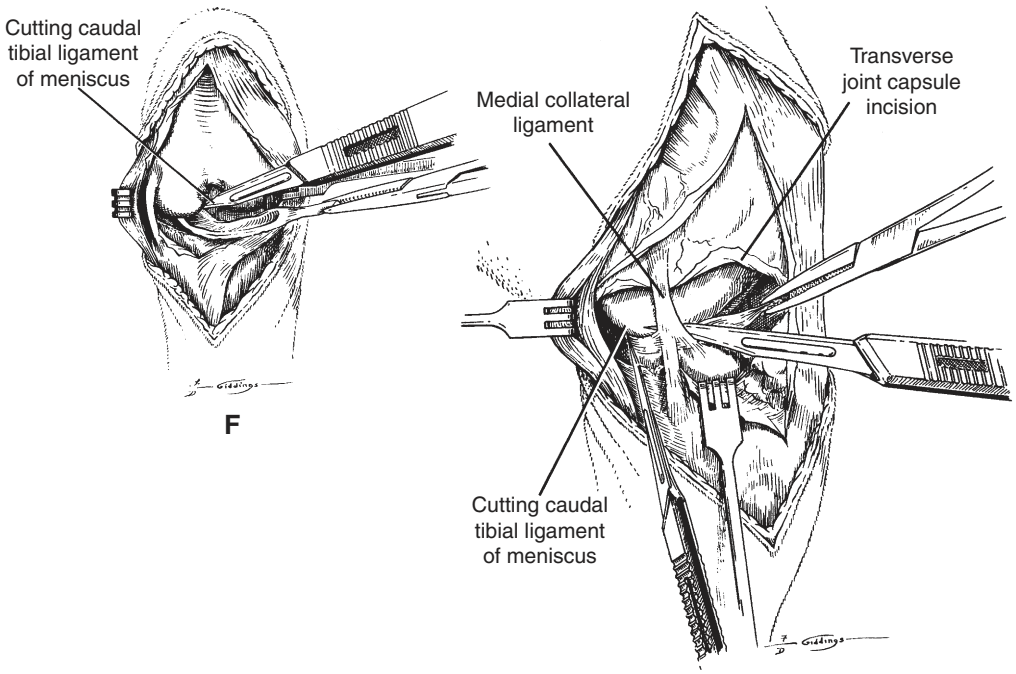


FIGURE 18-22. *Continued* **F,** The caudal tibial ligament of the meniscus is cut with the blade held parallel to the tibial surface. **G,** For additional exposure of the caudal peripheral attachments, a medial transverse joint incision is made from the parapatellar incision, extending caudally deep to the medial collateral ligament. Caudal capsular attachments can be easily cut, but care must be taken to avoid the popliteal vessels. The meniscus is dissected free of the deep portion of the medial collateral ligament. The caudal tibial meniscal ligament is cut, as in *F*. The transverse incision is closed with mattress sutures, followed by interrupted sutures in the parapatellar arthrotomy.

menisci will tear in the correct area at the caudal peripheral attachments. If the meniscus is "normal," it will not do this. A small, curved meniscus knife (Veterinary Instrumentation; Jorgensen Laboratories) greatly simplifies this part of the surgery. The knife is worked around the periphery of the meniscus, freeing it from the synovial membrane and collateral ligament. Alternatively, a #11 scalpel blade or a #64 Beaver blade can be used. If these attachments can be freed at this point (Figure 18-22, *D*), the entire meniscus can be pulled cranially, and the caudal tibial ligament can be cut (Figure 18-22, *F*) to free the meniscus.

If additional exposure is required, a medial transverse joint incision is made from the medial collateral ligament cranially to join the parapatellar incision (Figure 18-22, *G*). The medial collateral ligament is elevated to allow the incision to be extended caudally deep to it. The meniscus is dissected away from the caudal joint capsule and medial collateral ligament. Care is taken to avoid the popliteal vessels immediately caudal to the capsule. After the caudal capsular attachments are freed, the caudal tibial ligament is cut as previously described to free the meniscus.

If by mistake a cranial hemimeniscectomy has been created by inadvertently cutting too axially into the bucket handle, the abnormal caudal horn should be removed. Often this "lost" portion may be retrieved by levering the tibia forward and then sweeping a curved mosquito forceps caudally and along the inside of the medial collateral ligament. Another technique is to sweep the forceps from the caudal

tibial attachment area outward toward the abaxial side or medial joint capsule. Once the horn is displaced forward, the material is grasped and carefully incised.

Aftercare

No specific aftercare is required for meniscectomy. The care is usually dictated by repair of associated ligament damage. Heavy exercise should be withheld for 6 months, if possible, to allow for regeneration of the meniscus before extreme stress is placed on the joint.[64,68] Hannan and associates[69] have demonstrated a chondroprotective effect with the use of polysulfated glycosaminoglycan (Arteparon, Luitpold Werk, Munich, FRG; Adequan, Luitpold Pharmaceutical, Inc., Shirley, NY) following experimental meniscectomy. Dosage of 2 mg/kg body weight subcutaneously three times per week for 3 weeks, then twice weekly until the dogs were killed at 23 weeks, significantly improved the biochemical and morphological parameters studied in articular cartilage.

Meniscal Release

After the advent of the TPLO procedure, discussed earlier, Slocum subsequently recommended a prophylactic incision in the caudal half of a *normal* medial meniscus. This allows the caudal meniscus to "sag" caudally, theoretically decreasing the crushing effect of the femoral condyle on the meniscus during drawer motion and preventing a subsequent bucket-handle tear. Long-term results of this prophylactic procedure are unknown at this time, are controversial, and may be difficult to document.

COLLATERAL LIGAMENT INJURIES

Ligament injuries that overstress the structure and damage ligament fibers are known as *sprains* (see Chapter 7). Such injuries may be minor (first degree) or more severe, with stretching and rupture of ligament fibers (second degree), or they may result in tearing or avulsion of the ligament (third degree).[70] Only third-degree and some second-degree injuries require surgical therapy.

Damage to collateral ligaments of the canine stifle occurs relatively infrequently. Severe injury is usually associated with traumatic incidents, such as being hit by an automobile or direct blows. Meniscal and cruciate damage should always be suspected with any collateral ligament injury severe enough to produce instability of the joint.

An understanding of the functional anatomy of these ligaments is necessary to diagnose the resulting instability.[71] Both ligaments are taut in extension and function with the cruciate ligaments to prevent internal tibial rotation. In extension, the collateral ligaments are the primary stabilizers of lateral (valgus) and medial (varus) angulation of the tibia. In flexion, the lateral ligament relaxes and allows internal tibial rotation to be limited only by the cruciates while the medial ligament remains taut and limits external tibial rotation. Because the cruciates do not limit external tibial rotation, the medial collateral is the primary stabilizer of this motion.

Clinical Signs

Injury to the medial collateral ligament is more common than injury to the lateral side. Tearing of the cranial cruciate ligament is almost always present, and medial meniscus injury often accompanies the collateral damage. Joint effusion and tenderness with no weight bearing are the obvious signs. Tibial angulation is checked with

the joint in extension, and any drawer motion is reduced. Varus instability is present with lateral laxity, and valgus instability is present with medial laxity. When the medial collateral ligament is completely torn, marked external tibial rotation is possible with the stifle flexed.

Physical examination will usually provide the diagnosis, but radiographs with the joint stressed to accentuate the instability are often useful.

Surgical Treatment

Injuries that produce observable instability in large, active dogs should be surgically repaired as early as possible. Even if the ligament is grossly intact and even if it heals by fibroplasia, it will always remain loose and will allow joint laxity.

Stretched ligaments (second-degree injury) are tightened by suture imbrication, torn ligaments are sutured, and avulsed ligaments are reattached or synthetically replaced (Figure 18-23; see also Figures 7-6 and 7-7). Exposure of either ligament is readily done, either primarily or during an approach to the stifle joint.[7] Collateral ligaments of the stifle, especially the lateral ligament, must always be sutured or reattached with the stifle in extension to prevent shortening of the ligament, which either limits extension or overstresses the repair when the animal extends the joint.

Aftercare

All injuries are immobilized in a Thomas splint or long lateral splint for 4 weeks (see Figures 2-24 and 2-25), followed by 2 more weeks of leash-only exercise. Activity can be slowly increased after 7 or 8 weeks.

LUXATION OF THE STIFLE JOINT

Total derangement of the knee, with rupture of all four major ligaments, is a disastrous injury seen on occasion. Cats appear to have a higher incidence than dogs. Vascular integrity of the limb distal to the stifle must be carefully evaluated because the popliteal vessels may become entrapped by the tibial luxation.

Injury of the cranial and caudal cruciate and medial collateral ligaments is seen more often. Also damaged to varying degrees are the secondary restraints of the joint, such as joint capsule, menisci, and patellar ligament. Additionally, most patients have a variety of other traumatic injuries, such as fractures or ruptured viscera. Despite the magnitude of this injury, good function can be obtained if a meticulous repair is made of each injury.[72] Paramount to attempting such repairs is a thorough preoperative assessment of the stifle joint. Such an examination can be done adequately and humanely only under general anesthesia in this circumstance. Because of the multiple derangements of the joint, palpation can be confusing, and the diagnoses reached must always be regarded as presumptive.

Surgery should start with a thorough exploration of the joint, which requires adequate surgical exposure. Meniscal injuries in this condition do not often require meniscectomy; most damage is usually done to meniscofemoral or meniscotibial ligaments or the joint capsule attachments. These can usually be sutured and should be done first, while the exposure is greatest. The collateral ligament injury should be stabilized next, since this will restore basic alignment to the joint and simplify the remaining surgery. Stabilization of the cruciate instability follows. The authors have usually used extracapsular methods. It is most helpful to place a small (0.062-inch) K-wire temporarily across the joint with the joint held in a neutral, reduced position before tightening the sutures or tissues so that the tibia is not stabilized in a

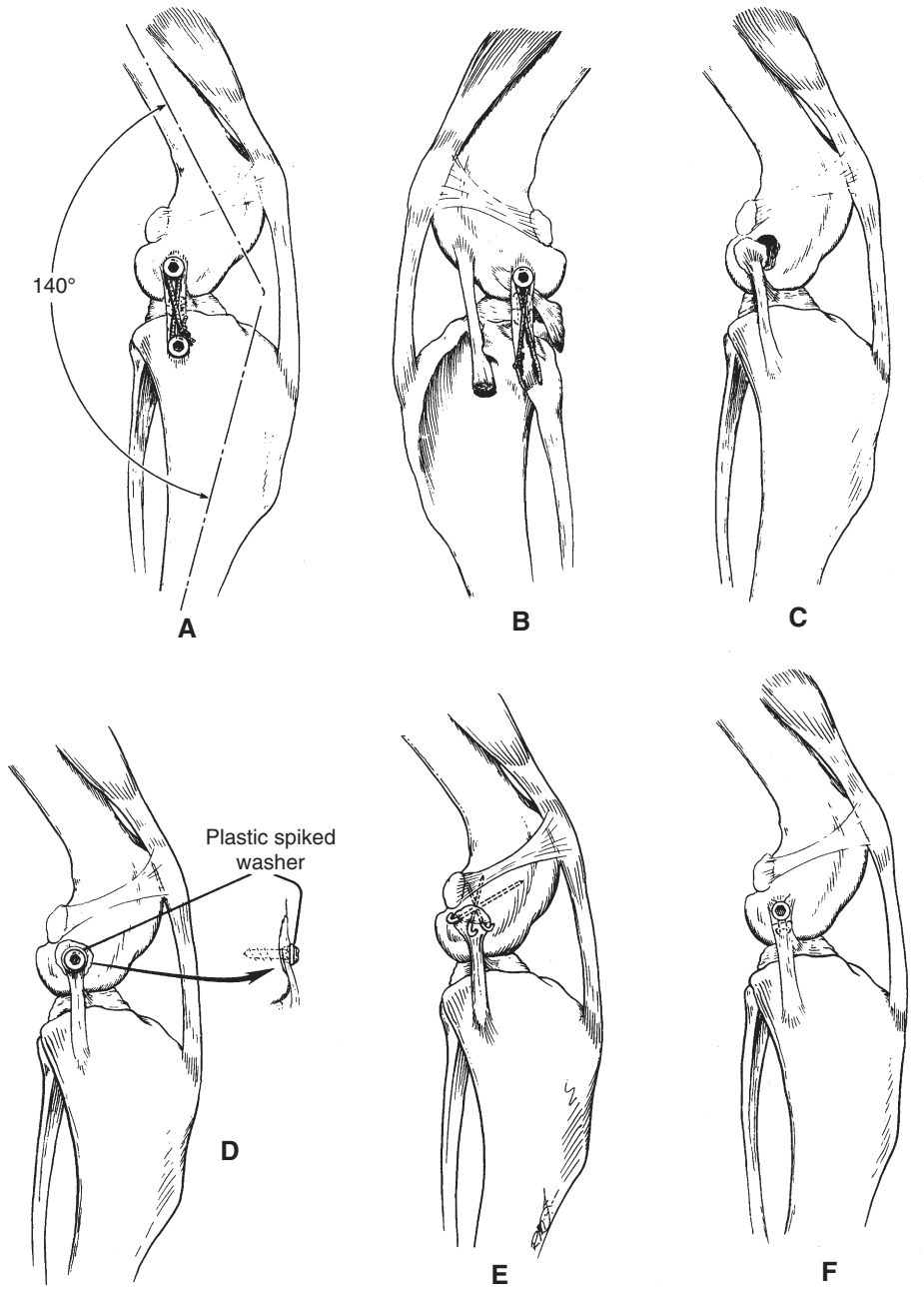


FIGURE 18-23. Surgical repair of collateral ligament injuries. **A,** Midportion medial collateral tear has been sutured, using a locking loop pattern (see Figure 7-6). The ligament repair is protected by heavy-gauge (0-3) braided polyester suture placed between two bone screws in the origin and insertion areas. This suture is tied with the joint extended or at a standing angle. **B,** Midportion lateral collateral tear has been sutured as in *A*. Only one bone screw is needed, since a bone tunnel drilled in the fibula functions well for the distal insertion of the protective suture. **C,** Avulsion of the origin of the medial collateral ligament. **D,** The avulsion has been secured using a plastic spiked washer on a 3.5-mm screw. **E,** Reattachment is also possible with three diverging Kirschner wires placed through the fragment. **F,** This tear close to the origin of the medial collateral ligament was sutured with a locking loop pattern, and the suture was then secured around a bone screw. When possible, a bone tunnel can be used rather than a screw, as in *B*.

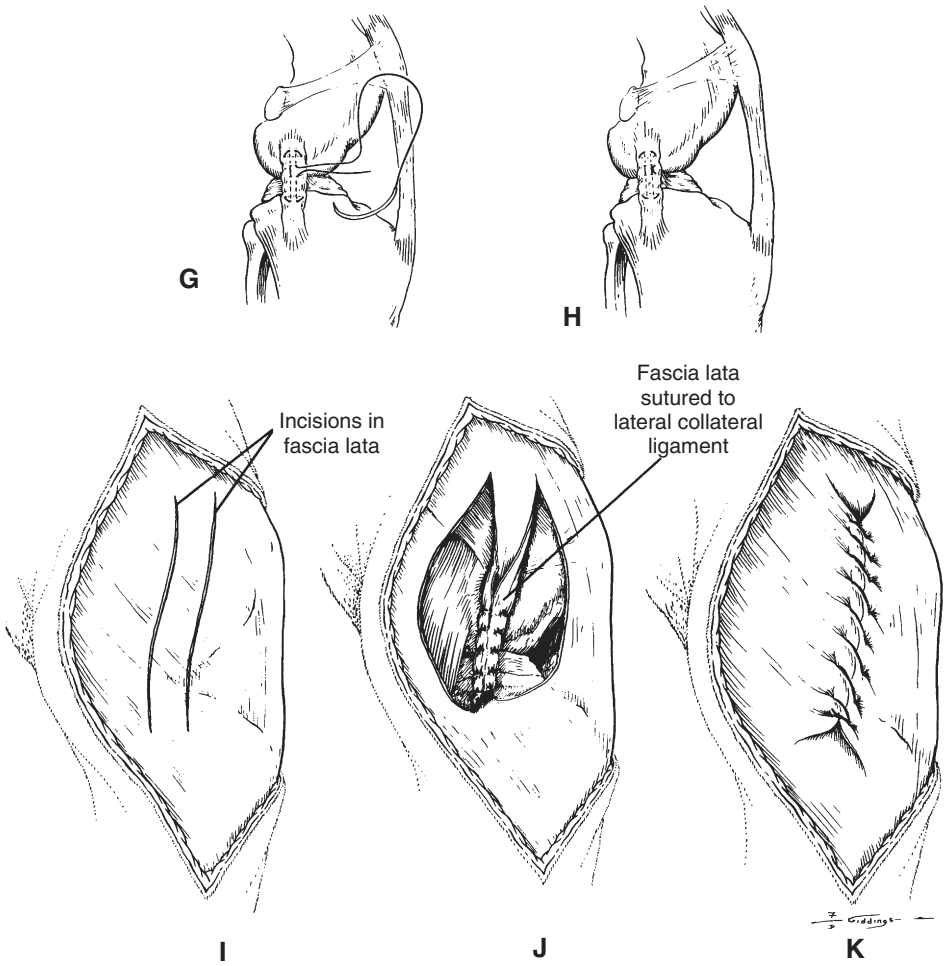


FIGURE 18-23. *Continued* **G,** A stretched ligament is being imbricated by means of a modified locking loop suture pattern. **H,** Tying the suture results in shortening of the ligament between the suture loops. **I,** Fascial lata reinforcement of a lateral collateral ligament injury[6] begins by elevating a strip of fascia that is left attached at each end. **J,** The fascia is sutured to the repaired ligament. **K,** The fascial defect is sutured.

deviated position. Hulse and Shires[72] attribute much of their success with these problems to intraarticular stabilization. Extraarticular repair of the cruciate ligament injuries and postoperative support with transarticular external skeletal fixators were successful in 13 cases reported by Aron.[73] The final step is careful imbrication of all available joint capsule and periarticular tissue to stabilize the joint further.

A newer stabilization procedure for luxated stifles in cats and small dogs (after joint exploration) is to cross the femorotibial joint temporarily with a 1/8- to 3/16-inch pin with the leg held at a functional angle of 30 to 40 degrees of flexion.[74] A reinforced bandage or cast is recommended until pin removal in 5 to 7 weeks. We have used this method successfully in selected small animals when cost constraints or open wounds were of concern.

Aftercare consists of exercise limitation, as previously described for the individual procedures. Surprisingly good function has been seen in these patients, both by us and others.[72,73] A consistent finding is reduction of 30 to 40 degrees in range of motion in the stifle joint. Arthrodesis is a possible option for a chronically unstable

and painful joint (see Figure 18-30, *A* and *B*), but amputation results in better overall function of the animal.

OSTEOCHONDRITIS DISSECANS OF FEMORAL CONDYLE

The pathophysiology of osteochondrosis and osteochondritis dissecans (OCD) is discussed in Chapter 6.

The shoulder joint is most often involved, but the stifle is occasionally involved and is often overlooked. OCD is seen in all large breeds of dogs, especially the retrievers. Signs are usually first noted at 5 to 7 months of age. Early surgical treatment is indicated to remove loose cartilage and minimize osteoarthrosis. The prognosis is more guarded than for lesions of the shoulder, but about 75% will be normally functional if surgical treatment is done at an early age. Some degree of osteoarthrosis is to be expected. Later in life, the meniscus beneath the OCD bed may become degenerate ("kiss lesion"), resulting in clinical lameness or worsening of previous lameness.

Clinical Signs

Lameness varies from minimal to severe. Measurement of the diameter of the thigh muscles may demonstrate evidence of mild disuse atrophy. Palpation of the joint is often unrewarding, although very slight drawer motion movement may be noted if muscle atrophy is present. Joint effusion can often be noted. If a "joint mouse" has formed from detachment of the cartilage flap, popping or crepitus can be present.

Radiographic Findings

Radiographs are necessary for diagnosis, and high-quality films are necessary to detect a small lesion. Mediolateral and caudocranial views are needed, the latter in two different degrees of flexion-extension. Lesions are most often found on the medial aspect of the lateral femoral condyle (Figure 18-24, *A* and *B*), although the medial condyle can be affected. Slight flattening of the articular surface and subchondral sclerosis are the most common findings. Care must be taken not to mistake the radiolucent area of the extensor fossa (where the long digital extensor tendon inserts craniolateral on the distal end of the femur) for an OCD lesion (Figure 18-24, *C*). On the lateral radiograph, a saucer-shaped lucency may be seen at the joint line (Figure 18-24, *A*).

Diagnosis

The diagnosis may be made based on the findings of lameness, stifle swelling, and the typical radiographic lesions in dogs over 4 1/2 months of age. At an earlier age, the osteochondrotic lesion may not become a flap and could spontaneously heal. However, joint effusion and large radiographic OCD lesions merit a joint exploration.

Surgical Treatment

Either a lateral or a medial parapatellar approach provides adequate exposure (Figure 18-25, *A*). The cartilage flap is excised, and the edges of the defect are trimmed to make a clean vertical border (Figure 18-25, *B*) and to ensure that the cartilage left has firmly adhered to the subchondral bone. Multiple drilling of the defect with a K-wire may assist in early revascularization of a sclerotic lesion.



FIGURE 18-24. **A,** Lateral radiograph of the distal femur. Note the saucer-shaped radiolucency *(white arrows)* indicative of osteochondrosis in this 4-month-old dog. This large radiographic lesion was explored and found to be mostly intact despite joint effusion. The cartilage and bone were drilled with several pinholes, and the cartilage never became a flap. **B,** Craniocaudal view of an osteochondritis dissecans (OCD) lesion *(black open arrow)* of the lateral femoral condyle. **C,** Craniocaudal view of a normal distal femur demonstrating the radiolucent area on the lateral femoral condyle *(black arrowhead)* that is at times mistaken for an OCD lesion.

If lesions are very deep, curettage with or without cancellous bone grafting may be indicated.

If a flap is not seen in surgery, it may mean that osteochondrosis, not osteochondritis dissecans, is present. Multiple drill holes (0.045-inch K-wire) have been successful in "tacking" down the cartilage and preventing the flap from forming.

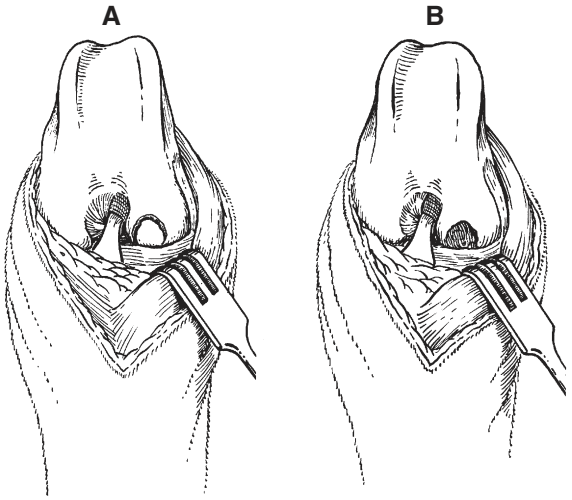


FIGURE 18-25. Osteochondritis dissecans of the femoral condyles. **A,** Lesion of the lateral femoral condyle has been exposed by a medial parapatellar approach.[7] **B,** The cartilage flap has been excised, and the edges of the lesion are debrided by curettage.

We have seen several cases of degenerate lateral meniscal lesions under presumed old OCD lesions in the lateral condyles of 4- to 6-year-old dogs. Meniscectomy in such cases has helped the lameness.

Aftercare and Prognosis

A light bandage is applied for 2 weeks to protect the arthrotomy, followed by 2 more weeks of restricted activity. The prognosis for large weight-bearing lesions is guarded to fair, depending on size and lesion location.

RUPTURE OF PATELLAR LIGAMENT

Rupture of the patellar ligament is a rare injury. If both the ligament and the joint capsule are torn, the patella rides at the top of the trochlea or proximal to it ("patella alta"). Repair of the ligament using 0-2 nonabsorbable suture material is accomplished with a tendon suture pattern (see Figures 7-6 and 7-7) as well as simple interrupted sutures in the joint capsule. A supporting figure-of-8 wire is also inserted from the proximal quadriceps tendon region to the tibial tubercle (Figure 18-26).

Additional auxiliary fixation, such as a modified Thomas splint or reinforced padded bandage, for 1 to 2 weeks relieves tension at the anastomosis site. Wire removal should be contemplated after 5 to 7 weeks if seroma or lameness is present.

AVULSION OF PROXIMAL TENDON OF LONG DIGITAL EXTENSOR MUSCLE

Although it occurs infrequently, avulsion of the origin of the long digital extensor (LDE) muscle is a disabling injury resulting in DJD.[75] Avulsion is a disease of skeletally immature, long-legged breeds such as sighthounds and Great Danes in the age range of 5 to 8 months, but rupture of the tendon can occur in mature animals, especially those with lateral patellar luxation.

The LDE muscle originates in the extensor fossa of the lateral femoral condyle. The tendon crosses the joint and passes deep to the cranial tibial muscle through a

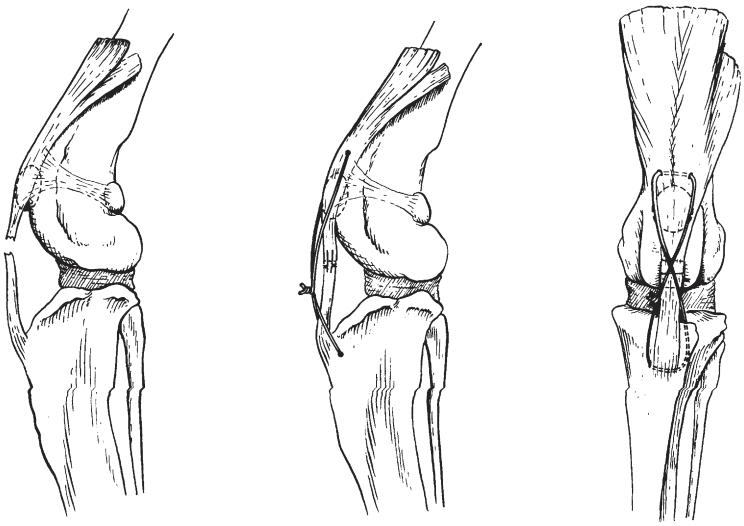


FIGURE 18-26. Rupture of the patellar ligament. **A,** Lateral view of rupture. **B,** Lateral view of ligament sutured, with a supporting figure-of-8 wire in place. **C,** Cranial view with sutures in place.

sulcus in the proximolateral tibia. It is apparently not important to stability of the stifle joint. The detached bony fragment rapidly hypertrophies to several times its original size. The injury rarely is associated with known significant trauma. Surgical treatment produces gratifying results if performed before DJD becomes evident.

Clinical Signs

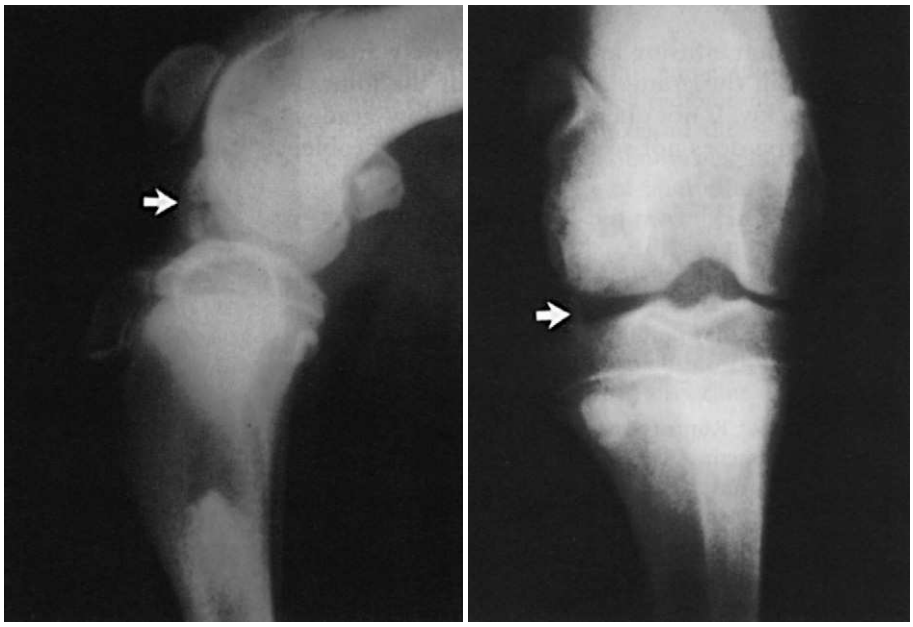
Pain and joint effusion are seen immediately after the injury. Pain is most pronounced in the craniolateral aspect of the joint. Lameness is variable and subsides quickly. If not surgically repaired, a chronic low-grade lameness may result. Loss of toe function does not seem to be a common problem. Firm nodular thickening of the lateral joint area is evident in 2 to 3 weeks, and pressure applied over this area may produce pain and crepitus.

Diagnosis

Radiographs of the stifle in flexed lateral and caudocranial views reveal an opaque density within the joint (Figure 18-27). On the lateral view, the opacity is seen cranial to the femoral condyle and distal to the extensor fossa. The caudocranial view reveals the calcified mass to be just lateral to the femoral condyle. The radiographic size of the mass is much less than actual size, since a portion of it is cartilaginous and secondarily fibrotic. An early lesion may appear only as a sliver on bone because of this cartilaginous nature.

Surgical Treatment

Reattachment of the avulsed fragment is the treatment of choice in recent injuries. If the fragment is so hypertrophic that the outline of the original fragment is no longer discernible, it is better to detach the bone fragment and reattach the tendon to adjacent soft tissue.



A B

FIGURE 18-27. Avulsion of the long digital extensor (LDE) tendon of origin from the lateral femoral condyle. **A,** The avulsed osteochondral fragment that was the origin of the tendon can be seen opposite the arrow in the cranial compartment of the stifle joint; mediolateral view. **B,** The fragment can also be seen in the lateral aspect of the joint in the craniocaudal view, but it is less obvious.

Exposure of the lesion is by way of a lateral approach to the stifle joint.[7] The avulsion is immediately visible when the joint capsule is incised (Figure 18-28, *A*). If the injury is recent and the avulsed fragment is not hypertrophied or covered with granulation tissue, it is reattached with a 3.5- or 4.0-mm lag screw and plastic spiked washer (Figure 18-28, *B*) (Synthes, Ltd., Paoli, Pa). Three diverging K-wires can also serve as fixation.

Because the tendon is not important in stabilizing the joint, it is better to exercise hypertrophic bone than to try reattachment and risk a delayed or fibrous union. This removes the mechanical irritation of the hypertrophic fragment. The bone can be cut free and the tendon attached to the joint capsule or fascia of the cranial tibial muscle (Figure 18-28, *C* and *D*).

Aftercare

Special precautions are not needed. Two weeks of house confinement and leash exercise are needed for soft tissue healing.

LUXATION OF PROXIMAL TENDON OF LONG DIGITAL EXTENSOR MUSCLE

This unusual luxation, in which the LDE tendon displaces caudally out of the tibial sulcus, causes variable clinical signs. The dog may show marked lameness, with the leg occasionally not bearing weight,[76] or the dog may have no lameness but a clicking sound accompanying each step. This sound mimics a meniscal "click" and often can

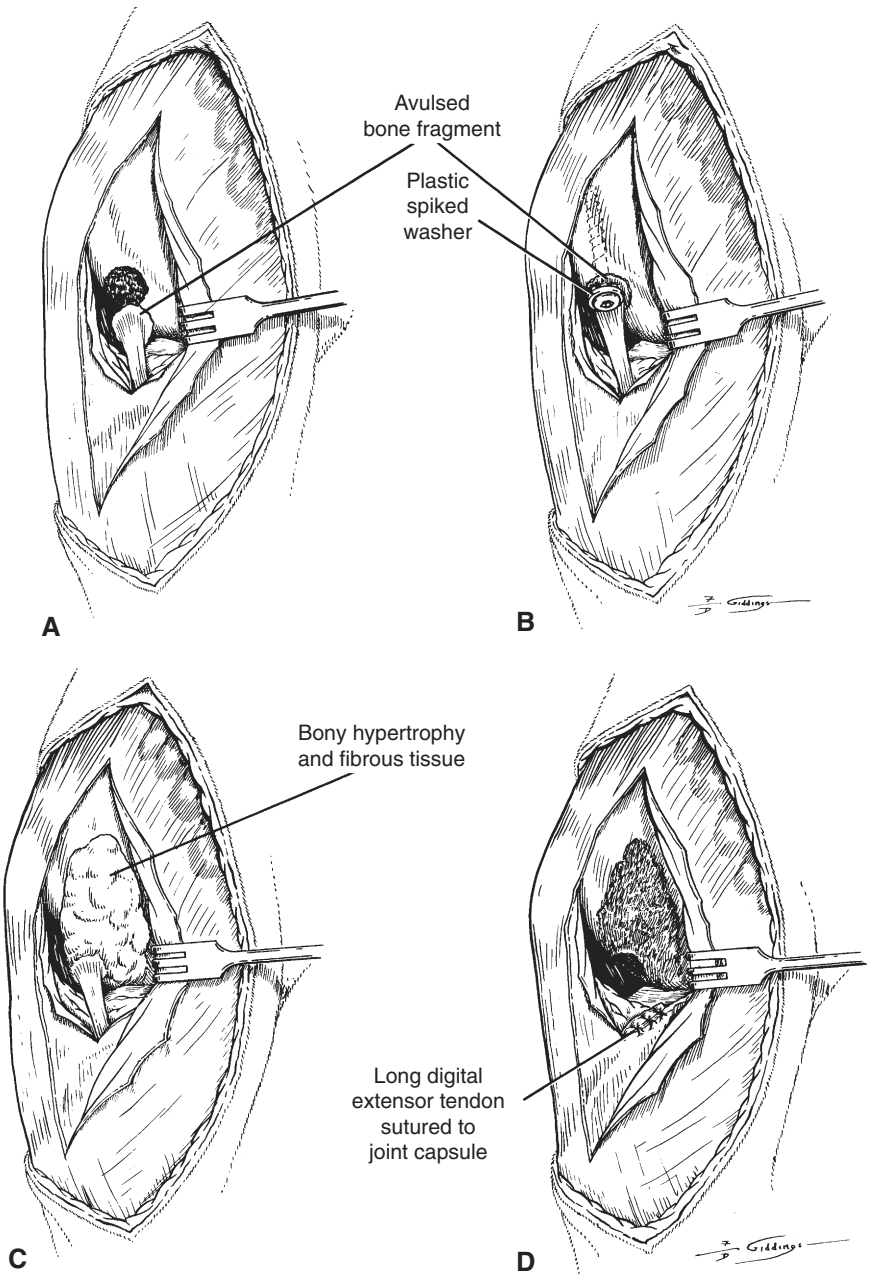


FIGURE 18-28. Avulsion of the tendinous origin of the long digital extensor muscle. **A,** Fresh avulsion fracture has been exposed by a lateral approach to the femur. The bone fragment and attached tendon have pulled away from the femur. **B,** A 4.0-mm lag screw and plastic spiked washer (Synthes, Ltd., Paoli, Pa) have been used to attach the avulsed fragment. **C,** Example of a case of several weeks' duration, with bony hypertrophy and fibrous tissue covering the avulsed fragment. The bone fragment is not reattached in this situation. **D,** The hypertrophic avulsed fragment has been resected and the tendon sutured to the joint capsule. The fascia of the cranial tibial muscle can also be used for attaching the tendon.

be produced on palpation by flexing the stifle while pushing proximally on the foot to simulate weight bearing, and it can be felt by placing a hand on the limb while the animal is walking. Surgical repair carries a good prognosis. We have also seen luxation of the LDE tendon accompany patellar luxation.

Surgical Treatment

Although an acute injury may respond to external immobilization for 2 to 3 weeks, most cases are chronic when seen and require surgery.

A vertical skin incision is made between the tibial tubercle and the fibula. Dissection will easily reveal the tendon and the tibial sulcus. Nonabsorbable sutures are used to create a "roof" over the sulcus to trap the tendon (Figure 18-29). If possible, the suture is placed through a bone tunnel along the edge of the sulcus. Where there are no suitable points for bony anchorage, the suture is placed through periosteum and fascia. In some cases it may be necessary to deepen the sulcus to obtain adequate reduction of the tendon.

Aftercare

External immobilization is not required; exercise should be restricted for 2 to 3 weeks.

ARTHRODESIS OF THE STIFLE JOINT

Chapter 7 provides a general discussion of indications for and principles of arthrodesis. Strict attention to detail to establish proper joint angle and rigid internal fixation is necessary for success.

Arthrodesis of the stifle is an alternative to amputation for severely comminuted intraarticular fractures, acute total luxation (Figure 18-30), chronic luxation or subluxation from a variety of causes, severe osteoarthritis, and severe patellar luxations that have not responded to conventional repair.

Function of the limb is greatly affected; however, when the fusion is at the proper angle (135-140 degrees in the dog and 120-125 degrees in the cat), function is

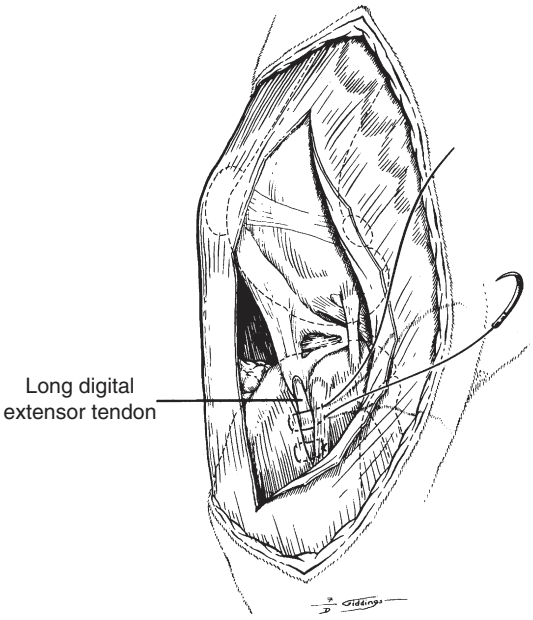
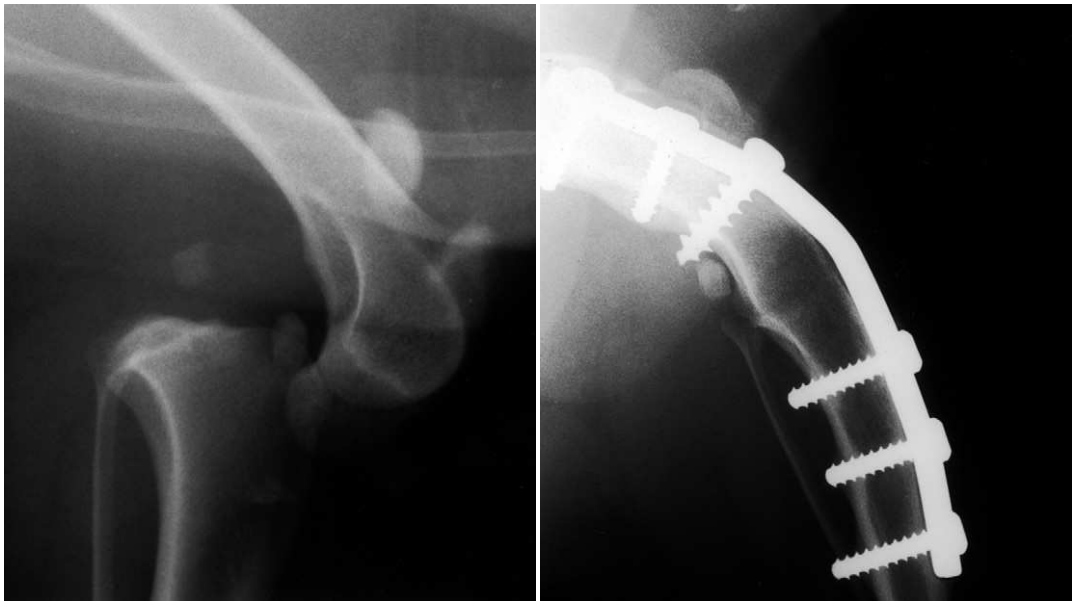


FIGURE 18-29. Luxation of the proximal tendon of the long digital extensor muscle. Two mattress sutures are placed across the tibial sulcus to prevent luxation of the tendon.



A B

FIGURE 18-30. A 4-year-old 20-kg mixed-breed dog sustained a vehicular accident resulting in a dislocated stifle and multiple small fractures surrounding the joint. **A,** Preoperative lateral radiograph. **B,** View 19 months after plate arthrodesis.

satisfactory for pet animals. With fusion, the limb is sometimes circumducted, especially at faster gaits, when the limb becomes relatively too long compared with the opposite limb. Knuckling of the toes may also occur at these times. Overall function of the fused limb is not as good in most dogs as with amputation. Bone plate fixation is the most suitable fixation for large breeds and is useful in all sizes of animals (see Figure 18-31). Lag screws and tension band wire are suitable for small to medium-sized animals (see Figure 18-32, *A*). Pins with tension band wire are satisfactory in cats and small breeds (see Figure 18-32, *B*).

Surgical Technique

Bone Plate

Because of the large size of the contact surfaces at the fusion site, it is difficult to change the angle of the joint after the initial cut to remove articular cartilage and subchondral bone without sacrificing large amounts of bone and thus shortening the limb. It is therefore worth the effort to do precise planning of the initial ostectomy cuts.

A bilateral approach is made to the stifle, and the tibial tuberosity is osteotomized to allow proximal retraction of the entire quadriceps group.[7] The meniscal cartilages are completely excised. Although the collateral ligaments can be sacrificed at this time, maintaining them simplifies intraoperative manipulation of the limb. Kirschner wires are driven into the distal femur and proximal tibia, perpendicular to the long axis of each bone (wires 1 and 2, Figure 18-31, *A*). Both these pins should lie in the sagittal midline plane of the limb. The selected joint angle is subtracted from 180 degrees to obtain the complementary angle. In the illustrated case, the chosen angle is 140 degrees and the complementary angle 40 degrees. Since bone can easily be removed from both the femur and the tibia, a 20-degree wedge of bone is removed from each. The plane of these ostectomies is parallel to K-wires placed at angles of 20 degrees to the original wires (wires 3 and 4, Figure 18-31, *A*).

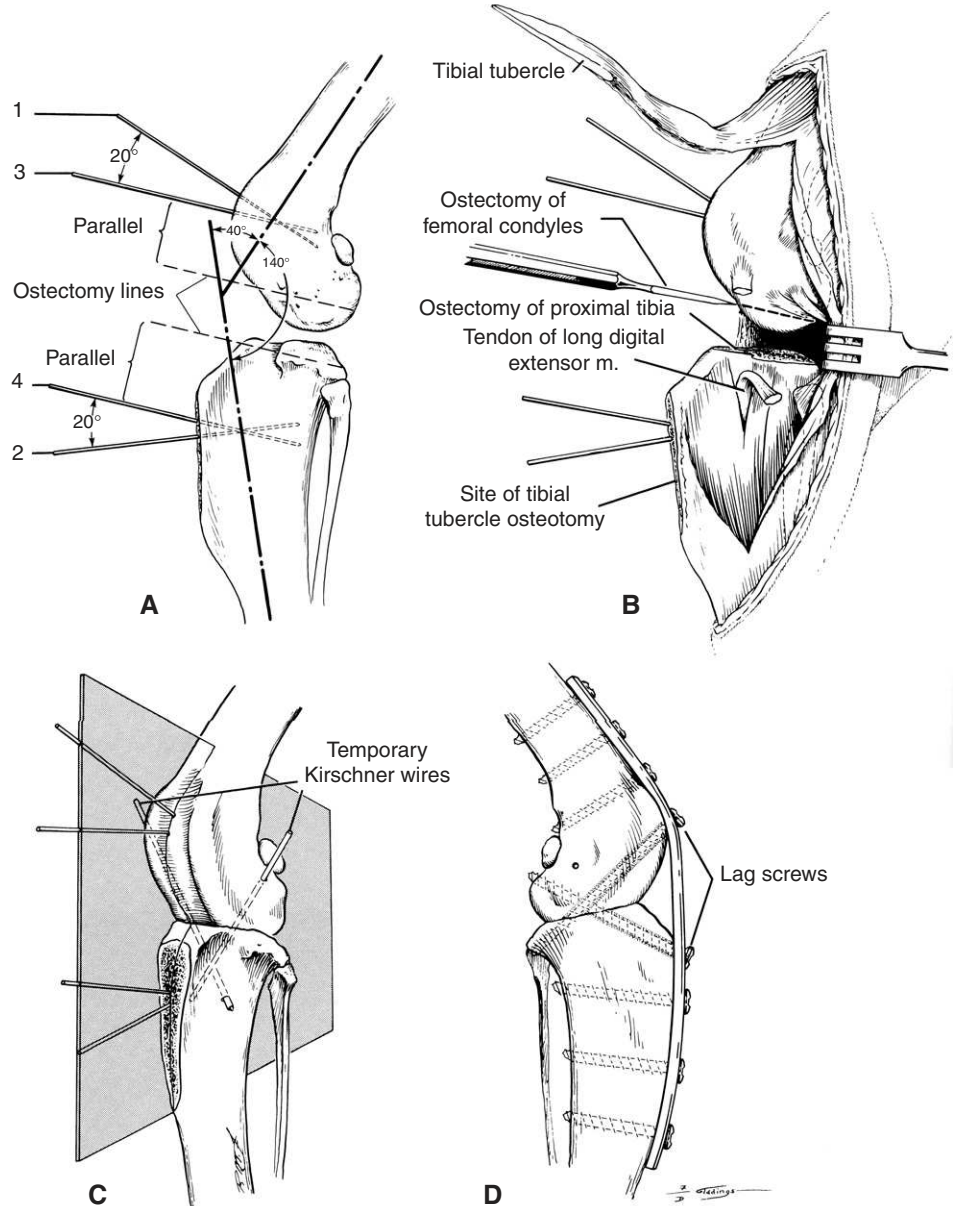


FIGURE 18-31. Arthrodesis of the stifle by bone plate fixation. **A,** Planning of the ostectomies. Kirschner wires 1 and 2 are placed perpendicular to the femoral and tibial shafts. The joint angle chosen, 140 degrees, has a complementary angle of 40 degrees. Dividing this by 2 gives a result of 20 degrees, so that pins 3 and 4, placed at an angle of 20 degrees to pins 1 and 2, are parallel to the ostectomy lines desired. **B,** The tibial ostectomy is complete. The femoral cut is made with an osteotome held parallel to pin 3. An oscillating saw can also be used. **C,** The joint is temporarily fixed by crossed pins. Kirschner wires 1 through 4 are kept in alignment with the sagittal plane to prevent rotation of the lower limb. The wires are removed after the crossed pins are placed. **D,** A bone plate is contoured after removing sufficient tibial crest to allow good contact. Screws 3 and 6 are placed first in a dynamic compression plate (Synthes) to supply compression, or a separate compression device can be used in the tibia. At least one lag screw should cross the joint, and two are preferable, as shown here.

The initial ostectomies are performed with an osteotome (Figure 18-31, *B*) or an oscillating saw held parallel to pins 3 and 4. The popliteal vessels must not be severed. Rongeurs or a rasp is used to smooth the contact surfaces. Once the proper angle has been established, the bones are temporarily stabilized with two K-wires placed in an "X" fashion (Figure 18-31, *C*). Pins 1, 2, 3, and 4 should be maintained in the sagittal midline plane during placement of the "X" pins to ensure that the lower limb is not rotated; pins 1 through 4 are then removed.

A bone plate that will allow at least four screws in each fragment is contoured to the cranial bone surfaces. Some of the tibial tuberosity and crest is removed to allow better contact of the plate (Figure 18-31, *D*). At least one screw should be lagged across the contact surfaces after compression is obtained with the plate screws inserted in a dynamic compression plate (Synthes, Ltd., Paoli, Pa) or with a separate compression device. The tibial tuberosity is pinned to one side of the plate in such a position that the patella does not contact the plate. Alternatively, the patella may be excised. The "X" pins can be removed or left in place. Bone graft is not needed because of the large contact surfaces of the femur and tibia.

Aftercare

Most dogs and cats do not require external support of the limb. Because the plate is functioning as a tension band, it provides very rigid fixation. However, because the plate is angled and because there is a natural fulcrum at the stifle joint, the plate or screws may break if activity is excessive. External support of the limb should be used if there is any question about the owner's ability to restrict the animal's activity. About 8 weeks is required for radiographic signs of fusion, and activity should be restricted during this period. Fracture of the tibia at the distal end of the plate sometimes occurs and is probably a good reason to remove the plate 6 to 9 months postsurgically. Pins, wires, and screws are not removed unless they loosen.

Screw and Pin Fixation

These procedures begin as just described for the other surgical techniques. After the contact surfaces are prepared, lag screws or pins are placed in an "X" fashion across the joint (Figure 18-32). The pins or screws must penetrate the tibial cortices

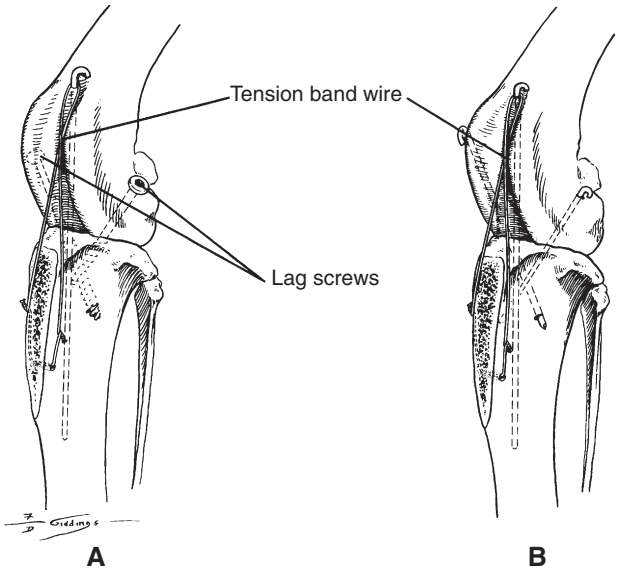


FIGURE 18-32. Arthrodesis of the stifle by lag screw or pin fixation. **A,** After the contact surfaces are prepared, crossed lag screws are placed from the femoral condyles to the proximal tibia. A small pin is driven from the proximal trochlear sulcus into the proximal tibia, and a tension band wire is placed from the head of the pin to the tibial crest. **B,** Pins can be substituted for lag screws in small dogs and cats.

for best holding power. Pins 1, 2, 3, and 4 are removed. A pin is then driven from the proximal trochlear sulcus into the proximal tibia, emerging on the cranial cortex distal to the tibial crest. A hole is drilled transversely through the proximal tibial crest, and a tension band wire (size 18-22 gauge; 1.0-0.6 mm) is placed between the pin and the tibial crest.

Aftercare

External support using a Thomas splint or a long lateral splint is advisable for 4 weeks postoperatively (see Figures 2-24 and 2-25). Exercise is severely restricted until radiographs show advanced fusion, usually about 8 to 10 weeks postoperatively.

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19

Fractures of the Tibia and Fibula

Fractures of the tibia are relatively common in dogs and cats, comprising 21% of long-bone fractures[1] and 11.7% of appendicular fractures.[2] The entire spectrum of internal and external fixation devices is applicable to these fractures. The AO Vet fracture classification scheme is used for nomenclature[1] (see Table 2-1), and treatment recommendations are keyed to the fracture patient scoring system detailed in Table 2-6 when applicable.[3,4]

FIXATION TECHNIQUES

Coaptation

A variety of coaptation devices are applicable in tibial fractures, particularly in type A1 and A3 diaphyseal fractures in skeletally immature animals, in which one study reported a relatively short healing time of about 4 weeks in 69 fractures.[5] Some distal fractures are amenable to external fixation, but very few proximal fractures can be adequately stabilized by this method because of their inherent instability and the difficulty of securing good immobilization of the distal femur.

The long-leg cylinder cast is useful for the tibia if care is taken to carry the cast high enough to immobilize the distal femur (see Figure 2-21). This is difficult in short-legged and muscular breeds. The same comments apply to the long lateral splint (see Figure 2-24). Thomas splints provide good fixation of the tibia, with the ability to cause cranial pull or caudal pull on either segment of the bone by varying the application of the wrapping and padding (see Figure 2-25). With all these devices it is important to maintain at least normal standing angles of flexion in both the stifle and the hock joints to both keep the device as short as possible and to minimize joint stiffness. The Robert-Jones dressing is an excellent emergency splint for the tibia, and it is particularly useful in type I open fractures to prevent protrusion of sharp bone fragments until definitive treatment is started (see Figure 2-33).

Intramedullary Pins

The main shortcoming of an intramedullary (IM) pin as the sole method of fixation is that it permits rotation at the fracture site. This method of fixation is reserved for transverse, short oblique, and minimally fragmented fractures of the tibia in skeletally immature or smaller mature dogs and cats.

The IM pin is best inserted from the proximal end of the tibia. Results of one study indicate that even when the pin is directed in a craniomedial direction, retrograde pinning from the middiaphyseal region may result in a significantly more caudal exit point on the tibial plateau, invasion of the joint space, damage to the insertion of the cranial cruciate ligament, and interference with the femoral condyles.[6] A similar study found no significant differences between craniomedially directed retrograde pins and normograde pins, although nondirected retrograde pins did cause more interference with the cranial cruciate ligament and femoral condyles.[7] This study also found that if the pin was not seated so that less than 1.5 cm protruded from the tibial plateau, interference with the femoral condyle was seen with all techniques. We continue to advocate normograde pinning because as in the femur, it eliminates some variables that can cause complications. Closed normograde pinning may be used for fractures that can be reduced closed with a minimum of manipulation and trauma to the soft tissue in the area.

Normograde Intramedullary Pin Technique

Figure 19-1, *A*, shows a short oblique fracture of the tibia. The proximal aspect of the left tibia shows the menisci and limits of the articular surface (Figure 19-1, *B*). It is usually advantageous to have the stifle flexed at a right angle and the animal in dorsal recumbency. The pin is then inserted through the skin and along the medial border of the patellar ligament, entering the proximal end of the tibia approximately one third to half the distance from the cranial surface of the tibial tubercle to

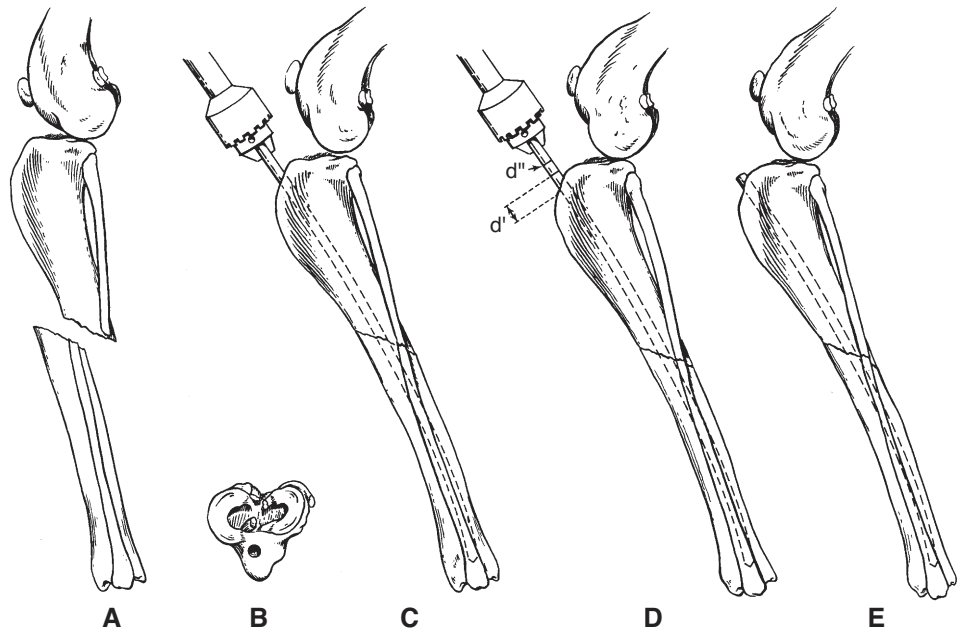


FIGURE 19-1. Intramedullary (IM) pinning technique for the tibia. **A,** Serrated short oblique fracture of the tibia. **B,** Proximal aspect of the left tibia showing menisci and limits of articular surface. Circle depicts the approximate location for insertion of an IM pin. The stifle should be flexed at a right angle. The pin is inserted through the skin along the medial border of the patellar ligament, entering the proximal end of the tibia approximately 1/4 inch caudal to the tibial tubercle. **C,** Reduced fracture and IM pin, lateral view. The pin should be inserted well into the distal end. **D,** IM pin retracted about 1/4 inch (*d′*); pin cut (*d″*). **E,** With a countersink and mallet, the IM pin is returned to the original depth. Sufficient pin is left protruding for removal at the time of clinical union.

the medial condyle of the tibia (Figure 19-1, *B* and *C*). Entering the pin too far caudally will not allow full extension of the stifle joint because of interference of the pin with the femoral condyle. The pin is started close to the medial border of the tibial plateau and angled slightly medially and caudally. After entering the marrow cavity, increased resistance and a coarse grating will be felt as the pin strikes the medial cortex. Drilling motion should stop, and the pin should simply be pushed until it bends slightly and then glides along the medial cortical surface. Because of its bending, a pin with a slightly smaller-than-normal diameter is necessary, typically about 50% of the medullary canal diameter. This bending causes the Steinmann pin to function more as a Rush pin than as a static IM pin, giving increased stability. If the pin is too large to bend, it will straighten the normal **S** curve of the tibia and cause valgus angulation of the distal tibia and hindpaw. Drilling back-and-forth quarter turns must be resumed as the pin is seated in the trabecular bone of the distal metaphysis (Figure 19-1, *D*), just short of the articular cartilage of the tibial trochlea. Palpation of the medial malleolus is used as a guide as to depth of penetration, using the radiograph to estimate how far the malleolus overhangs the surface of the tibial trochlea. The pin is retracted about 1/4 inch (6 mm), then cut. With a countersink and mallet, the pin is returned to the original depth. This seats the pin so that the proximal end does not interfere with movement of the stifle joint and still keeps the pin protruding sufficiently for removal (Figure 19-1, *E*). The fracture site should be compressed by counterpressure from the distal end of the bone while the pin is redriven with the countersink and mallet. If the pin has a diameter that is small enough to allow bending, the pin can be driven to the desired depth, bent craniomedially, and cut short with a pin cutter. The bend will ensure that the pin does not interfere with the femoral condyle.

A second method is to use a true Rush pin placed through the insertion of the patellar ligament on the tibial tuberosity (Figure 19-2). The pilot hole is drilled

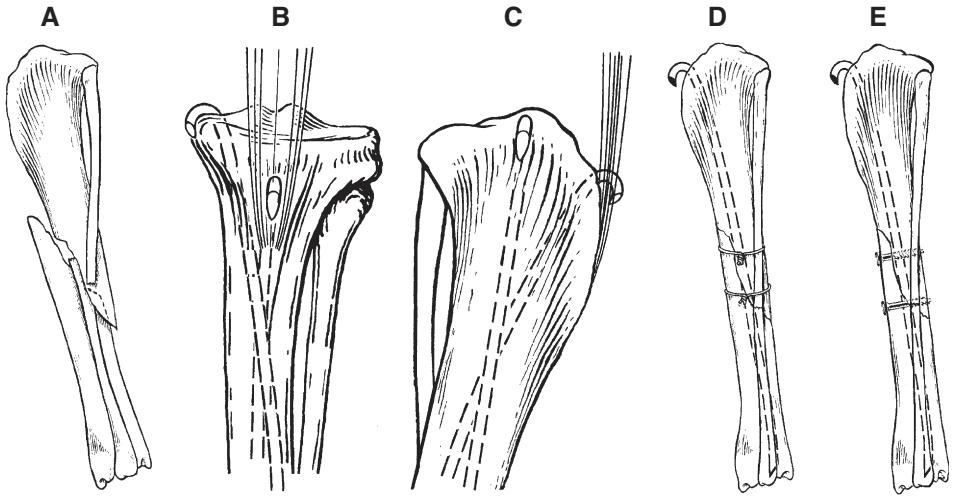


FIGURE 19-2. **A,** Long oblique fracture of the tibia. **B** and **C,** Insertion points in the proximal tibia for Rush pins. Either site can be used for a single pin, and both are used for double pinning. The cranial pin is placed through the tibial tuberosity at the insertion of the patellar ligament. The axial alignment of the pilot hole relative to the tibial shaft is approximately 20 degrees caudal and 5 degrees medial. The medial pin is positioned similar to the Steinmann pin (see Figure 19-1) but can be angled more laterally to provide for bending of the Rush pin. **D** and **E,** Fracture immobilized by Rush pin through the tibial tuberosity and cerclage wires or, in large breeds, with lag screws inserted off center to avoid the pin.

caudally and slightly medially from the tuberosity at an angle of 20 degrees to the long axis of the bone. The hook end of the Rush pin is driven close to the bone and produces no soft tissue reaction and therefore rarely needs to be removed. Rush pins can also be driven from the same point on the tibial plateau as described for Steinmann pins (see Figure 19-1).

Intramedullary Pin and Cerclage Wires

The use of cerclage wires in addition to an IM pin works well on long oblique fractures (Figure 19-3, *A*), spiral fractures, and certain reducible wedge fractures. Chapter 2 provides guidelines for cerclage application, and Figure 19-3, *B,* presents an example of this method. Note that it is usually necessary to place the cerclage wires around the fibula from the midshaft distally because of the interosseous ligament. The IM pin is usually removed after clinical union, and the cerclage wires are left in place.

Intramedullary Pin and Lag Screws

Figure 19-3, *C,* shows the same fracture as in *A* and *B,* immobilized with the use of an IM pin and lag screws inserted off center to avoid the pin. This procedure is most amenable to larger dogs. Lag screws and IM pins of relatively small diameter are used. The IM pin is usually removed after clinical union and the lag screws left in situ.

Interlocking Nail

Although the interlocking nail has been used mostly for fractures of the femur, this system is now described as an effective fixation method for diaphyseal tibial fractures.[8]

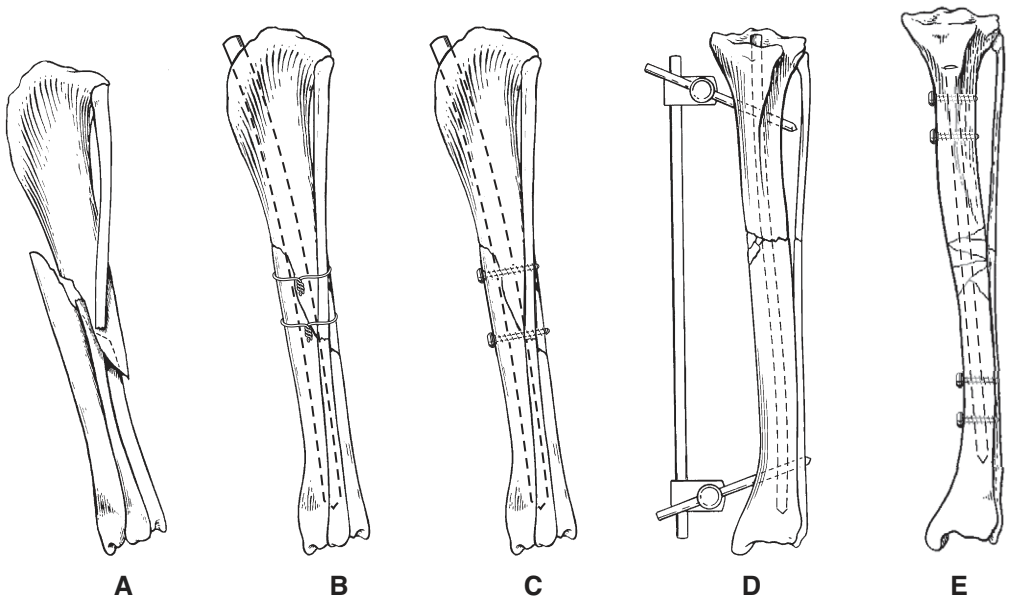


FIGURE 19-3. Rotational stability may be achieved for intramedullary fixation of tibia fractures by several different means. **A,** Long oblique fracture of the tibia. **B,** Two cerclage wires and an intramedullary (IM) pin are sufficient fixation for cats and small dogs. **C,** Two lag screws and IM pin. Care must be taken to avoid interference. **D,** IM pin and external fixator, 1/1 pin (half-Kirschner) splint, for unstable fractures. If this does not accomplish stability, use a 2/2 pin external fixator. **E,** Interlocking nail with two screws proximal and two screws distal to an unstable fracture.

Whereas the standard Steinmann IM pin has little value in unstable fractures, the interlocking nail provides rotational and axial stability (Figure 19-3, *E*) with insertion techniques that allow the surgeon to employ concepts of *biological osteosynthesis*. Less soft tissue dissection and bone fragment manipulation are required for interlocking nail insertion than for bone plate application. Bone healing with the interlocking nail has been very good in initial clinical reports; however, approximately 7% resulted in broken nails.[8] Clinical experience and biomechanical testing have led to revision of the 6-mm and 8-mm nails and expansion of the system to 4.0-mm and 4.7-mm nails. The current system now uses the appropriate sizes for tibial fractures of dogs of most sizes, except perhaps the largest giant breeds.

The introduction of the interlocking nail provides the surgeon with another good choice for tibial fracture fixation. Case selection should be limited to fractures with adequate intact bone proximally and distally for at least two interlocking screws. Interlocking nail fixation is not an optimal fixation choice for open, contaminated, or infected tibial fractures, especially since external fixators are available and so well suited for this application to the tibia.

Interlocking Nail Technique

Preoperative planning with a template onlay to the radiograph helps the surgeon to select the correct diameter and length of the implant. A choice of the standard nail with two screw holes proximal and distal or a nail with three holes is based on the proximity of the nail hole to the fracture. Maintaining a 2-cm distance from any nail hole to the fracture site is recommended to prevent nail breakage. A limited medial surgical approach to the tibia is completed for fracture reduction. IM pins of smaller diameter are used first in normograde manner to open the medullary canal. The interlocking nail is driven into the intramedullary space with "pin technique." The machined joint of the interlocking nail is attached to the tibial extension and the drill guide jig (see Figure 2-54, *E*). Drill guide inserts and sleeves are used through the jig to place the locking screws through each hole of the interlocking nail.

External Fixators

This splint may be used on almost all fractures of the tibial shaft, including delayed unions and nonunions. Choosing between bone plates, interlocking nails, and external fixators in many cases is merely a matter of personal choice by the surgeon. All types of fixator are applicable to the tibia because both medial and lateral aspects of the bone are available. Type I splints are placed on the medial surface of the leg; in this position they are less subject to being bumped or becoming hooked on objects, and they do not interfere with walking. Type IA one-plane splints, with the fixation pins placed in the same plane and connected by a common connecting bar, are used when there is load sharing between the bone and the fixator, as in simple, wedge, and segmental fractures (see Figure 19-14), as well as in most fractures of skeletally immature patients. Type IIA and B bilateral one-plane fixators are indicated when no load sharing is possible (see Figure 19-12, *B* and *C*), as in nonreducible complex wedge fractures. Type IB two-plane (see Figure 19-16) and type III bilateral two-plane splints are used when there is a very short proximal or distal segment.

The Kirschner-Ehmer external fixator system may be applied to tibial fractures using all fixator configuration types. Other fixator systems are also appropriate for the tibia, including the use of acrylic connecting bars or newer fixator systems, such as the IMEX SK (IMEX Veterinary, Inc., Longview, Texas). The increased stiffness of the carbon fiber or titanium connecting rods of the SK system allows simpler, type I fixator configurations to be applied to more complex fractures, without loss of

stability or concern for fracture healing. Another advantage of the SK system is that it permits the convenient use of positive-profile threaded pins through clamps at any or all positions on the fixator.

An important advantage of the external fixator in tibial fractures is the ability to employ the biological osteosynthesis concept by applying the splint with the fracture closed or with a very limited open approach and reduction. Because of the limited musculature of the crus, closed reduction is more feasible than in the humerus or femur. The animal is prepared and draped for surgery with the limb suspended as shown in Figure 2-12. Sterile towels or bandage material are wrapped around the suspending material a sufficient distance to prevent the chance of accidental contamination of the surgeon during reduction.

Although any type of fixator can be used, the type II has special application during closed reduction. If the most proximal and distal fixation pins are inserted first, at 90 degrees to the bone, they become a visual indicator of the adequacy of reduction in the frontal plane, since they will be parallel to each other when angular deformity in this plane is reduced. Additionally, they can be used to anchor a fracture distractor to aid in the reduction if desired. If difficulty is encountered in reducing the fracture closed, a limited open approach to the tibia will allow reduction under direct vision, but with minimal disruption of the fracture site, thus maintaining maximal vascularity of the fracture segments. The open approach also allows the use of auxiliary fixation, such as Kirschner wires or lag screws, both of which can be inserted with minimal disruption of soft tissues.

The external fixator is particularly adaptable to open fractures because the segments can be immobilized without invading or placing metallic fixation in the contaminated open area. On the other hand, the external fixator can also be used in combination with other supplemental fixation (e.g., cerclage wires, lag screws, IM pins; see Figure 19-3), although there seems little reason for the latter. The main reason for combining IM pinning with the external fixator in the humerus and femur is to allow early removal of the fixator and better limb function. Function with the fixator on the tibia is not a problem, however, because dogs walk well even with bilateral fixators. It would seem better simply to employ the appropriate fixator for the fracture and not use the IM pin.

Application of external fixators to the tibia results in few complications because of the limited musculature of the crus. Pin tract drainage is generally minimal, with the exception of pins placed lateral and proximal on the tibia. Soft tissue ulceration may develop at this site, and some surgeons will avoid this region for fixator pin placement. If a modified type II fixator is applied to the tibia, a half pin may be used at the proximal site, medially, with no pin at the lateral proximal site, thus avoiding later tissue ulceration. Pin sites that are positioned farther distally generally do not cause this same concern.

Bone Plates

Plates can be used on most fractures of the tibial shaft, including nonunions, and in corrective osteotomies.[9,10] Choosing between bone plates and external fixators often is merely a matter of personal choice by the surgeon. Plates are usually placed on the medial or craniomedial surface of the bone. Contouring of the plate to fit the curvature of the medial cortex closely is critical (see Figures 19-13 and 19-15). Failure to do so results in marked deformity of the tibia and lower limb. Most frequently the distal end of the plate is underbent and the distal tibia moved laterally (valgus deviation), as with the overly large Steinmann pin. Whenever possible, it is best to apply plates so that compression is exerted at the fracture site. (See Figure 2-75

for proper selection of plate and screw size relative to body weight.) The principle of biological osteosynthesis emphasizes limited fragment manipulation to minimize disruption of soft tissue and blood supply to healing bone. Complex tibial fractures with multiple fragments may necessitate the use of buttress configuration for the bone plate. The buttress plate may be combined with an IM pin, which prevents extreme or repetitive bending stress from causing plate failure.

Lag Screws

Bone screws applied in lag fashion to produce interfragmentary compression are applicable in many tibial fractures (see Figures 19-2, 19-5, 19-13, and 19-20; see Figure 2-75 for proper selection of screw size relative to body weight).

PROXIMAL FRACTURES

Fractures of the proximal segment are not common, comprising only about 7% of tibial fractures.[1] Most clinical fractures are the simple types, with multifragmentary types being extremely rare. These types are included here mainly to make the classification system complete.

Open Approaches

Exposing the medial side is done by simple skin incision over the area of interest, an extension of the approach to the diaphysis shown later. Exposing the lateral aspect will involve elevating a variable portion of the origin of the tibialis cranialis muscle from the tibial tuberosity and the lateral border of the tibial plateau.

Fracture Type 4-1-A; Proximal, Extraarticular (Figure 19-4, *A*)

Type A1, Avulsion

Avulsion of the tibial tuberosity occurs infrequently and is limited to younger animals, usually between 4 and 8 months of age. The tuberosity is a separate growth center and becomes fused to the proximal epiphysis and then to the metaphysis of the tibia as the animal reaches skeletal maturity. In large dogs the endochondral ossification process of the physis may be irregular, as seen radiographically; frequently, this is mistaken for a pathological process. The tibial tuberosity serves as the insertion point of the quadriceps muscles through the patellar ligament, and avulsions result

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FIGURE 19-4. Proximal fractures of the tibia. **A:** *A1,* Avulsion; *A2,* simple; *A3,* multifragmentary. **B:** *B1,* Lateral simple; *B2,* medial simple; *B3,* unicondylar multifragmentary. **C:** *C1,* Simple, metaphyseal simple; *C2,* simple, metaphyseal multifragmentary; *C3,* multifragmentary. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

from contraction of the muscle while the stifle is flexed and the foot firmly on the ground. Such a mechanism could easily occur during jumping or running and perhaps in a fall.

Clinically, the detached tuberosity can usually be palpated and is dislocated proximally, and the distal end is rotated cranially (Figure 19-5, *A*). The patella also rides higher in the trochlear groove of the femur and may be noted in radiographs, but not by palpation. Considerable joint effusion, soft tissue swelling, ecchymosis, and

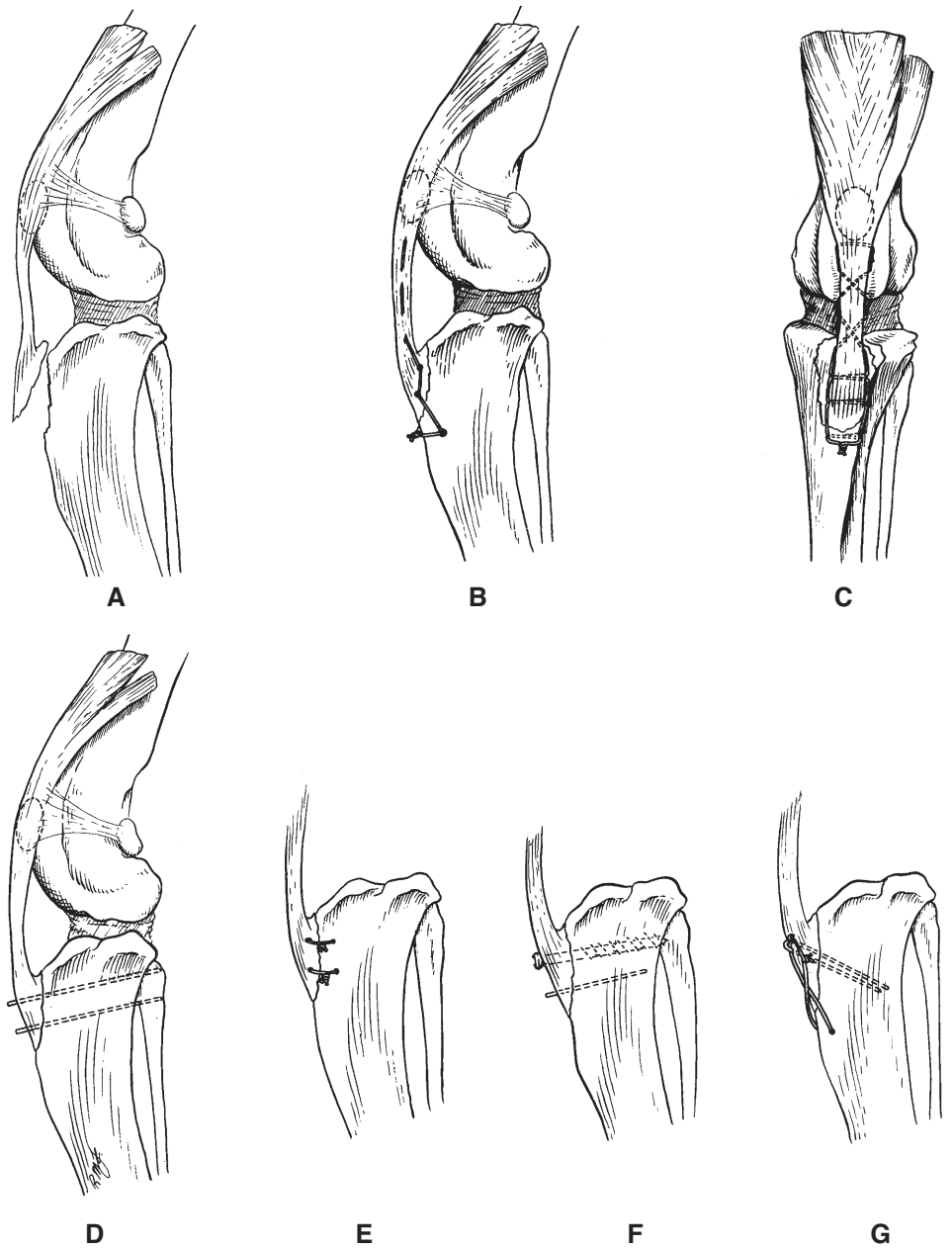


FIGURE 19-5. Operative treatment for the avulsed tibial tubercle. **A,** Type A1 avulsion. **B** and **C,** Ligament-bone suture technique using nonabsorbable suture material. **D,** Two Kirschner wires. **E,** Two stainless steel wire sutures. **F,** Cancellous bone screw and pin. **G,** Tension band wire.

lameness characterize the first 3 to 4 postinjury days. There are varying degrees of avulsion, from just a few millimeters to complete detachment, as seen in Figure 19-5, *A*. If in doubt about the displacement, the radiograph should be compared with one of the contralateral stifle.

Closed Reduction and Fixation

Conservative management can be considered when the displacement is only partial, that is, 2 to 3 mm, with only a slight angulation of the tuberosity. If the breed is small, and if optimal athletic function is not of paramount interest to the owner, external fixation will be adequate. It is less likely to be successful in the large, active breeds, partly because of the difficulties in maintaining external fixation on these vigorous young dogs. Any of the splints or casts mentioned in the Fixation Techniques section are applicable and should be maintained 2 to 3 weeks.

Open Reduction and Internal Fixation

When avulsion is complete, failure to return the tibial tubercle to its original position results in loss of power to the quadriceps muscles and in extension of the stifle joint. Loss of function can be significant in large, athletic breeds, especially racing greyhounds. Reduction and internal fixation should be accomplished early in these cases.

A longitudinal incision is made just medial or lateral to the patella, the patellar ligament, and the tibial tuberosity. The blood and fibrin clot is removed from the original location of the tuberosity (see Figure 19-5, *A*). With the hip flexed and the stifle extended, and with a hook or small, pointed reduction forceps attached to the ligament at its insertion on the tuberosity, the tuberosity is slowly and gently pulled back into its original position. A pull is necessary to fatigue and overcome the spastic contraction of the quadriceps muscles. At this stage the tuberosity can be rather friable, and care must be taken to avoid fragmentation. The tuberosity is then anchored in place using one of the methods shown in Figure 19-5, as follows:

1. Ligament-bone suture technique using nonabsorbable suture material (Figure 19-5, *B* and *C*).
2. Two Kirschner wires (Figure 19-5, *D*). This is recommended only for small breeds and in less than total avulsion.
3. Two stainless steel wire sutures (Figure 19-5, *E*). In very young animals the bone may not be well ossified, and the wire could tear out; recommended only for small breeds and in less than total avulsion.
4. Cancellous bone screw and pin (Figure 19-5, *F*). There is some danger of implant loosening or breakage because of being loaded in bending rather than tension.
5. Pins and tension band wire (Figure 19-5, *G*). This is the preferred technique because it is biomechanically sound and is universally applicable in both large and small breeds.

Aftercare

Additional support such as an off-weight-bearing sling may be indicated for the first 2 weeks in poorly controlled or unruly patients (see Figure 2-32). Exercise should be restricted for an additional 2 to 3 weeks. If the animal has a considerable amount of growth potential remaining (large and medium breeds under 6 months and small breeds under 3½ to 4 months), the fixation should be removed as early as possible to help avoid premature fusion of the tuberosity to the shaft and eventual distal translocation of the tuberosity.

Complications

Fixation complications include avulsion of the tuberosity from the implant, wire breakage, bending of a pin, patellar luxation, and a pin through the proximal tibial growth plate.[11] These can be largely eliminated by close attention to good reduction and proper placement and size of implants (see Chapter 2). An additional problem reported by Goldsmid and Johnson[11] was deformity of the tibial plateau, thought to be caused by injury to the germinal cells of the proximal tibial epiphysis (Salter type V injury), premature fusion of the tuberosity to the epiphysis, or a combination of both. Although the authors recognized distal translocation of the tuberosity, they did not attribute any interference with function to this, unlike our experience, where late lameness has been associated with this complication.

Type A2, Simple, Physeal

Type A2 physeal proximal fractures are usually Salter type I (Figure 19-6, *A*) or type II (Figure 19-6, *B*) injuries (see Chapter 22). After skeletal maturity, fractures in this region are slightly more distal (see Figure 19-7). The entire epiphysis and tibial

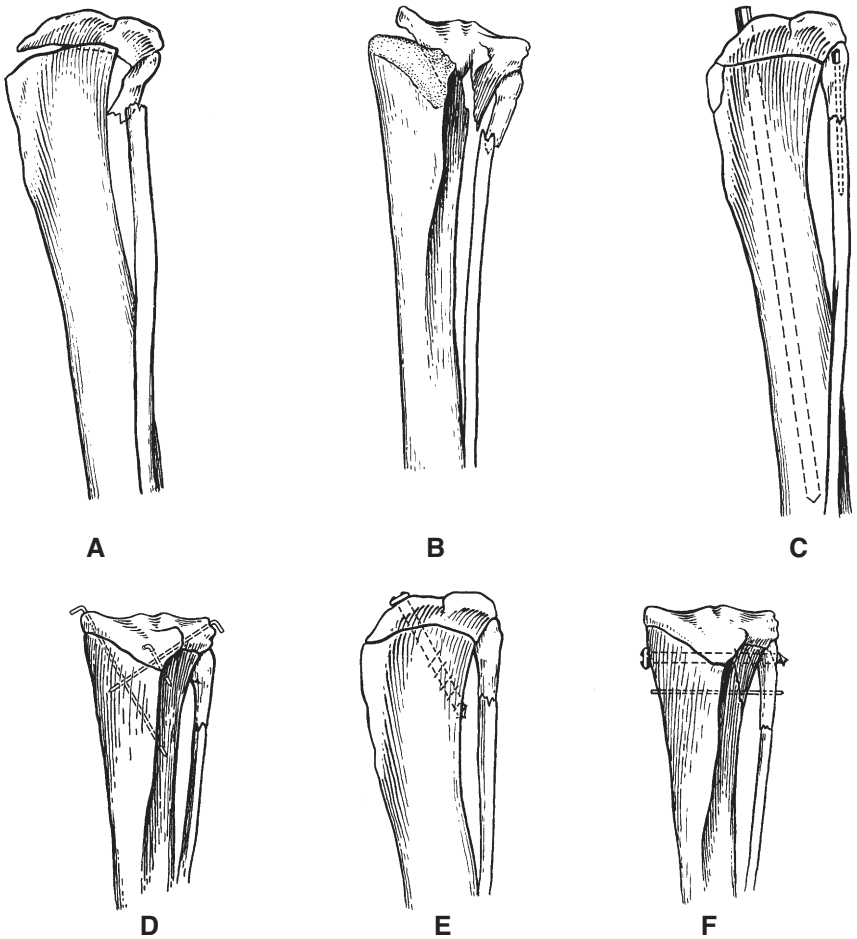


FIGURE 19-6. Fixation methods for type A2 simple fractures. **A,** Epiphyseal separation of the proximal tibia and fracture of the fibula. **B,** Fracture-separation of proximal tibia and fibular fracture. **C** and **D,** Insertion of pins through the epiphysis distally into the tibia. If it is unstable, the fibula may also be pinned. **E,** Insertion of a cancellous bone screw. **F,** Insertion of bone screws in a transverse direction, indicated in some impacted fractures.

tuberosity are usually involved, and the tendency is for dislocation in a caudolateral direction in relation to the tibial shaft. Occasionally the epiphysis will separate from the tuberosity. This injury may be accompanied by damage to the ligamentous structures (collateral ligaments in particular), which may vary from a sprain to a complete rupture. If the fracture is not reduced and maintained in position, both function and appearance are affected.[9]

Closed Reduction and Fixation

In some cases, further reduction is not essential, or it can be accomplished by closed means. Immobilization is achieved by a modified Thomas splint or long lateral splint for 2 to 3 weeks (see Figures 2-24 and 2-25). The splints are usually applied with the stifle in the angulation of the standing position. In addition, the Thomas splint can be attached so that some outward force is exerted on the medial surface of the proximal tibia, which aids in maintaining reduction. If this technique is used, the modified Thomas splint must remain firmly attached and kept in good repair. Loosening invariably results in a crooked leg.

Open Reduction and Internal Fixation

In most cases of type A2 physeal fractures, an open approach is necessary for returning the epiphysis to its proper position. A longitudinal skin incision is made on the craniomedial surface of the proximal tibia and stifle. In some cases it is advantageous to make the skin incision on the craniolateral surface of the proximal tibia and stifle. Reflection of the proximal belly of the tibialis cranialis muscle may aid in exposing the fracture to best advantage for reduction and fixation, particularly if a portion of the metaphysis remains attached to the epiphyseal end laterally. By gentle elevation of the epiphysis with an osteotome or similar instrument, the dislocated part can usually be levered back into position. It may be necessary to dislocate the proximal end farther, remove the blood and fibrin clot, and then reduce by levering. If the fibula is fractured and overriding, its reduction may be helpful in supporting and restoring length to the lateral surface. If the fibula cannot be reduced and is interfering with reduction of the epiphysis, it can be shortened to eliminate the interference. The method of fixation varies. Usually, one of the techniques shown in Figure 19-6 will accomplish the objective, as follows[9,10]:

1. Insertion of a Steinmann pin in the usual manner through the epiphysis and distally into the tibia (Figure 19-6, *C* and *D*). There may not be good rotational stability in some cases. The fibula may also be pinned in large breeds or an angled transfixation added, as described next, to provide rotational stability.
2. Transfixation by multiple Kirschner wires or small Steinmann pins (Figure 19-6, *D*). This is probably the easiest and most versatile fixation method. The medial and lateral pins are started near the periphery of the tibial plateau, where they do not interfere with the femoral condyles. These pins should penetrate the opposite cortex for best stability, and the proximal ends are bent away from the bone to further protect the femoral condyles. One pin medially and one laterally are often adequate, but a third one in the tibial tuberosity adds even better three-point stability. This pin need not penetrate the opposite cortex.
3. Insertion of a cancellous bone screw (Figure 19-6, *E*). This method is restricted to patients close to skeletal maturity so that there is no interference with growth.
4. Insertion of one or more cancellous bone screws in a transverse direction, indicated in some Salter type II fractures (Figure 19-6, *F*).

Aftercare

Additional support such as an off-weight-bearing sling may be indicated for the first 2 weeks in poorly controlled or unruly patients (see Figure 2-32). Exercise should be restricted for an additional 2 to 3 weeks. If the animal has a considerable amount of growth potential remaining (large and medium breeds under 6 months and small breeds under 3½ to 4 months), screw fixation should be removed as early as possible to help avoid interference with the growth plate. Pin fixation need not be removed unless it loosens and migrates.

Type A2, Simple, Nonphyseal

Fractures occurring in the proximal metaphysis of the tibia and fibula are usually transverse, impacted, or short oblique in nature.[9,10] If the proximal segment is dislocated, it will usually be tilted caudally (Figure 19-7, *A*).

Closed Reduction and Fixation

In some cases, reduction can be accomplished by closed manipulation and fixation by a modified Thomas splint (see Figure 2-25), long lateral splint (see Figure 2-24), or a Steinmann or Rush IM pin that is inserted normograde.

Open Reduction and Fixation

Most often, an open approach is indicated for reduction. In these cases, fixation is usually accomplished by the insertion of a Steinmann pin (Figure 19-7, *B*), a Rush pin (Figure 19-7, *C*), a medial bone plate, or rarely a cancellous bone screw (Figure 19-7, *D*). Additional filling with autogenous cancellous bone graft may rarely be indicated in some fractures in which a deficit remains after reduction. If the proximal end of the fibula is fractured and detached, it should be reattached by use of a bone screw because the lateral collateral ligament inserts on its lateral surface.

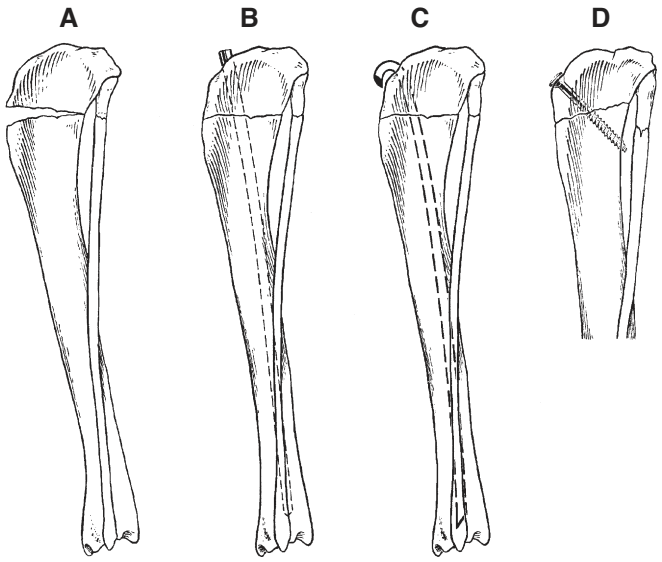


FIGURE 19-7. **A,** Type A2 simple fracture of the proximal metaphyseal area of the tibia and fibula. **B,** Fracture reduced and Steinmann intramedullary pin inserted. **C,** Fixation with Rush pin. **D,** Fixation with a cancellous lag screw.

Aftercare

Usually, no auxiliary immobilization is needed with IM pinning, bone screw fixation, or bone plating with type A2 nonphyseal proximal fractures. Exercise is severely restricted until clinical union, with a gradual return to full activity 1 month later.

Type A3, Multifragmentary

Type A3 is an infrequent fracture in the dog and cat. There is no real possibility of closed reduction and external fixation because of the instability of the fracture pattern. Open reduction and internal fixation are the norm, and the fracture is approached as described earlier. Buttress plate fixation by means of a T-plate is the most practical method of fixation (Figure 19-8). The plate must be applied on the side of the comminution to function as a buttress. Contouring of the plate is complicated on the lateral side by the extreme curvature of the metaphysis in this region. The two proximal screws must be carefully directed to avoid entrance into the joint surface. If possible, a third screw is directed into the proximal fragment. Aftercare is as described above for type A2 nonphyseal fracture.

Use of an external fixator may be possible if plate fixation is not an option. A hybrid type II-III splint can be applied as illustrated for distal radial fractures (see Figure 13-23). If the proximal segment is long enough for three fixation pins, the type IB two-plane fixator shown later is applicable (see Figure 19-16, *A*).

Fracture Type 4-1-B; Proximal, Partial Articular (Figure 19-4, *B*)

Unlike the case in humans, partial articular fractures are uncommon in quadripeds (Figure 19-9, *A*); when they occur, however, type B fractures are potentially devastating injuries because severe degenerative joint disease results from untreated or

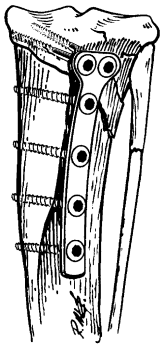


FIGURE 19-8. Fixation of type A3 multifragmentary, some type B3 partial articular, and most type C complete articular fractures will require a buttress plate. The T-plate is usually the most adaptable to this situation.

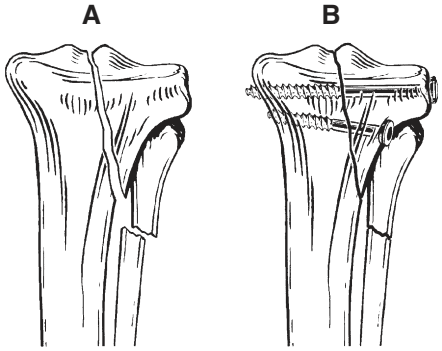


FIGURE 19-9. **A,** Type B1 lateral simple fracture of the proximal tibia. **B,** Fixation by two cancellous lag screws. The proximal screw is inserted parallel, and as close as possible, to the tibial plateau articular surface. The second screw ideally should be perpendicular to the fracture line, but the acute curvature of the lateral cortex here makes it difficult to insert the screw at that angle.

inappropriately treated cases. Fractures involving the medial condyle of the tibia are more demanding, since there are more weight-bearing forces on the medial side than the lateral side. As with all intraarticular fractures, precise anatomical reduction and rigid internal fixation are essential.

Reduction and Internal Fixation

Open approach to the area is by a medial or lateral parapatellar approach to the stifle,[12] with extension of the skin incision distally to expose the metaphyseal region, as for extraarticular fractures. The reduction must be viewed from within the joint to ensure the accuracy of reduction.

Fixation by lag screw is imperative to obtain good fixation (Figure 19-9, *B*). The interfragmentary compression obtained by screw fixation is the only method that will resist the shear forces present at the fracture line. Simple pin fixation is not appropriate here. Two lag screws are advisable if the fragment is large enough. The screws are paired horizontally or vertically, depending on the shape of the fragment.

Aftercare

Additional support such as an off-weight-bearing sling may be indicated for the first 2 weeks in poorly controlled or unruly patients (see Figure 2-32). Exercise should be severely restricted for an additional 4 to 6 weeks, then slowly returned to normal at about 12 weeks postoperatively. The implants are rarely removed.

Fracture Type 4-1-C; Proximal, Complete Articular

(Figure 19-4, *C*)

Even less common than type B partial articular fractures, complete articular fractures are treated by a combination of methods described earlier in this section. Reconstruction of the articular surface and fixation by lag screws is the first consideration.

Plate fixation of the metaphyseal part of the fracture is the most common and easiest method and is similar to that shown in Figure 19-8 for type A3 fractures. Because of the necessity for at least two and preferably three screws in the proximal fragment, T-plates are the usual choice. If the animal is small enough that 2.7-mm screws are appropriate (see Figure 2-75), two cuttable plates (Synthes, Ltd., Paoli, Pa) side-by-side can provide several screws in the proximal fragment. The proximal screws are usually inserted in lag fashion to secure fragments. If the fragments are entirely reducible and can be compressed by lag screws (type C1), the plate will function as a neutralization plate. If the fragments are irreducible, as in type C2 and C3 fractures, the plate must function as a buttress. Aftercare is as previously described for type B fractures.

Use of an external fixator for metaphyseal fixation may be possible if plate fixation is not an option. The intraarticular portion of the fracture must be reduced and stabilized by lag screws. Depending on the position and planes of the fracture lines, it may be possible to apply a hybrid type I-II splint as illustrated for distal radial fractures (see Figure 13-23). The fixation pins can be applied across, but not within, fracture lines. If the proximal segment is long enough for three fixation pins, the type IB two-plane fixator shown later may be applicable (see Figure 19-16, *A*).

DIAPHYSEAL FRACTURES

The tibia is the third most common long bone fractured, after the femur and radius/ulna,[2] and diaphyseal fractures account for 75% to 81% of all tibial fractures.[1,5]

Oblique and spiral fracture patterns are the most common in all ages, whereas multifragmentary fractures are seen most often in adults, as are open fractures.[5] Although clinicians typically believe that tibial fractures, especially of the distal diaphysis, heal more slowly and less predictably than in other long bones, this is not supported by facts; in a series of 195 fractures of canine and feline tibial diaphyseal fractures, the nonunion rate was only 4.1%.[5] Treatment recommendations are keyed to the fracture patient scoring system detailed in Table 2-6.[3,4]

Open Approach

Shaft fractures are invariably approached from a medial or craniomedial skin incision, since there are no significant muscles on the medial side of the crus (Figure 19-10). If access is required to the lateral cortex, it is easily attained by elevating the tibialis cranialis muscle.

Fracture Type 4-2-A; Diaphyseal, Simple or Incomplete

(Figure 19-11, *A*)

Type A1, Incomplete Tibial or Fibula Intact

Fracture patient scores of 9 to 10 are typical for these fractures (Table 2-6), which are seen primarily in immature animals. Because an intact fibula in the immature animal will maintain length, these fractures can be handled with either a long-leg cylinder cast or a Thomas splint (see Figures 2-21 and 2-25). In a young animal, less than 6 months old, a long lateral splint will usually suffice (see Figure 2-24). See previous discussion in Fixation Techniques relative to cast fixation.

Type A2, Simple Oblique Tibial

Because of their instability relative to shortening, simple oblique tibial fractures are not suitable to external coaptation.

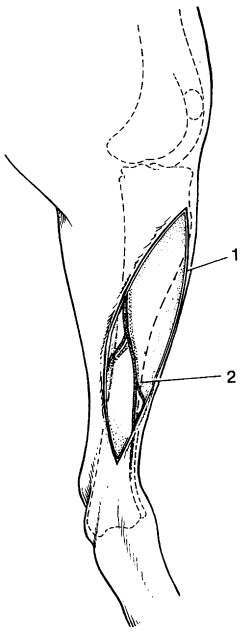


FIGURE 19-10. Approach to the shaft of the tibia.[12] *1,* Craniomedial skin incision showing approximate location of medial saphenous vessels and nerve. *2,* With care, the saphenous vessels and nerve, which cross the field obliquely in the middle third of the tibia, can be avoided. This approach can expose the entire length of the tibia.

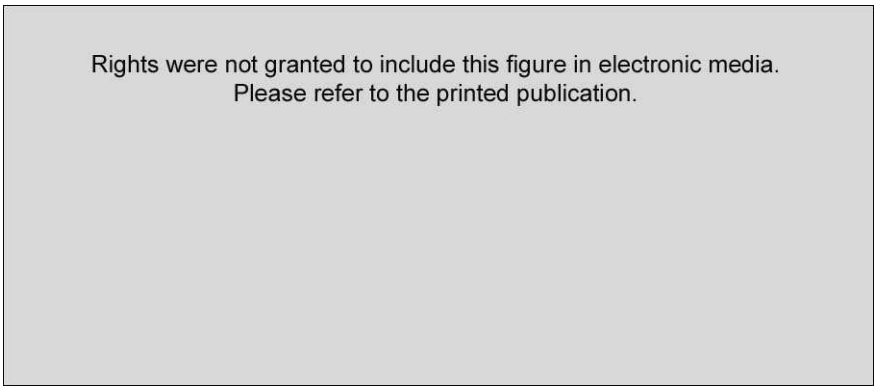


FIGURE 19-11. Diaphyseal fractures of the tibia. **A:** *A1,* Incomplete tibial or fibula intact; *A2,* simple oblique tibial; *A3,* simple transverse tibial. **B:** *B1,* One reducible wedge; *B2,* reducible wedges; *B3,* nonreducible wedges. **C:** *C1,* Reducible wedges; *C2,* segmental; *C3,* nonreducible wedges. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

Open Reduction and Fixation

A variety of fixation choices are available, depending on fracture patient score and available equipment.

Intramedullary Pin. In immature animals, typically with a fracture patient score of 9 to 10, simple Steinmann pinning will suffice (see Figure 19-1), since early callus formation would be expected to aid in providing rotational stability.

Intramedullary Pin and Auxiliary Fixation. With the long oblique fracture shown in Figure 19-3, *A,* the fracture patient score typically would be 8 to 9. If the fracture line length is at least twice the bone diameter, cerclage wires are placed at about 1-cm intervals (see Figure 19-3, *B*). In large patients, there may be an option to replace the cerclage wires with lag screws (see Figure 19-3, *C*). If the length of the fracture line is less than twice the bone diameter, the fracture is treated as a transverse type A3 fracture.

Interlocking Nail. Interlocking nails may be applied with closed reduction or minimal open reduction (see Figure 19-3, *E*). Nail sizes of 4.0, 4.7, 6.0, and 8.0 mm are applicable to tibia fractures for most sizes of dogs and large cats. Auxiliary fixation with cerclage wires may be used for long oblique fractures.

External Fixator. Type IA or IIA and B external skeletal fixators are easily applied here (Figure 19-12), often by closed, or minimal open, reduction (see Fixation Techniques). Auxiliary fixation in the form of interfragmentary Kirschner wires or lag screws can be used in oblique fractures.

Bone Plate. Neutralization plating of these fractures is an "elegant" method in the sense that it is applicable to animals of all sizes, the results are quite predictable, and minimal aftercare is required. The technique is identical to the medial neutralization plate shown applied to a type B1 wedge fracture in Figure 19-13. Six to eight cortices should be captured by the plate screws (see Figure 2-75 for choice of plate size).

Type A3, Simple Transverse Tibial

In skeletally immature dogs, a fracture patient score of 9 to 10 is usual, whereas in older animals and larger breeds it may go down to 8 (see Table 2-6).

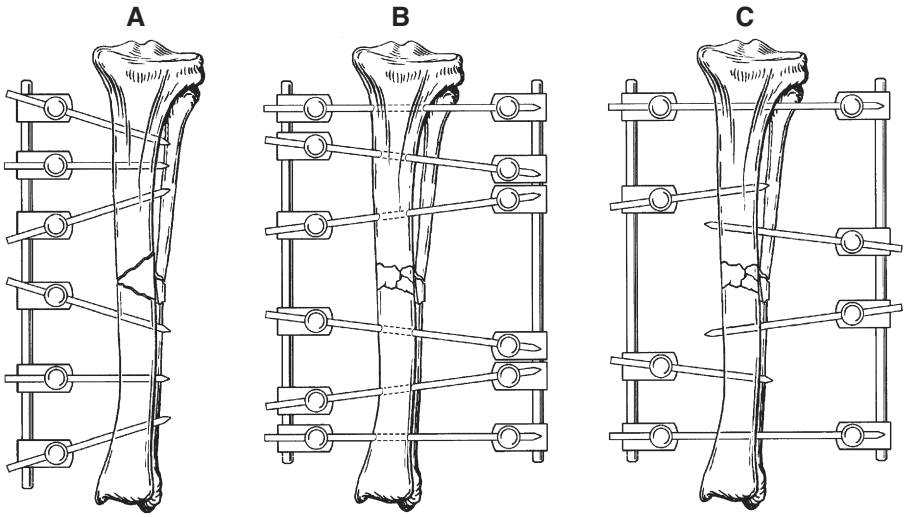


FIGURE 19-12. External skeletal fixation of diaphyseal fractures of the tibia. **A,** Type IA fixator on a wedge fracture. **B,** Type IIA full-pin fixator on fracture with several wedges. **C,** Type IIB fixator with half pins in the middle positions is simpler to apply than the type IIA, at a cost of some loss of stiffness.

Closed Reduction and Fixation

In theory, simple transverse tibial fractures are treatable by closed reduction and external fixation by cast or splint. This method should be reserved for fractures at or below midshaft, since it is difficult to achieve good stability of the proximal fragment by cast or splint if the fragment is short. Short-legged or heavily muscled breeds also present a problem in this regard. See the discussion earlier under Fixation Techniques relative to cast fixation.

Reduction and Internal Fixation

Providing rotational stability is the primary concern in these fractures. Age and size of the patient are important determinants as to type of fixation.

Steinmann Pin. If the patient is less than about 6 months of age, the exuberant callus expected will compensate considerably for lack of rotational stability, and simple Steinmann pin fixation would be adequate. In mature dogs, however, some additional auxiliary fixation is needed. If the patient is less than 15 to 20 pounds (7.0-9.5 kg), interfragmentary wire fixation is often adequate. These patterns are described in Chapter 2 (see Figure 2-63). The wires must be properly oriented on the bone to counteract the external rotation of the distal fragment that characterizes tibial fractures. Such wire fixation must be carefully applied to ensure that the wire is truly tight, and this author is very conservative in recommending it.

Interlocking Nail. The interlocking nail is most applicable to mature dogs greater than 20 pounds (see Figure 19-3, *E*). The interlocking screws counteract rotation at the fracture site until callus has developed. The nail may be applied with closed or minimally open surgical technique.

External Fixator. Fixators are applicable as described for type A2 diaphyseal fractures and are usually applied in a closed manner (see Figure 19-12).

Bone Plate. Compression bone plate fixation is a very simple and highly effective method of treatment in animals of all sizes, especially large and giant breeds. Six to eight cortices should be captured by the plate screws (see Figure 2-75 for choice of plate size).

Aftercare

See aftercare suggestions at the end of this section on diaphyseal fractures.

Fracture Type 4-2-B; Diaphyseal, Tibial Wedge (Figure 19-11, *B*)

None of these tibial wedge fractures is amenable to coaptation fixation because of their instability. Fracture patient scores are usually in the 4 to 7 range and occasionally as low as 3. If the wedges are reducible, a reconstructive approach can be taken with several fixation methods. If the wedges are not reducible, the choice of fixation is bone plating, bone plating with IM pin, external skeletal fixators, or interlocking nail.

Type B1; One Reducible Wedge

If there is only one reducible wedge, and if the fracture lines are long enough for cerclage wire fixation, an IM pin is possible, especially in small and medium-sized breeds with a fracture patient score of 6 to 7. Lag screw and neutralization plate fixation is a better option in larger animals (Figure 19-13), for which the fracture patient score could be 5 to 6. A minimum of six cortices must be captured by plate screws in each of the proximal and distal segments. Cerclage wire fixation can be substituted for lag screws in some cases. An external fixator of either type I or type II can be substituted for the bone plate (see Figure 19-12).

Type B2; Several Reducible Wedges

Increasing instability and complexity drive fracture patient scores to 4 to 6. Intramedullary pinning with cerclage wire fixation is not reliable, especially in large breeds. Neutralization plating and external fixators are the primary choices for fixation. Although the wedges are reducible, bridging fixation is also an option,

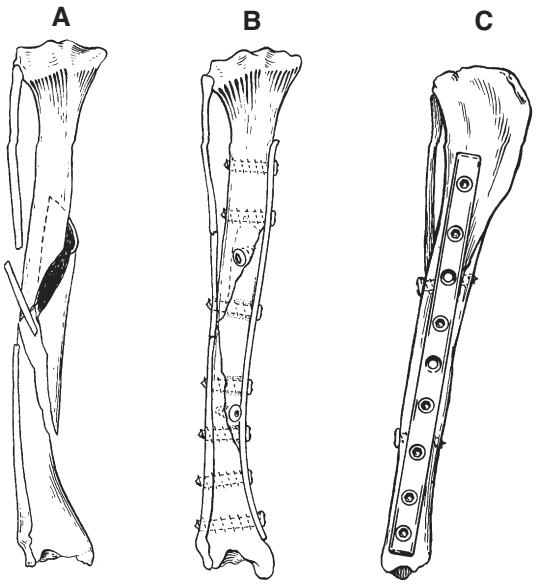


FIGURE 19-13. **A,** Multiple fracture of the tibia. **B** and **C,** Shaft has been anatomically reconstructed using two lag screws. Neutralization plate is applied on medial surface of tibia.

as described later for type C3 fractures. Bridging or buttress plate, pin and buttress plate combination, and interlocking nail are suitable choices for fixation.

Type B3; Nonreducible Wedges

Although not all the fragments can be reduced and stabilized, the bone still is able to assume some buttress function, and shortening of the bone is not the major problem as long as the major diaphyseal sections are held in alignment. It is best to take a biological osteosynthesis approach to these fractures because total reduction is not possible; on the other hand, a bridging or buttress fixation is not always needed. Fracture patient scores are typically 3 to 5.

Reduction and Internal Fixation

Bone Plate. The principles of biological osteosynthesis can be respected during plate fixation only if the surgeon resists the urge to attempt reduction of the fragments. The fracture hematoma and fragments should be disturbed as little as possible, consistent with reduction of the major diaphyseal fragments. If possible, the fracture should be placed under compression with the plate, which will add stability. Six to eight cortices must be captured by plate screws in each major segment.

The major problem with plate fixation occurs when the nonreducible fragments are on the lateral cortex, which is the natural buttress cortex. Failure to place bone graft in this area (see Chapter 3) can lead to plate failure resulting from repetitive bending stresses applied to the plate over a very short segment of the plate. If the fragmented area of the lateral cortex is relatively small or is in other areas of the cortex, autogenous cancellous bone graft will stimulate early callus formation and relieve the bone plate of bending stress. Larger, nonreduced areas on the lateral cortex can be physically reinforced by onlay or inlay grafts supplemented with autogenous cancellous graft (see Figure 3-3, *E*).

Bone Plate and Pin Combination. Another method to reinforce a bone plate subjected to bending stress is to use it in combination with an IM pin. The IM pin is placed first to allow efficient alignment of the major fragments with minimal disruption of the fracture site. A pin diameter is selected that will fill approximately 35% to 40% of the diameter of the medullary space. This diameter allows proper placement of the pin in the medullary space of the tibia to preserve alignment of the bone and also allows placement of bicortical screws through the plate (see Figure 19-15, *C*). If interference with the pin is encountered, unicortical screws may be placed. A minimum of three monocortical screws and one bicortical screw above and below the fracture is recommended.[13] Autogenous cancellous bone graft placed at the fracture site will encourage early healing.

External Fixator. Bending stresses caused by loss of the lateral cortex are less critical with type II fixators than with plates. A minimum of six fixation pins is recommended (see Figure 19-12). Closed reduction or limited open reduction (biological osteosynthesis) is the best choice for application because this will result in the least disruption of the vascular supply to the fragments (see Fixation Techniques). Proximal or distal fractures with a very short segment may require a type IB biplanar splint with three pins in the short fragment (see Figure 19-16, *A*).

Interlocking Nail. Whereas the standard Steinmann IM pin has little value in unstable fractures, the interlocking nail provides axial and rotational stability for this fracture type. The surgeon can use a minimally invasive approach for nail insertion, consistent with concepts of biological osteosynthesis. Considering the early reports

of nail failures on long-bone fixation with the interlocking nail,[8] this system should not be selected unless the interlocking screws can be positioned 2 cm from the fracture site in an average-sized dog.

Aftercare

See aftercare suggestions at the end of this section.

Fracture Type 4-2-C; Diaphyseal, Tibial Complex

(Figure 19-11, *C*)

As stated for wedge fractures, none of these injuries is amenable to coaptation. Fracture patient scores will be 1 to 3 or 4.

Type C1, Reducible Wedges

Type C1 fractures are similar to type B2 fractures, differing mainly in the amount of the diaphysis involved with the wedges, and their fixation is similar. Although the wedges are reducible, there is also the option of bridging fixation, as described for type C3 fractures.

Type C2, Segmental

Segmental fractures are treatable by either plates or external fixators (Figure 19-14). With dynamic compression plates, both fracture lines can be compressed, as shown in Figure 2-72. A minimum of four cortices must be captured by plate screws in each of the bone segments. The disadvantage with plate fixation is the need for a very long plate if the middle bone fragment is long. External fixators of type I or II are both applicable to segmental fracture. A minimum of two fixation pins is required in each fragment or three pins in each end segment.

Type C3, Nonreducible Wedges

Plate fixation in the bridging or buttress mode or in combination with an IM pin is applicable to type C3 fractures (Figure 19-15). The plate is supplemented with autogenous cancellous bone graft in the fragmented area.

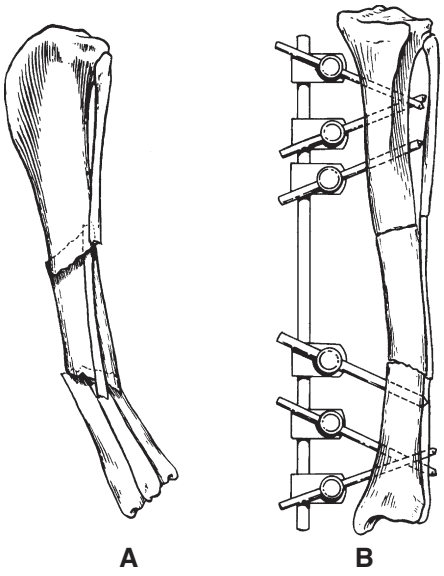


FIGURE 19-14. Unilateral external fixator, 3/3 pins. **A,** Open multiple fracture of the tibia. **B,** Splinting offers rigid uninterrupted fixation of fracture segments without invading the contaminated area. The use of 3/3 pins helps to further distribute the forces to which the pins are subjected, thus reducing the possibility of pin loosening before clinical union.

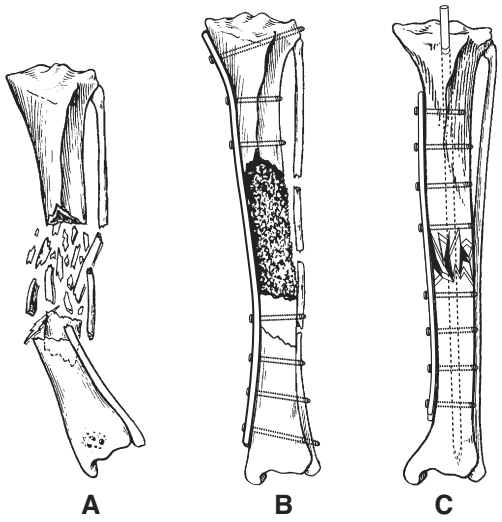


FIGURE 19-15. Multiple fracture of the tibia in a 10-year-old dog. **A,** Entire center portion is greatly comminuted. **B,** After application of a buttress plate, the small fracture fragments were left in place and the imperfections filled with autogenous cancellous bone. **C,** Buttress plate can be protected from bending stress by first placing an intramedullary pin. Pin size selection of 35% to 40% of the width of the medullary canal allows placement of bicortical screws.

Interlocking nail fixation is also applicable to nonreducible wedge fractures (see Figure 19-3, *E*). Proper nail selection is important, with a minimum distance of 2 cm between the fracture site and the nearest screw hole.[8] If sufficient distance is unavailable, another fixation system should be chosen.

Although bone plate fixation is feasible, these fractures heal more reliably and faster when a more biological approach is taken, with closed or limited open reduction and external skeletal fixation. Closed reduction or limited open reduction (biological osteosynthesis) is the best choice for application because this will result in the least disruption of the vascular supply to the fragments (see Fixation Techniques). Type II external fixators are sufficient for patients with the highest fracture patient scores for diaphyseal tibial fractures (see Figure 19-12, *B* and *C*). A short proximal or distal segment is an indication for the type IB biplanar splint or a type III splint in the largest breeds (Figure 19-16, *A* and *B*). The use of positive-profile threaded fixator pins and the new stiffer external fixation systems (IMEX SK) will enhance fixation longevity and fracture fixation stability (see Chapter 2).

Aftercare

Ideally the animal would be allowed early, limited active use of the limb. This requires totally stable internal fixation, good owner compliance with confinement and exercise restrictions, and a patient that will not overstress the repair because of hyperactivity. If any of these elements is less than optimal, an off-weight-bearing sling is advisable for 2 to 3 weeks (see Figure 2-32), although this will not be possible if an external fixator has been placed. Exercise should be severely restricted for 6 weeks, with a gradual return to unrestricted activity 3 to 4 weeks after clinical union. Radiographs should be taken at 6 to 8 weeks to confirm clinical union before any increase in exercise is allowed.

DISTAL FRACTURES

Fractures of the distal tibia account for about 21% of all tibial fractures.[1] In a series of 43 fractures, the predominant fracture patterns were physeal and malleolar, 41% were in animals less than 1 year of age, and 37% were open fractures, primarily shearing injuries of the malleoli.[14] Despite the percentage of physeal fractures,

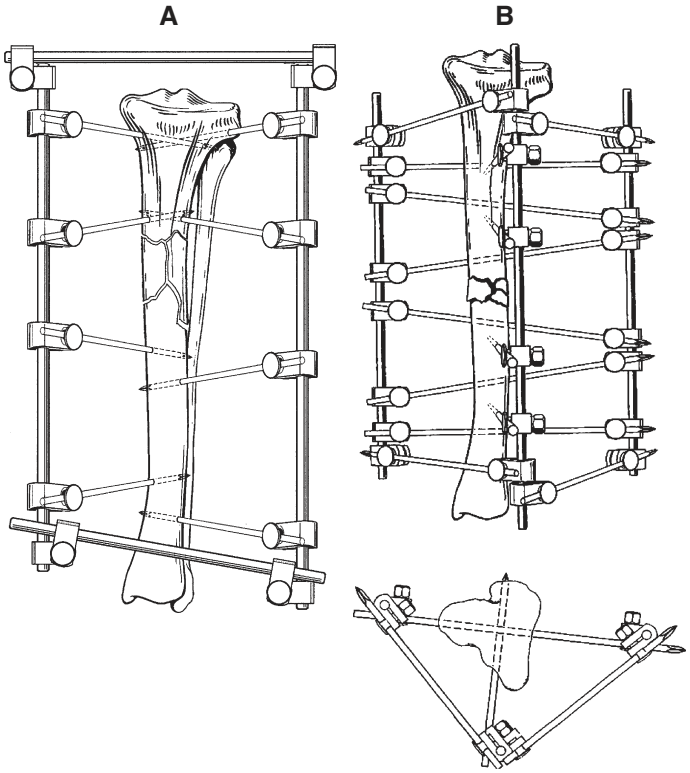


FIGURE 19-16. **A,** Type IB two-plane external fixator is useful when there is one short metaphyseal segment. **B,** Type III bilateral two-plane external fixator is used when there is a large area of bone loss or fragmentation, especially in gunshot fractures, and maximum stiffness and long-term stability are needed.

growth disturbance of the distal epiphysis is rare. Pin and wire fixation is the predominant approach because complex fractures are uncommon.

Open Approaches

Because the distal tibial region has no muscular covering, the bone is virtually subcutaneous. Proximal extension of the approaches to the malleoli shown in Figure 19-17 allows exposure of the metaphysis.

Fracture Type 4-3-A; Distal Tibia, Extraarticular (Figure 19-18, *A*)

Type A1, Simple

This fracture is observed primarily in the immature animal as a physeal fracture of Salter type I or type II (see Chapter 22). In mature animals, type A1 is a metaphyseal fracture with a very short distal segment (Figure 19-19, *A* and *B*).

Closed Reduction and Fixation

Reduction and fixation vary with the individual case. In some patients, reduction may be accomplished closed by a combination of traction, countertraction, and manipulation. If any degree of stability is obtained after reduction, fixation may be accomplished by use of a long-leg fiberglass cast or a modified Thomas splint (see Figures 2-21 and 2-25). Flexing the hock joint slightly beyond the normal

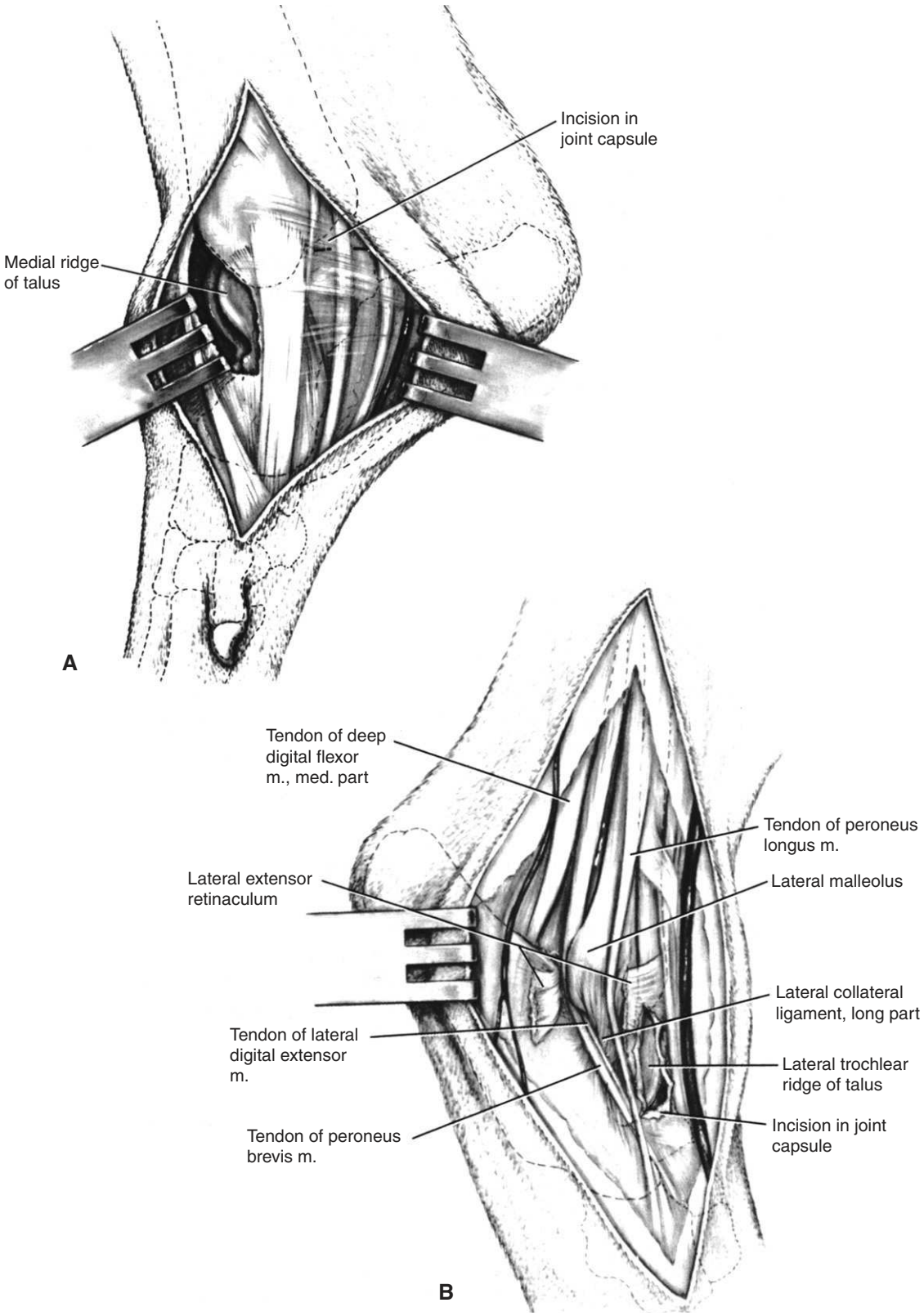


FIGURE 19-17. **A,** Approach to the medial malleolus and talocrural joint. **B,** Approach to the lateral malleolus and talocrural joint. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat*, ed 4, Philadelphia, 2004, Saunders.)

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FIGURE 19-18. Distal fractures of the tibia. **A:** *A1,* Simple; *A2,* wedge; *A3,* complex. **B:** *B1,* Lateral malleolar; *B2,* medial malleolar; *B3,* multimalleolar. **C:** *C1,* Simple, metaphyseal simple; *C2,* simple, metaphyseal multifragmentary; *C3,* multifragmentary. (From Unger M, Montavon PM, Heim UF: *Vet Comp Orthop Trauma* 3:41-50, 1990.)

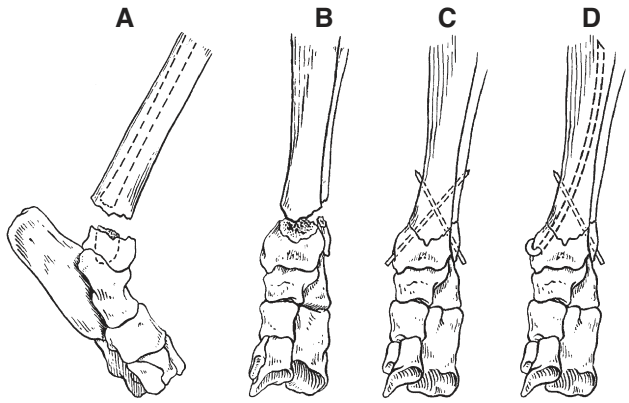


FIGURE 19-19. Fixation of a distal tibial type A1 physeal fracture. **A** and **B,** Salter-Harris I fracture of the distal tibia and fibula. **C,** Diagonally placed transfixation pins or Kirschner wires are started at the medial and lateral malleoli and driven into the opposite cortices. Supplemental coaptation fixation is also needed. **D,** Slightly more stability can be provided by placing a Rush pin from the medial malleolar region. Coaptation splintage may not be necessary if good stability is achieved. It is not usually possible to place a Rush pin similarly from the lateral side because the fibular malleolus interferes. A transfixation Kirschner wire can be used for additional rotational stability.

standing angle increases the stability. In very young patients, a short lateral splint may suffice (see Figure 2-26). Clinical union is usually achieved by 3 to 4 weeks.

Reduction and Internal Fixation

An open approach may be mandatory for satisfactory reduction in most cases; the approach is usually made on the medial side.

Transfixation Pins. The insertion of two small, diagonally placed pins starting at the medial and lateral malleoli is often the only practical method of fixation because of the shortness of the fragment (Figure 19-19, *C*). Supplemental fixation using a short lateral splint is indicated (see Figure 2-26), since rotational stability from the pins alone can be marginal. Additional rotational stability can also be achieved by a tension wire placed between the protruding pins on one or both sides.

Rush Pin. A small Rush pin can often be started on the medial malleolus and driven proximally into the shaft (Figure 19-19, *D*). Because it is difficult to insert this pin from the lateral malleolus, a small transfixation pin is used on the lateral

side to ensure rotational stability. A short lateral splint can be added if there is any doubt about rotational stability (see Figure 2-26).

Steinmann Pin. Another method of internal fixation is use of a Steinmann IM pin. The pin is inserted from the proximal end, traverses the entire length of the tibial shaft, and is anchored into the distal tibial epiphysis. The amount of anchorage gained is small but adequate if well supported by external fixation, usually a fiberglass cast or short lateral splint (see Figures 2-21 and 2-26). A transfixation pin from the medial malleolus can also be used for additional rotational stability.

Aftercare

Whichever form of immobilization is used, activity is restricted during the healing period. The external fixation can be removed when adequate primary callus has formed (in about 3 weeks). The IM pin or transfixation pins are usually removed after clinical union has been reached.

Type A2, Wedge

Type A2 fractures can be handled in basically the same manner as type A1 fractures, with the addition of some form of interfragmentary fixation of the wedge. Ideally, this would take the form of lag screw fixation, but cerclage wires may be possible in some cases. Some fractures can be adequately fixed entirely by lag screws. Transfixation by Kirschner wires is not as stable but is often adequate; supplementary external support is often essential.

Type A3, Complex

Fortunately, type A3 fractures are very rare injuries in the dog and cat because they are rarely injured while skiing, unlike their human masters. Buttress fixation is essential.

Bone Plate

Plate fixation is the best method of accomplishing the required buttress fixation. As many of the fragments as possible are stabilized by lag screws, either directly in the fragments or through the plate holes. The type of plate used is variable, depending on the size of the dog and the fracture pattern. Straight plates may be applicable in some cases, especially in large dogs. T-plates are useful if the length of the fracture area is not too long. Multiple cuttable plates spaced around the tibia may provide a method of inserting sufficient screws in the distal end to provide good buttressing. The drawback of this method is that the largest screws that can be used are 2.7 mm. Any cortical defects should receive autogenous bone grafting. External support, as described for type A1 and A2 fractures, is probably required in most cases.

External Fixator

At least two methods can be used to place external fixators in type A3 fractures. The first is the use of a hybrid type I-II splint as illustrated for distal radial fractures (see Figure 13-23), placing fixation pins across but not within fracture lines. The second method is a splint that bridges the joint and places it under tension (ligmentotaxis). Tension is applied to the distal tibial articular fragment through the collateral ligaments to maintain the bone in position. (Some transarticular fixator patterns are illustrated in Chapter 20.) The fragments can be reconstructed as best as possible by interfragmentary compression or by transfixation pinning. Alternately, they can simply be left unreduced to maximize their blood supply, a biological osteosynthesis approach. This is definitely a last resort when nothing else is possible.

Fracture Type 4-3-B; Distal, Partial Articular (Figure 19-18, *B*)

Fractures of either malleous or both malleoli give rise to instability of the tarsocrural joint, resulting in subluxation or dislocation. Many of these malleolar fractures are a result of shearing injury (see Chapter 20). The two most important factors in the treatment of articular fractures of the tarsocrural joint are the following:

1. Maintenance of integrity of the joint "mortise" created by the malleoli.
2. Complete reestablishment of the weight-bearing surfaces of the tibia and tibial tarsal bone.

The hock is functionally a hinge with motion in one plane, flexion and extension. The bony structure is designed as a mortise and tenon with considerable inherent stability. The *mortise* is formed by the lateral malleolus (distal end of fibula), distal articular surface of the tibia, and the medial malleolus. The *tenon* is the trochlea and body of the tibial tarsal bone, which is shaped to fit snugly into the mortise. The tibia and fibula and the tibial tarsal bone are bound together by numerous ligaments.

Complete malleolar fractures create ligamentous instability of the tarsocrural joint, and treatment by external fixation always results in malunion, continued instability, and eventual degenerative joint disease. Intraperiosteal fractures of the malleolus without displacement may be seen in immature animals, and these usually respond to casting or splinting.

Reduction and Internal Fixation

Rigid fixation can be best instituted by the use of bone screws, transfixation pins, or tension band wire and pins.

Lateral Malleolus

The lateral malleolus is part of the fibula and usually fractures some distance from the end, particularly in the cat (Figure 19-20, *A*). Fixation of the fracture is indirect; the fragment is fixed to the tibia. Screws are usually used in medium-sized and large dogs, and threaded Kirschner pins are used in small dogs and cats, although miniscrews in the 1.5-mm and 2.0-mm sizes are applicable in small breeds. The screws or pins should pass in a proximal direction and anchor completely through the cortex on the opposite side of the tibia (Figure 19-20, *B* and *C*). Stability of the joint should be tested after fracture fixation, and ligaments that have been ruptured should be repaired by suturing (see Chapter 20). Supplemental fixation may be indicated in the form of a short lateral splint for 3 to 4 weeks postoperatively (see Figure 2-26).

Medial Malleolus

Immobilization may be accomplished by use of a cancellous bone screw in large breeds (Figure 19-20, *E* and *F*). More widely applicable is the Kirschner wires and figure-of-8 tension band wire method (Figure 19-20, *G*). In small breeds the fixation can be accomplished with one Kirschner wire. With this fixation and restricted activity, no additional external fixation is usually needed. Bilateral malleolar fractures are treated in a similar manner (Figure 19-20, *F* and *G*).

Fracture Type 4-3-C; Distal, Complex Articular (Figure 19-18, *C*)

The least common of tibial fractures, complex articular injuries are treated by a combination of methods illustrated previously for type A and B fractures. Type C2 and C3 fractures are often a result of gunshot injury. As is typical for all complex

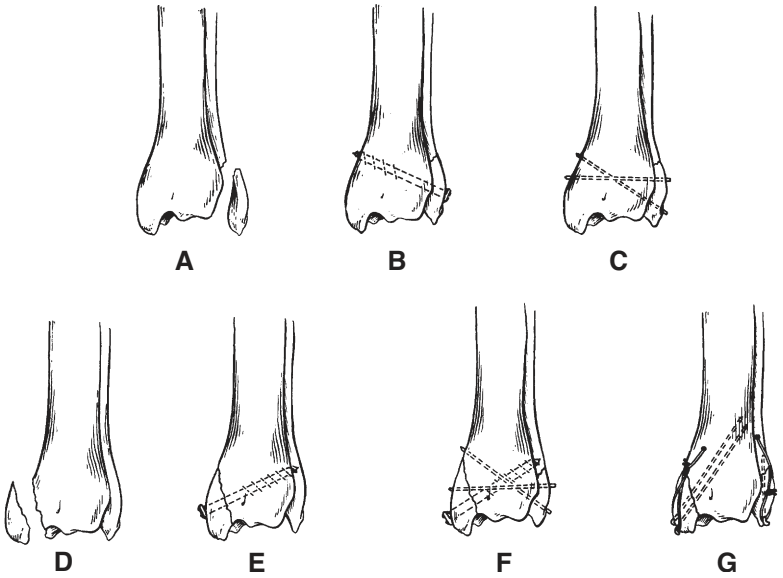


FIGURE 19-20. Malleolar fractures. **A,** Fracture of the lateral malleolus (distal end of fibula): immobilization using **B,** a cancellous screw, or **C,** two threaded Kirschner wires. **D,** Fracture of the medial malleolus. **E,** immobilization using a cancellous bone screw. **F,** Fractures of both malleoli with fixation. **G,** Fixation with two Kirschner wires and a figure-of-8 tension band wire.

fractures, the first order is to reconstruct the articular surface with lag screws parallel to the joint surface. The remaining extraarticular metaphyseal fracture is handled by the methods detailed for type A fractures. In some multifragmentary fractures, there is no hope of preserving a functional joint, and these should receive arthrodesis as primary treatment. (See Chapter 20 for a discussion of tarsocrural arthrodesis.)

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20

Fractures and Other Orthopedic Injuries of the Tarsus, Metatarsus, and Phalanges

Injuries to the tarsus generally involve fracture of one or more bones, impairment of ligaments, or occasionally a combination of both these injuries. Ligamentous injuries are most often seen in athletic animals, whereas fractures are common in a variety of animals. Ligamentous injuries of the tarsus resulting in varying degrees of instability are relatively common in athletic breeds because of the propulsive force supplied by the hindlegs. Unlike those of the carpus, tarsal injuries are more likely to be caused by spontaneous overstress rather than by outside traumatic forces. Conservative treatment of second-degree and third-degree ligamentous injuries by cast immobilization is not recommended because permanent instability is the usual result (see Chapter 7). Aggressive surgical treatment is much more rewarding, but it does require a good working knowledge of the anatomy of the region. Unfortunately, the official terminology of the tarsus differs greatly from that in current popular use.

OVERVIEW

Anatomy of the Hindpaw

The bony anatomy of the hindfoot is complicated and must be well understood before any repairs are attempted. Figure 20-1 reviews these bones and provides a comprehensive resource for interpreting radiographs. Ligaments of the hock and tarsus are shown in Figure 20-2. Beginning at the tarsocrural joint and continuing distally, the terms *cranial* and *caudal* are replaced by the terms *dorsal* and *plantar.*

The bones of the tarsus are arranged in several levels, with a complex arrangement of ligaments. The joint between the tibia and fibula and the talus and calcaneus is the *tarsocrural joint,* often called the tibiotarsal, talocrural, or hock joint. It consists of both the talocrural and talocalcaneal joints, which are continuous with

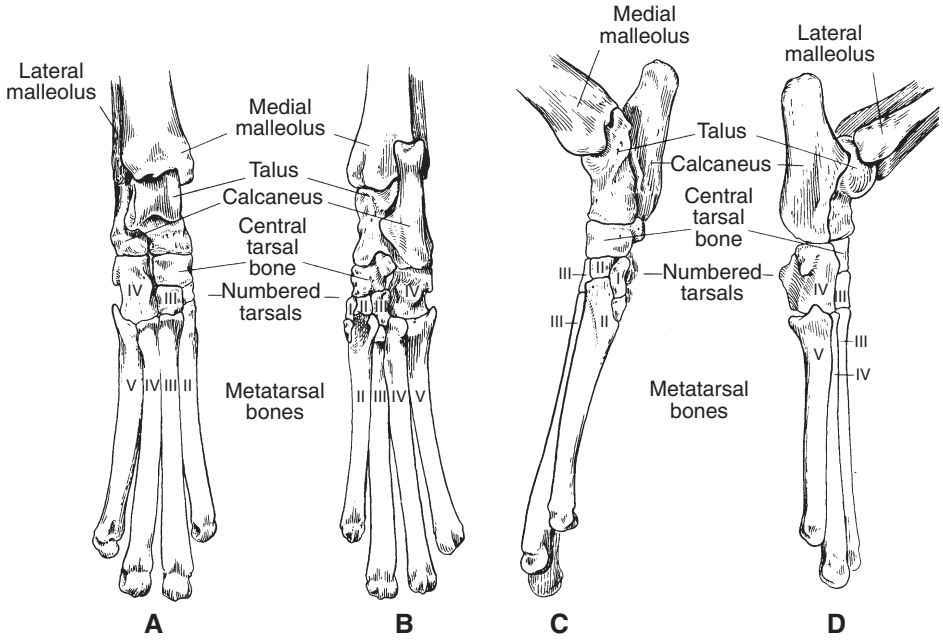


FIGURE 20-1. Bones of the tarsus, metatarsus, and phalanges. **A,** Dorsal view. **B,** Plantar view. **C,** Medial view. **D,** Lateral view.

each other. *Intertarsal joints* include all articulations between tarsal bones, with four of them named specifically, as follows:

1. *Talocalcaneal joint*. The joint between the talus and calcaneus.
2. *Talocalcaneocentral joint*. This joint is primarily an articulation between the talus and central tarsal bone, but the joint capsule is continuous with the calcaneus.
3. *Calcaneoquartal joint*. The joint between the calcaneus and the fourth tarsal. This joint and the talocalcaneocentral joint collectively are known as the "proximal intertarsal joint." This name is useful to the surgeon because of the awkwardness of the official names.
4. *Centrodistal joint*. The joint between the central tarsal bone and the distal numbered tarsal bones. The common name is the "distal intertarsal joint."

The remaining joints of the hindpaw include the following:

1. *Tarsometatarsal joints*. The joints between the distal tarsal and metatarsal bones.
2. *Metatarsophalangeal joints*. The joints between the metatarsal bones and the first phalanges.
3. *Interphalangeal joints*. The joints between the first and second and second and third phalanges.

The most common ligamentous injuries of this region involve the collateral ligaments of the tarsocrural joint (see Figure 20-2) and the plantar ligaments and tarsal fibrocartilage. Both collateral ligaments have long and short parts. The long parts serve to limit extension, and the short parts prevent hyperflexion. The plantar ligaments and tarsal fibrocartilage are tension bands that limit extension of the intertarsal and tarsometatarsal joints. The remaining ligaments are much smaller and shorter, connecting individual bones.

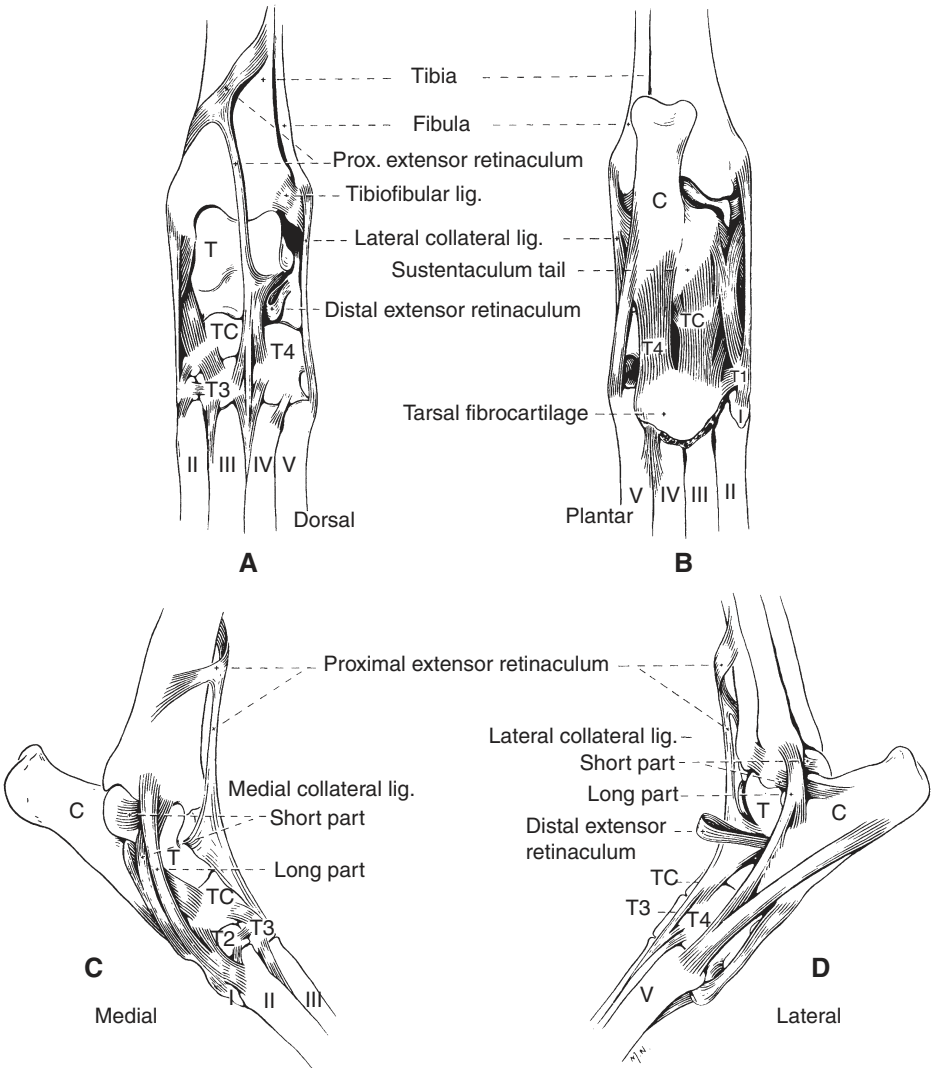


FIGURE 20-2. Ligaments of the left tarsus. **A,** Dorsal aspect. **B,** Plantar aspect. **C,** Medial aspect. **D,** Lateral aspect. *C,* Calcaneus; *T1, T3,* and *T4,* first, third, and fourth tarsals; *T,* talus; *I* through *V,* metatarsals; *TC,* central tarsal. (From Evans HE: *Miller's anatomy of the dog,* ed 3, Philadelphia, 1993, Saunders, pp 253, 254.)

Surgical Approaches and Technique

Several approaches to the bones and joints of the tarsus have been described.[1] Generally, approaches to the various bones are made directly over the injured bone or ligament because there are no muscles of any size covering them. Nerves, vessels, and tendons are retracted as necessary to allow exposure.

Surgery of the lower limbs can be done with a tourniquet, which is invaluable for decreasing oozing hemorrhage and thus increasing visibility and decreasing operating time. Although pneumatic cuffs are the best way of creating the tourniquet more proximally in the limbs, distal tourniquets can be made more simply. Vetrap (3M Animal Care Products, St. Paul, Minn) elastic bandage material has proved very satisfactory for this purpose, as illustrated in Figure 14-4. Although the bandage is best sterilized in ethylene oxide, it can be steam-sterilized at minimal time and temperature, similar to the method of sterilizing rubber gloves (250° F for 12 minutes).

Use of the tourniquet has the disadvantage of producing more postoperative swelling. Application of casts or splints should be delayed 48 to 72 hours postoperatively, with the lower limb supported in a Robert-Jones bandage during this time (see Figure 2-33).

Clinical Signs and Diagnosis of Injuries

Many tarsal injuries are a result of overstress of ligamentous structures and bone and occur without a history of known trauma. Sudden exertion, such as jumping, can be sufficient to damage plantar ligaments and cause a hyperextension injury or fracture of a metatarsal bone. Affected animals are usually non–weight bearing, have variable swelling in the tarsal region, and show varying degrees of instability of the tarsus or metatarsus. The limb is typically carried in flexion. Palpation is usually sufficient to localize the area of probable injury.

Radiographs are necessary to verify the diagnosis and to localize the damage. Stress radiographs will show the area of instability. Standard dorsoplantar and lateral or medial views, plus oblique views, will also identify avulsions and other fractures. Nonscreen film or fine-detail screens are essential.

THE TARSUS

Tarsocrural Luxation and Subluxation

Many complete luxations of the tarsocrural joint are accompanied by fracture of one or both malleoli, and internal fixation of the fractures results in stability of the joint. Treatment of such injuries is described in Chapter 19.

Clinical Signs

Rupture or avulsion of the collateral ligaments—grade 3 sprains—produces subluxation (Figure 20-3, *A* and *B*). Medial injuries allow valgus (lateral) deviation of the foot, and

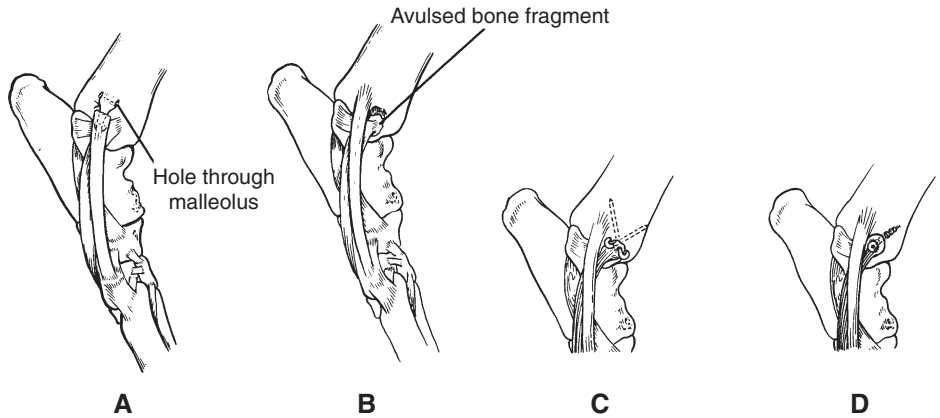


FIGURE 20-3. Collateral ligament injuries of the tarsocrural joint. **A,** Long part of the medial collateral ligament is torn near its origin on the malleolus. A hole is drilled through the malleolus, and a locking loop suture is passed through this hole to pull the ligament against the bone. **B,** Avulsion of origin of short part of the medial collateral ligament. **C,** Diverging Kirschner wires used to stabilize the avulsed fragment. **D,** Lag screw fixation is ideal if the fragment is large enough to allow screw placement.

lateral injuries allow varus (medial) angulation. These deviations are easily palpated and confirmed radiographically. Rupture of just the long or short part of the ligament produces only moderate instability and may be difficult to diagnose preoperatively.

Treatment

Principles of treatment are similar to those described in Chapter 7, such as imbricating, suturing, reattaching, or replacing ligaments as indicated. It is important to repair both the long and the short part of the ligament to achieve good function. Figure 20-3, *A,* illustrates reattachment of the long part of the ligament; a bone tunnel is used in the malleolus to anchor the suture. Figure 20-3, *B*, shows an avulsion of the short part, fixed with two diverging Kirschner wires passed through the fragment into the tibia or a small lag screw (Figure 20-3, *C* and *D*).

If good repair or reattachment of the ligament is not possible, the repair can be augmented by synthetic ligaments (see Figure 20-4, *C* and *D*). The purpose of synthetic ligaments is to provide ligamentous support to the joint until sufficient tensile strength is achieved in the healing ligament and joint capsule. Synthetic ligaments may be constructed using a screw and washer technique, or soft tissue (suture) anchors are available in numerous configurations as an alternative technique (see Figure 14-24, *D*). Tissue anchors have good pull-out strength and a low profile that may cause less tissue irritation than a screw and washer.

Aftercare

Ligamentous repairs are protected with a short lateral splint for 4 to 6 weeks (see Figure 2-26), followed by an elastic bandage for an additional 2 weeks (see Chapter 7). Exercise is restricted to leash walking until 8 weeks, then gradually increased to normal at 10 to 12 weeks.

Shearing Injury of the Tarsus

This abrasion injury occurs when the dog's lower limb is run over by the tire of an automobile with its brakes locked attempting to avoid the animal. Soft tissues in contact with the pavement are simply ground away, often eroding skin, muscle, ligaments, and even bone. The medial tarsal and metatarsal region is most often affected, with the medial malleolus and collateral ligaments often completely destroyed (Figure 20-4, *A* and *B*). One or more tarsal or metatarsal joints may be open, and various amounts of debris are ground into all the tissues. The lateral side is involved less often and represents a less serious injury than a comparable injury on the medial side. Because the dog normally stands with a few degrees of valgus (lateral) deviation of the hindpaw, ligamentous stability of the medial side of the tarsus and metatarsus is much more critical than on the lateral aspect.

Best results are obtained by treating these wounds in an open manner, with early stabilization of the joints and any accompanying fractures. Skin grafting is delayed and indicated only where granulation tissue does not adequately close the skin, which is a rare occurrence. Early or delayed arthrodesis is indicated when it is not possible to restore reasonable joint function. The following variables should be considered in choosing a plan of action:

1. Assuming that the joint(s) can be stabilized, is there enough articular surface to allow good function? Loss of bone in the tarsocrural articulation is critical. If the answer is "no," arthrodesis is indicated.
2. What will the owner accept as reasonable function? A large, active breed presents different problems from a small and sedentary animal. In the former,

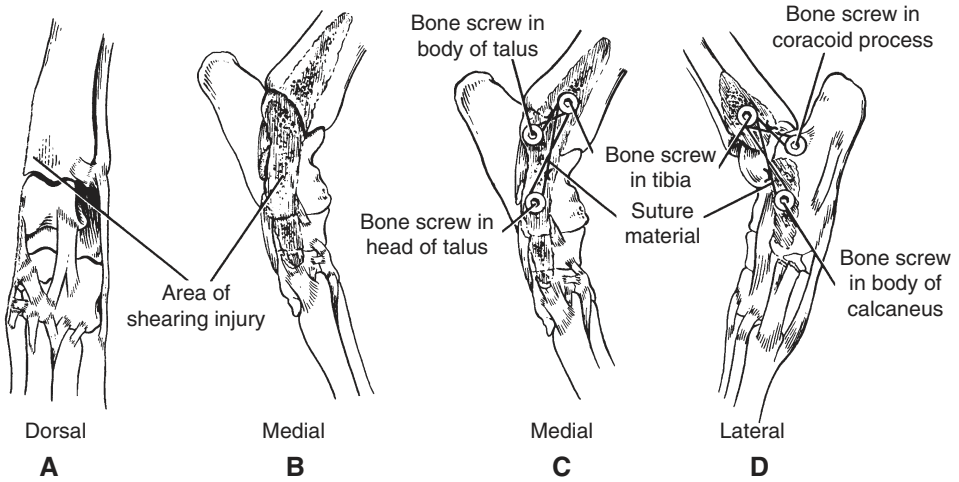


FIGURE 20-4. Shearing injury of the tarsus. **A** and **B,** Medial malleolus and medial aspects of the proximal tarsal bones have been ground away, resulting in instability and valgus deformity. **C,** Placement of medial synthetic ligaments.[2] The proximal screw is placed as distally as possible while the tibial cochlea is avoided. One screw is placed in the body of the talus to simulate the short part of the ligament, and another screw is placed in the head of the talus to simulate the long ligament. Two strands of size 0-2 braided polyester suture are placed between each of the screws and tied with the short portion taut in flexion and the long portion taut in extension. **D,** Placement of lateral synthetic ligaments.[2] Placement is similar to that of the medial side, with the screws placed in the coracoid process and base of the calcaneus.

aggressive ligamentous repair, augmentation, or replacement is necessary, whereas in the latter case it may be possible to obtain good results by very conservative methods. Stabilization of joints by scar tissue may well provide adequate support in the smaller and less active animals, but it rarely will support the tension loads of the medial side in large, athletic individuals.

3. How will support for the joints or fractured bones be provided? Regardless of which approach is taken to the ligamentous instability, the involved joints must be stabilized during the healing period. Because of the necessity for daily bandage changes for 2 to 3 weeks when treating these large open wounds, the use of conventional casts or splints is difficult. External skeletal fixators have greatly aided in solving this problem.

Reconstruction

Initial debridement must be meticulous but not too aggressive, with emphasis on removal of obviously dead tissue and foreign matter from both soft tissue and joint spaces. Copious irrigation with Ringer's or saline solution is very important at this time. Some recommend the addition of 10% povidone-iodine (after dilution of 10 parts water to 1 part 10% povidone-iodine) or 0.2% chlorhexidine. After adequate debridement, it may be possible to close the wound partially by suturing skin to minimize the amount of granulation tissue. This can be helpful, but care must be taken to do the following:

1. Leave adequate open area for unimpeded wound drainage. Placement of Penrose or tube drains under the sutured skin is usually advisable for 2 to 5 days.

2. Avoid closing skin under tension. Serious circulatory stasis develops because of the tourniquet-like effect of excessive skin tension in the lower limbs.
3. When in doubt about tissue viability, *do not suture skin.* Delayed primary closure can be done in a few days with no loss of healing time.

Several debridements over a number of days may be necessary to remove all devitalized tissue adequately because of the difficulty in determining viability of severely traumatized tissue. If portions of ligaments, joint capsule, or other tissues can be sutured to support the joint and to close the synovial membrane, this should be done. Monofilament or synthetic absorbable suture is most trouble free. Reestablishment of the tibiotarsal collateral ligament complex is usually hampered by loss of bone, and small bone screws may need to be used to anchor the synthetic ligament. There is a tendency to use monofilament wire in this contaminated area, but heavy braided polyester or monofilament nylon suture is a much more functional ligament and has resulted in very few problems related to suture sinus drainage tracts.

Three bone screws are positioned to mimic the normal ligaments as closely as possible (Figure 20-4, *C* and *D*). Precise placement of these bone screws for attachment of heavy braided polyester suture and adequate soft tissue debridement are necessary for successful treatment.[2] The proximal screw is placed as distally in the tibia as possible, bearing in mind that the tibial cochlea is recessed a considerable distance into the distal tibia and can be seen by stressing the tarsus to open the joint. The screw must not enter the joint. The distal screws are placed to simulate the insertion points of the long and short parts of the collateral ligaments. Medially, both screws are placed in the talus, with the proximal one in the body (Figure 20-4, *C*). This screw should be angled slightly distad to avoid the trochlear sulcus of the talus. The distal screw is placed in the head of the talus, approximately halfway between the base of the medial trochlear ridge and the distal articular surface. Laterally, the screws are similarly placed in the calcaneus (Figure 20-4, *D*). The proximal screw goes into the base of the coracoid process, and the distal screw is placed halfway between the distal base of the coracoid process and the distal articular surface. Double strands of heavy braided polyester suture (size 0-2) or a single strand of 40- to 60-pound test monofilament nylon fishing line are placed between the screws. The short ligament should be moderately taut in flexion and the long portion taut in extension. The sutures are tied tightly enough to stabilize the joint, but motion without binding should still be possible. The long ligament is tied with the joint in extension, and the short ligament is tied with the joint flexed. Steel washers can be used on the screws to prevent the suture from slipping over the head of the screw. Soft tissue anchors can be used as an alternative to the screw and washer technique (see Figure 14-24, *D*). Most tissue anchors require intact cortical bone for maximum pull-out strength. If the cortical bone has been lost in a shearing injury, a deeply seated screw, with washer, may be a better choice for ligament fixation than a tissue anchor.

Treatment of the open wound is simplified by use of transarticular external skeletal fixator to stabilize the joint (Figure 20-5). Fixation is maintained until granulation tissue has covered the defect, usually 3 to 4 weeks. A recently introduced external fixator hinge joint has potential for application in this situation (Jorgensen Laboratories, Inc., Loveland, Colo). This device allows for joint motion in one plane and would stabilize the joint during healing while allowing motion, which should have a beneficial effect in organizing collagen to form a pseudoligament. In either case, sterile laparotomy sponges soaked in saline or saline solutions of povidone-iodine or chlorhexidine are loosely bandaged to the limb for several days, and debridement is repeated daily or every other day until all dead tissue is removed.

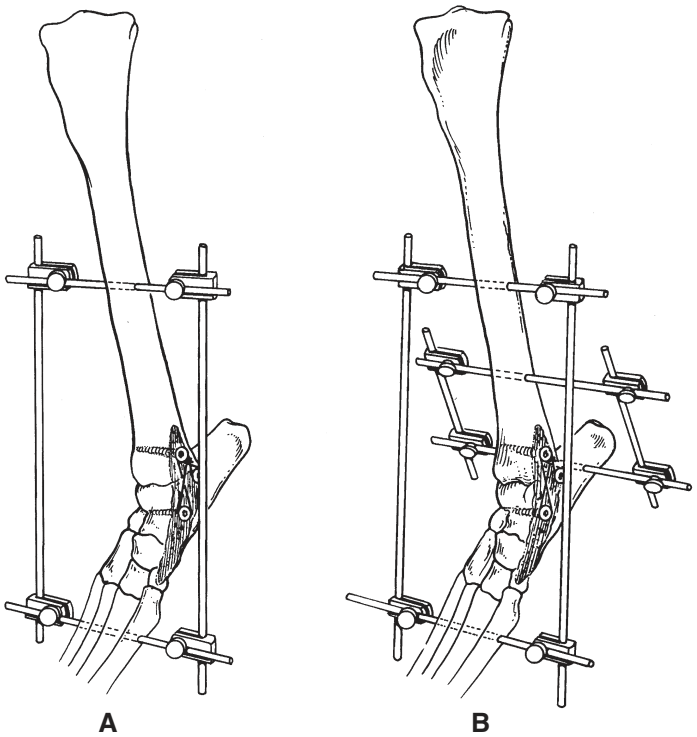


FIGURE 20-5. **A,** Simple external skeletal fixation splint used to support and protect a medial tarsocrural ligament repair in small breeds. **B,** Stiffer external fixator frame for support of ligamentous repair in large breeds.

The wound must be kept moist and provision made for adequate drainage of exudate.[3] Moist gauze with copious absorbent padding covered by a moisture barrier (e.g., polyvinyl sheet) and dressing changes are used daily until healthy granulation covers the wound. (Hydrocolloid, hydrogel, and polyethylene semiocclusive dressings have received considerable attention for treatment of full-thickness skin wounds. Hydrogel and polyethylene dressings were significantly better in all parameters tested in one study.[4]) At this point, nonadherent dressings, either dry or with antibacterial ointment, and minimal absorbent padding are used in place of the moist dressings. Intervals between dressing changes can gradually be extended as discharge lessens. The wound must be kept protected until it is well epithelialized, which may take up to 10 to 12 weeks.

Prognosis

A retrospective study of 98 shearing injuries by Beardsley and Schrader[5] revealed some previously unknown facts regarding the outcome of these cases. All were treated essentially as just described, except that none received joint stabilization by means of external fixators; all were supported in some form of external coaptation. Healing time ranged from 2 to 9 weeks, depending on the size and depth of the wound and the amount of the wound that was able to be closed by suture. A mean of 1.7 surgical procedures was performed on each patient, with a mean of 5.5 rechecks required after hospital discharge. "Good to excellent" outcome was attained in 91% of the dogs, defined as clinically normal or with only minimal functional abnormalities after healing of the injury. Only one case required skin grafting. As can be seen, these are expensive injuries because of the amount of care required, and owners not

prepared for this type care are well advised to consider amputation as a primary treatment. It is our subjective opinion that support with external fixators simplifies treatment because owners can do more therapy at home due to the absence of the coaptation splint, but we do not have data to suggest that it shortens the healing period or affects the final outcome.

Aftercare

When granulation tissue completely covers the wound, but not before 3 weeks postoperatively, the external fixator is removed. An elastic support bandage should be maintained for another 3 weeks with very restricted activity. Normal exercise is not allowed until weeks 8 to 12, depending on the stability achieved. Loosening of the bone screws and skin irritation from screw heads are both indications for removing the screws. This should not be done before 3 to 4 months postoperatively if possible. Failure to stabilize the joint adequately will result in degenerative joint disease and poor function. In such a situation, arthrodesis offers the best chance of restoring function.

Arthrodesis

Some shearing injuries of the tarsus are too extensive to be successfully reconstructed. These injuries are invariably those with extensive bone loss of the medial malleolus, tibial trochlea, and less often the condyle of the talus. If the bone loss extends into the articular surface of the tibia, there may not be sufficient articular support for the talus. Additionally, the ability to provide sufficient medial ligamentous support is questionable. In this situation, arthrodesis of the talocrural or tarsocrural joint is the best method of maintaining limb function. Although it is possible to attempt reconstruction and then follow with arthrodesis if reconstruction fails, a great deal of time and expense can be wasted.

With the use of external skeletal fixation (see Figures 20-24 and 20-25, *A*), the arthrodesis can be performed very early, before the wound is healed, with a high probability of successful fusion and a low chance of bone infection. The procedure can be delayed for a few days, until the debridement phase is complete and, it is hoped, some granulation tissue has begun to appear. The tarsus is supported during this phase entirely by the bandage, sometimes augmented by thermomoldable plastic splints or wire frames. If it seems necessary to use the external fixator immediately to support the joint, the fusion is done at the same time. The technique is performed basically as described later in this chapter under Tarsocrural Arthrodesis. The major difference is in the manner of applying the autogenous cancellous bone graft, since there must be sufficient soft tissue available to cover the graft and allow its early vascularization. Exudation is another contraindication to early grafting because the exudate may physically carry the graft fragments away. In this situation the joint debridement and fixation are completed as usual, but grafting is delayed until there is a healthy granulation tissue bed, without exudation. At that point the granulation tissue is carefully elevated from the joint surfaces sufficiently to allow the graft to be packed into the joint spaces. The area is kept covered by petrolatum-impregnated gauze sponges for several days, until granulation tissue again covers the area. Aftercare from this point onward is as described earlier.

Fractures of the Calcaneus

A calcaneal fracture is a very disabling injury because it destroys the ability of the gastrocnemius muscle and the rest of the common calcanean tendon apparatus to prevent hyperflexion of the hock joint, resulting in a plantigrade stance. As a result

of muscle tension on the tendons, there is considerable pull on the free fragment and therefore marked displacement of the fragment.

Fractures occur most often at the tuber or in the shaft (see Figures 20-7, *A,* and 20-8, *A*) and less often near the base (see Figure 20-9, *A*). Because the plantar ligament of the calcaneoquartal part of the proximal intertarsal joint originates at the base of the calcaneus, fractures in this region cause subluxation and hyperextension of this joint (see later for further discussion of tarsal hyperextension). Calcaneal fractures may be seen in the racing greyhound and are usually associated with central tarsal bone fractures. When there is no accompanying central tarsal bone fracture, there is invariably a plantar proximal intertarsal subluxation.[6]

Open Approach

The calcaneus is exposed by a lateral approach, with medial displacement of the tendon of the superficial digital extensor muscle when tension band wire fixation is employed (Figure 20-6).

Treatment

The bending loads on the free fragment in calcaneal fracture make conservative treatment with an external cast impossible. Fixation by a Steinmann pin or a screw is very questionable as well because both will usually bend, even with the limb in

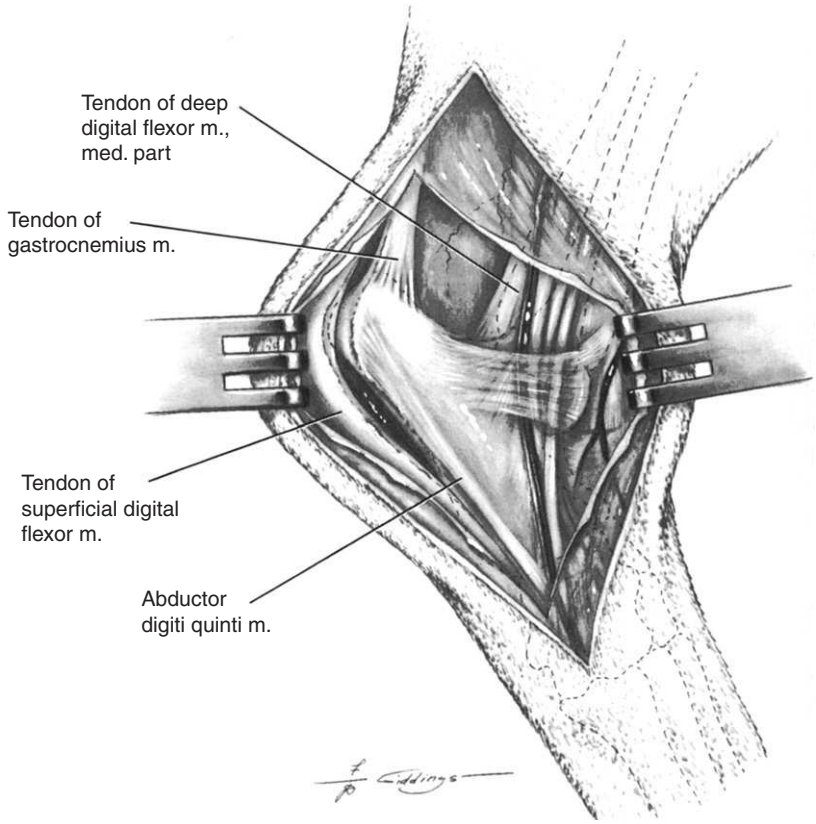


FIGURE 20-6. Approach to the calcaneus from the lateral aspect. The superficial digital flexor tendon has been elevated by incising the retinaculum attaching it to the bone. (From Piermattei DL, Johnson KA: *An atlas of surgical approaches to the bones and joints of the dog and cat,* ed 4, Philadelphia, 2004, Saunders.)

a splint. Tension band wiring with Kirschner wires is an ideal fixation method in most cases because it allows the bending loads to be converted to compression forces, is applicable to any size of animal, is inexpensive, and requires no special equipment. To be successful, however, the cortex opposite the tension band wire must be intact to act as a buttress. (For further explanation of the tension band technique, see Figure 2-64.)

Tension Band Wire Fixation

Surgical approach by means of a lateral incision to the calcaneus is not complicated. Reduction of the fracture and application of fixation are simplified if the tendon of the superficial digital flexor is freed from the tuber by incision of the lateral retinaculum and retracted medially. The tension band wires must be applied between the tendon and the bone, not superficial to the tendon (Figure 20-7, *B* and *C*).

Two methods of application of the tension band are shown. The method shown in Figure 20-7 is the conventional one and is used for fractures of the tuber. It has the disadvantage of creating some irritation of the tendon of the superficial digital flexor as it glides over the tuber. This is minimized by placing the pins as plantarolateral and medial as possible and seating the bent end of the pin close to the bone. After bone healing, these pins and the wire occasionally must be removed because of soft tissue irritation. The method shown in Figure 20-8 eliminates these problems by countersinking the pin, but it is applicable only to fractures of the shaft or base. Note the option of placing the pins in the sagittal plane shown in Figure 20-8, *D*; this is helpful in small breeds. The stainless steel tension wire must be adequate in size. The following sizes are recommended: up to 15 to 20 pounds, 22 gauge (0.635 mm); 20 to 40 pounds, 20 gauge (0.812 mm); and over 40 pounds, 18 gauge (1.02 mm).

Tension Band Wire and Lag Screw Fixation

Comminuted fractures involving the base of the calcaneus (Figure 20-9, *A* and *B*) usually require small lag screws for fixation of the slablike bone fragments from the distolateral region of the bone, as illustrated in Figure 20-9, *C* and *D*.

Bone Plate

Occasionally, a comminuted fracture requires application of a bone plate, which is best placed laterally. When possible, the plate should be supplemented with a tension band wire, placed as shown in Figure 20-8.

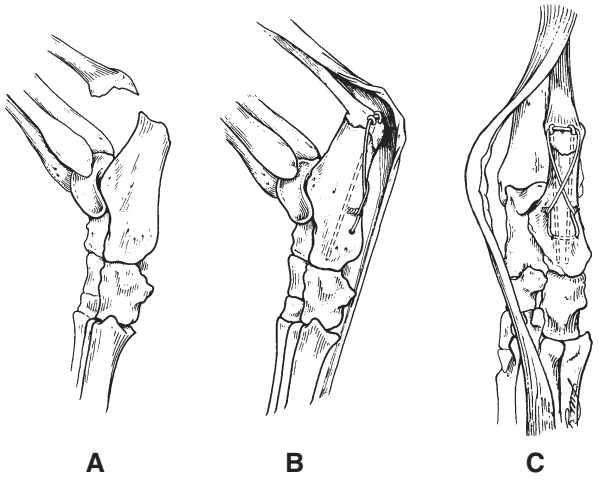


FIGURE 20-7. **A,** Fracture of the tuber calcanei. **B** and **C,** Two Kirschner wires 0.045 or 0.062 inch in diameter, placed side by side, as far medially and laterally as possible. Note that the tendon of the superficial digital flexor has been retracted medially. The exact position of the transverse hole for the wire is not critical and is usually at midshaft or slightly distal, as shown here.

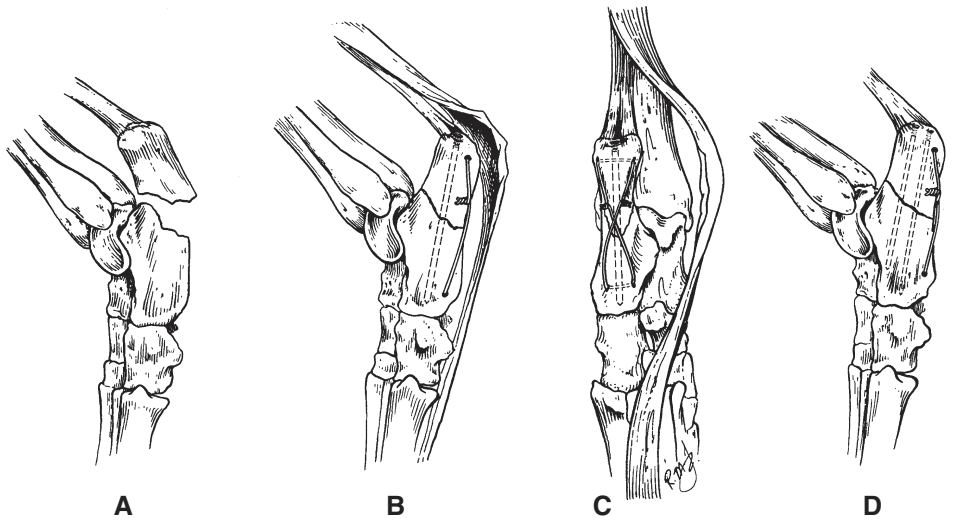


FIGURE 20-8. **A,** Fracture of the shaft of the calcaneus. **B** and **C,** Single Steinmann pin 5/64 to 1/8 inch in diameter has been countersunk in the tuber. This pin position allows the wire to be placed through a drill hole in the tuber, which minimizes irritation of the tendon of the superficial digital flexor. A single pin is used when the fracture reduces well and is stable relative to rotation in the reduced position. **D,** If the fracture line is smooth or slightly comminuted, two smaller countersunk pins or Kirschner wires in the sagittal plane are used because they provide more rotational stability.

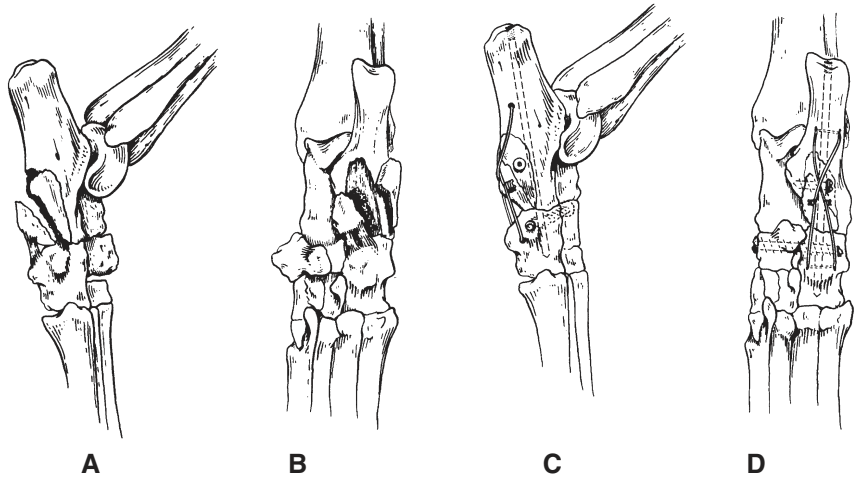


FIGURE 20-9. **A** and **B,** Comminuted fracture of the base of the calcaneus. The tarsus hyperextends at this level. Further instability is created by a dorsomedial luxation of the central tarsal bone, a fairly common complication of this type of calcaneal fracture. **C** and **D,** The central tarsal bone is reduced first to establish some stability at the proximal intertarsal joint. Fixation is accomplished with a 3.5-mm bone screw through the central tarsal bone into the fourth tarsal bone. This screw is not lagged but is threaded into both bones with the central tarsal held in a reduced position with vulsellum forceps. (For more details, see Figure 20-30.) The slab fracture on the lateral side of the calcaneus is lag-screwed with a 2.0- or 2.7-mm screw. A 5/64-inch Steinmann pin is placed in the calcaneus and seated in the fourth tarsal bone. The tension band wire is placed from midshaft in the calcaneus to the plantar tubercle of the fourth tarsal bone, dorsal to the tendon of the superficial digital flexor tendon. The tension band wire holds the second fragment in place. An additional lag screw may be useful in some cases.

Aftercare

Generally, external casts are not necessary postoperatively, except for severely comminuted fractures. In such cases a short lateral splint is applied for approximately 4 weeks or until some radiographic signs of bone healing are seen (see Figure 2-26). A Robert-Jones bandage may be useful for a few days to minimize soft tissue swelling (see Figure 2-33). Exercise is restricted until clinical union occurs. Prognosis is generally good.

Luxation of Tendon of Superficial Digital Flexor Muscle

The superficial digital flexor muscle and tendon form the most superficial part of the calcanean tendon group and cross the tuber calcanei as a flat tendon, with a bursa between tendon and bone. The tendon continues distally to split into branches to each toe. Spontaneous rupture of the medial or lateral retinacular insertion of this tendon on the tuber calcanei allows the tendon to luxate medially (Figure 20-10, *A*) or, more often, laterally. The injury is usually associated with vigorous activity and may be caused by rotational force applied to the tendon's insertion on the calcaneus. The medial insertion and retinaculum seems to be less well defined than the lateral insertion and may rupture more easily.[7] Dysplasia of the tuber calcanei has been proposed as either causing or contributing to the luxation.[8] The groove of the calcaneus was observed to be shallow or absent, with a distolateral slant in some patients, both of which could lead to instability of the tendon. The sheltie and collie breeds seem overrepresented in our cases. Surgical repair done before the development of extensive fibrosis is very successful. Chronic tendinitis and bursitis can cause marked changes in the tendon and decrease chances for success.

Clinical Signs

Lameness is not dramatic and may be intermittent. Moderate swelling on either side of the calcaneus may be noted, and a distinct popping sensation will be felt as the hock is flexed and extended. Accompanying bursitis may result in somewhat fluctuant swelling over the tuber calcanei. The tendon can sometimes be palpated in the luxated position and then reduced as the hock is extended. Flexion then results in reluxation.

Surgical Repair

An incision is made along the calcaneus on the side opposite the direction of the luxation, curving from the distal calcanean tendon toward the calcaneus. This approach

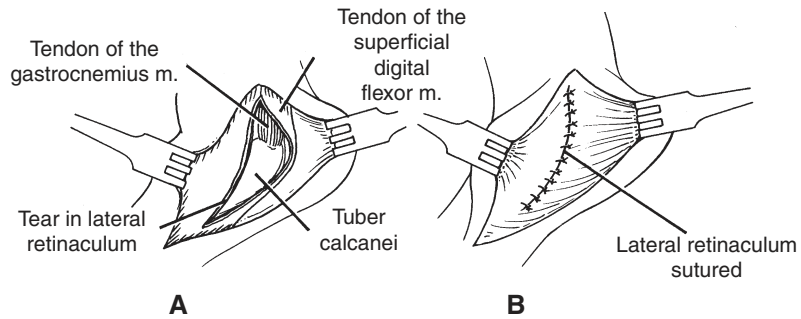


FIGURE 20-10. **A,** Medial luxation of the tendon of the superficial digital flexor muscle follows tearing of the lateral retinaculum at the calcaneus. **B,** Surgical repair consists of suturing the retinaculum with nonabsorbable suture material.

is similar to that previously described for the calcaneus. The bursa is opened and any fibrinous debris removed, and the tendon is reduced. Interrupted nonabsorbable sutures are placed from the edge of the tendon to adjoining retinacular insertion tissue to maintain the tendon in the reduced position (Figure 20-10, *B*). Redundant retinacular tissue may result from stretching and can be imbricated or excised. Because the medial soft tissue available for attachment is often scant, it may be necessary to create another method of attachment of the tendon to the calcaneus. One or two 1.5- to 2.0-mm screws can be inserted in the calcaneus near the tendon edge and sutures from the tendon attached to the screw heads. Alternatively, holes can be drilled through the calcaneus to allow a horizontal mattress pattern for placement of sutures through the bone and tendon.[7]

Aftercare

The lower limb is supported in a short lateral splint for 2 weeks (see Figure 2-26), and exercise is restricted for 2 to 3 more weeks.

Prognosis

Normal function can be routinely expected.[7] We have seen shelties break down in the opposite limb within a few weeks of the first injury.

Avulsion of Gastrocnemius Tendon

The common calcanean tendon, or Achilles mechanism, consists of three tendons that insert on the tuber calcanei of the talus: the gastrocnemius; the common tendon of the biceps femoris, semitendinosus, and gracilis muscles; and the tendon of the superficial digital flexor muscle. The gastrocnemius tendon is the largest of this group and the most powerful extensor of the tarsocrural joint. It can be avulsed from the tuber by normal activity, without outside trauma.[9] Most injuries develop during running and presumably occur as the animal pushes off the limb with the foot firmly planted. Affected dogs are primarily from the large sporting and working breeds and are usually 5 years of age and older. The Doberman pinscher and Labrador retriever breeds seem to be overrepresented. These facts suggest that degenerative changes in the tendon may play a part in the pathogenesis of this injury, but this is only speculative at this time. Bilateral injury is also seen, resulting in severe disability. Prolonged weight bearing in a bilateral plantigrade stance may cause development of full-thickness skin ulceration, exposing the calcaneus, which further complicates orthopedic repair. Obesity and other systemic diseases, such as diabetes or Cushing's disease, are sometimes associated with this presentation. Because of contracture of the muscle, any attempt at nonsurgical treatment will invariably result in permanent deformity. Surgical reattachment of the tendon to the bone is necessary to restore function.

Diagnosis

Clinical Signs

The lameness seen with an avulsed gastrocnemius tendon is severe, and the patient is non–weight bearing for several days; within 1 to 2 weeks, however, the animal starts using the leg again. During weight bearing at this time, the stifle will be seen to be slightly extended, the tarsocrural (hock) joint moderately flexed, and the digits flexed. The position of the digits results in a crablike stance, with the foot resting on the distal ends of the digital pads. Because the superficial digital flexor tendon is intact, it is forced to take a longer course to reach the digits when the hock joint is flexed beyond the normal standing angle. The result is as if the digital flexor muscle were

contracted, so the digits stay flexed during weight bearing. They can easily be manually extended if the tarsocrural joint is extended with the stifle flexed. This is a type 2C injury in the Achilles tendon lesion classification system proposed by Muetstege.[10]

Shortly after the injury, regional edema and pain are the predominant physical findings. Later the region becomes engulfed in fibroplasia and the gastrocnemius muscle contracts, pulling the distal end of the tendon proximally. Often, careful palpation will reveal the end of the tendon 2 to 3 cm proximal to the tuber and deep to the superficial digital flexor tendon. The distal end of the tendon mushrooms and becomes very firm on palpation because of the fibroplasia. Eventually the gap between the tuber and the tendon becomes filled with fibrous tissue and gives the impression during palpation that the tendon is intact. Radiographs are useful at this time in establishing the diagnosis.

Radiographic Signs

During the acute phase, edema of the soft tissues will be appreciated, and it may be possible to visualize the retracted tendon if soft tissue radiographic technique is used. Small, avulsed bone fragments near the tuber calcanei are diagnostic (Figure 20-11). More chronic cases have visible roughening of the tuber and increased soft tissue density in the region between the tuber and the retracted tendon. Rarely, a large fragment from the tuber calcanei may be seen attached to the retracted tendon.

Surgical Repair

A lateral paramedian approach is made over the distal tendon and tuber calcanei. Proximally, the superficial digital flexor tendon is separated from the gastrocnemius tendon, and its lateral retinacular insertion on the calcaneus is incised to allow medial retraction of the tendon (see previous discussion regarding reluxation of tendon of superficial digital flexor muscle). In acute injuries the avulsed end of the



A B

FIGURE 20-11. Avulsion of the tendon of the gastrocnemius muscle tendon at the tuber calcanei. **A,** Large bone fragment is visible here. The position of the fragment is an indication of how far the tendon has retracted. **B,** Two avulsed bone fragments are seen with the retracted tendon *(broad arrowheads)*. A roughened area on the tuber calcanei *(narrow arrowhead)* indicates the area of avulsion. Marked soft tissue density in the area suggests a chronic course.

gastrocnemius tendon will be immediately evident (Figure 20-12, *A*). The tendon is debrided to create a smooth end for suturing. In chronic cases, considerable debridement is necessary to free the tendon and tuber from the fibroplasia. The tuber should be cleared of all tissue before suturing, and the tendinous end should be resected proximally until normal tendinous tissue is identified. With moderate tension it should be possible to bring the cut end into apposition with the tuber when the stifle and hock joints are at normal standing angles. Medial and lateral bone tunnels are drilled from the center of the tuber toward the medial and lateral cortices (Figure 20-12, *B* and *C*).

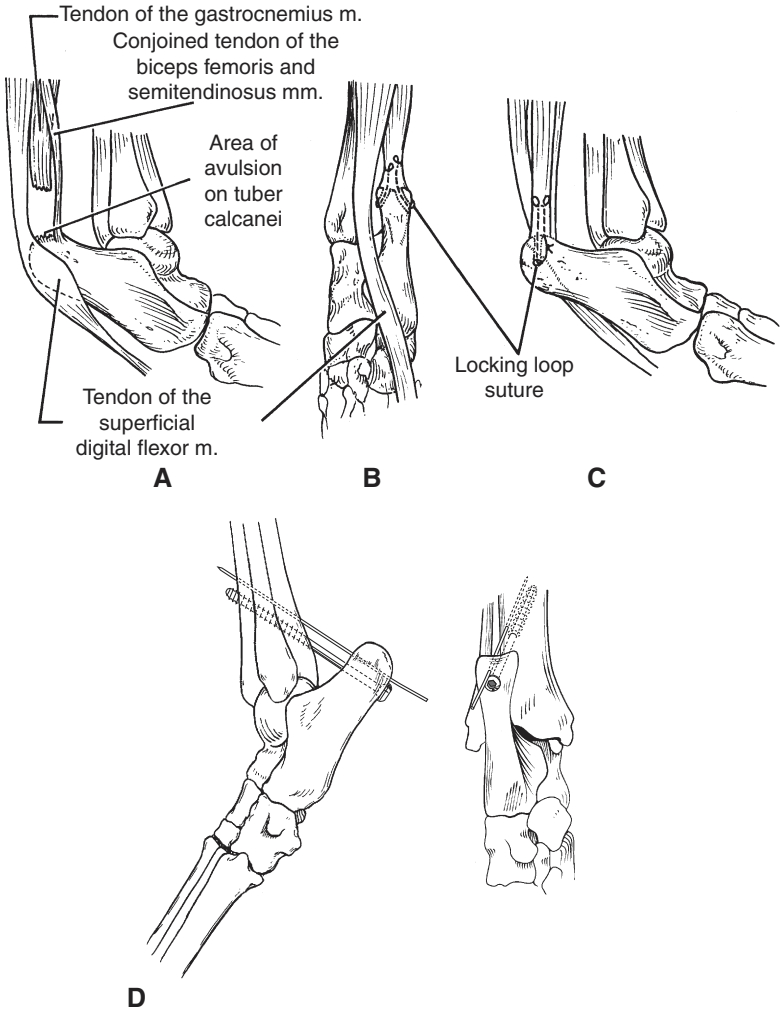


FIGURE 20-12. **A,** Avulsion of the tendon of the gastrocnemius muscle from the tuber calcanei. Note that the tendon of the superficial digital flexor muscle and the conjoined tendons of the biceps femoris and semitendinosus muscles are intact and partially support the tarsocrural joint. **B** and **C,** The tendon of the gastrocnemius muscle is reattached to the tuber calcanei with locking loop sutures (see Figure 7-1) of size 0-2 nonabsorbable suture secured through bone tunnels in the calcaneus. **D,** Temporary tarsocrural immobilization. In medium-sized and larger dogs, a malleolar screw (to avoid tapping through the soft tissue) is inserted from the widest part of the calcaneal tip into the tibia and is angled above the joint. It is helpful to preplace a stay pin above the intended screw placement to immobilize the joint during the screw placement process. It is removed after screw insertion. The screw is normally left in place for 8 weeks and supported with a soft bandage.

These holes should emerge in an area where they will not interfere with gliding of the superficial digital flexor tendon. Alternatively, these tunnels can be drilled transversely through the calcaneus. Locking loop sutures are placed medially and laterally in the tendon. Suture material should be large, size 0-2, and preferably monofilament nylon, polybutester, or polypropylene for ease of handling in the tendon. Braided polyester is also acceptable, but monofilament stainless steel wire should be avoided because it will quickly fracture as a result of movement in this area. One end of each suture is then passed through a bone tunnel, the hock is extended and the stifle flexed to relax the gastrocnemius, and each suture is tied over the bone to its opposite end. The lateral retinaculum of the superficial digital flexor tendon is sutured, and the remaining tissues are closed in layers.

In the event of a large bone fragment from the tuber being attached to the tendon, it may be possible to reattach this by the pins and tension band wire technique shown in Figure 20-7.[11]

Aftercare

A short-leg cylinder cast or lateral splint is applied for 6 to 8 weeks (see Figures 2-22 and 2-26). Alternatively, an external fixator, such as that shown in Figure 20-5, may be used if difficulty arises in maintaining a coaptation device. It is not necessary to immobilize the stifle joint. The splint is followed by a Robert-Jones bandage for 7 to 10 days (see Figure 2-33). Exercise is severely restricted until 8 weeks postoperatively, then slowly increased to normal at 12 weeks.

An alternative stabilization method in large dogs is to place a 4.5-mm malleolar (self-tapping) screw from the calcaneus to the tibia proximal to the tarsocrural joint, along with a soft padded bandage[12] (Figure 20-12, *D*). Placed with the joint in slight extension, the screw relaxes the tendon to allow healing. Restricted activity is imperative because the screw can break. The screw is removed after 6 to 7 weeks.

Prognosis

Very good function has been obtained in our cases and has been reported by others.[9,11] Considerable periosteal bony proliferation of the tuber has been seen in some animals, but this abates and remodels with time and does not cause permanent changes.

Laceration of Calcanean/Achilles Tendon and Superficial Digital Flexor Tendon

Mowing machines, fan belts, and blunt injuries from snowboards, bed frames, and other objects have been known to tear the Achilles tendon and superficial flexor tendon. Skin laceration may not be present. Acutely, the animal carries the leg, and a plantigrade weight-bearing position of the distal limb may not be observed. Careful palpation demonstrates a gap in its normal cordlike structure. After a couple weeks, however, this gap is filled with granulation tissue, and a thickening or nodular swelling may be palpated. If forced to bear weight, or if pain has decreased to allow voluntary weight bearing, the animal displays an obvious plantigrade ("bearlike") stance.

Treatment

Surgical treatment consists of primary repair if undertaken within the first 4 to 5 hours of a skin wound. If longer than 5 hours, a secondary repair should be considered after infection is controlled. At surgery, blood clots and devitalized tissue are removed. With primary repair, tendon ends are mobilized with small hooks (skin hooks) and placed in the peritendon. A locking loop (see Figure 7-6), pulley tendon

(see Figure 7-7), or double Bunnell-Meyer suture pattern can be used with 0-2 monofilament nylon, polybutester, or polypropylene. Simple interrupted sutures with smaller sutures can be used to fine-tune apposition. While these sutures are tightened, the hock should be extended to relax the anastomosis site. No effort is made to suture the superficial digital flexor tendon separately.

With tears of the gastrocnemius muscle, the surgeon may be well advised to delay surgery for several weeks, then resect a portion of the Achilles tendon (about ¼-½ inch) to shorten it. Otherwise, a permanent plantigrade stance will result. Sutures do not hold well in muscle. Postoperative care is undertaken as previously outlined for gastrocnemius avulsion.

Chronic Calcanean/Achilles Tendinitis

Chronic swelling of the common calcanean tendon just proximal to the tuber calcanei is seen occasionally in large-breed dogs. There is increased flexion of the digits, as described earlier for avulsion of the gastrocnemius tendon, and there may be pain with forced extension of the toes, but there is no increase in tarsocrural flexion. Lameness is variable but is usually slight to none. This may represent chronic tendinitis of the superficial digital flexor tendon or a grade II strain injury of the gastrocnemius tendon (see Chapter 7). We have seen this as a bilateral condition in English setters and Doberman pinschers.

Treatment consists of resting the tendon by immobilizing the tarsocrural joint. This can be accomplished by a coaptation device, such as a short-leg cylinder cast or a lateral splint (see Figures 2-22 and 2-26). Alternatively, an external fixator, such as that shown in Figure 20-5, or a calcaneal/tibial screw (Figure 20-12, *D*) could be used if difficulty arises in maintaining a coaptation device. Surgical invasion of the swollen tendon itself is unnecessary. Immobilization is maintained for 6 to 8 weeks.

Osteochondritis Dissecans of the Talus

Osteochondritis dissecans (OCD) occurs in the same canine population as do the other manifestations of osteochondrosis, although the Rottweiler, Labrador retriever, and bullmastiff are overrepresented (see Chapter 6). The disease may be bilateral and may affect either the medial ridge (most common) or the lateral ridge of the talus, where it is most often seen in the Rottweiler.[13] The cartilage flap usually contains bone because, unlike OCD of the shoulder, elbow, and stifle, the flap usually remains connected to and vascularized by the synovial membrane, allowing endochondral ossification to progress. At times the flap may become extruded and lie outside the weight-bearing surface of the joint, or it may migrate up the deep digital flexor tendon sheath, creating a tendinitis (see Figure 20-13, *D*).

Surgical treatment of OCD of the talus is controversial, with conflicting results reported in the literature. OCD and traumatic injury to the tarsocrural joint are less forgiving than in other joints. In one study, surgical treatment resulted in a worse score for function and radiographic changes 16 to 79 months postoperatively (blinded assessments) than did nonsurgical treatment in another series of cases (11 dogs, 17 joints: 11 surgical, 6 nonsurgical).[14] All dogs had significant degenerative joint disease clinically and radiographically. Another study, involving 12 cases with a mean follow-up of 52 months, found that only 25% had attained full function postsurgically and that osteoarthritic changes had progressed in all joints.[15] Despite these apparently discouraging figures for surgical treatment, Montgomery and co-workers[16] noted that of 98 treated joints (74 surgical, 24 nonsurgical) with treatment response reported in the literature, 39% of the surgically treated animals were free of lameness versus 8% of

the nonsurgical cases. Some degree of lameness persisted in 57% of surgical and 79% of nonsurgical cases, and severe lameness was reported in 4% of surgical and 13% of nonsurgical cases. The authors concluded that surgical treatment was preferable to conservative treatment.

Early surgical removal (4-6 months of age) of the semidetached cartilage flap is essential for best results.[14] With each passing month, the chances of good results decrease because of the progress of degenerative joint disease. Dogs older than 1 year at surgery have a poor prognosis and should probably be treated conservatively. Animals with severe lameness of short duration may have a poorer prognosis than those with less severe and slower development of lameness. Degenerative joint disease may progress after surgery because of instability or incongruity of the joint following removal of a large flap. If the flap is large enough to be reattached, every effort should be made to do so in order to minimize postoperative instability. Early surgery increases the probability of being able to reattach the flap. It is imperative to remove all loose and undermined articular cartilage. If arthrotomy inspection alone cannot ascertain the edge of the lesion, rectangular osteotomy should be performed. This allows inspection of the entire talar surface and detection/removal of undermined flaps as well as extruded loose bodies under the medial collateral ligament. Failure to detect remaining flaps or osteotomy technical errors may be reasons for previous poor clinical response.

Diagnosis

Diagnosis of OCD is based on finding caudomedial or caudolateral tarsocrural joint swelling and effusion in appropriate breeds with a history of lameness beginning after 4½ months of age, as well as appropriate radiographic signs.

Clinical Signs

Hindlimb lameness is characterized by a shortened stride. Often there is hyperextension at the tarsocrural joint. Caudomedial or caudolateral (less common) joint effusion is seen early, and thickening of the tarsus on the medial aspect of the joint develops later as degenerative changes progress within the joint; these are consistent signs. Less effusion and soft tissue changes are appreciated when the lateral ridge of the talus is involved. Pain may be manifested on flexion and extension of the joint, which may also show a decreased range of motion in flexion. Crepitus is occasionally present.

Radiographic Signs

Radiographs in the extended dorsoplantar and flexed lateral position will reveal a defect in the medial ridge of the trochlea (Figures 20-13, *A* and *B,* and 20-14). A dorsolateral-plantaromedial 45-degree oblique view in full extension further outlines the medial ridge of the talus. Increased joint space is often seen, and free ossicles may also be seen occasionally. Fragments may dislodge caudally in the slightly older dogs (11-13 months of age). Occasionally, "joint mice" are found in the tendon sheath of the flexor hallicus longus muscle, which communicates with the tarsocrural joint. In addition, some fragments may be extruded and trapped under the medial collateral ligament. Mediolateral views may show flattening of the dome of the talus. Lateral lesions are much more difficult to demonstrate because of the superimposition of the calcaneus in conventional craniocaudal views. The dorsal 45-degree lateral-plantaromedial view is usually helpful in outlining the lateral trochlear ridge[13] (Figure 20-13, *C*). A flexed dorsoplantar view has also been proposed for outlining the trochlear ridges without summation from the calcaneus.[17] With the dog in dorsal recumbency, the calcaneus is elevated from the table to allow the



FIGURE 20-13. Osteochondritis dissecans of the talus. **A,** In this chronic case, many signs of degenerative joint disease are present, such as osteophytes and subchondral sclerosis. Note flattening of the ridge of the talus *(black-outlined arrowheads)* and the free osteochondral fragment within the joint *(white-outlined arrowhead);* lateromedial view. **B,** Large fragment can be seen on the medial ridge of the talus in this craniocaudal-lateromedial oblique view. **C,** Displaced fragment of the lateral ridge of the talus is visualized in this caudocranial-mediolateral oblique view. **D,** Mineralized "joint mice" can be seen proximal to the joint in the deep digital tendon sheath *(top arrow)* and distally *(bottom arrow)*. **E,** Postsurgical view after removal of a fragment from the medial ridge. Note the precise reduction of the malleolar osteotomy achieved by predrilling the lag screw hole before performing the osteotomy.

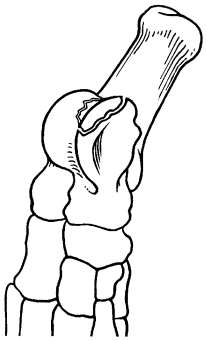


FIGURE 20-14. Osteochondritis dissecans lesion on the medial ridge of the talus. The lesion can be located anywhere on the ridge but is most likely to be centrally placed, as here, or more proximally.

x-ray beam to be parallel to the metatarsus and capture a skyline view of the talar ridges. Changes are often subtle in lateral lesions, and arthrography or computed tomography (CT) scanning may be needed for a definitive diagnosis.

Surgical Technique

Electrocautery is very helpful in surgery for OCD because there is a tremendous proliferation of blood vessels. A tourniquet may also be used but may impede joint manipulation. For lesions of the medial ridge, a medial approach to the joint is made with arthrotomies dorsal and palmar to the collateral ligament.[1] Synovial incision superficial to the deep digital flexor tendon allows palmar retraction of the tendon to permit visualization of the caudomedial part of the joint and exploration for migrated joint mice.[18] If exposure is inadequate because of lesion size or position, the medial malleolus can be osteotomized in rectangular fashion (Figure 20-15). The rectangular bone gives inherent rotational stability to the fragment, allowing one screw and washer to suffice for fixation. The periosteum is incised 1 1/2 inches proximal to the tip of the malleolus and the origin of the medial collateral ligament. Cranial and caudal periosteal incisions connect the proximal incision to the joint.

Predrilling and pretapping a screw hole 3/4 inch above the malleolar tip before osteotomy help ensure accurate reduction and fixation of the malleolus, using a 4.0-mm malleolar or 3.5-mm cancellous screw and washer (Figures 20-13, *D* and *E*). An osteotome 6 to 7 mm wide is used to cut bone in the following manner (see Figure 20-15). First, a transverse cut 1/4 inch deep at the center is made in the proximal limit of the fragment to be removed. This cut stops short of the most cranial or caudal extremes of the tibia. Second, the small tendon (lateral part of digital flexor tendon, or flexor hallucis longus) lying in the caudal tibial sulcus is sharply dissected from its tight fascial covering and retracted caudally. The osteotomy connects the proximal osteotomy cut to the joint along the caudal tibial sulcus. During osteotomy, care must be taken not to injure the talus, which curves up and under the concave tibial joint surface. Third, the cranial osteotomy connects the proximal cut to the joint and the caudal osteotomy. The fragment of bone and collateral

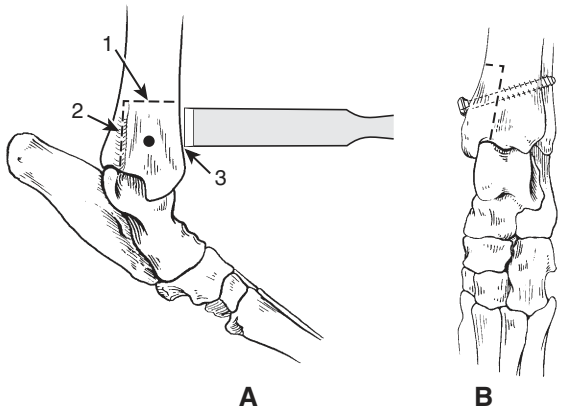


FIGURE 20-15. Medial malleolar osteotomy. **A,** Screw head represents the location of the predrilled, pretapped screw hole. Cut #1 is the location of the first osteotomy, penetrating approximately 1/4 inch deep. Cut #2 is made vertically in the caudal tibial sulcus, joining the proximal cut to the end of the tibia, again 1/4 inch deep, except near the joint, where the talus lies underneath. Cut #3 connects the proximal osteotomy to the caudal cut #2. **B,** Location of this third cut is important. The tip of the osteotome should be just proximal to the medial ridge of the talus. Leaving part of the malleolus will not allow luxation of the joint.

ligament are reflected distally, allowing exposure of the entire joint, including rare, lateral OCD lesions and the inside region of the medial collateral ligament, where extruded loose bodies are occasionally attached. In addition, the eroded tibial surface may be evaluated. Loose cartilage and bone are removed and all nonadherent edges curetted. Forage, bed curettage, or possibly stabilization of large bone and cartilage pieces (not currently performed) is possible. If the third osteotomy is too superficial, a shelf of malleolar bone remains, making exposure inadequate.

Because the tendon sheath of the deep digital flexor is confluent with the tarsocrural joint, free cartilage fragments can escape proximally into the sheath. In this situation, they calcify and become visible on radiography. In some cases the fragments can be "milked" distally into the joint arthrotomy. If this fails, the tendon sheath must be opened proximally to free the joint mice.

Reduction of a bone fragment is easily achieved by placing a screw and washer in the predrilled hole.

We have seen two dogs with OCD in which lameness did not develop until 2 to 4 years of age. On exploration, the large lateral portion of the deep digital tendon (flexor hallucis longus) was either lacerated or inflamed because of impingement by a large caudal osteophyte on the distal tibia. Both patients responded to osteophyte debridement and additional fascial coverage of the tendon sheath. In addition, we have seen two older dogs with OCD that worsened suddenly, caused by cracks of a long caudal tibial osteophyte. Both responded to osteophyte removal.

An arthrotomy approach dorsal and palmar to the lateral collateral ligament can be made to expose the lateral ridge, where OCD lesions are more often located on the distal part, near the body of the talus. If the lesion cannot be fixed in place, the loose cartilage fragment is removed and minimal curettage performed to minimize the amount of instability produced. Evidence suggests that some lateral lesions may actually be traumatic osteochondral fractures.[19] If large enough, these lesions may lend themselves to fixation, as explained later; small fragments are excised.

Aftercare

A padded bandage is maintained for 2 weeks, and normal exercise is not allowed until 4 to 6 weeks postoperatively.

Prognosis

Although the debate over surgical versus conservative treatment for OCD remains open, the message is clear. Surgical treatment must be done early, and the lesion must be small for surgical treatment to be worthwhile. In any case, the prognosis is not encouraging because a substantial portion of the ridge is absent, and the owner should be forewarned regarding long-term function of the dog. Large lesions may benefit from internal fixation with biodegradable pins, but as yet this remains untried.

Fractures of the Talus

Fractures of this bone may be intraarticular, involving either the medial or the lateral ridge of the trochlea (see Figures 20-16 and 20-17), or fractures may be extraarticular in the talar neck (see Figure 20-18), the talar body (see Figure 20-19), or the base of the talus (see Figure 20-20). Fractures of the ridges, especially the lateral ridges, are difficult to visualize radiographically. Dorsolateral oblique views in both flexion and extension are most useful. (See previous section on diagnosis of OCD for further discussion of radiographic views.) Lameness is severe, and there is generally some effusion in the joint. Severely comminuted fractures may require arthrodesis. The etiology is usually obscure but may involve a fall or jump. Prognosis for intraarticular fractures

is variable, depending on the accuracy of reduction of the fracture. Moderate to severe degenerative joint disease (DJD) is common after these injuries. The prognosis is good for talar neck and body fractures.

Fracture of Trochlear Ridges

Internal Fixation

These talar fractures are generally stabilized by 0.035- or 0.045-inch (0.9- to 1.2-mm) Kirschner wires that are countersunk beneath the articular surface (Figure 20-16). Lag screw fixation is preferable, but the fragments are often too small; when fragment size permits, 1.5-mm and 2.0-mm screws can be used. The screw heads may be countersunk beneath the cartilage surface when used in an articulating area. Fractures of the medial ridge are approached by incision of the joint capsule proximal and distal to the collateral ligament (see previous OCD discussion) when possible. Rectangular osteotomy of the medial malleolus of the tibia gives much better visualization but is a second choice because of increased surgical complexity (see Figure 20-15). Nevertheless, it is often the only way of accessing the joint for fixation. In the same way, the lateral ridge is approached by osteotomy of the distal fibula to allow maximum exposure of the lateral side if simple arthrotomy is not sufficient (Figure 20-17).

Aftercare. A lateral splint is placed on the lower limb for 4 weeks (see Figure 2-26), followed by a support bandage for 2 weeks. Exercise is restricted for 8 to 12 weeks.

Prognosis. The outlook for trochlear ridge fracture ranges from poor to good, depending on the exactness of reduction and stability achieved. DJD is the sequela when this joint fracture does not heal perfectly but may ensue regardless of exact reduction and good stability.

Fracture of Talar Neck

A fracture of the talar neck is usually accompanied by luxation of the body of the bone, with the fracture surface rotating dorsally and distally (Figure 20-18, *A* and *B*).

Closed Reduction

In cats and small dogs seen soon after injury, it may be possible to do a closed reduction and to maintain fixation by a snug-fitting short-leg cylinder cast (see Figure 2-22). In most animals, however, it will not be possible to maintain position of the fragments with a cast.

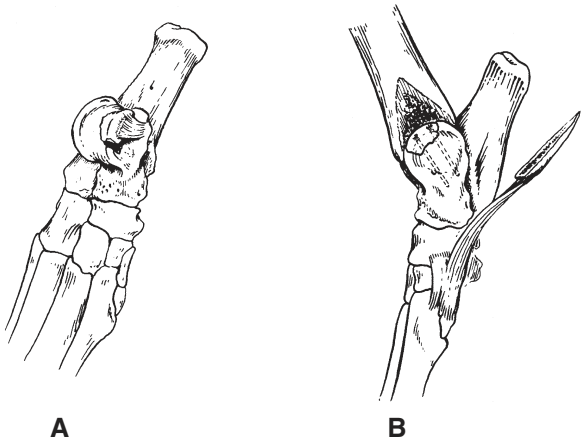


FIGURE 20-16. A, Fracture of the medial ridge of the talus. **B,** Medial malleolus osteotomized and reflected to allow placement of two Kirschner wires, which are countersunk beneath the surface of the articular cartilage. Alternatively, 1.5- or 2.0-mm screws could be used. The malleolus is replaced by the pin and tension band wire technique (see Figure 2-64).

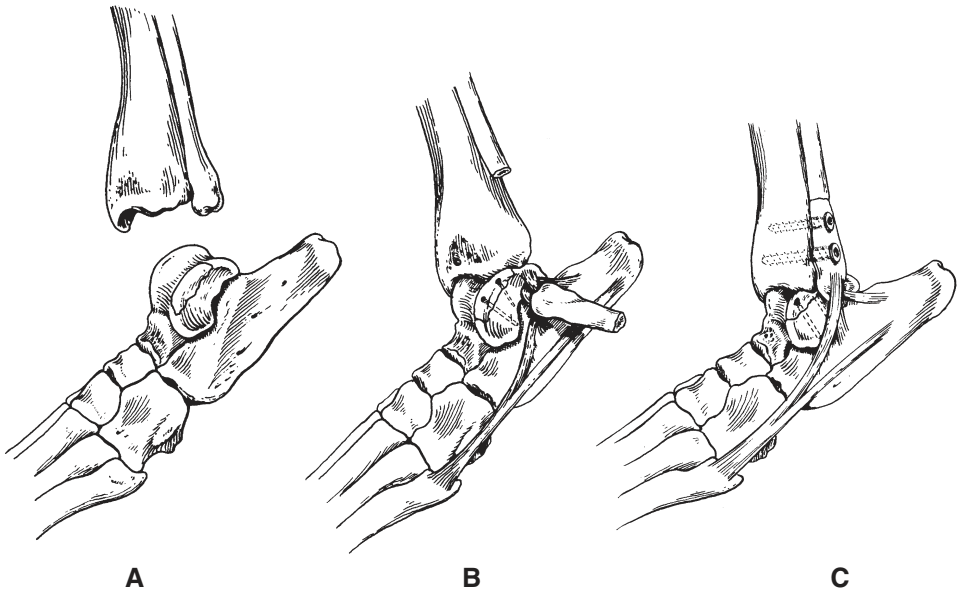


FIGURE 20-17. **A,** Fracture of the lateral ridge of the talus. **B,** The fibula is osteotomized 1.5 to 2.0 cm from the tip of the malleolus, dissected free from the tibia, and rotated caudally or distally on the intact short part of the collateral ligament. (See Figure 20-3 for more detail.) It is necessary to cut a short ligament between the tibia and fibula to reflect the fibula. When the foot is supinated (rolled inward), the fracture can be visualized. It is fixed by two or three Kirschner wires countersunk beneath the articular cartilage. Alternatively, 1.5-mm or 2.0-mm screws could be used. **C,** The fibula is attached by two lag screws, small pins, or Kirschner wires. The small cut ligament is not sutured. *Note:* If exposure of the caudal portion of the condyle is essential, the short collateral ligament is cut close to the fibula. It is reattached with a suture that engages the ligament and is then passed medial to lateral through two drill holes in the malleolus and tied on the lateral side.

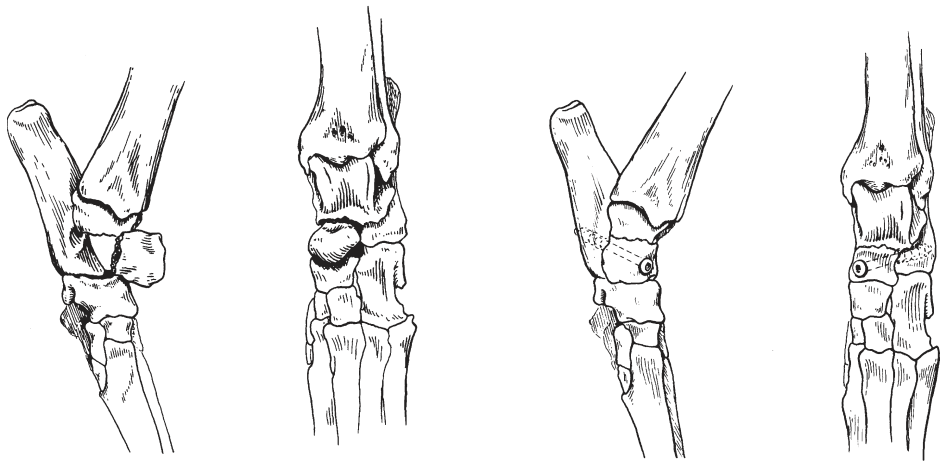


FIGURE 20-18. **A** and **B,** Fracture of neck of talus with typical luxation of body and base. **C** and **D,** Reduction is obtained by flexion and lateral bending at the proximal intertarsal joint and is maintained with vulsellum forceps. A 3.5- or 4.0-mm screw (shown here) is used in average-sized to large breeds. It is not essential that this screw be lagged if the bone is properly reduced and held in place with forceps.

Internal Fixation

Most animals require internal fixation, which is best supplied by a lag screw between the body of the talus and the calcaneus (Figure 20-18, *C* and *D*). A neck fracture is exposed by proximal extension of the approach to the central tarsal bone.[1] The 3.5-mm cortical screw is considerably stronger in bending than the 4.0-mm cancellous screw shown here and may be a better choice in this application.

Aftercare. Because the lag screw crosses the tarsal sinus (a gap between calcaneus and talus), it is somewhat subject to bending with early weight bearing. Thus the screw is best protected by a short lateral splint for 4 weeks (see Figure 2-26). Exercise is restricted for 8 to 12 weeks.

Prognosis. Good long-term function is expected after repair of talar neck fracture.

Fracture of Talar Body

In fractures of the talar body the base of the talus does not luxate, but there is a slight subluxation of the talocalcaneal joint (Figure 20-19, *A* and *B*).

Internal Fixation

Fixation is usually by means of multiple Kirschner wires because the neck of the bone is often too small to accommodate a lag screw. Ideally, two wires are crossed in the talus (Figure 20-19, *C*, *D,* and *E*). In some cases, bone plates can be used for fixation. T-plates of the 1.5-, 2.0-, and 2.7-mm series can be adapted to this fracture and provide relatively good stability (Figure 20-19, *F*). The bone is approached by a combination of the approaches to the medial malleolus and the central tarsal bone.[1]

Aftercare. Neither fixation is very rigid, and both should be protected for 4 to 6 weeks postoperatively by a short lateral splint (see Figure 2-26). Exercise is restricted for 8 to 12 weeks.

Prognosis. Good long-term function is expected after repair of talar body fracture.

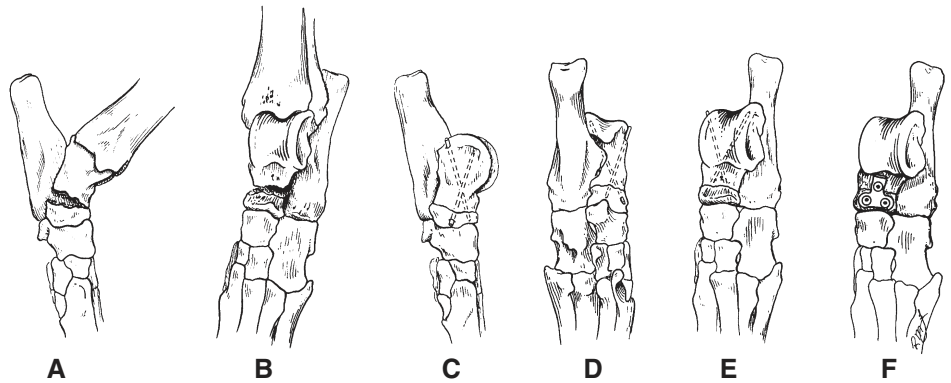


FIGURE 20-19. **A** and **B,** Fracture through the body of the talus. **C, D,** and **E,** Kirschner wires are crossed in the bone. The proximal pin must be cut close to the bone to avoid irritation of the deep digital flexor tendon. **F,** T-plates of the 1.5-, 2.0-, and 2.7-mm series can be used in some cases. Here, a 2.7-mm plate has been cut to fit the bone. Because only one screw is placed in the proximal fragment, external support is essential.

Luxation of Base of Talus

Luxation of the base of the talus is an infrequent but very disabling injury that is difficult to repair if not diagnosed early (Figure 20-20, *A*). Surgical stabilization is quite successful and is indicated in most animals, but closed reduction and casting have been satisfactory in cats and small dogs.

Diagnosis

Considerable swelling and deformity of the proximodorsal tarsus are evident, with lameness typified by the animal carrying the leg. Because of possible concurrent damage to the insertion of the medial collateral ligament, the tarsus should be evaluated for medial instability. Radiographs are necessary to confirm the diagnosis.

Internal Fixation

The bone is exposed by a proximal extension of the approach to the central tarsal bone.[1] The base of the talus can be reduced after the proximal intertarsal joint is opened by flexion and lateral (varus) stress on the metatarsus. A positional screw is placed between the talus and calcaneus and as distally as possible in the talus to avoid crossing the tarsal sinus (Figure 20-20, *B* and *C*). If medial instability remains at the talocentral joint, joint cartilage of the calcaneocentral joint is debrided, and a second bone screw is placed in the medial side of the central tarsal bone. Stainless steel wire is placed around the head of both screws and tightened, similar to the procedure illustrated for distal intertarsal instability in Figure 20-35, *D* and *E*.

Aftercare. A short lateral splint is applied and maintained for 4 weeks (see Figure 2-26). Exercise is limited through the eighth postoperative week.

Talocrural Arthrodesis

Indications for arthrodesis of the hock joint may be seen in small animal practice under the following circumstances:

1. Severe shearing injury.
2. Degenerative joint disease (most often caused by OCD).

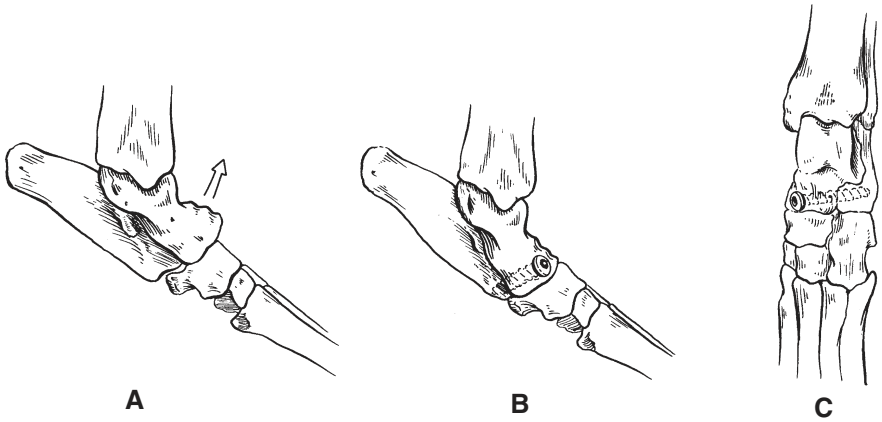


FIGURE 20-20. Luxation of the talus. **A,** The base of the talus luxates dorsally. There may also be injury to the insertion of the medial collateral ligament. **B** and **C,** Positional screw is placed distally in the talus to avoid the tarsal sinus. The screw is driven into the calcaneus.

3. Chronic instability or hyperextension.
4. Comminuted intraarticular fractures.
5. Irreparable injury of the calcanean (Achilles) tendon apparatus.
6. Sciatic nerve palsy when combined with transposition of the long digital extensor tendon.[20]

Assuming there are no disease conditions of the hip or stifle, function of the fused limb is satisfactory. These joints must flex more than normal to compensate for fusion at the hock level, and if they do not function normally, the leg will be circumducted markedly during the forward swing phase of gait. As with all arthrodeses, additional strain is placed on adjacent joints and may lead to DJD, particularly in the more distal tarsal joints. For this reason, pantarsal arthrodesis is receiving increased attention as a substitute for talocrural arthrodesis.[21,22]

Surgical fusion of the talocrural joint is a great challenge to the surgeon because of the magnitude and orientation of weight-bearing forces. Additionally, the small size of the bones of the tarsus imposes limitations on the size and shape of implants used in internal fixation. Failure rates, as high as 50% in our hands[23] and in other reports,[21] have led us to be much more aggressive in using more and larger implants and in supporting the bones with external casts and splints until fusion is certain. It also seems useful to cross the joint with one of the screws or pins in order to neutralize shear forces. Lag screw, bone plate, and external skeletal fixation techniques are all applicable when properly executed.

The talar and tibial articular surfaces can be prepared either by osteotomy with a bone saw (Figure 20-21, *A*) or by curettage manually or with a high-speed bur (Figure 20-21, *B*). Osteotomy by saw provides a flat surface that is more stable relative to bending shear forces, but it makes rotational alignment more difficult. Reference Kirschner wires can be placed in the tibia and tarsus to help realign the parts before fixation is applied.

Screw Fixation

Single–lag screw fixation is suitable only for cats and dogs weighing less than 8 to 10 kg. All others should receive two or three screws. The joint is approached medially by malleolar osteotomy.[1] The malleolus and medial collateral ligaments are detached, and the bone is cut into very small chips with a rongeur to be used as bone graft to supplement autogenous cancellous bone from the proximal tibia. The functional angle for dogs is typically between 135 and 145 degrees; in cats it is 115 to 125 degrees. This angle should be carefully checked in the opposite limb preoperatively. In Figure 20-21, *A*, the angle chosen is 135 degrees; the complementary angle is 45 degrees. Because it is most convenient to cut the distal tibia at 90 degrees to its long axis, the talus is cut at a 45-degree angle to the axis of the tarsus-metatarsus. Considerable bone must be removed from the tibia because of the depth of the cochlea. The cartilage can also be removed with power burs, curettes, or rongeurs by following the bony contours (Figure 20-21, *B*). In some cases the fibula will prevent apposition of the tibia and talus after bone and cartilage removal, and it may be necessary to resect the lateral malleolus or perform a short supramalleolar ostectomy of the fibula through a separate, short lateral incision.

Initial fixation and rotational alignment are obtained by two Kirschner wires driven across the contact surfaces in a plantarolateral direction (Figure 20-21, *C*). Drilling for the lag screw can then proceed without motion of the contact surfaces. Screws of 4.5 mm are appropriate for animals of 15 to 18 kg or larger, and 3.5-mm screws are ideal for smaller animals. Fully threaded screws are preferred because of their ease of removal and greater strength. The glide hole is drilled in the tibia

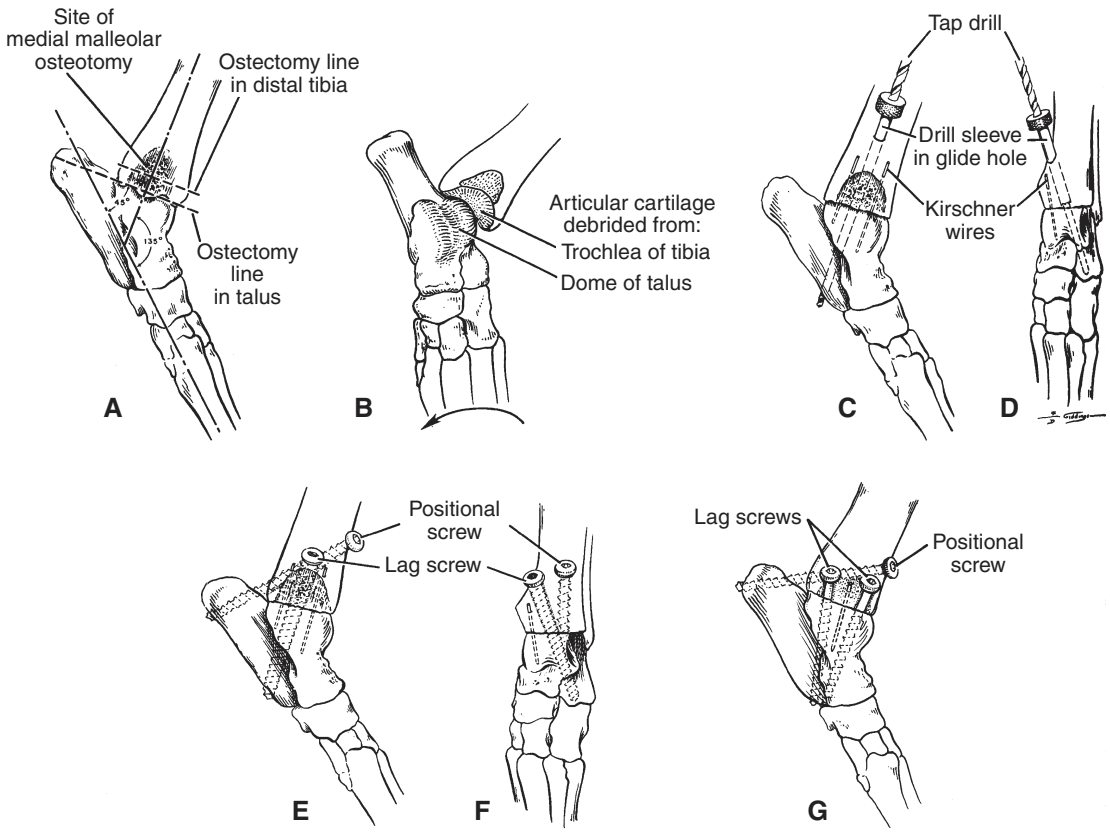


FIGURE 20-21. Arthrodesis of the tarsocrural joint by screw fixation. **A,** The angle chosen here for the fusion is 135 degrees. The complementary angle of 45 degrees also describes the angle to be cut through the talus, since the tibia is best cut 90 degrees to its axis. The joint is exposed medially by a malleolar osteotomy.[1] **B,** An alternative method of removing articular cartilage involves debridement with a power bur or curettes, following the normal contour of the articular surface. **C** and **D,** Temporary fixation is obtained by two Kirschner wires placed across the joint at an angle. A 4.5-mm (or 3.5-mm) glide hole has been drilled, and the 3.2-mm (or 2.0-mm) tap drill is inserted through a drill sleeve. The drill penetrates the plantarolateral cortex of the calcaneus near its base. **E** and **F,** The hole is tapped, and a screw of appropriate length and diameter is inserted. A second hole is drilled from the cranial aspect of the distal tibia into the tuber calcanei with a tap drill sized for the screw diameter selected. Soft tissue in the space between the distal tibia and calcaneus must be protected. *Both* bones are tapped and the screw inserted. **G,** In dogs weighing more than 10 kg, it is preferable to insert two screws across the joint. In this situation a single Kirschner wire is placed between the screws.

first (Figure 20-21, *C* and *D*). The tap hole is then drilled through the talus and calcaneus. (Placement of 4.5-mm screws is illustrated in Figure 20-21.) The glide hole is started at a point on the tibia 2.0 to 2.5 cm from the end of the bone and at an angle of 15 to 20 degrees from the tibial sagittal plane. The hole is measured with the depth gauge and is tapped, and a screw of appropriate length is inserted and tightened (Figure 20-21, *E* and *F*). An alternate technique consists of drilling the 3.2-mm tap hole first, then enlarging the tibial hole with the 4.5-mm glide drill. A second hole is drilled from the cranial aspect of the distal tibia into the tuber calcanei with a tap drill sized for the screw diameter selected. Soft tissue in the space between the distal tibia and calcaneus must be protected. *Both* bones are tapped,

and the screw is inserted. This positional screw protects the lag screw from bending loads. In dogs weighing more than 10 kg, it is preferable to insert two screws across the joint (Figure 20-21, *G*). In this situation a single Kirschner wire is placed between the two screws. Autogenous cancellous bone graft is packed into and around the contact surfaces (see Chapter 3). The Kirschner wires are left in place.

Aftercare

External support is *imperative* to prevent bending loads on the screws. A short lateral splint or cylinder cast is maintained for 8 weeks (see Figures 2-22 and 2-26) or until radiographic signs of fusion are evident. Exercise is severely restricted until radiographic fusion is complete, then slowly increased to return to normal 6 weeks later. Implants should be removed routinely about 6 months postoperatively. Because of bending loads exerted on the fusion site, micromotion eventually results in screw loosening or breakage, which causes irritation and pain. Fully threaded screws are more easily removed than partially threaded cancellous screws.

Bone Plate Fixation

Talocrural arthrodesis with a *cranially* placed bone plate is possible if one screw is placed through the plate and into the calcaneus to act as a positional screw (Figure 20-22). All four cortices are tapped, since the purpose of this screw is to prevent bending loads on the plate. Care must be taken to avoid extending the plate beyond the proximal intertarsal joint. Autogenous cancellous bone graft is packed around the arthrodesis site before closing the soft tissues.

Talocrural arthrodesis with a *laterally* placed straight plate is possible with a plate that allows a large number of screws per unit of length, such as the veterinary cuttable plate (VCP) (Synthes, Ltd., Paoli, Pa). Because the plate is loaded on edge, it is very resistant to the bending loads of this joint. Despite this mechanical advantage, such techniques have not been satisfactory in the past because of inability to place a sufficient number of screws distal to the arthrodesis site. The VCP solves this difficulty by the number of screw holes available. Additionally, the plates are available in both 1.0- and 1.5-mm thickness and can be stacked to increase their thickness and stiffness. In Figure 20-23 a 1.5-mm-thick plate and 2.7-mm screws are used, following the method of Sumner-Smith and Kuzma.[24] The distal one third of the fibula

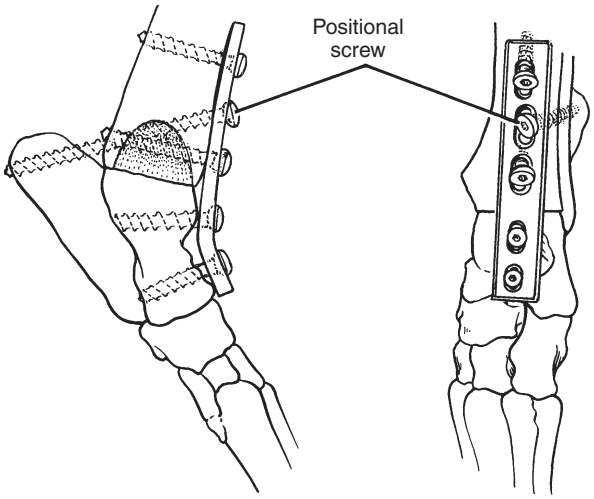


FIGURE 20-22. Talocrural arthrodesis with a cranially placed bone plate is possible if one screw is placed through the plate and into the calcaneus to act as a positional screw. All four cortices are tapped. Care must be taken to avoid extending the plate beyond the proximal intertarsal joint.

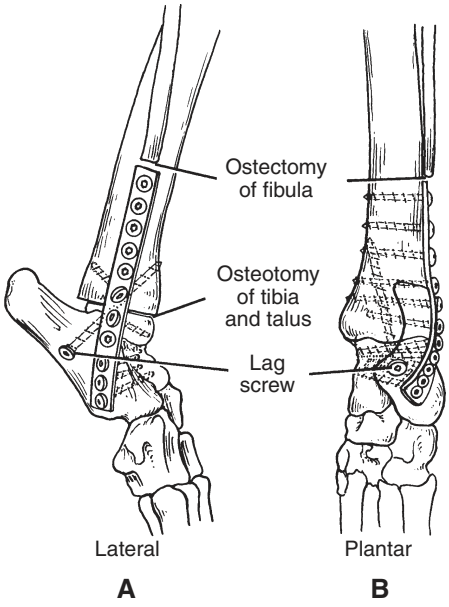


FIGURE 20-23. Talocrural arthrodesis with a laterally placed plate is possible only with a plate that allows a large number of screws per unit of length, such as the AO/ASIF veterinary cuttable plate (Synthes, Ltd., Paoli, Pa). Here, a 1.5-mm-thick plate and 2.7-mm screws are used, following the method of Sumner-Smith and Kuzma.[24] At least one screw must cross the joint as a lag screw, to provide compression at the arthrodesis site. The distal one third of the fibula is resected to allow lateral placement of the plate, which is molded around the calcaneus distally.

is resected, and the joint surfaces are prepared as in Figure 20-21. A lag screw (3.5- to 4.5-mm diameter) is placed across the joint to provide compression at the arthrodesis site, from the calcaneus distally, through the talus, and into the tibia proximally (Figure 20-23, *A*). Drilling the glide hole from the talus to the calcaneus before reduction ensures accurate placement of this hole. In small breeds the lag screw may be passed from the distal plate hole.

The plate is molded to the tibia and around the calcaneus distally, where a sharp bend and slight twist are necessary to fit the bone closely. Screw placement starts distally with two screws in the calcaneus. The next screw is placed in the distal tibia and is positioned eccentrically in the plate hole to provide compression. Two more screws are similarly placed in the tibia, taking care to avoid the lag screw. The rest of the screws are placed in the center of the plate holes, and the lag screw is retightened. Autogenous cancellous bone graft is packed around the arthrodesis site before closing the tissues (see Chapter 3).

A second method of lateral plating involves the use of a reconstruction plate (Synthes). These plates can be curved on the flat dimension to follow the curvature from the tibia to the tarsus (see Figure 20-25, *B*). The illustration shows application for pantarsal arthrodesis; for talocrural arthrodesis the plate would be shortened to extend only to the distal end of the calcaneus. Lag screw fixation across the talocrural joint is accomplished as described for the VCP.

Aftercare

External support is *imperative* to prevent bending loads on the screws. A short lateral splint or cylinder cast is maintained for 8 weeks or until radiographic signs of fusion are evident (see Figures 2-22 and 2-26). Exercise is severely restricted until radiographic fusion is complete, then slowly increased to return to normal 6 weeks later. Implants should be removed routinely about 6 months postoperatively. Because of bending loads exerted on the fusion site, micromotion eventually results in screw loosening or breakage, which causes irritation and pain. Fully threaded screws are more easily removed than partially threaded cancellous screws.

External Skeletal Fixator

Fixation by means of the external fixator is particularly applicable to open or shearing injuries of the hock (Figure 20-24). Open luxation with comminuted fractures of the tibial trochlea or condyles of the talus is also a relatively common injury best treated by arthrodesis. Minimal metal at the area of contamination reduces infection problems, and all the metal can easily be removed. Because of the morbidity associated with the prolonged casting or splinting needed for the procedures previously described, the external fixator has become the method of choice in our hands. A variety of configurations are useful, depending on patient size. Mechanical studies of transarticular fixators are lacking, so their application is more art than science. In all methods the contact surfaces are prepared as already described after adequate soft tissue debridement (see Figure 20-21, *A*).

Type II Fixator and Steinmann Pin

A Steinmann pin is driven through the calcaneus and talus into the distal tibia with the joint at the desired angle (Figure 20-24, *A*). If the pin follows the medullary canal, it is driven into the proximal metaphyseal region. If the pin penetrates the tibial cortex, it is driven completely through the cortex. The pin is cut about 1 cm from the calcaneus and left protruding through the skin. An alternative method consists of driving the pin from the proximal tibia, as described for fracture repair in Chapter 19. After penetrating the calcaneus, the pin is pulled from the distal end until the proximal end is below the proximal articular surface of the tibia and cut distally. Centrally threaded positive-thread-profile transfixation pins are driven through the tibia and through the bases of the metatarsals. These pins are connected by single clamps and connecting rods in small dogs and cats (Figure 20-24, *A*). A large autogenous cancellous bone graft taken from the proximal tibia will significantly speed healing and can be used in a contaminated site. Fixation can be made even more rigid in larger breeds (10-20 kg) by placing a transfixation pin through the calcaneus and connecting it with double clamps to the proximal ends of the other connecting rods (Figure 20-24, *B*). Double clamps can be avoided by using single clamps outboard of the tibial fixation pin clamps.

Type IIB Fixator

In larger breeds over 20 kg, a more rigid frame is used to neutralize bending loads at the arthrodesis site. One of the easier methods is shown in Figure 20-24, *C*, using curved connecting rods, which are prepared to the desired angle of the joint as previously described. Using half pins for the middle sets of fixation pins simplifies the problem of fitting the pins to the connecting rods on both sides. At least one of the fixation half pins should cross the talocrural joint to control shearing motion at the arthrodesis site. Three half pins on each side of the joint can be substituted for the second full pin, as illustrated in Figure 20-25, *A*, which simplifies application. The use of double clamps can be avoided by using single clamps attached outboard of the proximal and distal pin clamps.

Aftercare

Healing of the arthrodesis will be slow in the case of open injuries, and fixation may need to be maintained for 10 to 12 weeks or until radiographic signs of fusion are present. Closed cases generally show radiographic fusion by 8 to 10 weeks. Exercise should be restricted to the house, a small pen, or a leash until the apparatus is removed. The transfixation pins are removed when good fusion is present, but Steinmann pins can be left in place for several months to absorb some of the bending stress on the arthrodesis during the remodeling phase of bone healing.

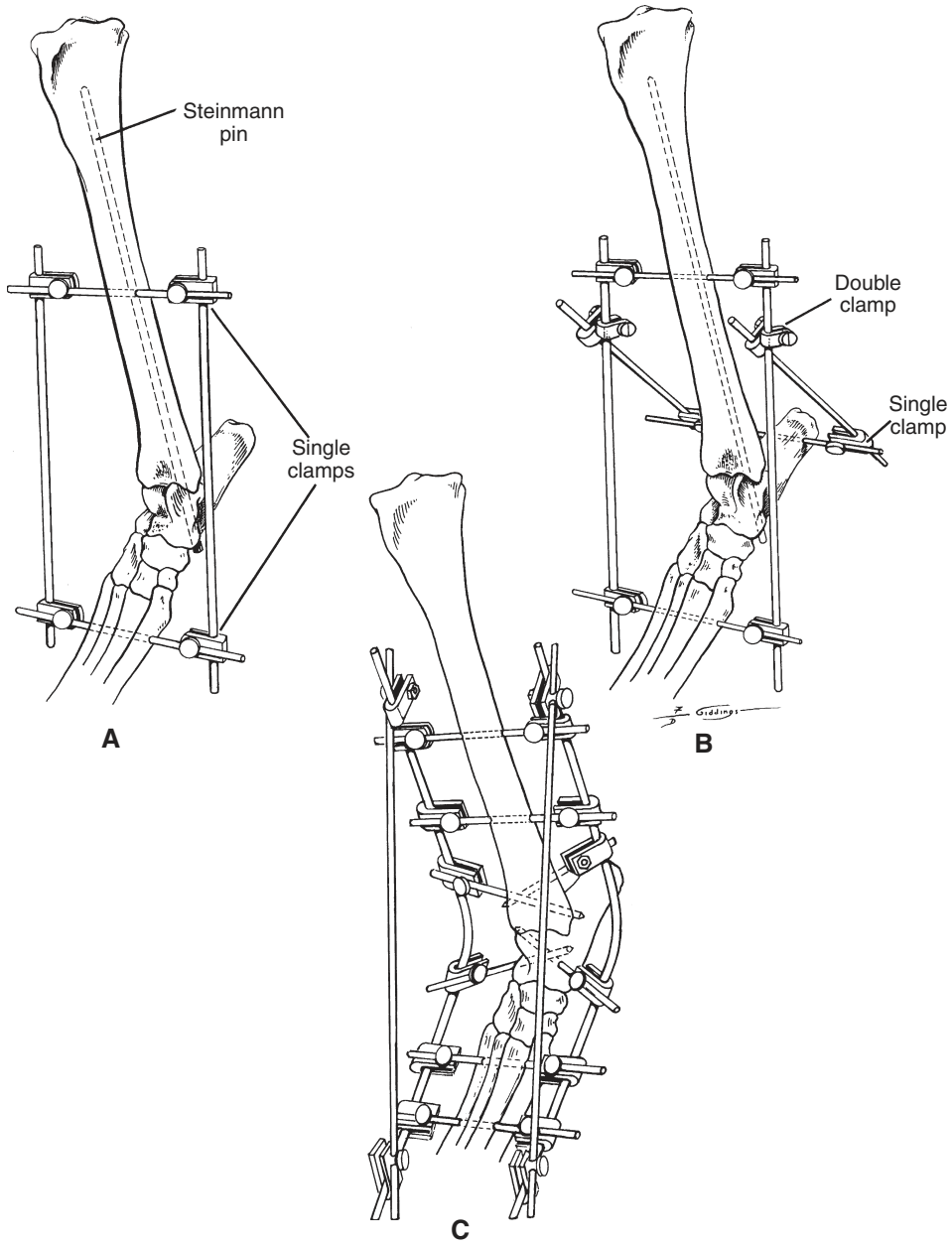


FIGURE 20-24. Arthrodesis of the talocrural joint by external skeletal fixation. **A,** The joint surfaces are prepared as in Figure 20-21, *A* or *B*. A Steinmann pin is driven from the calcaneus into the proximal tibia with the joint at the selected angle. Transfixation pins are driven through the tibia and metatarsal bones. These pins are connected with bilateral rods secured by single clamps. **B,** Additional stability in large dogs is provided by a second transfixation pin in the calcaneus. This pin is connected to the first set of connecting rods with single clamps distally and double clamps proximally. **C,** When no intramedullary pin is used, a more rigid frame is used to prevent bending loads at the arthrodesis site. One of the easier methods is shown here, using a curved connecting rod to eliminate the need for double clamps. Using half pins for the middle sets of fixation pins simplifies the problem of fitting the pins to the connecting rods on both sides when drill guides are not available. At least one of the fixation pins should cross the tarsocrural joint to neutralize shear forces.

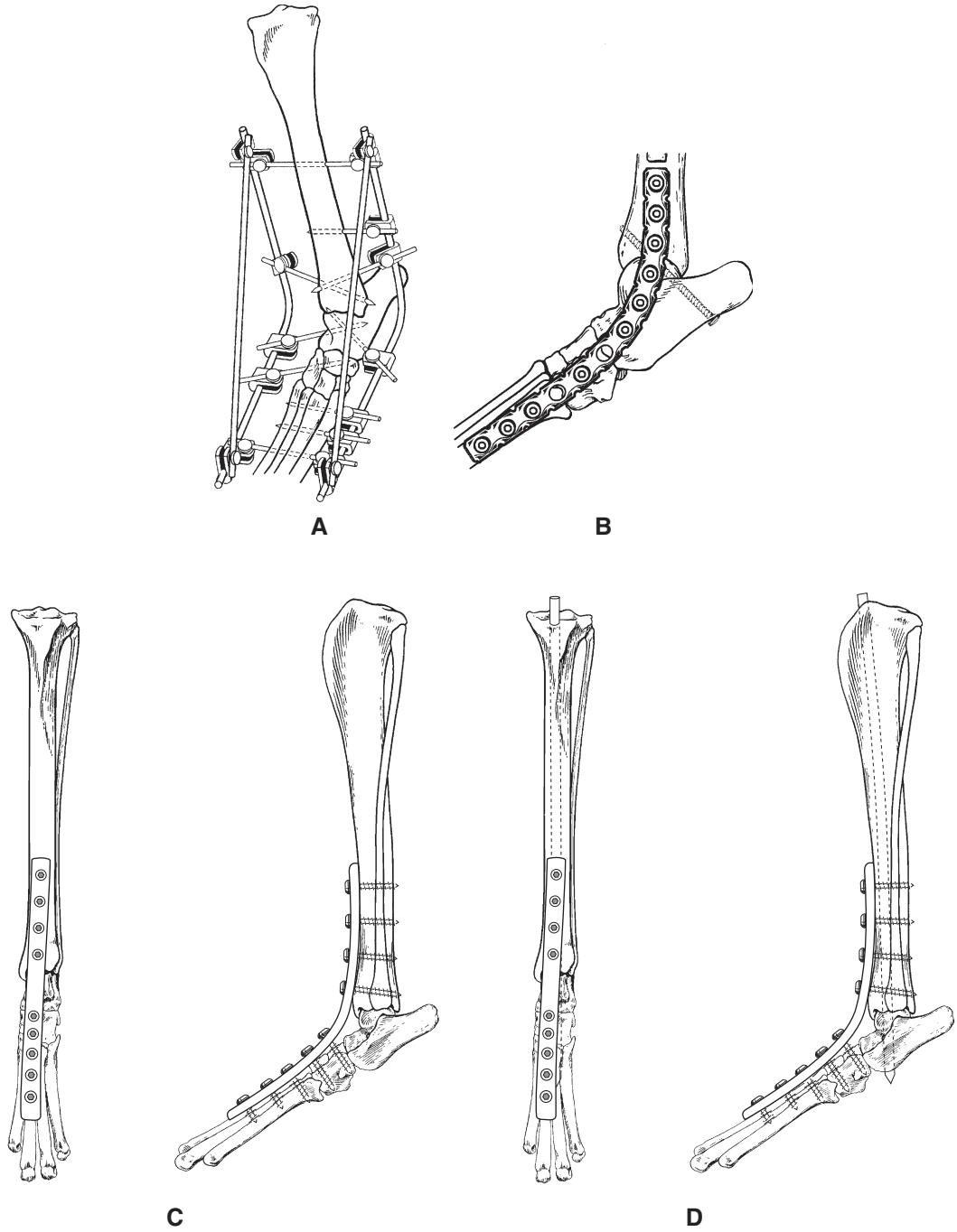


FIGURE 20-25. Pantarsal arthrodesis. **A,** The type IIB external fixator used for tarsocrural arthrodesis (see Figure 20-24, *C*) has been extended to place fixation pins in the central and fourth tarsal bones. Also note that all the fixation pins except the proximal and distal are half pins, which simplifies construction of the frame. **B,** The reconstruction plate can be contoured on edge to follow the curvature of the lateral aspect of the tibia and tarsus. The distal fibula is ostectomized as in Figure 20-23 to allow good contact of the plate with the tibia. **C,** A standard bone plate may be used as fixation if placed along the cranial and dorsal surface of the tibia and tarsus. External coaptation is needed for 8 to 12 weeks after surgery because the plate is subjected to considerable bending stress until fusion of the tarsus is complete. **D,** An intramedullary pin may be used with the plate, extending through the talus and calcaneus to the medullary canal of the tibia, to reduce the bending stress on the plate during healing. External coaptation is advised as previously described.

Pantarsal Arthrodesis

We have noted that some dogs with apparently successful talocrural fusion do not return to full function. In many of these patients, no specific reason for the decreased function has been found, but in some cases, progressive DJD of the more distal tarsal joints has been documented.[21,22] Because the talocrural joint is the site of most motion in the tarsus, when it is fused, the other joints are subjected to increased functional loads that they are not designed to accommodate. Chronic sprain injury to the ligaments as well as DJD may account for the functional problems observed. For this reason, pantarsal arthrodesis may be a better solution to talocrural problems, just as carpal panarthrodesis has yielded better function than antebrachiocarpal arthrodesis. Gorse and colleagues[22] found a tendency for better function with panarthrodesis than with lag screw fixation of the talocrural joint.

Surgical Techniques

The basic preparation of the talocrural joint and establishing the angle of the joint are carried out as described for talocrural arthrodesis. The additional consideration is curettage of articular cartilage in the other joints involved and the additional fixation required to immobilize them. Although the small joints of the tarsus do not require as thorough debridement as do the large joints, bony bridging still will progress more surely if most of the cartilage is removed. It is difficult to insert curettes into the small joints, and if high-speed power burs are not available, several passes with a powered twist drill will suffice. The intertarsal joints often fuse spontaneously when they are bridged by a screw or pin, but the transverse joints require more preparation. The curettage is done primarily from the dorsal, medial, and lateral aspects, leaving the large plantar ligaments intact. Multiple incisions may be necessary to approach all the joints.[1]

External Fixator

Perhaps the simplest method of fixation is the type IIB fixator (Figure 20-25, *A*). This is essentially the same device shown in Figure 20-24, *C,* for talocrural arthrodesis, modified to place fixation pins in the central and fourth tarsal bones. Aftercare is as described for talocrural arthrodesis with the external fixator.

Bone Plate Fixation

Dynamic compression plates, limited-contact dynamic compression plates, and lengthening plates can be used for panarthrodesis by application to the cranial and dorsal surface of the tibia and tarsus (Figure 20-25, *C*). A minimum of three screws is placed in the tibia and metatarsus, one or two screws in the talus, and one screw may be placed in the central or third tarsal bone. Lengthening plates (with no central screw holes) may be used only for very large dogs; only proximal tibial and distal metatarsal screws are placed for this plate type.

In using reconstruction plates for panarthrodesis (Figure 20-25, *B*), the plate is applied laterally to the tibia after resection of the distal fibula (see Figure 20-23), then contoured to allow attachment to the calcaneus, fourth tarsal, and proximal metatarsus. A minimum of three screws must be anchored in the tibia and in the metatarsal bones. Regardless of plate type, plate fixation may be combined with a Steinmann pin driven from the calcaneus and talus into the distal tibia. The pin is driven before plate application with the joint at the desired angle. The plate is then applied, taking care to avoid the pin during placement of the screws (Figure 20-25, *D*). The addition of the Steinmann pin reduces bending stress on the plate during weight bearing.[25]

Aftercare is as described for plate fixation of talocrural arthrodesis. All plate applications for pantarsal arthrodeses are subjected to considerable bending stresses.[25] Successful outcome depends on meticulous adherence to aftercare protocols.

Fractures of Central Tarsal Bone

Fractures of the central tarsal bone are seen infrequently except in the racing greyhound, where they are usually seen in the right foot[26,27] (see Figures 20-26 through 20-29). When these fractures occur in other breeds, there is no predilection for right or left. In the racing greyhound the right foot is the "off" foot—toward the outside of the track—and the bone is subject to tremendous compression forces during turns. These forces literally explode the bone out of its position in the midst of the other six tarsal bones, producing a variety of fractures and subluxations of the bone.

In nonracing animals the simpler fracture types are seen; more often, however, the bone is luxated intact except for a portion of the plantar process. Fixation is by one or two lag screws, followed by coaptation in a lateral splint or short cast; closed reduction and simple coaptation are not effective. The bone is approached by a dorsomedial incision.[1]

Fixation methods for each fracture type are discussed next.

Type 1 Fracture

A small slab is seen on the dorsal surface of the bone, with minimal displacement (Figure 20-26, *A*). In the past, type 1 fractures have been treated primarily with a short lateral splint. Generally, they heal well with 4 to 6 weeks of immobilization, but occasionally they displace a little more during healing and thus create a slight incongruity at the proximal intertarsal joint space. For this reason, type 1 fractures are best treated with a lag screw, as are type 2 fractures.

Type 2 Fracture

Slightly more displacement of the dorsal slab differentiates a type 2 fracture from a type 1 fracture (Figure 20-26, *B*). A single 2.7- or 3.5-mm lag screw centered in the middle of the fragment is placed in a dorsoplantar direction (Figure 20-26, *C*).

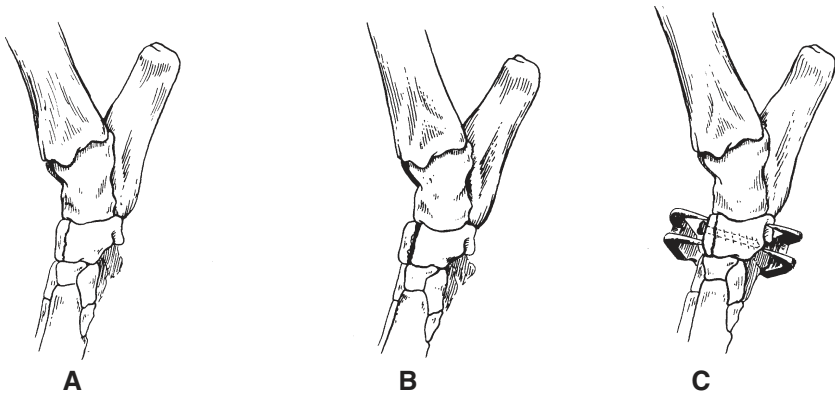


FIGURE 20-26. **A,** Dorsal slab fracture of the central tarsal bone with minimal displacement (type 1). **B,** Dorsal slab fracture of the central tarsal bone, slightly displaced (type 2). **C,** A 2.7-mm lag screw is placed in the center of the fragment. The fragment is held in the reduced position with vulsellum forceps, and the screw is placed between the teeth of the forceps.

Type 3 Fracture

Approximately one third to one half of the bone is fractured in the median plane and is displaced medially or dorsally (Figure 20-27, *A* and *B*). A single 3.5-mm or 4.0-mm lag screw is placed in a mediolateral and slightly plantar direction and seats in the fourth tarsal bone. The screw is placed just proximal to the origin of the ligament between the central and third tarsal bones (Figure 20-27, *C* and *D*).

Type 4 Fracture

Type 4 fractures are most common (68%) and are usually accompanied by associated fractures of the fourth tarsal bone (T4), the calcaneus, or T4 and the lateral aspect of the base of metatarsal V.[28] This injury is a combination of fracture types 2 and 3 (Figure 20-28, *A* and *B*). The distance between the talus and T1-3 may be narrowed if the lateral undisplaced half of the bone is comminuted. This will lead to slight hyperextension and varus deformity of the foot. Because of the severe instability of the tarsus induced by this injury, fractures of other tarsal bones, especially the base of the calcaneus and T3 and T4, should be suspected.

Fixation for type 4 fracture is a combination of the two lag screws used for type 2 and 3 fractures. Exact placement of the screws is critical to ensure that both can be placed in this small bone (Figure 20-28, *C* and *D*). The mediolateral screw must be placed first at the junction of the middle and distal third of the bone. The dorsoplantar screw is placed at the junction of the proximal and middle third of the bone. The angle of the drill bit is important because it must pass proximal to the first screw and also avoid entering the proximal intertarsal joint. If other fractures are present, they are often reduced spontaneously during reduction of the central tarsal bone. Fixation of these fractures is illustrated in Figures 20-9, 20-31, and 20-32.

Type 5 Fracture

Severely comminuted and displaced, type 5 fractures carry the poorest prognosis for racing (Figure 20-29, *A* and *B*). If soundness of the animal for kennel activity

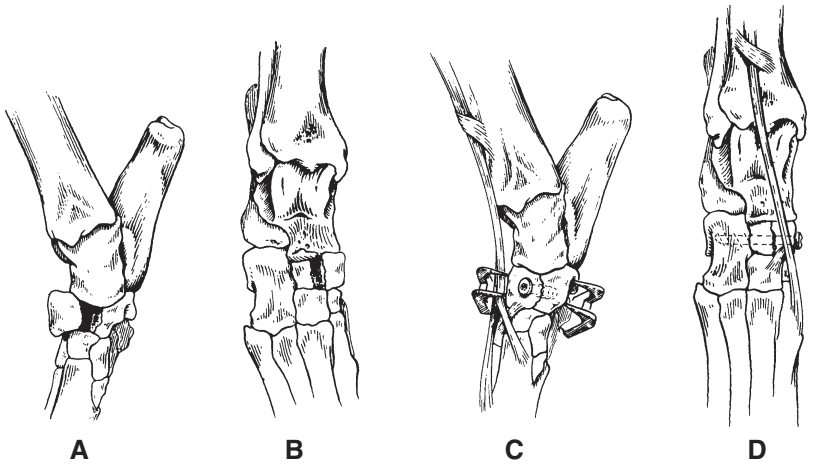


FIGURE 20-27. **A** and **B,** Dorsomedial displacement of the medial portion of the central tarsal bone (type 3 fracture). **C** and **D,** The 3.5- or 4.0-mm lag screw has been inserted in a mediolateral direction. The tendon of insertion of the tibialis cranialis muscle and the ligament between the central and third tarsal bones are shown for orientation. Reduction is accomplished by laterally displacing and flexing the metatarsus to allow the fragment to be wedged back into the joint space. It is held by vulsellum forceps while the screw is inserted.

is the only consideration, closed reduction and immobilization in a short cylinder cast for 6 weeks are sufficient. These animals will have slight hyperextension and varus deformity of the foot. If optimal results are desired, a buttress plate and cancellous bone graft (see Chapter 3) are utilized (Figure 20-29, *C* and *D*). The objective is to restore and maintain the normal joint space and thereby prevent deformity of the foot. Fragments of the bone are left in place, and cancellous graft is packed

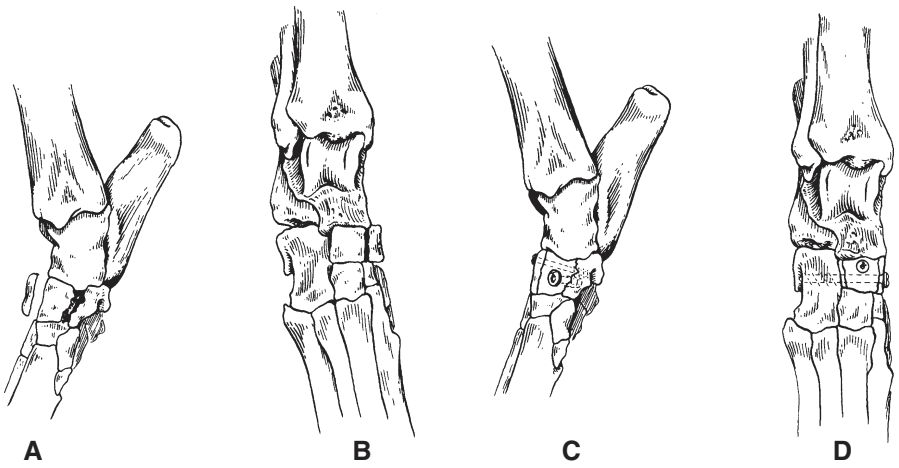


FIGURE 20-28. **A** and **B,** Dorsal and medial displacement of two fracture fragments of the central tarsal bone (type 4 fracture). There may be comminution of the central part of the bone with slight varus deformity of the foot. **C** and **D,** The medial fragment is reduced first, and the 4.0-mm lag screw is placed mediolaterally as far distally in the bone as possible. The 2.7-mm lag screw is placed next in a dorsoplantar direction. Because this screw must not enter the proximal intertarsal joint, the exact angle of the drill hole is critical. Using partially threaded 4.0-mm screws for the mediolateral lag screw gives an extra millimeter of clearance between the two screws over the fully threaded 3.5-mm screw.

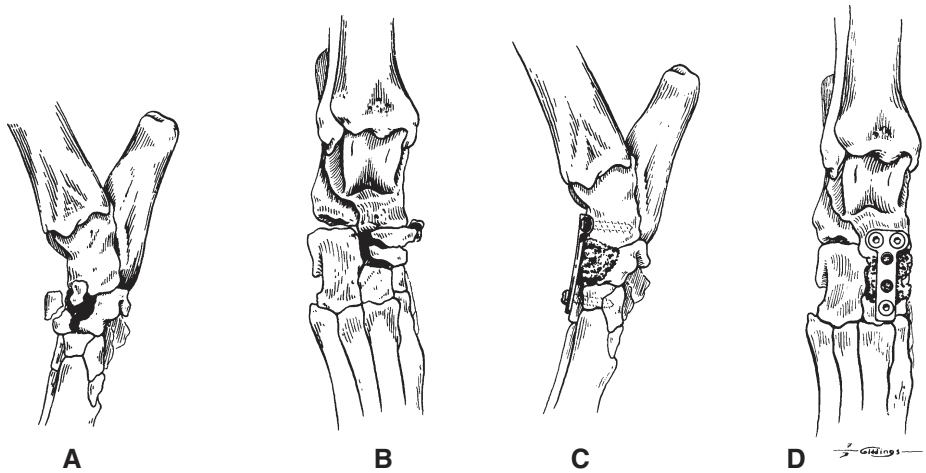


FIGURE 20-29. **A** and **B,** Comminuted fracture of the central tarsal bone (type 5). Note the varus deformity of the tarsus and metatarsus. **C** and **D,** Finger plate (2.7-mm screws) has been used as a buttress plate to restore the joint space occupied by the tarsal bone. No fixation of the fragments is possible because of their small size. The fragments are placed loosely back into the space, and the entire area is packed with autogenous cancellous bone graft obtained from the proximal tibia.

into the spaces. Ligamentous injury on the lateral side of the joint may accompany these fractures and may be difficult to evaluate until the fracture is stabilized. Repair of the ligament or arthrodesis of the unstable joint should be performed for optimum function (see following discussion).

Aftercare

Lag screw fixation in these central tarsal fracture cases is not sufficiently rigid to allow early weight bearing, especially in the greyhound. These animals are very tolerant of pain and will use the limb excessively, even in kennel confinement. A short lateral splint or short cast is applied for 4 weeks (see Figures 2-22 and 2-26). Close confinement is maintained for 8 weeks, at which point radiographs are made. If fracture healing is satisfactory, gradually increasing exercise is allowed; at 12 weeks postoperatively, regular training is allowed. Bone screws do not need to be removed unless the screw enters the proximal intertarsal joint, as may happen with the dorsoplantar screw in type 4 fractures (see Figure 20-28, *C* and *D*). These animals remain slightly lame until the screw is removed. A screw in the joint may also loosen and back out, again requiring removal. The plate used in type 5 injuries should be removed in most cases at 3 to 6 months postoperatively, especially if any attempt will be made to race the dog. Motion in the tarsus will cause the screws to loosen, which causes pain and prevents return to racing form.

Prognosis

With anatomical reduction and rigid fixation, good healing and return to competitive racing can be anticipated in 71% of dogs with fracture types 1 through 4.[29] Type 5 injuries carry a more guarded prognosis for racing, although most patients will become sound for breeding or pet purposes. Some type 4 and 5 injuries also have fractures of the base of the calcaneus (see Figure 20-9) or proximal intertarsal plantar ligament injuries with subluxation and hyperextension of that joint (see following discussion). Again, the prognosis for racing is poor, but soundness of condition for kennel activity can be expected. Treatment is a combination of the methods previously described with the methods for a fracture of the calcaneus and for hyperextension at the proximal intertarsal joint.

Fracture-Luxation of Central Tarsal Bone

Unlike most fractures of the central tarsal bone, which are almost exclusively a fracture of the racing greyhound, fracture-luxation of this bone is seen sporadically in all breeds (Figure 20-30, *A* and *B*). Fracture of the bone occurs at the plantar tubercle, which remains attached to the plantar ligaments, while the rest of the bone displaces dorsomedially. Closed reduction and cast fixation are rarely successful, and surgical stabilization is always advisable. Good function can be anticipated.

Diagnosis

Protrusion of the bone is readily palpable because there is minimal soft tissue swelling. If the bone is luxated completely out of contact with the talus and distal tarsal bones, mild varus deformity and hyperextension may be noted. Radiographs confirm this diagnosis.

Internal Fixation

The bone is approached by an incision directly dorsal to it.[1] The bone is reduced by flexing and lateral bending at the joint. A positional screw is directed laterally into the fourth tarsal bone (Figure 20-30, *C*); Figure 20-27 further illustrates placement

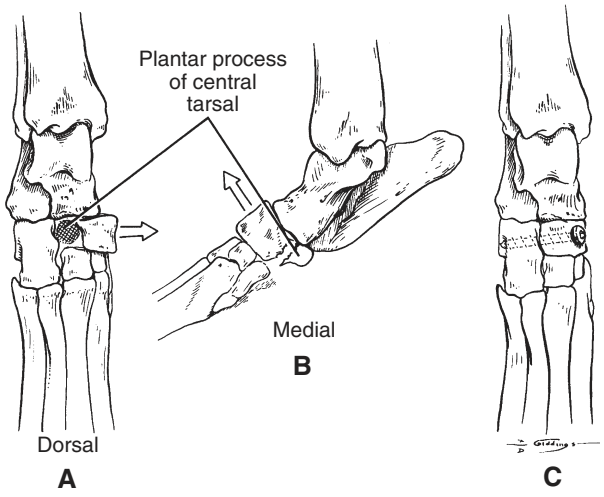


FIGURE 20-30. Fracture-luxation of the central tarsal bone. **A,** The central tarsal luxates dorsomedially. **B** and **C,** Fixation is by means of a positional screw through the central tarsal into the fourth tarsal bone. A threaded Kirschner wire or small pin may be substituted in small dogs.

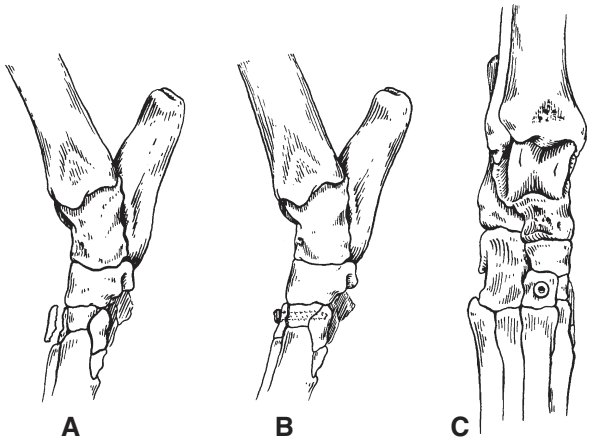


FIGURE 20-31. **A,** Dorsal slab fracture of the third tarsal bone. **B** and **C,** Lag screw fixation with 2.7-mm screw placed in the center of the fragment.

of this screw. Threaded Kirschner wire has been successfully substituted for the bone screw in toy breeds.

Aftercare

A short lateral splint is applied and maintained for 4 weeks (see Figure 2-26). Exercise is limited through the eighth postoperative week.

Fractures of Numbered Tarsal Bones

In our experience, we have not seen fractures of the first and second tarsal bones. Occasionally, the third tarsal bone may be fractured on the dorsal surface in racing greyhounds (Figure 20-31, *A*). This slab fracture is similar to the central tarsal type 1 and 2 fractures and may be treated by closed reduction and casting or preferably by lag screw fixation (Figure 20-31, *B* and *C*). Fractures of the fourth tarsal bone seen in nonracing animals are usually nondisplaced and respond well to casting.

More serious injuries are seen in greyhounds, usually in conjunction with fractures of the central tarsal bone (Figure 20-32, *A*). Some of these require internal fixation, whereas others heal well with a cast after internal fixation of the central tarsal bone.

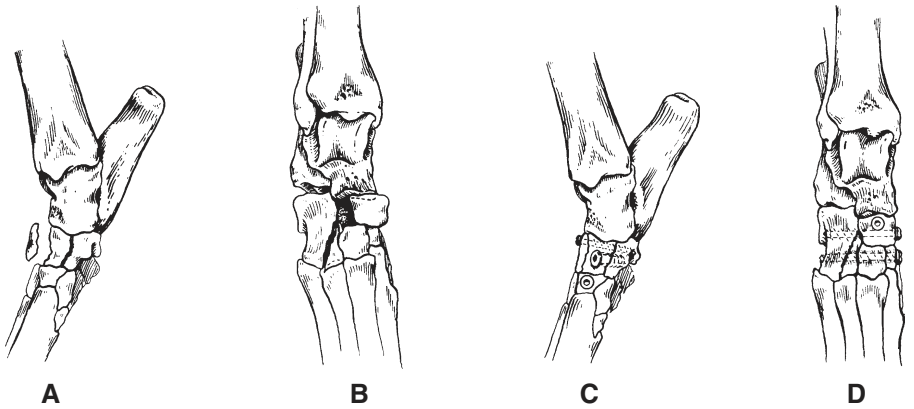


FIGURE 20-32. **A** and **B,** Type 4 fracture of the central tarsal bone with fracture of the head of the fourth tarsal bone. **C** and **D,** Double–lag screw (4.0 and 2.7 mm) fixation of the central tarsal bone is accomplished first, followed by placement of a 3.5-mm lag screw that is started in the second tarsal bone and passes through the third and into the fourth tarsal bone.

The decision is based primarily on the amount of displacement, always bearing in mind that the fracture will probably displace farther while in the cast. If internal fixation of the central tarsal bone is indicated, it is minimal additional work to place a screw or Kirschner wire in the fourth tarsal bone (Figure 20-32, *C* and *D*). The third and fourth tarsal bones are exposed by incision directly over the bones. The third tarsal incision is simply a distal continuation of the approach to the central tarsal bone.

Aftercare

A short lateral splint or short-leg cylinder cast is applied for 4 weeks (see Figures 2-22 and 2-26). Exercise restrictions for racing animals are the same as for animals with central tarsal fractures. For nonracing animals, close confinement is maintained for 6 weeks, followed by 4 weeks of gradual return to normal activity.

Hyperextension with Subluxation of Proximal Intertarsal Joint

This is a common injury of the tarsus in small animals (Figure 20-33, *A*). The majority of affected animals have no history of known trauma. Although hyperextension (dorsiflexion) is seen in all breeds of dogs, the Shetland sheepdog and collie seem to be predisposed, whereas the injury is apparently unrecorded in the cat. Affected animals fall into two groups: highly athletic animals, such as racing greyhounds or coursing dogs, and obese, poorly conditioned dogs.

Diagnosis

Although the entire proximal intertarsal joint is affected, the primary instability is at the calcaneoquartal joint. Stability of the talocentral joint distinguishes this injury from complete luxation, described next (see Figure 20-34, *A*). Tearing or avulsion of the plantar ligament between the fourth tarsal and calcaneus is the primary injury (Figure 20-33, *A* and *B*). Loss of this tension band structure results in a characteristic hyperextension and variable degrees of plantigrade stance. The degree of plantigrade stance varies; the worst cases appear to be standing on the calcaneus bone, whereas many have only 30 to 40 degrees of angulation. Pain and soft tissue swelling are not severe, and most animals tolerate palpation with little show of resentment. The joint is unstable only on the plantar aspect.

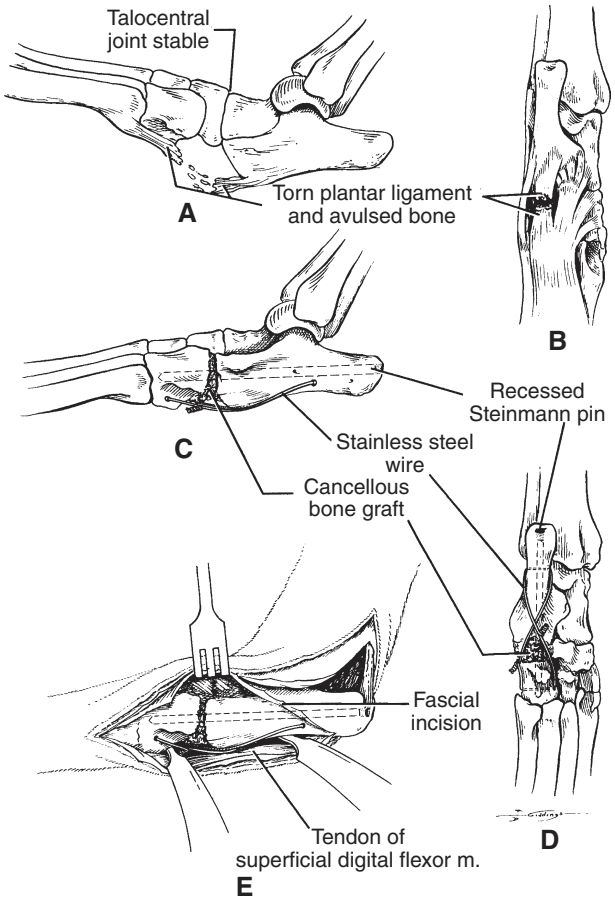


FIGURE 20-33. Arthrodesis of the calcaneoquartal joint for hyperextension with subluxation of the proximal intertarsal joint. **A** and **B,** Tearing or avulsion of the plantar ligament of the calcaneoquartal joint allows hyperextension (dorsiflexion) at the proximal intertarsal joint. **C** and **D,** The joint is exposed by a plantarolateral approach with medial retraction of the superficial digital flexor tendon.[1] The calcaneoquartal joint cartilage is debrided, and an autogenous cancellous bone graft is inserted. A tension band wire (18-20 gauge) is placed between the calcaneus and plantar tubercle of the fourth tarsal but not tightened. A small Steinmann pin 5/64 to 1/8 inch in diameter is driven through the calcaneus into the fourth tarsal and then countersunk beneath the cartilage of the tuber calcanei. The tension band wire is now tightened. **E,** Plantarolateral view of the completed fixation. The superficial digital extensor tendon is retracted medially.

A mediolateral radiograph, with the joint stressed in extension, will confirm the site of instability and may demonstrate avulsed fragments of bone from either the fourth tarsal bone or the base of the calcaneus (Figure 20-33, *A*). Note that the talocentral joint remains unaffected by the instability of the calcaneoquartal joint.

Arthrodesis

Primary repair of the soft tissue injury or cast fixation is rarely successful, and arthrodesis of the calcaneoquartal joint is recommended. Arthrodesis of this joint causes little functional disability, although racing animals rarely return to the track. The tension band wire fixation described here is applicable to any size of animal and is relatively simple to perform.

The joint is exposed by a plantarolateral approach, with medial retraction of the tendon of the superficial digital flexor.[1] Fragments of the torn or avulsed ligament are excised to allow access to the joint. Articular cartilage is debrided on the joint surfaces with a high-speed bur or by curettage. A hole is drilled transversely through the midportion of the calcaneus and the plantar tubercle of the fourth tarsal bone (Figure 20-33, *C* and *D*). An 18- to 20-gauge (1.0- to 0.8-mm) stainless steel wire is threaded through both holes in a figure-of-8 manner. A pilot hole for the intramedullary pin is drilled through the shaft of the calcaneus, favoring the dorsal aspect of the medullary canal. This hole is best made with a slightly undersized bone drill rather

than a pin because of the extreme hardness of this bone. Autogenous cancellous bone graft from the proximal tibia is placed into the joint space with the joint extended to open it. A single pin 5/64 to 1/8 inch (1.9-3.2 mm) in diameter is started at the proximal calcaneus and driven to the distal end of the fourth tarsal bone. The pin is retracted 1 cm, cut, and countersunk beneath the surface of the tuber calcanei to protect the superficial digital flexor tendon. The tension band wire is now tightened by twisting in both halves of the figure-of-8 (Figure 20-33, *D* and *E*). The twists are cut and bent flat against the bone. The lateral retinaculum of the superficial digital flexor tendon is sutured as in Figure 20-10, *B,* to prevent its luxation, and the skin is closed routinely.

Aftercare

Although external casts or splints are not required, a padded bandage is useful during the first postoperative week. Exercise is restricted to the house, a small pen, or a leash until radiographic signs of fusion are noted, usually 6 to 8 weeks postoperatively. At this time, activity can be slowly increased to normal at 12 weeks.

Hyperextension with Luxation of Proximal Intertarsal Joint

A much less common injury than subluxation, this luxation is usually a result of severe trauma and may be complicated by fractures of the tarsal bones (Figure 20-34, *A*). Arthrodesis of the joint is the preferred method of fixation, since primary repair of the ligaments is fruitless. Function is excellent with this fusion. Because the entire proximal intertarsal joint is involved, bone plate fixation results in more stable fixation of the talocalcaneal portion of the joint than does tension band wire fixation (see Figure 20-33). The tension band wire method can be used if modified to provide additional stability of the talocalcaneal joint by adding the medial wire fixation shown in Figure 20-35, *C*, *D*, and *E*. External skeletal fixators are also adaptable to this procedure.

Diagnosis

This condition is differentiated from subluxation by instability of the joint in all planes and is confirmed radiographically by marked dorsal displacement of the distal segment rather than hinging at the dorsal aspect of the proximal intertarsal joint. This shows clearly in stressed mediolateral radiographs.

Arthrodesis

Bone Plate Fixation

The joint is exposed by a lateral incision from the tuber calcanei to the base of the metatarsals. An alternative plantar approach for plate fixation has also been described but will not be detailed here.[30] Articular cartilage is removed from the entire joint by high-speed bur or curettage. The lateral side of the base of the calcaneus must be flattened to allow firm seating of the bone plate. This may involve sacrificing a portion of the insertion of the long part of the lateral collateral ligament, which can be reattached by a suture running beneath the plate. A seven-hole plate of a 3.5- or 2.7-mm screw size is typically used (Figure 20-34, *B* and *C*), although the VCP (Synthes) is particularly useful here to ensure an adequate number of plate holes to match the bones. A minimum of three screws is placed proximally, one penetrating the calcaneus and talus and the rest attached only to the calcaneus. One screw spans the tarsus distal to the proximal intertarsal joint, and at least three screws are placed in metatarsals IV and V. Autogenous cancellous bone graft is used in the joint space (see Chapter 3).

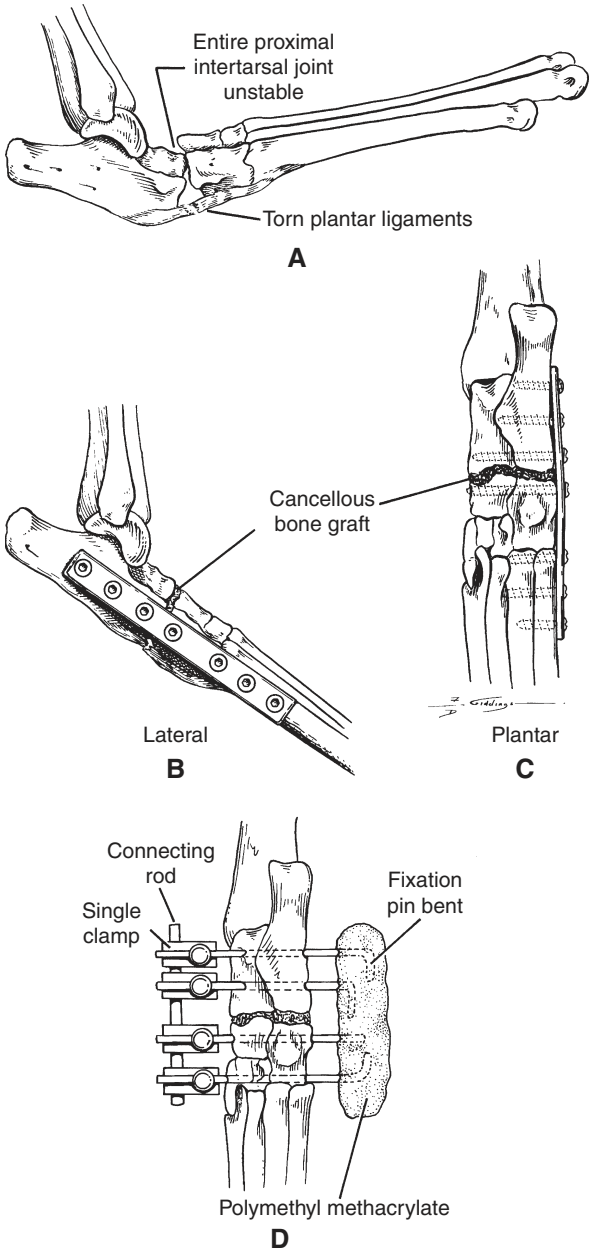


FIGURE 20-34. Arthrodesis for hyperextension with luxation of the proximal intertarsal joint. **A,** Complete luxation is differentiated from subluxation by marked dorsal displacement of the distal tarsus at the proximal intertarsal joint. **B** and **C,** After curettage of the proximal intertarsal joint. Bone plate fixation requires smoothing of the lateral surface of the calcaneus and base of the fifth metatarsal. Plates are usually of the 3.5- or 2.7-mm screw size. At least three screws are placed in the calcaneus. The third screw is angled to engage the head of the talus, and the fourth screw spans the tarsus. The distal screws are placed in metatarsals IV and V. **D,** External skeletal fixation is applicable to this surgery. Both the use of conventional clamp fixation *(left)* and the use of polymethyl methacrylate dental tray cement as a connecting rod *(right)* are illustrated. Fixation pins are bent for more stability in the cement. See text for details.

In larger breeds it may be possible to place three screws in the fourth tarsal bone by using the VCP. If so, the plate does not need to be extended distally to the metacarpal bones; this helps prevent some complications explained next.

Aftercare. External support is advisable because the lateral plate is not in the tension band position. A short lateral splint or cylinder cast is maintained until radiographic signs of fusion are present, usually 6 to 8 weeks (see Figures 2-22 and 2-26). If the plate crosses the tarsometatarsal joint, it will always loosen as a result of joint motion, which causes the metatarsal screws to loosen. The plate should be left in place at least 4 months, preferably 6 months. If the distal metatarsal screws loosen before this, it is advisable to remove them, but the tarsal screws should be

left in for 4 to 6 months. Loss of blood supply to the skin as a result of the original or surgical trauma may lead to skin necrosis over the plate. This should be treated as an open granulating wound, with the plate left in place. The plate is removed about 4 months postoperatively if fusion is good, and if still present, the skin defect is grafted or allowed to granulate.

External Skeletal Fixator

Stabilization of this arthrodesis is also possible by means of a type II external skeletal fixator. This method is advantageous when open wounds are associated with the injury and when bone plate fixation is not available. The fixation pins can be connected conventionally with clamps, as on the left side of Figure 20-34, *D,* or by means of polymethyl methacrylate cement (dental tray cement or hoof repair acrylic; see Chapter 2), as on the right side of Figure 20-34, *D*. The joint is approached from a dorsal incision centered over the joint, and articular cartilage is removed by high-speed bur or curettage. Autogenous cancellous bone from the proximal tibia is placed in the joint space (see Chapter 3). Two fixation pins are placed transversely in the calcaneus and talus. If the fixation will use connecting clamps, care must be taken to ensure that the pins are spaced widely enough to allow placement of the clamps. Two more pins are placed distally in the tarsal bones. If there is not sufficient room to place both pins in the tarsus, the distal pin is driven through the bases of the metatarsal bones. The pins are then connected by clamps or cement. If cement is to be used, the fixation pins can be bent at a right angle at the protruding end to provide more surface contact for the cement. The cement is mixed until reaching a doughlike consistency, then molded into a rod approximately 3/4 inch (2 cm) in diameter and hand-packed onto the fixation pins. The arthrodesis site must be stabilized until the cement has hardened, typically 8 to 10 minutes from the start of mixing.

Aftercare. The animal is closely confined and the fixator maintained until radiographic signs of bony fusion are well defined, typically 8 to 10 weeks. Exercise is slowly returned to normal 4 weeks after fixator removal.

Proximal Intertarsal Subluxation with Dorsal Instability

This subluxation injury is much less common than hyperextension at the proximal intertarsal joint. Although the primary damage is to the dorsal ligaments (Figure 20-35, *A* and *B*), medial or lateral instability is often present, with varus deformity resulting from lateral instability being most common. The condition is evidently caused by overstress (i.e., self-induced) because outside trauma is rarely reported by the owner, although some animals have sustained this injury while climbing woven wire fences.

Diagnosis

Diagnosis of the condition can be difficult because the proximal intertarsal subluxation can be demonstrated only by palpation. There are few clinical signs with this condition other than a mild hindlimb lameness. The dog stands normally because the plantar ligaments are intact, but instability creates inflammation and pain in the joint and causes mild lameness, which is worse if medial or lateral instability is superimposed. Physical examination will reveal abnormal flexion at the proximal intertarsal joints. Medial and lateral stability should be tested, and stress-position radiographs should be made to confirm the physical findings. Figure 20-35, *A* and *B,* illustrates the dorsolateral instability.

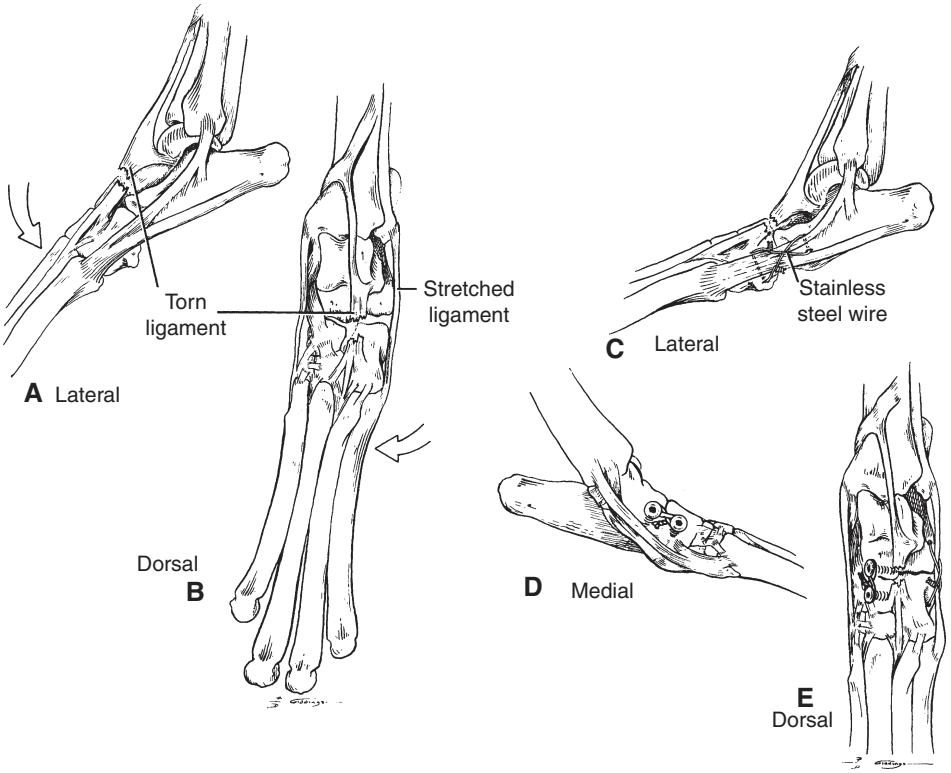


FIGURE 20-35. Surgical repair of proximal intertarsal subluxation with dorsal instability. **A** and **B,** Excessive flexion and often varus deformity occur when the dorsal ligaments are ruptured. **C,** Lateral instability is stabilized with stainless steel wire (20-22 gauge) placed through drill holes in the bony prominences of the distolateral calcaneus and proximolateral fourth tarsal bones. **D** and **E,** Dorsomedial instability is stabilized by placing stainless steel wire (20-22 gauge) between screws placed in the base of the talus and central tarsal bones.

Treatment

Because the dorsal ligaments do not function as tension bands, conservative treatment by casting for 3 to 4 weeks is often effective if there is no medial or lateral laxity. The smaller the patient, the more likely conservative treatment is to succeed. In larger breeds and in athletic animals, surgical treatment is more frequently indicated.

Arthrodesis

Surgical repair is indicated when dorsal ligamentous instability is complicated by medial or lateral instability. Surgery becomes even more important in a large athletic dog. Stabilization from both the medial and the lateral side is usually indicated. Because primary repair of such small ligaments is usually not possible, arthrodesis is preferred. The areas are approached by incisions directly over the bones. Medial and dorsal instability can be eliminated by placing stainless steel wire of 20 to 22 gauge (0.8-0.6 mm) between screws placed in the talus and central tarsal bones (Figure 20-35, *D* and *E*). Articular cartilage of the proximal intertarsal joint is debrided before screw placement, and suturing of any available ligament fragments is useful. Bone grafting is not routinely needed. If there is significant lateral instability, a tension band wire can be added laterally (Figure 20-35, *C*). Bony projections are available on both the

distal calcaneus and the proximal fourth tarsal to allow bone tunnels to be drilled for wire placement. Stainless steel wire of 20 to 22 gauge (0.8-0.6 mm) is used for the tension band.

Aftercare. A short lateral splint is applied for 4 weeks (see Figure 2-26), with activity restricted through 8 weeks postoperatively. If the joint does not completely fuse, the screw may loosen and back out, thus requiring removal.

Distal Intertarsal Subluxation with Dorsomedial Instability

This subluxation injury can be seen in isolation or combined with hyperextension at the proximal intertarsal joint or tarsometatarsal luxation with dorsal instability (Figure 20-36, *A*). Cast fixation has been disappointing in our experience, and we advise surgical stabilization.

Diagnosis

Valgus deformity resulting from dorsomedial ligamentous instability can be appreciated on palpation. Soft tissue swelling is minimal. Radiographs in the stressed position confirm the site of instability and should be studied carefully for fractures of the fourth tarsal bone, a frequent complication.

Treatment

Because primary repair of such small ligaments is usually not possible, arthrodesis is preferred. The technique shown here is combined with proximal intertarsal arthrodesis when the distal intertarsal subluxation is concurrent with hyperextension.

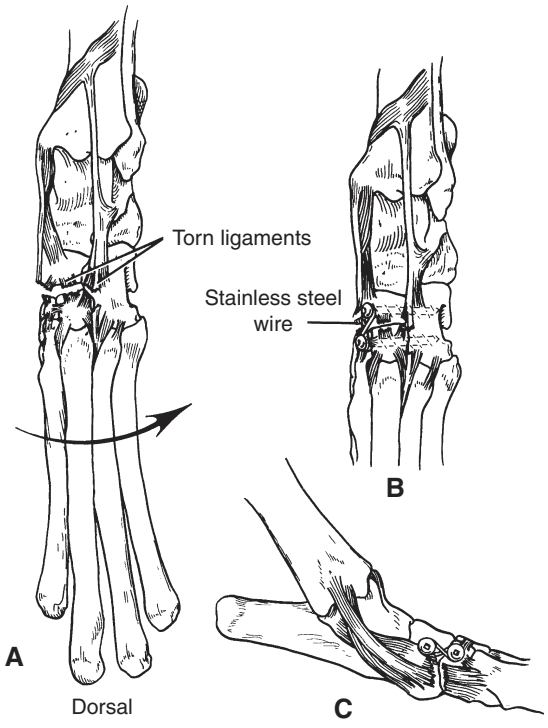


FIGURE 20-36. Distal intertarsal subluxation with dorsomedial instability. **A,** Valgus deformity is evident after rupture of the medial and dorsal ligaments of the centrodistal joint. **B** and **C,** Bone screws are placed through the central and distal tarsals into the fourth tarsal. Articular cartilage of the centrodistal joint is debrided, and stainless steel wire (20-22 gauge) is looped around the screw heads and tightened.

Arthrodesis

The area is exposed by a distomedial extension of the approach to the central tarsal bone.[1] Articular cartilage is removed from the centrodistal joint by high-speed bur or curettage. Bone screws are placed from the central and second tarsal bones laterally into the fourth tarsal bone. Stainless steel wire, 20 to 22 gauge (0.8-0.6 mm), is looped around the screw heads and twisted tightly (Figure 20-36, *B* and *C*).

Aftercare. A short lateral splint is applied and maintained for 4 weeks (see Figure 2-26). Exercise is limited through the eighth postoperative week.

THE METATARSUS, PHALANGES, AND SESAMOIDS

Fractures of these bones are virtually identical to fractures of the corresponding bones of the metacarpus and forefoot and are covered in Chapter 14.

Hyperextension with Subluxation of Tarsometatarsal Joints

This injury is not as common as proximal intertarsal hyperextension. The plantar tarsal fibrocartilage is torn in this hyperextension injury with subluxation of the tarsometatarsal joints (Figure 20-37, *A*).

Diagnosis

This condition seems to be related more often to known trauma than does proximal intertarsal hyperextension; thus, more soft tissue swelling is seen. The injury often occurs when an animal becomes tangled in a wire mesh fence while attempting to climb it. Pain is not marked, and most animals will attempt weight bearing within a few days, with a typically plantigrade stance. Radiographs taken with hyperextension stress readily confirm the injury (Figure 20-37, *A*). In some cases, more complete luxation with plantar displacement of the bases of one or more metatarsal bones will be seen. Rarely are all four metatarsals completely luxated.

Treatment

As with other hyperextension injuries, conservative treatment by cast fixation is usually unsuccessful. Arthrodesis of the tarsometatarsal joints is the best treatment and yields good results, and virtually normal function is anticipated.

Arthrodesis

The joints are exposed by means of a dorsal or plantar approach.[1] The digital flexor or extensor tendons are alternately retracted medially and laterally to allow debridement of articular cartilage of the joints. These joints do not form a straight line across the tarsus; therefore, each one must be curetted independently. Several fixation techniques are adaptable to this condition.

Intramedullary Pin and Tension Band Wire. This method works well and requires minimal equipment (Figure 20-37, *C* and *D*). Transverse holes for the wire (18-20 gauge) are drilled in the bases of the calcaneus and the metatarsal bones. Placing the proximal end of the wire in the base of the calcaneus shortens the wire compared to placing it over the pin at the tuber calcanei and causes the wire to cross closer to the tarsometatarsal joint. The wire must be placed deep to the superficial digital flexor tendon. Because of the collective quarter-moon cross-sectional shape of the proximal metatarsal bones, it is unlikely that the drill will go through more

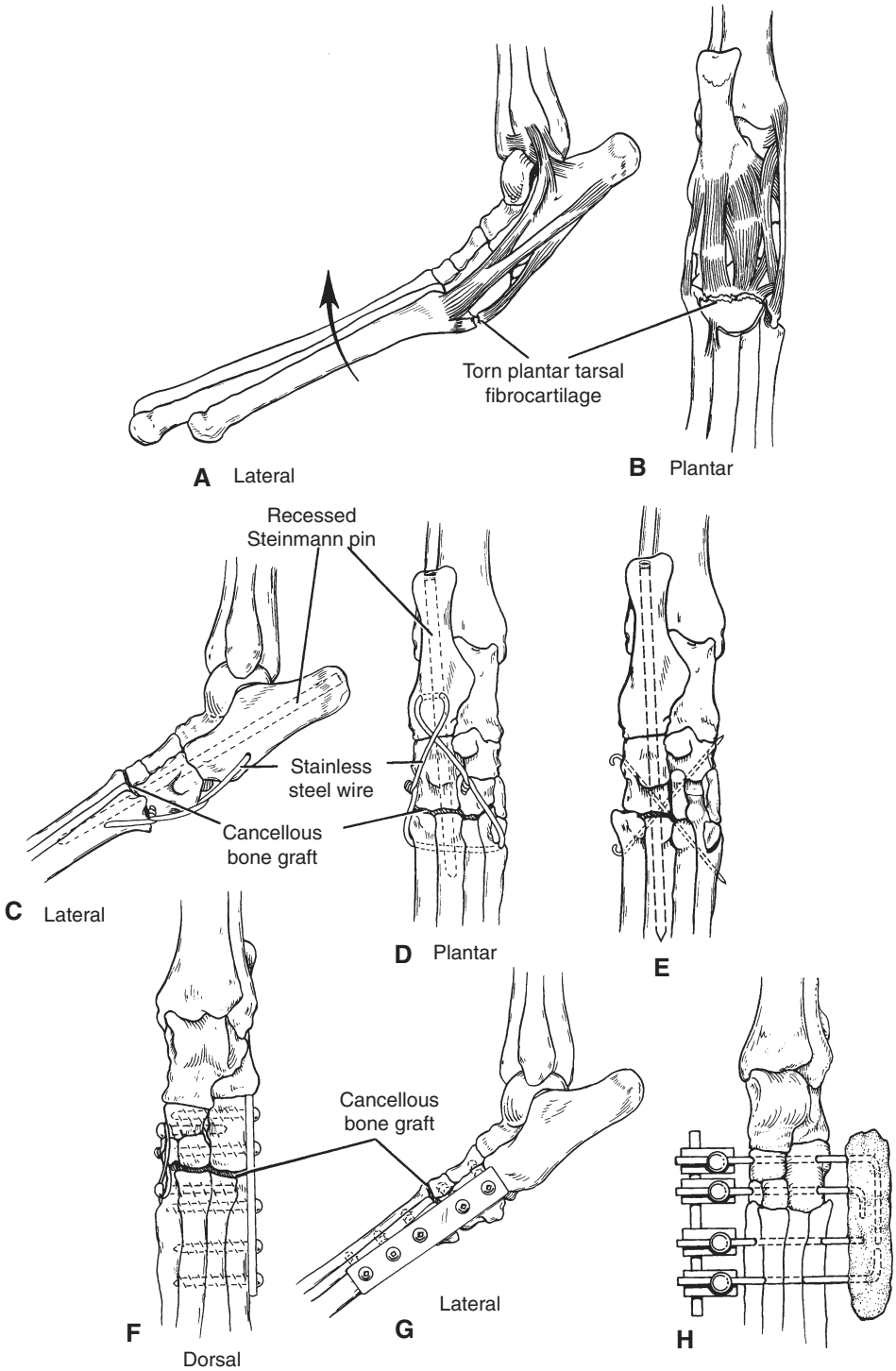


FIGURE 20-37. Hyperextension of the tarsometatarsal joints. **A** and **B,** Rupture of plantar tarsal fibrocartilage removes the tension band support for the joint and allows hyperextension to develop. **C** and **D,** Arthrodesis by pin and tension band wire. A plantar approach is used to expose the joint for cartilage debridement.[1] Stainless steel wire (18-20 gauge) is placed through bone tunnels in the distal calcaneus and proximal metatarsals. The Steinmann pin 5/64 to 1/8 inch (2.0-3.2 mm) in diameter is driven into the fourth metatarsal and recessed into the calcaneus to prevent damage to the superficial digital flexor tendon. **E,** A technically

simpler method than the tension band wire involves replacing the wire with two transfixation pins placed to penetrate tarsal and metatarsal bones. The cost of this simpler procedure is the use of coaptation splintage until fusion is present. **F** and **G,** Lateral bone plate fixation for arthrodesis. At least two screws in the fourth tarsal bone and three screws in the metatarsals are needed for this situation. The cuttable plate (Synthes, Ltd., Paoli, Pa) will simplify placing an adequate number of screws in each segment. In large breeds, bending loads on the medial side are neutralized with screw and wire fixation. External support in a cast or splint is necessary. **H,** External skeletal fixation is applicable to this surgery. Both the use of conventional clamp fixation *(left)* and the use of polymethyl methacrylate dental tray cement as a connecting rod *(right)* are illustrated. Fixation pins are bent for more stability in the cement. See text for details.

than three of the four bones. A small Steinmann pin 5/64 to 1/8 inch (2.0-3.2 mm) in diameter is driven through the calcaneus, across the fourth tarsal bone, and into the base of metatarsal IV. It is then retracted 1 cm, cut short, and countersunk beneath the cartilage of the tuber calcanei. It is worthwhile to predrill a hole in the calcaneus for the pin with a slightly undersized bone drill. Autogenous cancellous bone graft is packed into the joint space before the wire is tightened (see Chapter 3). Because the pin crosses the calcaneoquartal joint, spontaneous fusion of the joint often follows. If the joint does not fuse, the IM pin will usually migrate proximally and irritate the superficial digital flexor tendon, necessitating removal of the pin.

Intramedullary Pin and Transfixation Pins. A simplified method of tarsometatarsal arthrodesis has been reported by Penwick and Clark.[31] The tension band wire is replaced by transfixation pins that cross the joint in an X pattern (Figure 20-37, *E*). The advantage of being able to do the procedure from a dorsolateral approach and thus avoid the more complicated plantar area for wire implantation is offset by the need for coaptation splintage until fusion. The Steinmann pin can be placed in a retrograde manner from the distal surface of the fourth tarsal proximally through the calcaneus, where it is retracted and then driven distally into metatarsal IV. The Steinmann pin can be countersunk in the calcaneus or left protruding for later removal.

Bone Plate. Lateral plate fixation also provides excellent stabilization (Figure 20-37, *F* and *G*). A five-hole plate of appropriate size is attached to the fourth, central, and distal tarsal bones proximally and to the metatarsals distally. Ideally, three screws should be placed in the fourth tarsal bone, but this is rarely possible with normal plates. The VCP (Synthes) is particularly adaptable to the small and medium-sized breeds because it will ensure an adequate number of screws in each bone. Rarely will more than three of the metatarsals be engaged by any drill hole. A lateral bony projection of the base of metatarsal V will need to be removed to allow seating of the plate. Addition of wire and screw fixation medially is indicated in large breeds because of the difficulty in extending the plate screws to metacarpal II. Autogenous cancellous bone grafting of the joint spaces is advisable (see Chapter 3). An alternative plantar approach for plate fixation for arthrodesis of the tarsometatarsal joints has been described.[30]

External Fixator. Stabilization of this arthrodesis is also possible by means of a type II external skeletal fixator. This method is advantageous when open wounds are associated with the injury and when bone plate fixation is not available. The fixation pins can

be connected conventionally with clamps, as on the left side of Figure 20-37, *H,* or by means of polymethyl methacrylate cement (dental tray cement or hoof repair acrylic; see Chapter 2), as on the right side of Figure 20-37, *H*. The joint is approached and articular cartilage removed by power bur or curettage as described earlier. Autogenous cancellous bone from the proximal tibia is placed in the joint space (see Chapter 3). Two fixation pins are placed transversely in the distal tarsal bones. If the fixation will use connecting clamps, care must be taken to ensure that the pins are spaced widely enough to allow placement of the clamps. Two or more pins are placed distally in the metatarsal bones. The pins are then connected by clamps or cement. If cement is to be used, the fixation pins can be bent at a right angle at the protruding end to provide more surface contact for the cement. The cement is mixed until reaching a doughlike consistency, then molded into a rod approximately 3/4 inch (2 cm) in diameter and hand-packed onto the fixation pins. The arthrodesis site must be stabilized until the cement has hardened, typically 8 to 10 minutes from the start of mixing.

Aftercare. External casting is not needed with the tension band wire or external fixator technique, but it is advised with bone plating, because the plate is not in a tension band position, and for the pin and transfixation pin method. A short lateral splint or cast or the external fixator is maintained until radiographic signs of fusion are noted, usually 8 to 10 weeks postoperatively. Exercise should be severely limited through this period and is slowly returned to normal 4 weeks after splint or fixator removal. If the calcaneoquartal joint does not fuse spontaneously with IM pin and tension band wire or transfixation pin fixation, the pin may migrate because of motion at the joint. This will create considerable soft tissue irritation and require removal of the pin after fusion is complete.

Tarsometatarsal Subluxation with Dorsomedial Instability

Although angular displacement may not appear severe with this injury, it is nonetheless a disabling problem (Figure 20-38, *A*). This is because the medial tarsus is the tension side, and attempted weight bearing further aggravates valgus deviation.

Diagnosis

Tarsometatarsal subluxation with dorsomedial instability is rarely spontaneous and usually is directly attributable to trauma; thus it may be associated with other local or remote injuries. The instability can be appreciated on palpation but probably cannot be differentiated from distal intertarsal subluxation. Radiographs of the animal in the stressed position are necessary to confirm the diagnosis.

Treatment

Cast fixation generally yields poor results, and primary repair of these small ligaments is rarely possible. However, simple arthrodesis carries a good prognosis.

Arthrodesis

A medial incision is made directly over the affected joints. Articular cartilage is debrided in the second and third tarsometatarsal joints by high-speed bur or curette. Bone screws are placed in the central and fourth tarsal bones and in the bases of metatarsals II, III, and IV. Stainless steel wire (20-22 gauge; 0.8-0.6 mm) is looped around the screw heads and tightened (Figure 20-38, *B* and *C*). A second technique applicable here is cross-pinning of the tarsometatarsal joint with Kirschner wires (Figure 20-38, *D*). A tension band wire placed between the pins provides good stability.

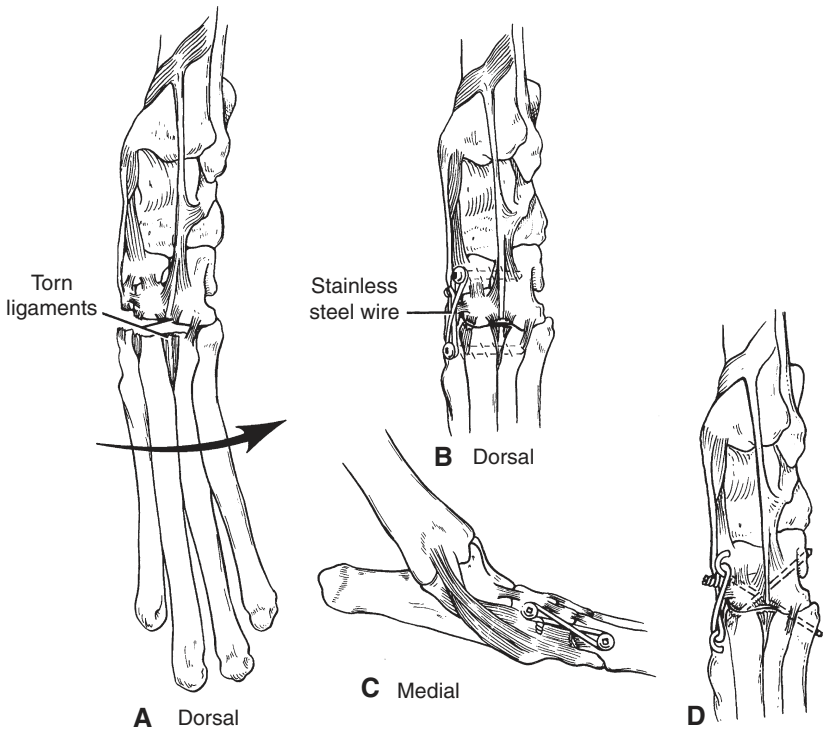


FIGURE 20-38. Tarsometatarsal subluxation with dorsomedial instability. **A,** Valgus deformity develops as a result of disruption of the dorsomedial tarsometatarsal ligaments. **B** and **C,** Direct medial approach exposes the affected joints, and articular cartilage is removed. Bone screws are placed in the central and fourth tarsal and metatarsals II, III, and IV. Stainless steel wire (20-22 gauge) is placed around the screw heads and tightened. **D,** Support can also be provided with Kirschner wires and a tension band wire placed between the pins.

Aftercare. A short lateral splint or cast is applied and maintained for 3 weeks (see Figures 2-22 and 2-26). Exercise is limited throughout the eighth postoperative week. The pins may migrate after active weight bearing starts, at which time they should be removed.

Tarsometatarsal Subluxation with Dorsal Instability

As with dorsal instability at the proximal intertarsal level, this injury is apparently self-induced in most cases; it is rarely associated with known trauma (Figure 20-39, *A*).

Diagnosis

History and clinical signs of tarsometatarsal subluxation with dorsal instability are similar to those of proximal intertarsal dorsal instability, that is, a rather vague and intermittent lameness. Because the deformity is not seen when the dog is standing, palpation to exert flexion stress is important in diagnosis. Radiographs showing the stress position will confirm the site of instability.

Treatment

This tarsometatarsal subluxation may be one of the lesser tarsal injuries, often responding to cast fixation for 3 to 4 weeks. The larger the dog and the more instability present, the greater is the need for surgical treatment. All chronic cases should

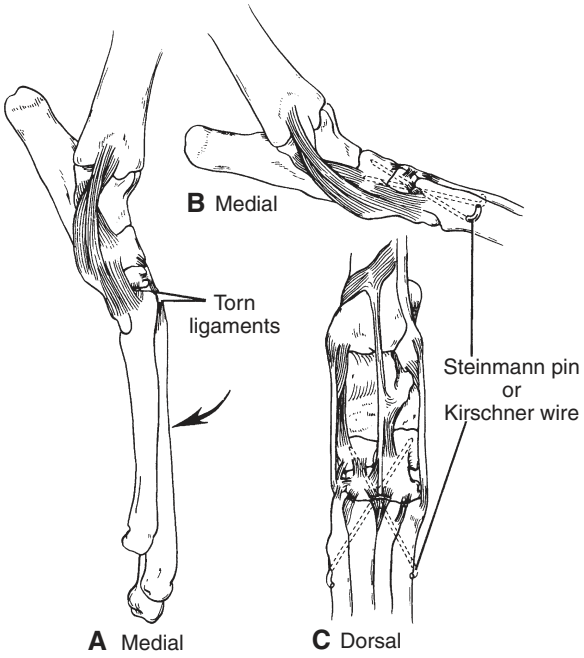


FIGURE 20-39. Tarsometatarsal subluxation with dorsal instability. **A,** Flexion deformity can be induced from tearing of the dorsal ligaments of the tarsometatarsal joints. **B** and **C,** Cross-pinning through paired medial and lateral incisions is sufficient to stabilize this condition. The pins should be seated close to the bones to prevent skin irritation. These pins can also be driven from the tarsus in the opposite direction.

undergo surgical treatment. Primary repair of these small ligaments is rarely possible, but simple arthrodesis carries a good prognosis. Because the plantar ligaments and fibrocartilage are intact, only minimal fixation is required.

Arthrodesis

Paired medial and lateral incisions expose the joints. Small pins or Kirschner wires are driven from the proximal metatarsals into the tarsal bones in an X fashion (Figure 20-39, *B* and *C*). It is best not to cross the proximal intertarsal joint with the pins. Each pin is driven to the desired depth, retracted 1 cm, and cut 1 cm from the bone. A hook is bent in the pin and is then tapped back against the bone. Pins can also be driven in the opposite direction, from the tarsus into the metatarsals.

Alternatively, combined medial and lateral screw and wire fixation similar to Figure 20-38, *B* and *C,* can be used.

Aftercare. A short-leg lateral splint or cast is maintained for 4 weeks (see Figures 2-22 and 2-26). Exercise is restricted through 8 weeks postoperatively. The pins will almost certainly migrate when active weight bearing starts; they should then be removed.

Luxation and Subluxation of Metatarsophalangeal and Interphalangeal Joints

These injuries are identical to those of the forefoot (see Chapter 14, Figures 14-39 through 14-43).

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21

Fractures and Luxations of the Mandible and Maxilla

Fractures of the jaws are usually caused by automobile or other forms of trauma and are characterized by swelling, deviation of the segments, malocclusion of the teeth, and blood-stained saliva.[1] With few exceptions, all jaw fractures are open and contaminated or infected. These fractures may be unilateral or bilateral with single or multiple fracture lines. Mandibular fractures accounted for 3% of all canine and 15% of all feline fractures in two studies.[2,3] Symphyseal fractures were the most common injury in cats (73%), and the premolar region of the mandibular body was the most common site for fractures in the dog. Fractures of the maxilla are relatively rare compared with mandibular fractures. Vehicular trauma is the most common cause of fractures in the head; therefore, associated life-threatening trauma of other regions is often present. Small and toy breeds with gingivitis and alveolar disease are prone to pathological fracture. Extreme care must be taken during dental extraction to avoid iatrogenic problems.

In general, healing is rapid (3-5 weeks) in the rostral mandible but more delayed (4-17 weeks) in the caudal region.[2] The exception to this general statement on healing is fractures through infected sockets and symphyseal fractures in elderly toy breeds when considerable osteoporosis precedes the fracture. Complications are fairly common (34% in dogs), with malocclusion the most frequent complication, followed by infection and delayed union or nonunion.[2]

DIAGNOSIS AND GENERAL TREATMENT

Diagnosis is usually based on a history of trauma, sudden onset, appearance, and a palpable fracture. Radiography is also helpful in discerning fracture lines and displacement; however, it is supplemental to a thorough physical examination under anesthesia or sedation because fracture lines can be difficult to see and to orient radiographically.

The objective of treatment should be restoration of functional occlusion by fixation that allows the animal to have sufficient use of the mouth to eat and drink after reduction and fixation. With few exceptions, this goal can be achieved.

Treatment varies considerably, and in many cases, some type of internal fixation is indicated. The tension band side of both jaws is the alveolar border, and fixation should be applied as close to this side as possible (Figure 21-1). With a few exceptions, bone fragments are replaced in the reduction process and are not discarded. Realignment is usually best checked with the jaw closed and the teeth occluded.

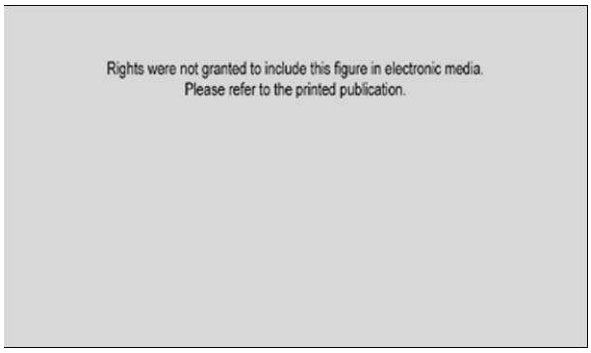


FIGURE 21-1. Masticatory forces exerted by muscles *(black arrows)* cause ventral bending of the mandible, with tension forces on the lingual border and compressive forces on the ventral border *(open arrows)*. (From Sumner-Smith G: Fractures of the mandible and maxilla. In Brinker WO, Hohn RB, Prieur WD, editors: *Manual of internal fixation in small animals*, New York, 1984, Springer-Verlag.)

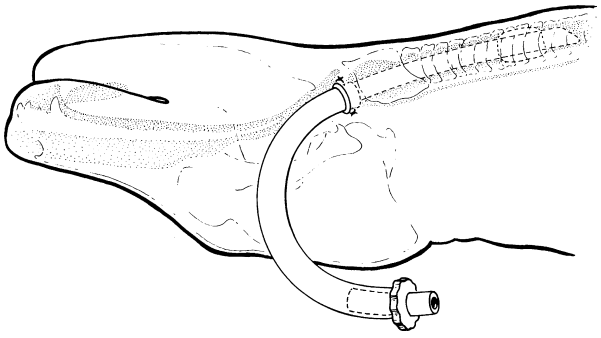


FIGURE 21-2. Pharyngostomy tube. After the animal is stabilized on gas anesthesia, the tracheal tube is changed to pass through a pharyngostomy opening and down the trachea. This allows fixation to be applied with the mouth closed and the teeth occluding.

After reduction and fixation, the torn gingiva is sutured to keep food and contaminants out of the wound. Suturing also aids in stabilizing the fracture segments and in converting the area to a closed fracture. Even though the tissues in the mouth are effective in eliminating infection, administration of systemic antibiotics is recommended.[3] Chronic osteomyelitis associated with primary jaw fractures is rare when the patient is treated with antibiotics at fixation.

When performing the fixation procedure in many patients, particularly in the more complicated cases, a tracheostomy, or preferably a pharyngostomy, is done to maintain anesthesia. This technique ensures an open airway while the animal's mouth is closed, and the teeth can be occluded during the procedure, ensuring adequate reduction during application of fixation. After the animal is stabilized on gas anesthesia, the tracheal tube is changed to pass through the pharyngostomy opening (Figure 21-2). After the surgery is completed, the tracheal tube is removed, and the pharyngostomy opening is allowed to heal by granulation. In some cases a stomach tube is implanted through the pharyngostomy for postoperative feeding, although direct gastrostomy intubation is preferred.

FRACTURES OF THE MANDIBLE

Mandibular Symphysis

The method of immobilization depends on the presence or absence of incisor teeth, the stability of the reduced fragments, presence of infection or osteoporosis, and to some extent the size of the patient.[1,4]

Fixation Methods

Interdental Wiring

If the incisor teeth are present and the fracture-separation is stable, a simple, stainless steel interdental wire may be adequate, especially in smaller patients (Figure 21-3, *A*). If the bases of the third incisor and canine teeth fit too close together to permit

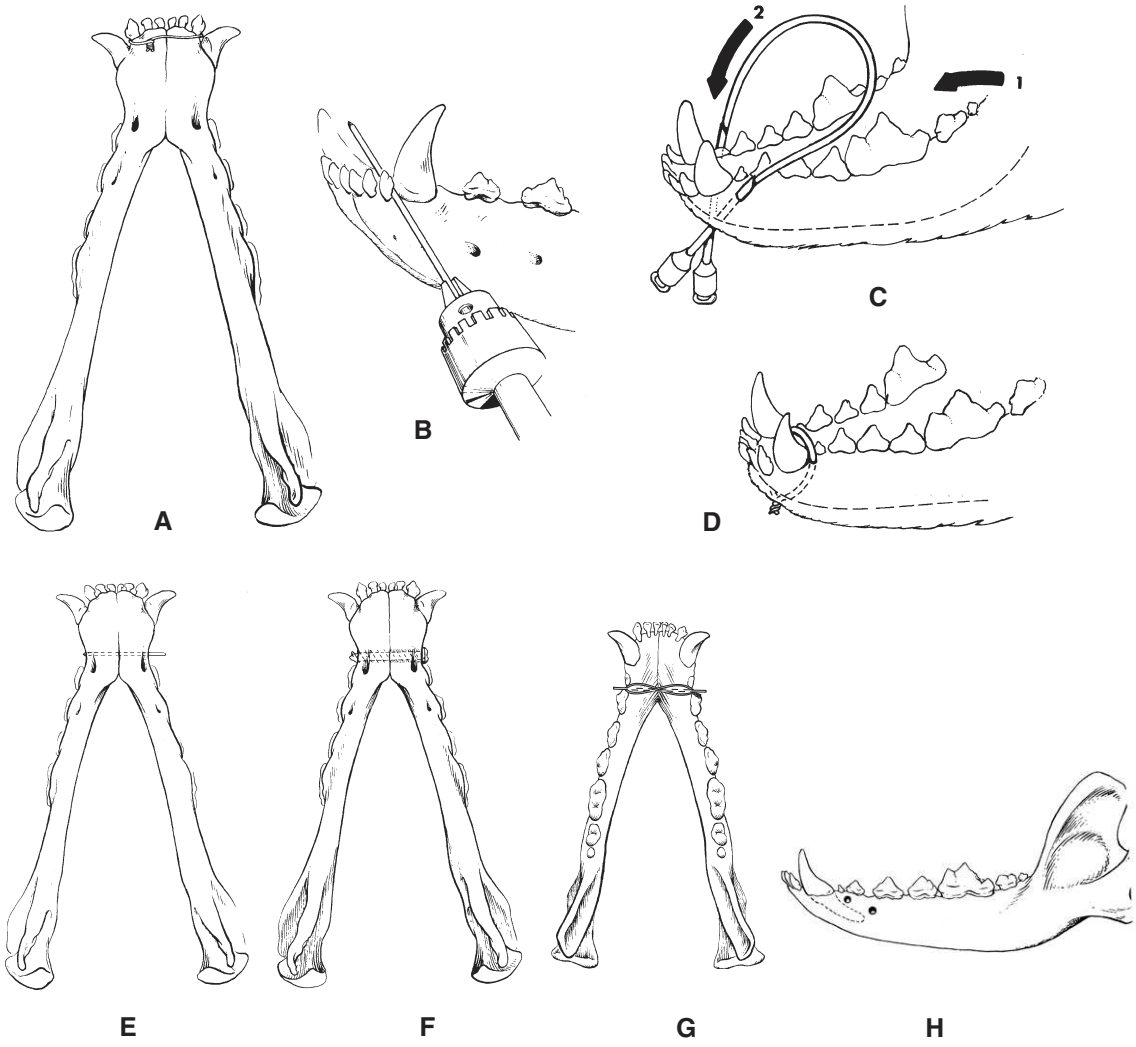


FIGURE 21-3. Fixation of the mandibular symphysis. **A,** Simple interrupted stainless steel wire suture. **B,** Hand chuck forces a Kirschner drill wire between the base of the third incisor and canine teeth, allowing easy placement of wire sutures. **C** and **D,** Immobilization by use of an encircling wire. The wire (usually 20 gauge) is inserted by using two 16-gauge needles and is twisted outside the skin on the ventral surface. The mouth is closed with the teeth occluding when the final twisting is done. **E,** Insertion of a mandibular transfixation pin, smooth or threaded, or a bone screw (**F**) to improve stability. **G,** Additional stability can be achieved by adding a figure-of-8 orthopedic wire to a mandibular transfixation pin. This wire loops around each end of the pin and is laid across the surface of the oral mucosa to compress the fracture as it is tightened. **H,** Suggested location from the lateral surface for insertion, which is usually just rostral to the mental foramen.

passage of the wire, a hand chuck may be used to force a Kirschner wire between them, allowing easy placement of the wire (Figure 21-3, *B*). Wire gauge size 20 to 22 (0.8-0.6 mm) is usually applicable.

Cerclage Wire

The method most often used in smaller dogs and cats consists of an encircling wire (Figure 21-3, *C* and *D*). Table 21-1 lists the gauges of wire that fit into preplaced holes and of surgical wire that fits into different sizes of needles.

The wire is inserted through the skin using a 16- to 18-gauge hypodermic needle from the ventral midline at a point that will result in the wire being placed at the caudal gingival margin of the incisor teeth. The needle is directed along the bone on one side to follow the bone under the skin and gums, and the wire is inserted through the needle. The needle is withdrawn so that the wire protrudes ventrally, after which the needle is redirected through the same skin hole to the opposite side of the mandible. The free oral end of the wire is inserted into the needle, and the needle and wire are withdrawn ventrally. The wire is *tightened until no vertical shearing motion can be induced* between the mandibles. It is important to test for this motion because the fracture line cannot be seen. The twist is cut so that it just protrudes from the skin; removal is accomplished by cutting the wire intraorally and pulling it out ventrally by means of the twist. Wire of 20 to 22 gauge (0.8-0.6 mm) is used in cats and small dogs, with 18 gauge (1.0 mm) used for larger breeds.

Transfixation Pin or Lag Screw

Stability may be improved by the insertion of a transmandibular pin (smooth or threaded) or a bone screw to neutralize shear forces at the fracture site (Figure 21-3, *E* to *H*). Figure 21-3, *H,* suggests the location from the lateral surface for insertion, which is usually just rostral to the mental foramen. These methods, especially the lag screw, are indicated when gross instability is present, as is often the case when the symphyseal fracture is associated with other mandibular fractures. Combining cerclage wiring and transfixation pinning is also a simple way of providing excellent stability.

Transfixation Pin and Figure-of-8 Wire

Another fixation method for rostral fractures, if other wiring techniques are insufficient for stability, is the pin and figure-of-8 wire. After the fracture has been reduced, a small Steinmann pin is inserted across the mandibles, either just rostral or caudal to the canine teeth, carefully avoiding the teeth roots. Figure-of-8 orthopedic wire

TABLE 21-1. STAINLESS STEEL WIRE (SSW) DIAMETER SIZES FOR PINHOLES AND NEEDLES

Gauge	Fits Into/Through	Pinhole/Needle
18-gauge SSW	Fits into	0.045-inch Kirschner pinhole
20-gauge SSW	Fits into	0.045-inch Kirschner pinhole
22-gauge SSW	Fits into	0.035-inch Kirschner pinhole
24-gauge SSW	Fits into	0.028-inch Kirschner pinhole
18-gauge SSW	Fits through	16-gauge needle
20-gauge SSW	Fits through	16-gauge needle
22-gauge SSW	Fits through	18-gauge needle
24-gauge SSW	Fits through	20-gauge needle
18-gauge needle	Fits into	0.062-inch Kirschner pinhole
20-gauge needle	Fits into	0.035-inch Kirschner pinhole

of 22, 20, or 18 gauge (0.6-1.0 mm) is placed around each end of the pin and through the mouth over the oral mucosa of the mandible. The figure-of-8 wire is tightened with the knot at the aboral surface, and the pin is cut off short or bent over (Figure 21-3, *G*). A small quantity of dental acrylic may be applied to the sharp points of the pin and wire to reduce irritation of the mucosa of the lips and gums.

Aftercare

Good stability is usually achieved by these fixation methods, and postoperative care is not complicated. Food should be fairly soft, and no "chew" toys or bones should be allowed. Fractures in the mandibular symphysis usually heal rapidly, but there is little that can be done to evaluate healing because no callus is usually seen radiographically. The implants cause little irritation, so there should be no urgency to remove them. Eight weeks is adequate for healing in most cases, and this allows for the delay seen in older osteoporotic patients and the delay caused by infection.

Mandibular Body

A wide variety of fractures may be encountered in the mandibular body because it is the most common fracture location in the dog.[2] Ingenuity is required to devise the best type of fixation. No single technique is applicable to all fractures, and the choice often must be made between several applicable methods. A method or combination of methods must be used that gives stability at the fracture site. Critical to understanding the mechanics of fixation in the mandible is to appreciate that normal masticatory muscle forces will bend the rostral fragment ventrally (see Figure 21-1). Thus the gingival margin of the bone is loaded in tension and the ventral cortex is loaded in compression, and the effects of both these forces must be evaluated relative to each specific fracture and each fixation technique.

Open Approach

The body of the mandible is approached simply by an incision over the ventral border (Figure 21-4) or by incision and elevation of gingival tissue.

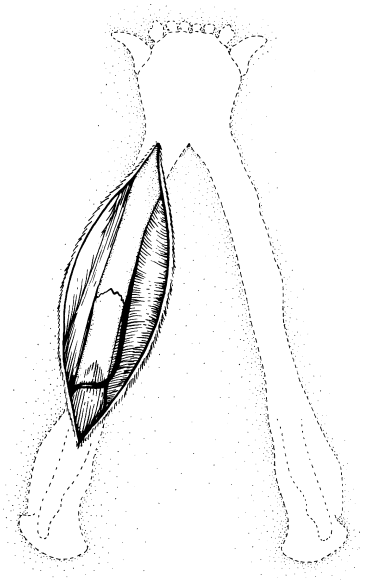


FIGURE 21-4. Ventral approach to the body of the mandible showing the digastricus muscle (caudal), platysma muscle (lateral), and mylohyoid muscle (medial). A branch of the facial vein crosses the digastricus muscle.

Fixation

Tape Muzzle Coaptation

Simple tape muzzles are typically used on many shaft fractures. Muzzling the upper and lower jaws together provides mediolateral stability to the mandible by the interdigitation of the canine teeth, as well as stability in the vertical plane by simply limiting motion. Muzzles are used for primary fixation and for support and protection of internal fixation. Primary fixation muzzles are most useful for stable body fractures in the midbody and caudal regions; these muzzles are not suitable for rostral fractures or for cats or brachycephalic breeds. Soft tissue injuries of the facial or mandibular regions can complicate muzzle application.

Muzzles are best applied to the sedated or anesthetized patient. They usually are not applied tightly enough to shut the mouth completely; rather, an opening large enough for the tongue is left rostrally so that liquids can be consumed. A 1- to 3-ml syringe casing works well as a bite block during muzzle application, as shown in Figure 21-5. Feeding consists of slurried dog food. The small amount of motion of the mandible permitted by this opening does not create a problem if the fracture is reasonably stable. If the muzzle is used for unstable fractures, however, it must be applied tightly, and feeding by stomach, pharyngostomy, or jejunostomy tube is necessary. This results in considerable nursing care and is a good reason to consider internal fixation for unstable fractures. Muzzle support may also be used a few days after internal fixation (see following discussion). This prevents muscle spasms from deviating the adequately reduced jaw to the side. Fixation for 3 to 4 weeks is adequate in many midbody fractures, especially in immature patients.

Interarcade Wire

Wiring the mandible to the maxilla can be substituted for muzzle application when the muzzle cannot be used, for the reasons stated earlier. The basic method shown in Figure 21-6 can be applied at many levels of the mandible, taking care to avoid teeth roots. As with the muzzle, the mouth can be left slightly open to allow liquids

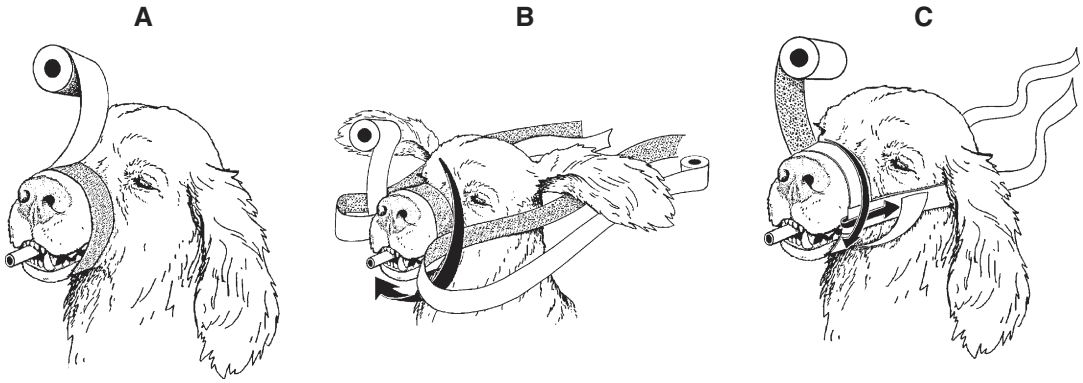


FIGURE 21-5. Tape muzzle application. **A,** Bite block, such as a syringe case, is placed between the incisor teeth. The block should be just thick enough to allow passage of the tongue for drinking. Adhesive tape is placed around the jaws with moderate pressure, with the adhesive facing out. **B,** Straps for tying behind the head, to prevent slippage of the muzzle, are fashioned by additional pieces of tape on either side, with the adhesive side out and then folded back onto itself. **C,** Additional circular wraps of tape anchor the straps. A ventral chin strap can be added at the caudal end of the mandible to prevent the tied straps from coming over the top of the head. Test to be certain that there is room for the tongue to protrude.

to be consumed, or it can be closed tightly for maximum stability. Maximum stability is provided by the method shown in Figure 21-17.

Interdental Wire

Wiring around the crowns of the teeth near the gingival margin works best when there is a solid tooth on each side of the fracture line and when the fracture is simple in nature (Figure 21-7, *A* and *C*). The wire functions as a tension band, and the

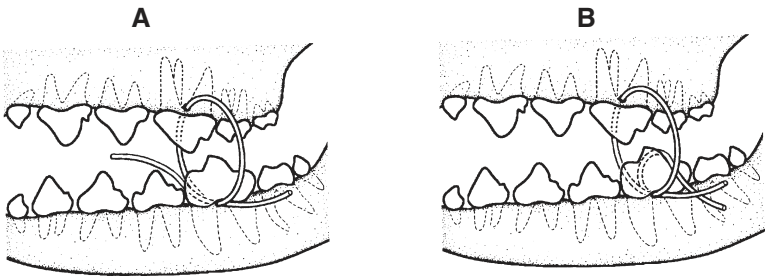


FIGURE 21-6. Interarcade wiring is useful when the tape muzzle is not applicable because of soft tissue injuries, in brachycephalic dogs, or in cats. **A,** Kirschner wire is used to develop a hole at the margin of the alveolar bone between the roots of the fourth premolar teeth, and a loop of 20- to 22-gauge (0.9- to 0.7-mm) wire is placed through the holes. **B,** With a bite block in place as in Figure 20-5, one end of the wire is brought over or around the crown of the lower premolar and twisted. Test to be certain that there is room for the tongue to protrude.

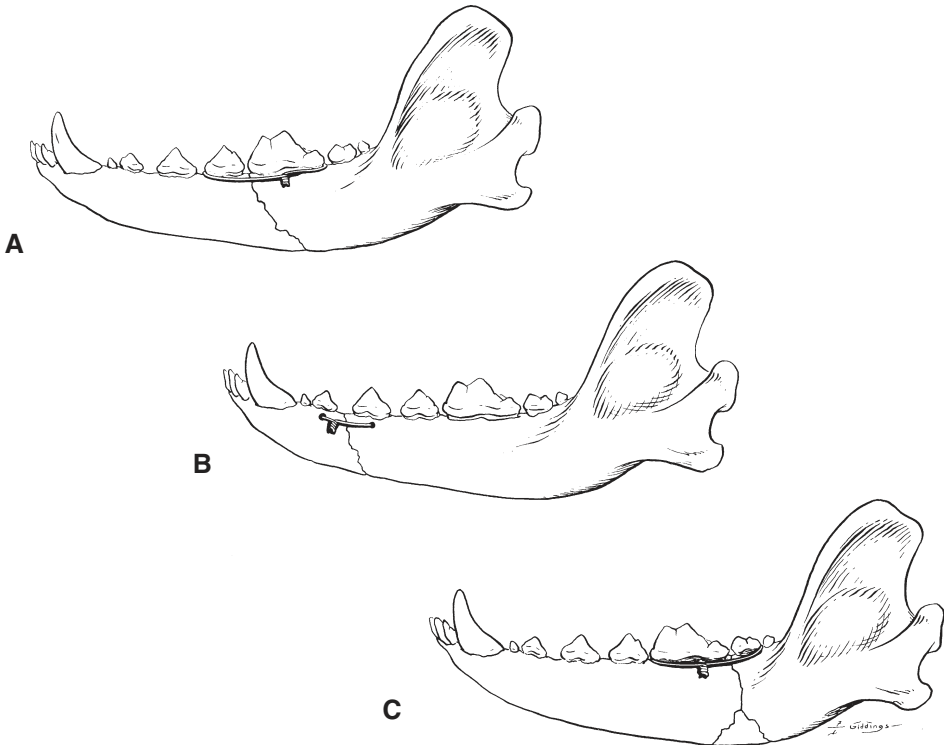


FIGURE 21-7. Fixation of a fracture of the body of the mandible. **A,** Interdental wire around the bases of the fourth premolar and the first molar. **C,** Interdental wire around the bases of the first and second molars. **B,** Modified method, with wire through drill holes between the roots of the adjacent teeth.

ventral cortex must be intact to buttress the compression forces. Occasionally, wire placement is modified so that the wire can be passed between the roots of the adjacent teeth when the shape of the crown prevents secure wire anchorage (Figure 21-7, *B*). The guide hole is made with a small Kirschner wire and a pin chuck. The wire is passed through gingival tissue, with no attempt made to elevate the soft tissue. The twisted ends should be kept on the labial side of the gum and must be carefully bent flat with the gum to ensure no soft tissue irritation. Pressure necrosis of gingiva will result eventually in complete or partial covering of the wire by gum tissue and little irritation as long as the wire remains tight and stable. (See later section for aftercare instructions.)

Interfragmentary Wire

Additional stability can be added to interdental wiring by supplementing it in some oblique, multiple, and noncomminuted unstable fractures with simple interrupted wire fixation placed ventrally on the mandible (Figure 21-8). After a ventral open approach, the fragments are drilled, usually with a Kirschner wire or 2-mm bone drill, so that the inserted wire crosses the fracture line at a right angle. These wires are left in place unless removal is indicated because of loosening or infection. Stability must be accomplished at the fracture site; if not, some modification or another fixation method is in order. (See later section for aftercare instructions.)

Intramedullary Pinning

Although intramedullary pin fixation has been used for mandibular fractures, the difficulty of pin insertion and the marginal stability provided argue against their continued use when so many other methods are available.

Intraoral Splint

A simple intraoral splint can be used for midbody and rostral fractures (Figure 21-9). A Steinmann pin 5/64 to 1/8 inch (2.0-3.2 mm) in diameter is bent to fit on the lingual side of the mandible along the gingival margins. It is then secured to the mandible by wire that is looped around the pin and then passed through the bone to the labial side, where the wire ends are twisted and bent flat.

Intraoral splinting with dental acrylic molded to the crowns of the teeth has been used by some, but results have not been encouraging, with accumulation of food

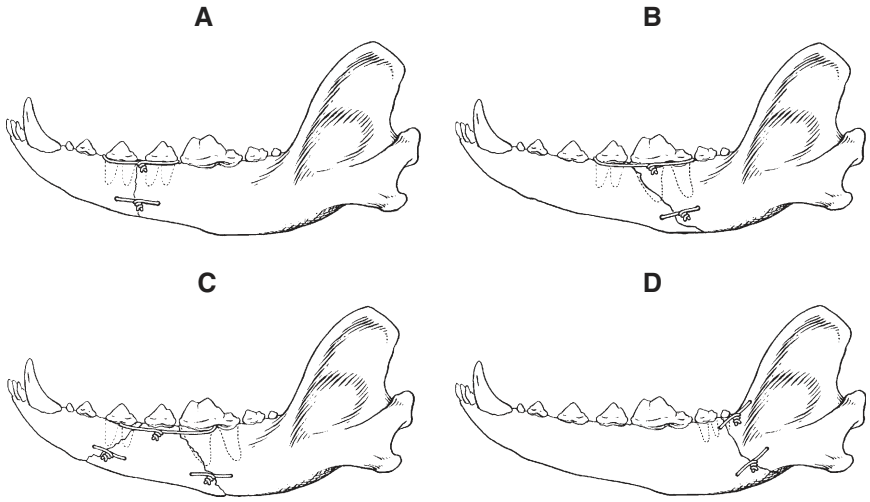


FIGURE 21-8. Examples of combined interdental and interfragmentary wiring of stable mandibular body fractures.

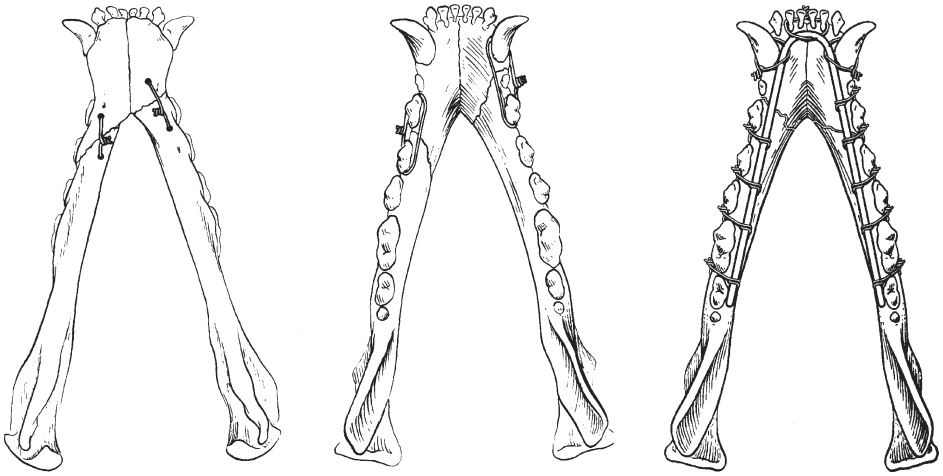


FIGURE 21-9. **A** and **B,** Dorsal and ventral views of a rostral stable bilateral body fracture treated with both interfragmentary and interdental wires. **C,** Dorsal view of bilateral rostral body fracture stabilized with an intraoral splint fashioned from a Steinmann pin. The splint is bent to shape and wired to the mandible through holes in the mandibular body placed between teeth or between tooth roots. Rostrally, the wiring incorporates the canine and incisor teeth. The most rostral wire may also be placed through a drill hole if good wire security cannot be obtained on the teeth.

particles and exudate complicating postoperative treatment.[5] An alternative is to use dental composite to cement the canines of the upper and lower jaws together; in effect, this splints the fractured mandible to the intact maxilla.[6] Teeth are cleaned and smoothed with pumice to prepare them for bonding. The canine teeth are etched with acid, and a dental adhesive is applied. The fracture is then reduced, and the dental composite is applied to fixate the canines of the upper and lower jaw together, with the mouth open approximately 1 cm. The effect is similar to the interarcade wiring technique. One study reports consistent success at achieving healing of mandible fractures, although the dental composite usually broke at 3 to 7 weeks after repair.[6]

External Fixator

Th external fixator device is useful for the following[1,4,5,7]:

1. Nonunion fractures; bone grafting is indicated in many cases (see Chapter 3).
2. Multiple fractures (Figure 21-10, *A* and *B*).
3. Bilateral fractures (Figure 21-10, *C*).
4. Unstable or gunshot fractures when bone is missing (Figure 21-10, *D*). The gums are sutured after reduction and fixation. During the healing process the missing segment may fill in if bone chips and periosteum are still present. In other cases a bone graft is indicated.

Surgical Procedure. Two pins are usually inserted in each fragment, but one pin in the rostral fragment may be sufficient if it passes transversely through both halves of the mandible (Figure 21-10, *A*, *B*, *C*). The procedure is usually as follows:

1. Close the animal's mouth with the fracture reduced and the teeth occluding.
2. Insert the rostral and caudal pins through the skin and soft tissues into the bone as ventrally as possible to avoid tooth roots, nerves, and vessels.

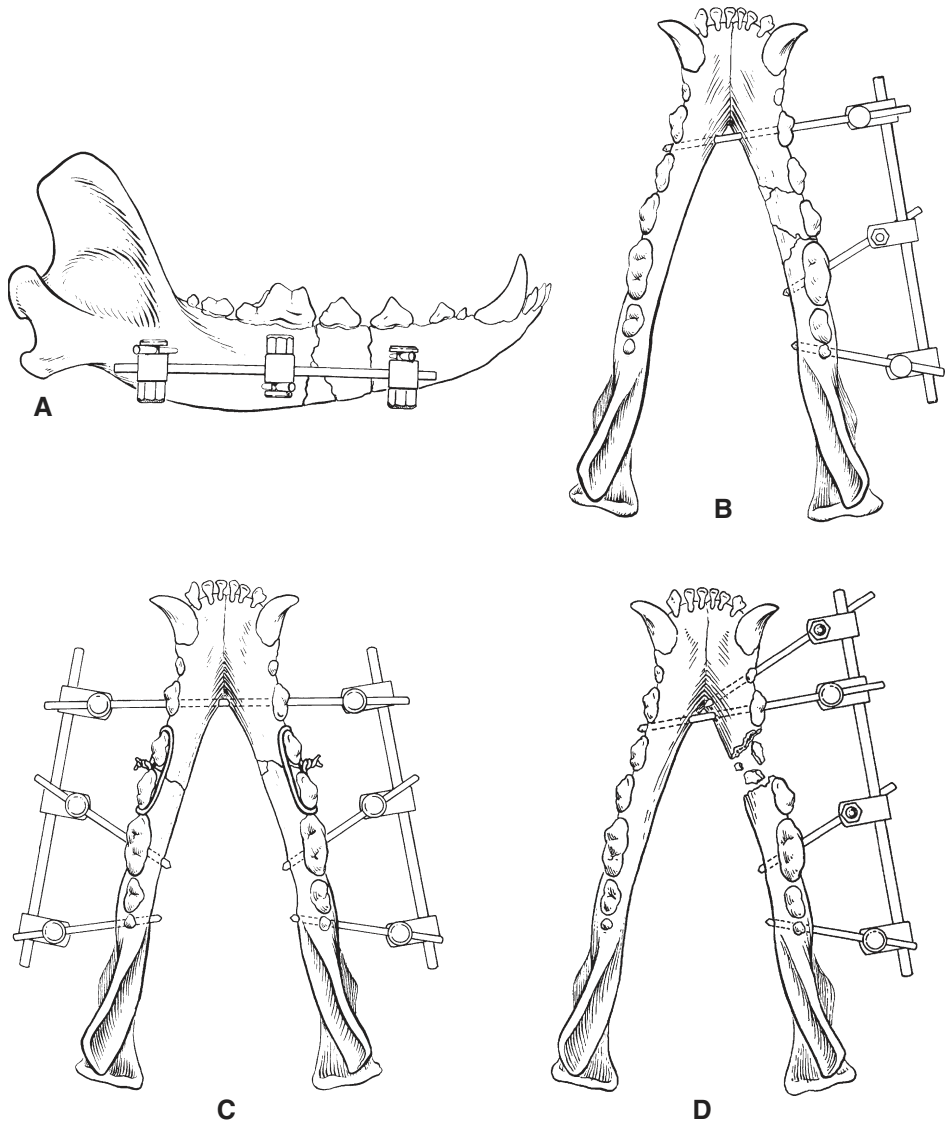


FIGURE 21-10. External fixator. **A** and **B,** Multiple fractures. **C,** Bilateral fractures. **D,** Unstable fracture with bone missing. In most cases the splint can be applied so that it does not extend beyond the length of the mandible; thus it does not interfere with eating or drinking. If the bone chips are left in place and the gums closed, in most cases the bone deficit will bridge over without the addition of a bone graft.

3. Positive-profile threaded fixator pins improve fixator stability and durability. The use of threaded fixator pins is most important in comminuted mandibular fractures or fractures with deficits of bone that may require longer-duration fixator stability.
4. Attach the bar with single clamps and an empty center clamp.
5. Insert the third and fourth (if needed) pins through the center clamp and tighten. This essentially lines up the pins in a common plane and attaches them with single clamps and a common connecting bar.

In some patients, interdental wiring is indicated to improve stability (Figure 21-10, *C*). In general the splint is well tolerated. (See later section for aftercare instructions.)

Acrylic Bar External Fixator

Because the external fixator splint has some inherent limitations in pin placement and connecting bar attachment, polymethyl methacrylate (nonsterile dental acrylic) may be substituted as the connecting bar and is often simpler to apply than the splint with clamps[5] (Figure 21-11, *A*-*C*). See Chapter 2 for more complete description of the application of this type of connecting bar.

Surgical Procedure. A tracheal tube is inserted through a pharyngostomy or tracheostomy incision to ensure an open airway. The mouth is closed, and functional reduction of the fracture results from occlusion of the teeth. At least two pins should be placed in each major bone segment. Small fragments may be skewered with divergent Kirschner wires. A major advantage of this technique is the ability to stabilize multiple fragments from a variety of angles, usually using more and smaller-diameter pins than with clamp fixation. This is especially important in smaller dogs and cats with complex fractures, where there is no room for standard fixator clamps. "Mini" positive-profile threaded fixator pins (IMEX Veterinary, Inc., Longview, Texas) are available with a roughened pin surface that is designed to assist with adherence to the acrylic (see Figure 21-11, *A*). If smooth pins are used, the protruding pins are bent to better hold the molded acrylic connecting bar (Figure 21-11, *C*). The acrylic usually takes about 8 to 10 minutes to set, and the teeth are maintained in occlusion until hardening is well advanced. Unilateral or bilateral splints can be constructed depending on the instability of the fracture (Figure 21-11, *B* and *C*). (See later section for aftercare instructions.)

After healing, the pins can be cut between the acrylic and jaw and removed with a hand chuck. Alternatively, the acrylic bar can be cut with a saw between each pin to allow pin removal. Because bilateral fixation extends rostrally beyond the lower jaw, it may interfere with eating, and hand feeding of semisolid food may be necessary.

Bone Plates

Bone plates are particularly useful for the more complex fractures and bilateral fractures.[5,7] They afford good rigidity and almost unrestricted use of the jaws immediately after surgery.

Surgical Procedure. A pharyngostomy or tracheostomy incision is made, with insertion of a tracheal tube to ensure an open airway. The jaw is exposed with a ventral incision. Compression forceps are applied to compress the fracture segments and hold them in the reduced position while the bone plate is contoured to fit the surface as perfectly as possible (Figure 21-12, *A* and *B*). The plate is then attached with bone screws. Contouring the plate is the most important step in ensuring proper occlusion of the teeth. Reduction and occlusion will be lost as the screws are tightened unless the contouring is almost perfect. The plate is usually placed laterally near the ventral border to avoid placing the screws in the mandibular canal and injuring tooth roots. The reconstruction plate (Synthes, Ltd., Paoli, Pa) is particularly useful to allow bending to follow the curve of the ventral cortex of the mandible (Figure 21-12, *C*). (See Figure 2-75 for suitable plate and screw sizes.) In some cases, it is advisable to add interdental wiring for additional tension band stability.

Microplates and miniplates are available in stainless steel and titanium for use in mandibular and maxillary fractures in small dogs and cats.[8-10] Plates vary from 0.4 to 1.0 mm in width, with screw sizes of 0.9 to 2.0 mm, depending on the manufacturer. These tiny plates are similar to the larger reconstruction plates in that they are malleable in three dimensions. Some are also designed as cuttable plates.

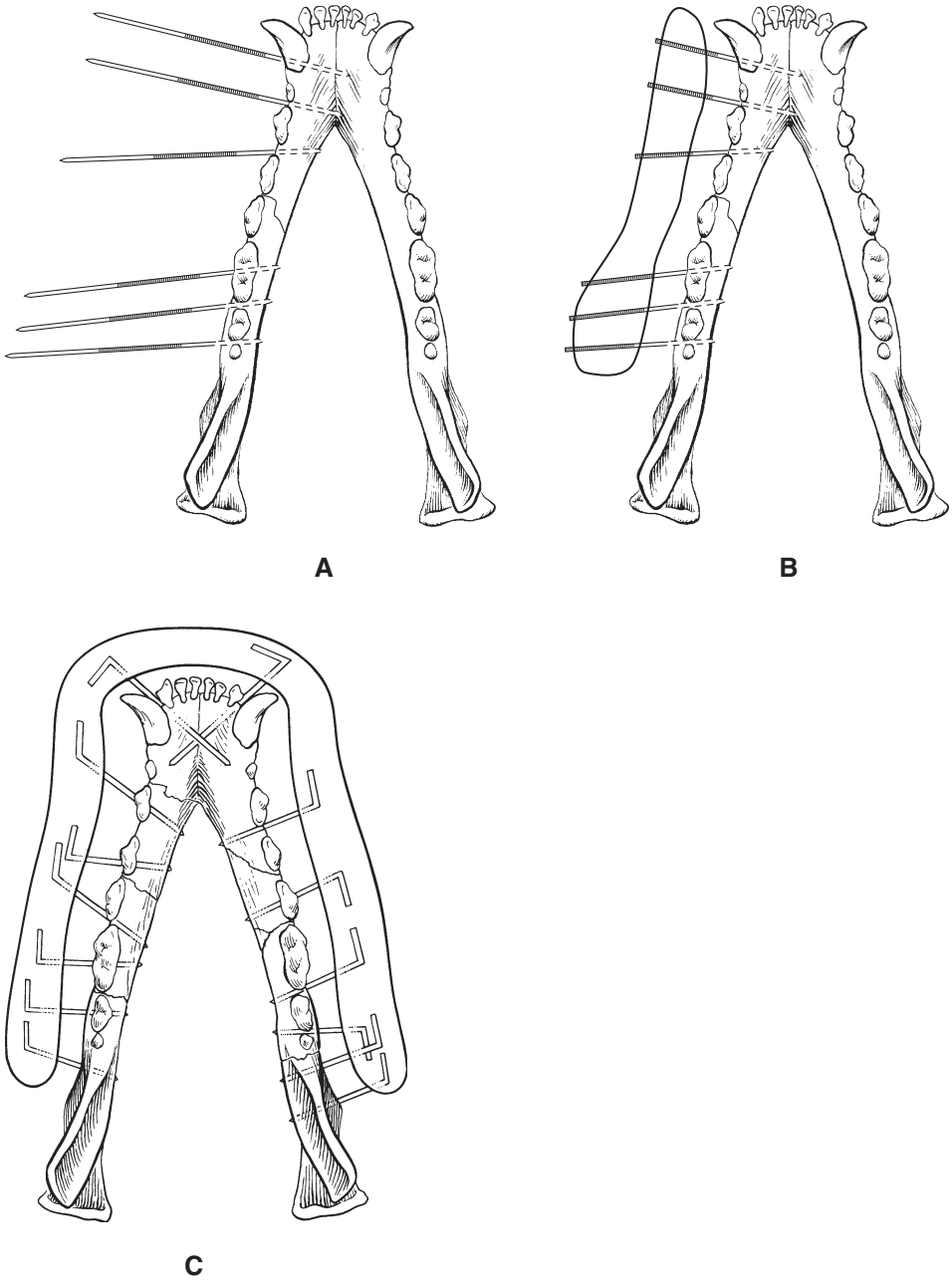


FIGURE 21-11. Modified acrylic external fixator. **A,** With the mouth closed, the fracture reduced, and the teeth occluding, two or more Kirschner wires are inserted into each major segment. "Mini" positive-profile threaded fixator pins (IMEX Veterinary, Inc., Longview, Texas) are available with a roughened pin surface designed to aid in adherence to the acrylic. **B,** Acrylic has been molded to incorporate the pins into a unilateral fixator. **C,** Smooth pins have been used to construct this bilateral fixator. The wires are bent and included in an acrylic mold to prevent slippage of the pins. This apparatus has the disadvantage of protruding beyond the length of the jaw, thus making it more vulnerable to bumping and cumbersome when eating. In many cases the same Kirschner-Ehmer configuration can be applied by first bending the stainless steel connecting bar of the external fixator, then inserting the fixator pins through the holes in the clamps and through the skin and soft tissue and into the bone.

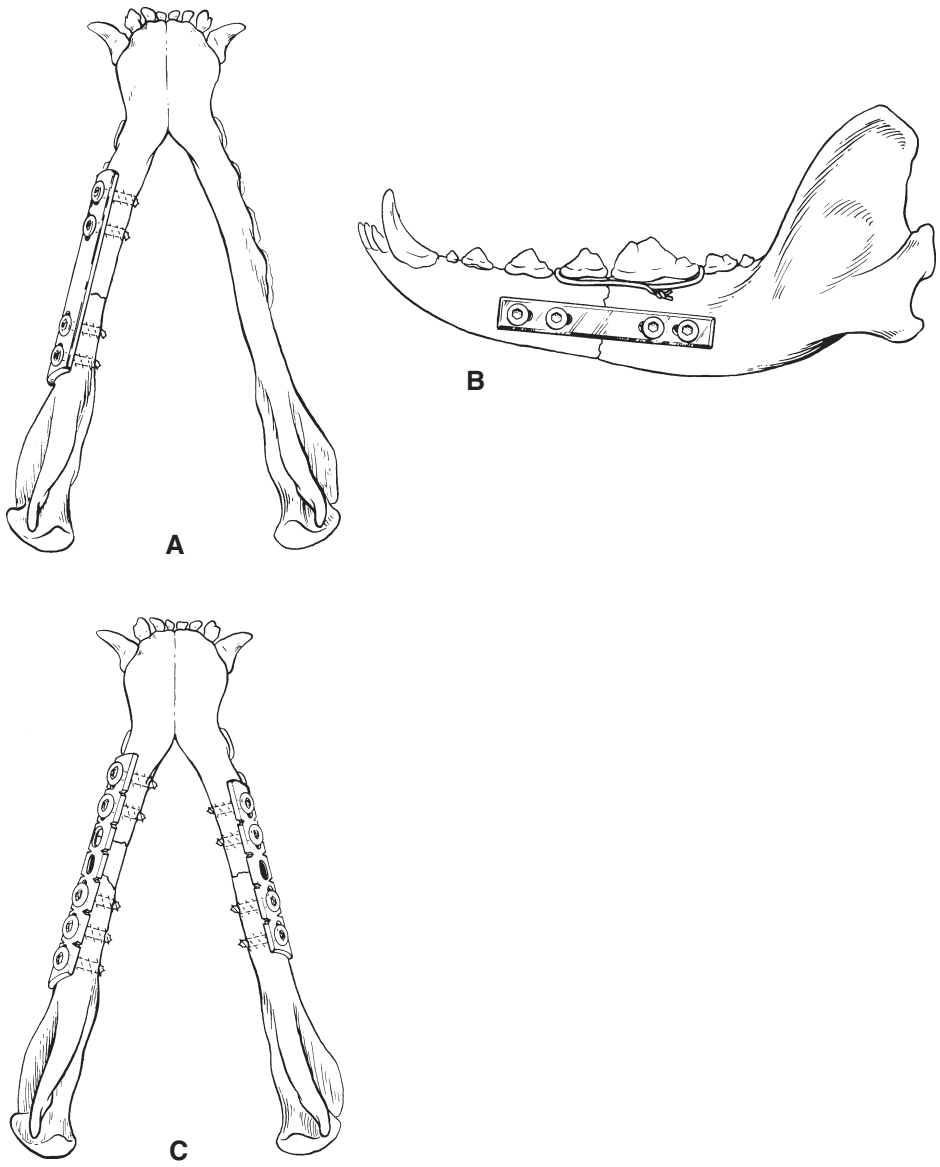


FIGURE 21-12. **A,** Fractured mandible immobilized with a "mini" dynamic compression plate and tension wire, ventral view. **B,** Lateral view. **C,** Bilateral fracture immobilized with two reconstruction plates, ventral and lateral views. The reconstruction plate is very adaptable to contouring to fit the bone surface.

Although most appropriate for jaw fractures in small dogs and cats, microplates and miniplates may also be used in larger dogs.

Aftercare

Postoperative treatment in all cases of internal fixation consists primarily of restricting the animal's jaw activity by feeding soft, small pieces of food. As mentioned earlier, a muzzle interlocking the canine teeth helps prevent deviation caused by muscle spasm. Chew bones, toys, or play that would stress the jaws should be eliminated until healing is evident. Wire fixation requires the most protection, and plates or fixators

require the least. Some care must be exercised with fixators to keep food particles cleaned from between the lips and the splint, particularly when the splint is bilateral.

Vertical Ramus

Because of the extensive musculature covering the vertical ramus region, there is often little displacement of the fragments, and most ramus fractures can be treated conservatively by muzzling or interarcade wiring. Various methods of internal fixation may be used when conservative treatment is not practical, including Kirschner wires, interfragmentary wire, and "mini" bone plates. External fixators are not applicable because of the mediolateral thinness of the ramus.

Figure 21-13 illustrates a lateral approach to the ramus and temporomandibular joint. Fixation methods for fractures of the ramus are shown in Figure 21-14. Fractures of the condyles are usually not amenable to fixation because of the small size of the bone fragments. Initial conservative treatment is indicated; if good function does not return after removal of the muzzle or interarcade wires, excision arthroplasty will permit adequate function. The condyle is excised to remove bony contact between the mandible and temporal bone and to allow fibrous tissue invasion and a subsequent false joint.

Luxation of Temporomandibular Joint

The temporomandibular joint (TMJ) can luxate either cranially or caudally as a result of trauma. TMJ luxation may occur as an isolated injury, especially in the cat, or may be associated with fractures of the mandible.

Diagnosis

The mandible and lower canine teeth are visibly displaced to either side of the upper canines. Palpation will establish mediolateral laxity of the mandible, but it is usually not possible to be sure of the direction of luxation. Standard-position radiographs adequately outline the canine TMJ, but in the cat, slight rotation of the head in the lateral view provides better visualization. The mandibular condyle can be seen either cranial or caudal to the mandibular fossa. When the luxation is cranial, the rostral mandible will be displaced to the contralateral side, and with a caudal luxation, the displacement will be toward the ipsilateral side.

Reduction

Closed reduction is usually possible for TMJ luxation. A fulcrum is introduced at the level of the last molar teeth on the affected side. This is usually a plastic tuberculin syringe for a cat, up to a 3- or 5-ml syringe for a large dog. The syringe is placed transversely between the upper and lower last molars, and the rostral end of the mandible is squeezed dorsally toward the maxilla, thus levering the caudal end ventrally and "unlocking" the luxation. While holding the mandible in this position, the rostral end is levered in the appropriate direction to reduce the luxation, then slowly released. Reduction is verified by interdigitation of the canine teeth, since several attempts may be needed to obtain reduction. Failure to reduce may lead to open reduction, but little joint capsule is available to imbricate, and excision arthroplasty as described earlier for condylar fractures may be indicated.

Aftercare

In the rare instance where the TMJ luxation is stable after reduction, no stabilization is necessary, and soft food is provided as previously described for fractures.

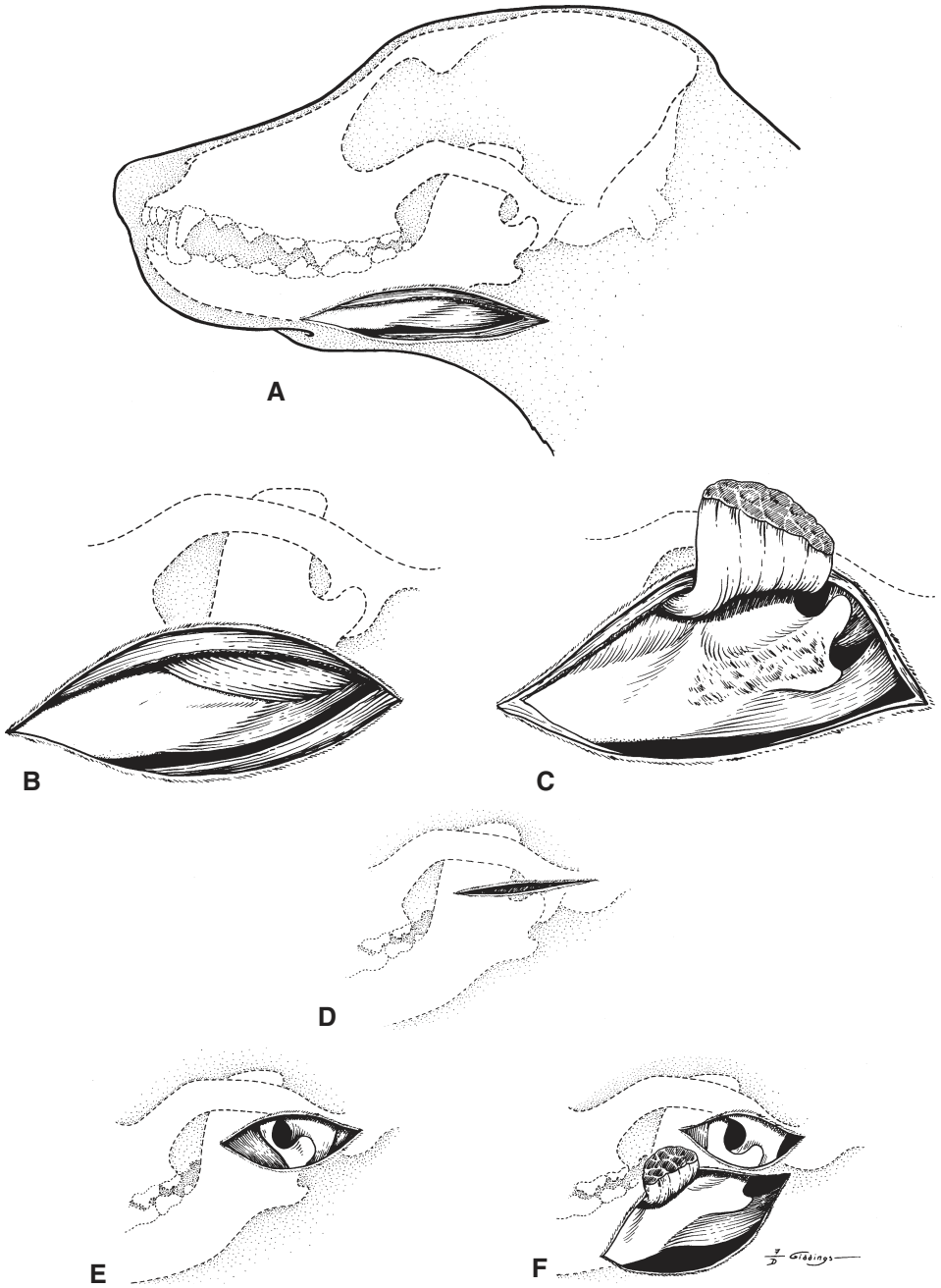


FIGURE 21-13. Surgical approach to the ramus and temporomandibular joint. **A,** Ventrolateral approach to the caudal angular portion of the ramus. Skin incision along the ventrolateral border; separation of the platysma muscle exposes the digastricus muscle. **B,** Further separation of the soft tissue exposes portion of the mandible, masseter muscle, and digastric muscle. **C,** Subperiosteal reflection of the masseter muscle exposes angular and condyloid processes and masseteric fossa. **D,** Longitudinal skin incision along ventral border of zygomatic arch and temporomandibular joint. **E,** Platysma muscle and fascia incised along same line. This tissue is reflected ventrally, exposing the lateral surface of the joint and the upper portion of the condyloid process. **F,** The tissue between the two incisions is tunneled beneath the visualization, reduction, and fixation.

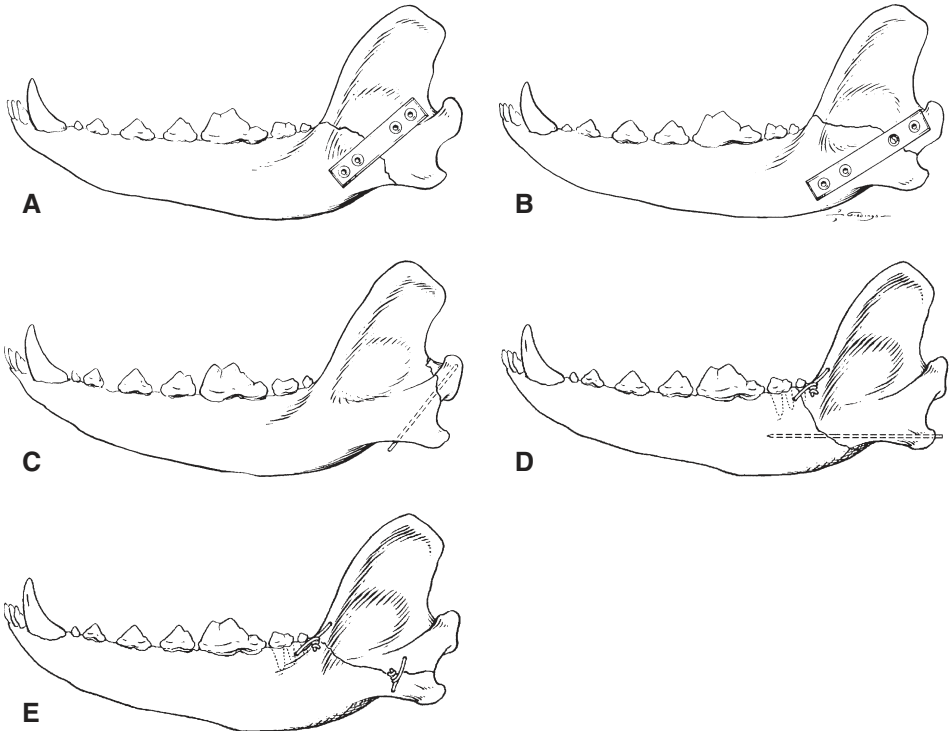


FIGURE 21-14. Fixation methods for fractures of the ramus. **A,** Fracture just rostral to the angular process immobilized by a bone plate. **B,** Fracture between the angular and condyloid processes immobilized by a bone plate. **C,** Condyloid process fracture immobilized by an intramedullary pin placed from the ventral border of the mandible. **D,** Fracture rostral to the angular process immobilized with an intramedullary pin placed through the angular process and an intraoral wire at the angle of the mandible. **E,** Fracture between the angular and condyloid processes immobilized by an interfragmentary wire and an intraoral wire at the angle of the mandible.

In most cases, 1 to 2 weeks of support with a tape muzzle or interarcade wiring is indicated.

Spontaneous Locking Open of Temporomandibular Joint

Dysplasia and subluxation of the TMJ may result in locking of the jaw of the dog in an extreme open position by lateral displacement of the mandibular coronoid process outside and lateral to the zygomatic arch.[11] This condition is generally spontaneous and is not the result of trauma. The clinical presentation is very dramatic and causes serious mental distress to both dog and client. The dog can sometimes successfully reduce the subluxation, but recurrence is common and may result in chronic inflammation and fibrosis of the tissues surrounding the mandibular coronoid process.

Diagnosis

The mandible is fixed in an extreme open position and cannot be closed manually. Careful palpation of the zygomatic arch may reveal the malposition of the mandibular coronoid process, or palpation may be nondiagnostic because of local swelling. Lateral deviation of the jaw may be difficult to appreciate in the extreme open position.

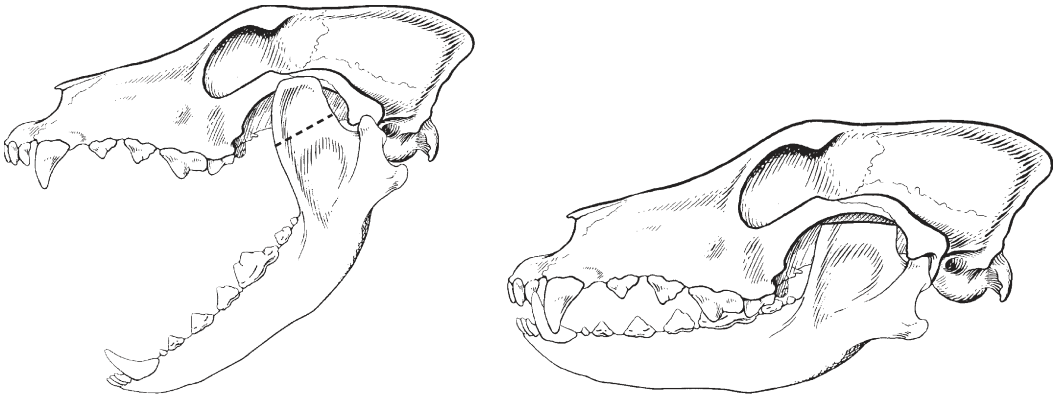


FIGURE 21-15. Spontaneous locking open of the temporomandibular joint. **A,** Coronoid process of the mandible is displaced and "locked" lateral to the zygomatic arch. **B,** Coronoid process may be resected in recurrent cases and is generally curative.

Standard-position and oblique radiographs demonstrate the mandibular coronoid captured lateral to the zygomatic arch (Figure 21-15, *A*). Computed tomography is generally not needed for diagnosis; however, it can describe the fibrotic mass associated with the mandiublar coronoid in cases of chronic recurrence.

Reduction

Reduction is usually not possible without anesthesia. The mandible is opened as far as possible, and direct pressure is applied to reduce the mandibular coronoid process medial to the zygomatic arch. A tape muzzle will prevent acute recurrence of the locked position, although chronic recurrence is common. Surgical resection of the mandibular coronoid is very successful and prevents recurrence of the coronoid's malposition (Figure 21-15, *B*). An alternative surgical method is partial resection of the zygomatic arch. The condition is usually unilateral; however, an intermittent bilateral condition is possible.

Aftercare

No ancillary stabilization is necessary. Soft food is recommended for 1 month. The client should be cautioned that locking could develop on the side opposite the surgery.

FRACTURES OF THE MAXILLA

Fractures of the incisive and maxillary bones are usually diagnosed readily by observation and palpation.[4,5,7] These fractures are accompanied by bleeding from the nose and mouth, swelling, and varying degrees of malocclusion. The primary objective is reestablishment of dental occlusion and closing any communication between nasal passages and the mouth. Accomplishing this goal usually returns approximately normal appearance to the nose, upper jaw, and face.

Maxillary Fractures of Facial Region

Many undisplaced fractures require no fixation at all. Closed reduction and taping or wiring the jaws together represent the next level of stabilization. Wiring of fragments

is easily accomplished and useful, especially when fragments are depressed into the nasal cavity. Open approach and reduction of these nonoral fractures are done by incision directly over the affected areas. Fractures in this thin bone area frequently collapse inward and are reduced with a small, hook-shaped probe that can be used to lever the fragments outward from below. Occasionally, a flat spatula or probe can be inserted from the nares to aid in reduction. Most of these fractures do not need fixation, and those that do can be handled by interfragmentary wire or Kirschner wire stabilization. Little stability is required once the fragments are reasonably reduced. In the case of multiple fractures with marked displacement, the acrylic bridge external fixator is valuable. The fragments are "speared" on Kirschner wires, reduced, and then connected by acrylic. This technique is applicable to a variety of situations.

Intraoral Maxillary Fractures

Midsagittal fracture of the hard palate in the cat is the most common injury of this area. Most of these fractures are a result of hitting the nose on the ground after a fall or an automobile strike. A wire suture(s) inserted underneath the mucosal covering of the hard palate and anchored to a tooth on each side is the simplest method of stabilization (as in Figure 21-16). The torn gingiva of the palate can be sutured, although this is not necessary if the fracture is well reduced and stabilized.

Various other fracture patterns are seen. Fixation can usually be accomplished by placing a stainless steel wire around the base of the teeth on each side of the fracture line (Figure 21-16, *A*, *B*, and *C*). If interdental wiring is insufficient fixation, pin and

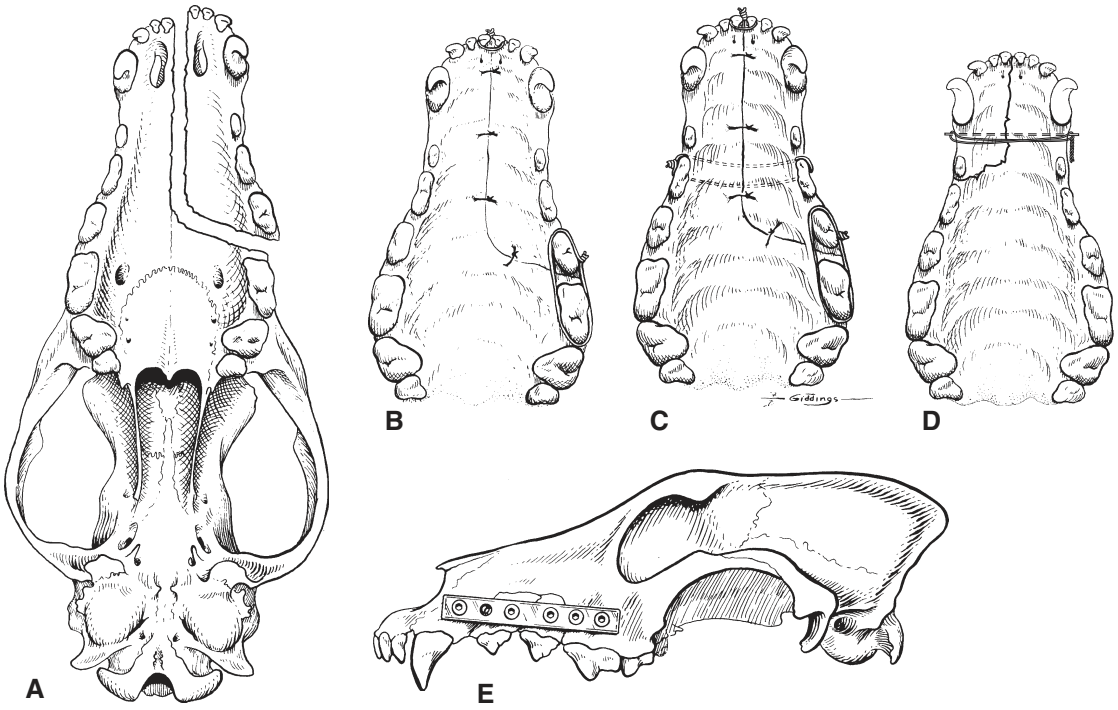


FIGURE 21-16. Fixation of fractures of the upper jaw. **A** and **B,** Suturing of a torn gingiva and palate with interdental wiring of adjacent teeth. **C,** Insertion of wire suture underneath mucosal covering of hard palate and anchored to a tooth on either side, in addition to the above. **D,** Additional stability may be achieved with application of a transfixation pin and figure-of-8 wire. The pin may be placed rostral or caudal to the canine teeth, depending on location of the fracture. The wire is placed around the ends of the pin and over the surface of the oral mucosa. **E,** Bone plate fixation.

figure-of-8 wire can be a useful fixation for rostral fractures, as discussed for mandibular fractures. After the fracture has been reduced, a small Steinmann pin is applied across the maxilla and fracture site, either just rostral or caudal to the canine teeth, carefully avoiding the roots. Figure-of-8 orthopedic wire of 22, 20, or 18 gauge (0.6-1.0 mm) is placed around each end of the pin and through the mouth over the oral mucosa of the hard palate. The figure-of-8 wire is tightened, and the pin is cut off short or bent over. A small quantity of dental acrylic may be applied to the sharp points of the pin and wire to reduce irritation of the mucosa of the lips and gums (Figure 21-16, *D*). Some fractures of the incisive bone or maxilla are amenable to bone plate fixation (Figure 21-16, *E*). Exposure is gained by incising the gums along the base of the teeth and reflecting the soft tissue dorsally to expose the fracture area.

As described for mandibular fractures, microplates and miniplates are available in stainless steel and titanium for use in maxillary fractures.[8-10] Plate widths vary from 0.4 to 1.0 mm, with screw sizes of 0.9 to 2.0 mm. These tiny plates are similar to the reconstruction plate in that they are malleable in three dimensions. Some are designed as cuttable plates. Microplates and miniplates are most appropriate for application in jaw fractures of small dogs and cats but may also be used in larger dogs.

Another fixation device is the intraoral pin splint (see Figure 21-9), which is adaptable to the maxilla and is useful for fractures of the incisive bone that leave the entire rostral end of the jaw loose.

Occasionally, massive bilateral fractures of the nasal and maxillary bones and mandible are encountered. Reconstruction and immobilization are best accomplished with acrylic external fixators[5] used in combination with other fixation techniques described in this chapter. An alternate method is wiring the jaws together using the eyelet method to maintain occlusion during the healing period (Figure 21-17). Food and liquids may need to be given through an implanted pharyngostomy, jejunostomy,

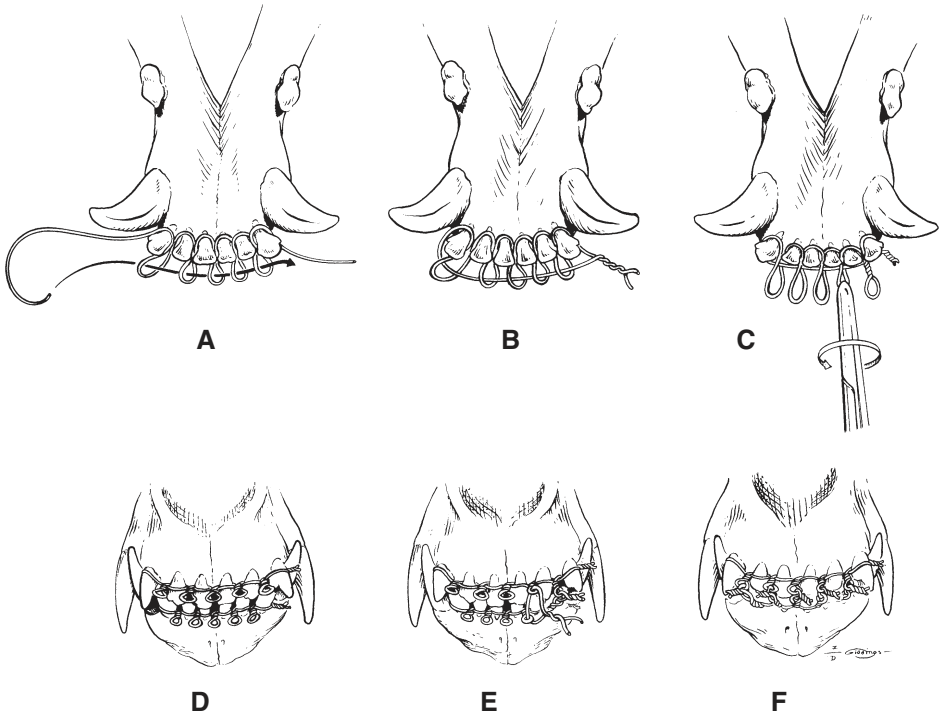


FIGURE 21-17. Surgical procedure for bilateral fractures of both upper and lower jaws if they cannot be stabilized separately. **A** through **F,** Procedure for wiring the jaws together using the eyelet method.

or gastrostomy tube. Healing is usually rapid, and the jaws are wired together for 3 to 6 weeks. *Note:* Occasionally the eyelet style of wiring can be used to advantage on certain fractures of the mandible to provide immobilization of the entire lower jaw.

Large deficits of maxillary or incisive bones occur with gunshot wounds or other major trauma and may result in large oronasal fistulas that cause serious dysfunction in mastication and chronic nasal infection. Primary closure of the soft tissues may be possible; however, debridement and delayed closure techniques may be needed for grossly contaminated wounds with compromised soft tissue. Mucosal advancement flaps or labial mucosal rotation flaps are useful to provide soft tissue closure to prevent large oronasal fistulas.

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22

Fractures in Growing Animals

This chapter describes separations and fractures involving the physis before closure and diaphyseal fractures in animals up to 4 or 5 months of age. After this age, treatment of shaft fractures is basically the same as for the adult animal. A variety of fractures involve the growth plate, and all have the potential to retard or arrest bone growth and create limb deformities as a result of shortening or angular changes.[1] Correction of these deformities is discussed in Chapter 23.

Although the growth plate of long bones is often referred to as the "epiphyseal plate," it is actually the *metaphyseal growth plate*. The term *physis*, referring to the zone of growth in a long bone, is more convenient and is used throughout this text. The *epiphysis* is a separate center of ossification found at the ends of long bones, is initially entirely cartilaginous, grows by endochondral ossification, and forms the articular surface in many bones. Fractures involving the physis may, but do not necessarily, involve the epiphysis.

The shafts of long bones are more resilient and elastic than older bones and thus withstand greater deflection before incomplete or complete fracture. Incomplete, or "greenstick," fractures are common in puppies and kittens. The *periosteum* is attached loosely to the diaphysis and strips easily when subjected to trauma. Blood collects beneath it, and the resulting subperiosteal hematoma is soon converted to callus. The periosteum is thick and may act as a restraining and stabilizing sleeve, helping to prevent displacement of bone fragments and generally adding stability.

Healing is rapid—2 to 4 weeks, depending on age—and most animals produce an abundant callus regardless of the method of stabilization. Remodeling is very active and is completed quickly, with all evidence of the fracture obliterated within a few weeks. Nonunion is very unusual. Physeal fractures are accompanied by considerable hemorrhage, rapid organization of callus, and often considerable displacement resulting from muscle forces. Because these changes occur so quickly after trauma, it is fundamental that reduction and fixation of physeal fractures be carried out as soon as possible. In articular fractures, anatomical reduction and rigid fixation are necessary to restore a functional joint.

DIAPHYSEAL FRACTURES

External Fixation

Some fractures may be treated by closed reduction and supported by coaptation (Figure 22-1), as described in Chapter 2. If used, limb splintage must be properly applied and kept in good repair; otherwise, adverse effects may result, including valgus

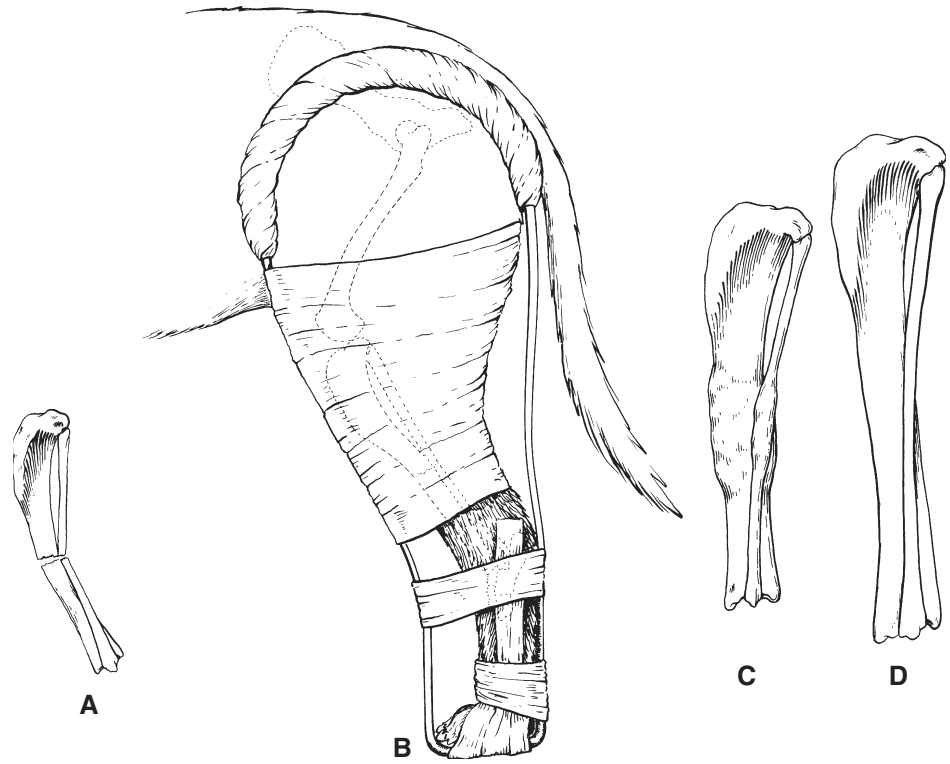


FIGURE 22-1. **A,** Transverse fracture of the tibia in a toy poodle 8 weeks of age. **B,** After reduction, a modified Thomas splint was applied. **C,** Splint removed 2 weeks after treatment. **D,** Fracture remodeled 4 weeks after treatment.

deformity, rotation, ligamentous laxity, and joint stiffness. Immobilization of the hindlimb that deprives the hip joint of weight-bearing forces causes coxa valga and increased anteversion, and the result is identical to the pathology of congenital hip dysplasia (see Chapter 16). This effect is most pronounced in the large breeds but can affect dogs of all sizes. Hindlimb immobilization also can result in quadriceps tie-down and fibrosis of the stifle joint. Immobilization of the forelimb typically causes laxity and hyperextension to develop in the carpus. Fortunately, these carpal conditions are usually reversible, whereas the hip and stifle problems are not. Coaptation should be left in place for the absolute minimal amount of time necessary for clinical union.

Internal Fixation

Internal fixation is used primarily for the following types of acute fractures:

1. Fractures causing rotational deformity or excessive shortening.
2. Fractures resulting in incongruency of an articular surface.
3. Fractures affecting the physeal plate and thus future bone growth.
4. Fractures of the femur, especially in large breeds.

Applicable types of fixation for diaphyseal fractures include the intramedullary (IM) pin, external fixator, and bone plates.

Intramedullary Pin

In proportion, IM pins used in the young animal are relatively smaller in diameter than those used in the adult.[2] Because cancellous bone is present in a high percentage

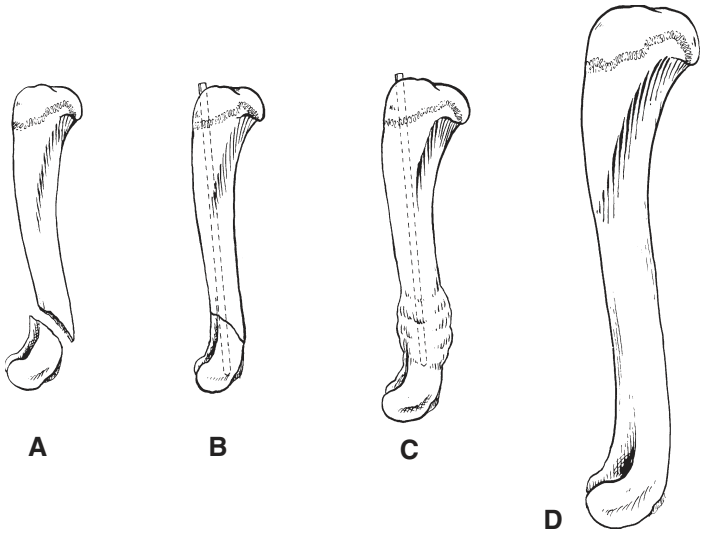


FIGURE 22-2. **A,** Oblique fracture of the distal humerus in a 7-week-old animal. **B,** Postoperative Steinmann pin fixation. **C,** Pin removed 2 weeks postoperatively. **D,** Fracture remodeled 4 months postoperatively.

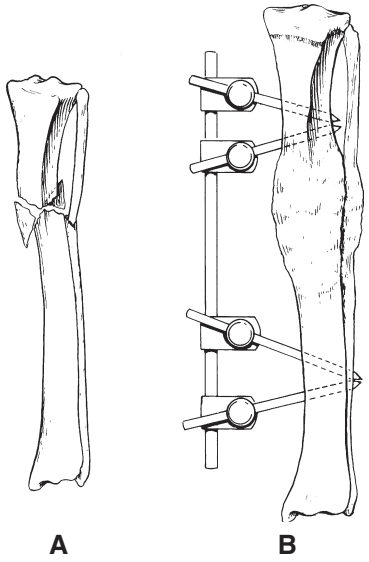


FIGURE 22-3. **A,** Comminuted open fracture of the tibia in a 9-week-old animal. **B,** Clinical union at 2½ weeks; the external fixator was removed at this time.

of the medullary cavity, the IM pin stabilizes the fracture better in young animals. Auxiliary fixation is rarely used because the rapid development of periosteal callus stabilizes rotational and shortening forces (Figure 22-2).

External Fixator

The fundamentals of using the splint are the same in young as in adult animals; however, healing is rapid, less fixator stiffness is required, and 2/2 pins are usually sufficient (Figure 22-3). The fixation pins should not traverse the physis or penetrate paired bones such as the radius and ulna. The splint must not bridge the physis; keep all fixation pins in the diaphysis and metaphysis. Because fissure fractures of the

shaft often accompany complete fractures, care must be taken not to place fixation pins into these fissures. It is acceptable to cross the fissure lines with pins.

Bone Plate

Although often disregarded, bone plates offer many advantages in juvenile patients, especially in femoral fractures of the large breeds. Highly unstable and multifragment fractures of the femur are difficult to repair by any other means (Figure 22-4). Latte[2] has devised a unique approach to plate application in growing animals, specifically in femoral fracture stabilization. The femoral cortex in growing animals is quite thin, more so than in other long bones. This thinness, combined with the rigidity of bone plates relative to the bone, causes screw loosening in many cases, especially when contact of the main fragments cannot be reestablished. Latte proposed using relatively small (2.7-mm) and flexible plates, combined with 3.5-mm screws, and placing the screws only in the end holes of the plate, where the bone is metaphyseal; that is, containing much trabecular bone within the medullary canal. This allows the surgeon to avoid the thin cortex in the middiaphyseal area. Some motion of the fracture will occur, but since callus formation is rapid and quickly stabilizes the fracture, this motion is not important. Latte's recommendations for *biological osteosynthesis* of femoral fractures include the following:

1. Wait 36 hours after injury before fixation to allow for some attachment to fragments and organization of the hematoma.
2. Do not attempt to reduce fragments. Correct angular and rotational malalignment and restore length only to the extent possible without disruption of the hematoma. Use only pointed reduction forceps on the major fragments to avoid damage to periosteum.
3. Use radiographs of the normal limb to measure and contour the plate. Do not cross growth plates with the plate.
4. Do not use any lag screws, and do not place screws close to the fracture line. Three screws on each major fragment are needed. No tapping is done in metaphyseal areas.
5. Do not use limb splintage postoperatively.

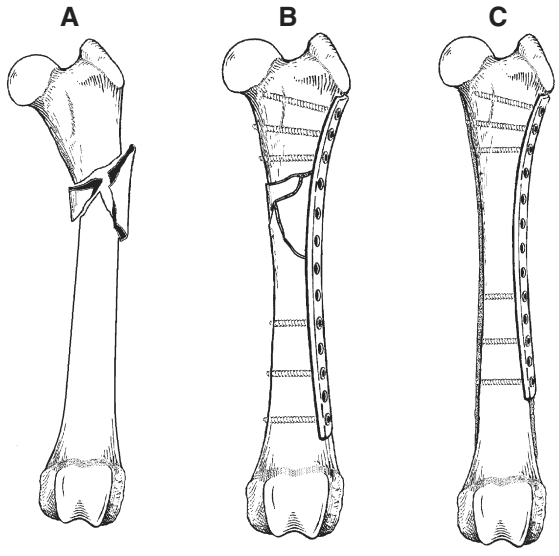


FIGURE 22-4. A, Type C complex diaphyseal fracture with nonreducible wedges in an 11-week-old large-breed dog. **B,** Postoperative view showing plate fixation in the manner of Latte.[2] A 2.7-mm plate is attached in the metaphyseal regions with 3.5-mm screws. No screws are used in the diaphysis, and the fragments are not reduced. **C,** At 6 weeks the femur is completely healed and remodeled. The bone has continued to increase in length distally, which is the normal pattern. The plate is removed at this time.

Good results have been reported using conventional plating technique in fractures of the radius in growing animals.[3] The cortex of the radius, humerus, and tibia in the young animal is much thicker than the femur, and screw loosening is not an issue. When used, bone plates should be removed early, after approximately 3 to 5 weeks, depending on age and circumstances. Early removal is necessary to prevent entrapment of the plate by appositional bone growth.

PHYSEAL FRACTURES

Longitudinal growth of bone is the result of enchondral ossification occurring in the epiphyseal and metaphyseal areas. The process is a sequence of coordinated events: (1) multiplication, growth, and degeneration of the cartilage cell; (2) calcification and vascularization of the cartilage matrix; (3) production of primary spongiosa; and (4) bony trabeculae of the metaphysis. Excess load applied to the immature bone may result in dislocation, fracture, or a crushing type of injury. Because the strength of the fibrous joint capsule and ligaments is two to five times greater than that of the metaphyseal-physeal junction, the latter is more prone to injury (e.g., separation, dislocation, fracture).

Growth plates can be classified on the basis of their location. There are two types: pressure and traction growth plates. *Pressure growth plates* are located at the ends of the long bones and transmit forces through the adjacent joint. Pressure growth plates produce the majority of the longitudinal growth. *Traction growth plates* are located where muscles originate or insert. A traction growth plate contributes little to bone length (e.g., tibial tuberosity).

Salter and Harris[4] have anatomically classified physeal injuries into five types (Table 22-1 and Figure 22-5). Although the original intent was to give prognostic information based on fracture type, this has not proved to be a valid concept. In a histological study of 13 physeal fractures, 10 were shown to have damage to the physeal proliferative zone cartilage.[5] Most physeal fractures occur in the proliferative zone because it is the weakest area of the physis. It would appear that growth

TABLE 22-1. SALTER-HARRIS CLASSIFICATION OF SEPARATIONS OR FRACTURE-SEPARATIONS INVOLVING A GROWTH PLATE AND THE ADJACENT METAPHYSIS AND EPIPHYSIS

Type of Fracture	Radiographic Findings	Principal Anatomical Regions Involved
Type I (Figure 22-5, *A*)	Physeal separation; displacement of epiphysis from metaphysis at growth plate.	Proximal humerus and femur, distal femur
Type II (Figure 22-5, *B*)	Small corner of metaphyseal bone fractured, with displacement of epiphysis from metaphysis at growth plate.	Distal femur and humerus, proximal humerus, proximal tibia
Type III (Figure 22-5, *C*)	Fracture through epiphysis and part of growth plate, but metaphysis unaffected.	Distal humerus
Type IV (Figure 22-5, *D*)	Fracture through epiphysis, growth plate, and metaphysis; several fracture lines may been seen.	Distal femur, distal humerus
Type V (Figure 22-5, *E*)	Soft tissue swelling but no bony abnormalities seen after injury.	Distal ulna, distal radius, distal femur
Type V (Figure 22-5, *F*)	Two months after trauma, shortening of ulna and partial closure with angular deformity of radius.	

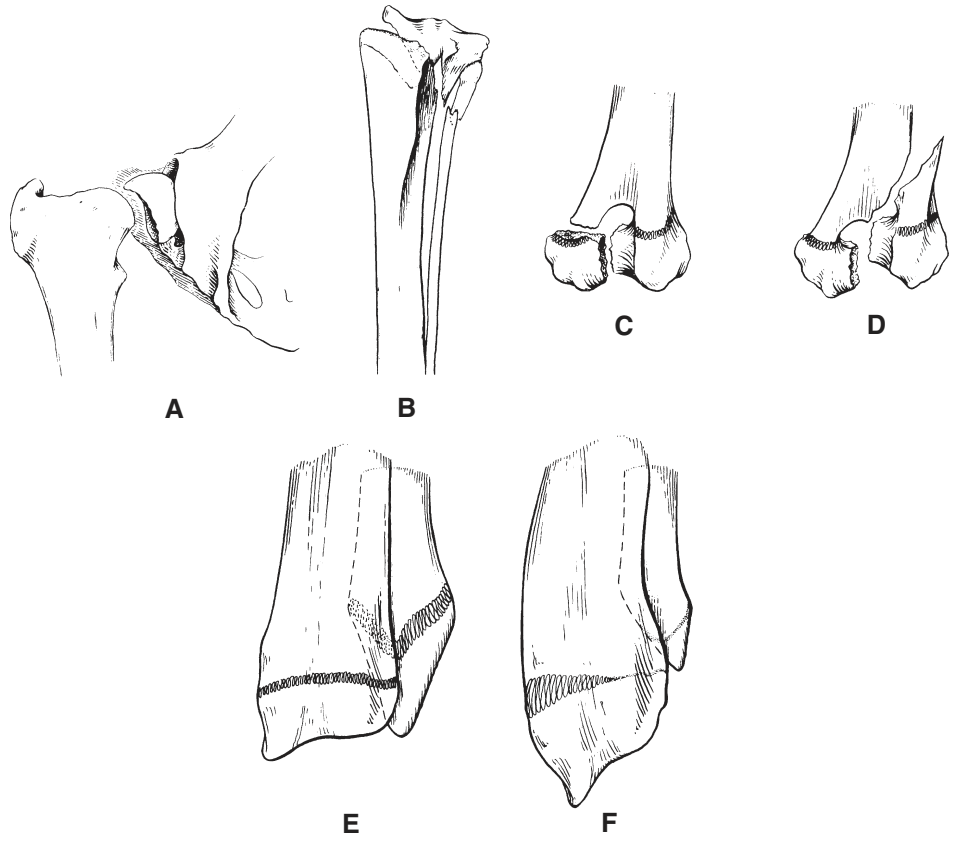


FIGURE 22-5. Salter-Harris classification of epiphyseal fractures involving the growth plate, adjacent metaphysis, and epiphysis. **A,** Type I physeal fracture, with displacement of the epiphysis from the metaphysis at the growth plate. **B,** Type II fracture of small corner of the metaphyseal bone, with displacement of the epiphysis from the metaphysis at the growth plate. **C,** Type III fracture through the epiphysis and part of the growth plate; metaphysis is unaffected. **D,** Type IV fracture through the epiphysis, growth plate, and metaphysis. **E,** Type V injury, with soft tissue swelling but no bony abnormalities seen immediately after injury. **F,** Type V injury, 2 months after the trauma; closure and shortening of the ulna and partial closure with an angular deformity of the radius are evident.

disturbance is not the only factor related to the type of fracture, and that other factors are important as well, such as the age of the patient, extent of displacement, degree of reduction, time since injury, and type of fixation. The various types of injuries are the result of different types of forces being applied to various areas of the leg at different stages of maturity of the growth plate. The younger the animal, the greater is the chance for growth deformity, even with early reduction and fixation. Despite failure to fulfill the original expectations, the Salter-Harris classification remains as a standard system for nomenclature.

Incidence[6]

About one fourth to one third of long-bone fractures involve the physes, and Salter-Harris type II injuries predominate. The physis most important to the length of the bone is most often involved, except in the humerus, where the distal physis is injured more often than the proximal physis. The distal femoral physis is most often injured,

followed by distal humerus, proximal femur, distal ulna, distal radius, proximal tibia, and distal tibia. Between 5% and 10% of these patients will develop growth deformities, of which the majority will require corrective osteotomy to restore normal function. The tendency to develop a growth abnormality is most likely in medium-size to large-breed dogs that are less than 5 months old at time of injury. Salter-Harris type V injuries of the distal ulnar physis are more likely to produce significant deformity than any other injury.

Treatment of Salter-Harris I to IV Injuries

Open reduction and internal fixation of fractures involving joints are indicated if congruent articular surfaces cannot be obtained and maintained by conservative means. The majority of fractures in small animals require open reduction and rigid internal fixation.[1] Kirschner wire fixation of bone fragments is an excellent method; healing is rapid, and the wires can be removed in 2 to 4 weeks. With meticulous surgery, early reduction, and rigid fixation, the response to Salter-Harris I to IV injuries is very encouraging for healing and return to normal or at least satisfactory function. The surgical approach and fixation methods are similar to those described for the corresponding areas in the adult animal (see Chapters 11, 13, 17, and 19). Figures 22-6 and 22-7 depict most fracture-separations that occur in the region of the physes and suggest methods of stabilization.

Principles of Treatment

1. Do the least reduction and fixation that is compatible with good function and rapid healing. The younger the animal, the less reduction and fixation are needed.
2. Closed reduction and fixation are preferable when possible, as in the distal tibia, distal radius, and occasionally the distal humerus. The ability to perform a closed reduction successfully is limited to cases that are seen early and have minimal displacement. Be aware of the problems associated with coaptation splintage in growing animals, as discussed earlier with diaphyseal fracture treatment. Splints can usually be removed in 2 weeks for physeal fractures in animals less than 5 months of age.
3. Reduce physeal fractures as early as possible. Within 72 hours, many are virtually impossible to reduce because of rapid organization of the copious fracture hematoma, along with severe muscular contracture.
4. The following principles apply during open reduction:
   - Be aware of the epiphyseal blood supply and spare it during all manipulations
   - Do not grind germinal cartilage off the epiphyseal fragment in types I, II, and III during the reduction process.
   - Be careful with bone clamps because they can easily crush the epiphysis or damage articular cartilage. Pointed reduction clamps will minimize these injuries, but reduction should be accomplished by traction and leverage of the epiphysis through the ligaments attached to the adjoining long bone.
5. Principles for internal fixation are as follows:
   - Do not bridge the physis with any fixation that prevents an increase in bone length (e.g., lag screws, bone plates, tension band wires, threaded pins, external fixators). The younger the animal, the more important this is to prevent growth disturbances.

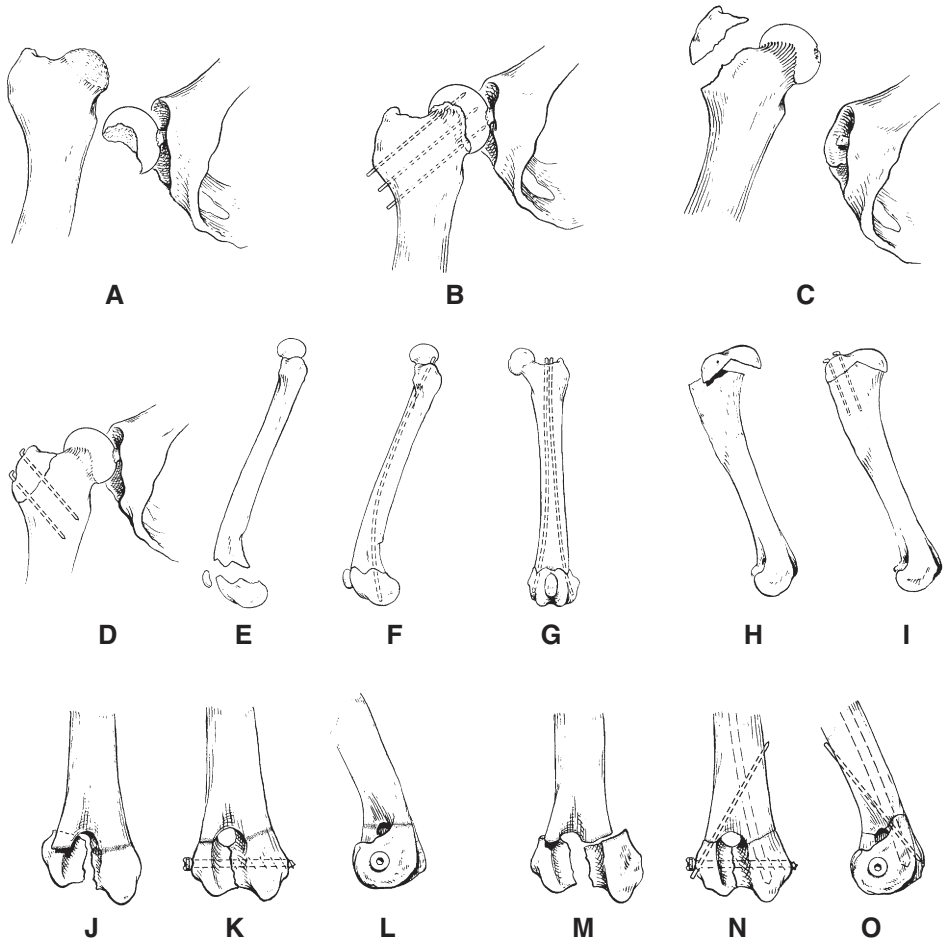


FIGURE 22-6. Physeal fractures of the femur and humerus. **A,** Type 1 injury (Salter-Harris type I) to the pressure physis; separation of the proximal femoral physis. **B,** Fixation is with three smooth Kirschner wires. **C** and **D,** Type 1 injury to the traction physis; avulsion or fracture of the trochanter major and dislocation of the coxofemoral joint. After reduction of the femoral head, the trochanter is relocated and fixed in place with two Kirschner wires. **E, F,** and **G,** Type 1 injury to the pressure physis; separation of the distal femoral physis. Reduction and fixation are accomplished using two small intramedullary pins. **H** and **I,** Type 1 injury to the pressure physis; fracture of proximal humeral epiphysis. Fixation is by insertion of two Kirschner wires entering on the ridge of the greater tuberosity. **J, K,** and **L,** Type 3 injury (Salter-Harris type III) to the pressure physis; fracture between the medial and lateral aspects of the humeral condyle with separation at the lateral part of the epiphyseal line. Fixation is with a transcondylar lag screw. **M, N,** and **O,** Type 3 bicondylar fracture of the humeral condyles with separation along the entire epiphyseal line. Fixation is with a transcondylar screw and two pins.

- Small-diameter, smooth Steinmann pins or Kirschner wires are adequate fixation in most cases. Diameters typically range from 0.035 to 5⁄64 inch (1-2 mm). With smooth pins the epiphysis is free to grow in length and glide along the pin, which often becomes completely buried within the epiphysis. Bone will quickly grow into threads, locking the pin to the implant and preventing growth unless the pin slides backward with epiphyseal growth. Lag screws are needed in Salter-Harris types III and IV, but these run parallel to the physis and do not cross it.

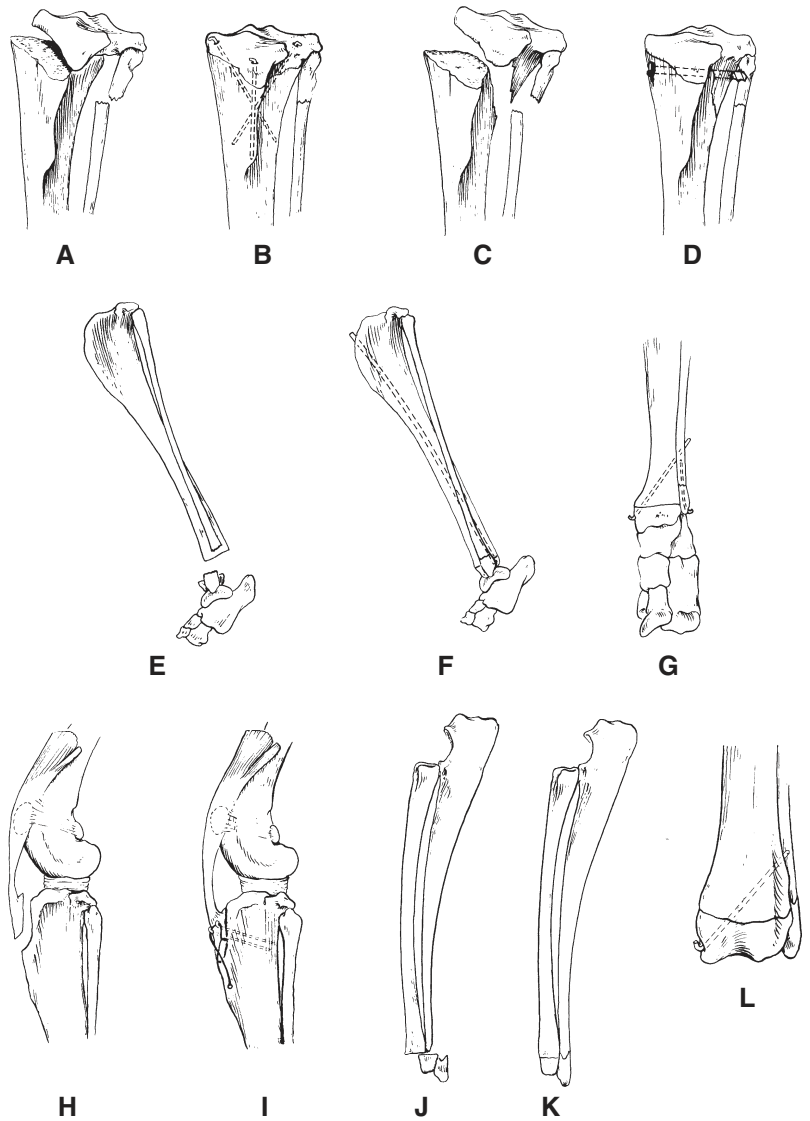


FIGURE 22-7. Physeal fractures of the tibia and radius and ulna. **A** and **B,** Type 1 injury (Salter-Harris type I) to the pressure physis; fracture of the proximal tibial physis with a fracture of the fibula. Fixation is with three obliquely inserted Kirschner wires. **C** and **D,** Type 2 injury (Salter-Harris type II) to the pressure physis; fracture of the proximal tibial physis and a small portion of the metaphysis. Fixation is with a cancellous screw under the physis. **E, F,** and **G,** Type 1 injury to the pressure physis; fracture of the distal tibial and fibular physis. If the parts are stable on reduction, the hock is flexed to a right angle and fixed in this position for 2 to 3 weeks with a cast. The right angle places the bone segments in the most stable position. If this fracture is unstable on reduction, a small intramedullary pin is inserted from the proximal end of the tibia down into the epiphysis, or two small pins are inserted through the malleoli. A cast is applied for additional stabilization. **H** and **I,** Type 1 injury to the traction physis; avulsion of the tibial tubercle. Fixation is by a tension band wire. **J, K,** and **L,** Type 1 separation of the distal physis of the radius and fracture of ulna. The segments are usually stable on reduction (**K**) but require external stabilization with a coaptation splint. If segments appear unstable after reduction, a Kirschner wire (**L**) should be inserted diagonally through the radial styloid process into the diaphysis.

- Pins should cross the physeal plate at an angle as perpendicular as possible to minimize any effect on the plate. Angles greater than 45 degrees will cause some locking effect and predispose to epiphysiodesis. Rush pins will produce a locking effect because of the hooked end, preventing movement of the epiphysis along the pin. These hooks should be cut off after the pin is seated.
- If a form of fixation that does bridge the physis is unavoidable to secure fixation, it should be used. The first priority is to obtain fracture healing with a functional reduction. In this situation the fixation is removed as soon as possible, usually within 3 to 4 weeks, and as early as 2 weeks in very young animals.
- Strive for stable internal fixation that will allow early, limited, active weight bearing on the limb to minimize secondary bony deformity resulting from disturbed stress/strain patterns on other bones.

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23

Correction of Abnormal Bone Growth and Healing

Angular and rotational deformities of long bones induce considerable functional problems when the deformity is beyond the animal's ability to compensate. Angular deformities have the effect of shortening the limb, and although dogs and cats have remarkable ability to compensate for this, beyond a certain point the gait is greatly altered. Both rotational deformity and angular deformity cause abnormal stress and strain on adjacent joints, which will induce degenerative joint disease over time. These deformities are most often caused by premature arrest of long-bone growth plates or by healing of a long-bone fracture in a position of incomplete reduction. Many deformities can be corrected by division and repositioning of the bone, which is the subject of this chapter.

OSTEOTOMY

An osteotomy is the surgical division of the bone and is usually indicated to correct bony deformities that may include length, angular, or rotational changes. These changes may occur in one plane, but most involve two or more planes.

Angular deformities are most common and include varus, valgus, hyperextension, and hyperflexion. Length can be shortened or (rarely) lengthened, and rotation can be internal or external. Malunion can include the previous conditions plus overriding of diaphyseal segments in all planes and directions. These deformities are treated by *corrective* osteotomy; *simple* osteotomies are usually performed as part of a surgical approach or as part of another procedure, such as arthrodesis.

Common Indications for Corrective Osteotomy

Corrective osteotomy is typically performed for the following conditions:

- Angular deformity of the radius and ulna caused by premature physeal arrest of the radius and/or ulna.
- Angular deformity of the distal tibia caused by premature physeal arrest of the distal tibia and/or the distal fibula.
- Correction or prevention of hip dysplasia.
- Malunion of all long bones and pelvis.

Types of Corrective Osteotomy

Transverse Osteotomy

The transverse technique is used for correction of rotational deformity (Figure 23-1, *A*, *B*, and *C*). Kirschner wires may be inserted in each section of bone *(dashed lines* in *B* and *C*) before the osteotomy is done so that the amount of derotation can be determined.

Opening Wedge Osteotomy

The opening wedge technique is a transverse osteotomy used to correct an angular deformity (Figure 23-1, *D* and *E*). Rotational correction is also possible, and length is maintained.

Cuneiform Osteotomy

The cuneiform technique is a closing wedge osteotomy, with a predetermined-size wedge of bone removed from the point of maximal deformity (Figure 23-2, *A* and *B*). Some limb length is lost. Figure 23-17 provides a case illustration of its use.

Oblique Osteotomy

In this technique an oblique cut is usually made parallel with the articular surface to be realigned. The point of the long segment is inserted into the medullary cavity of the articular fragment (see Figure 23-7). The oblique procedure maintains or increases length slightly and can be used to correct rotation and varus or valgus deformity. It is most frequently used in corrective surgery for radius curvus. The oblique approach is less suitable to diaphyseal osteotomies because of the large gaps that it creates.

Stair-Step Lengthening Osteotomy

A simple method for lengthening is the stair-step method illustrated in Figure 23-2, *C* and *D*.

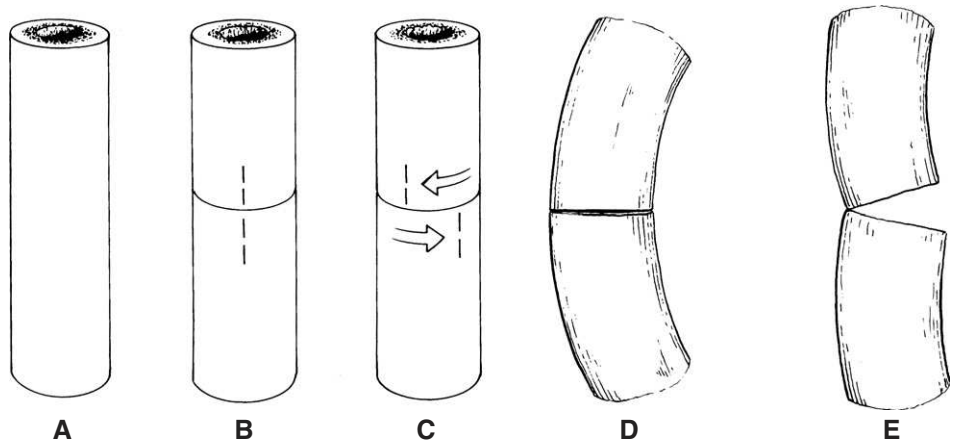


FIGURE 23-1. Transverse osteotomy. **A, B,** and **C,** Correction of a predetermined rotational deformity. **D** and **E,** Opening wedge type. A single transverse cut is made, rotational and angular deformities are corrected, stabilization is applied, and the deficit is filled with a bone graft.

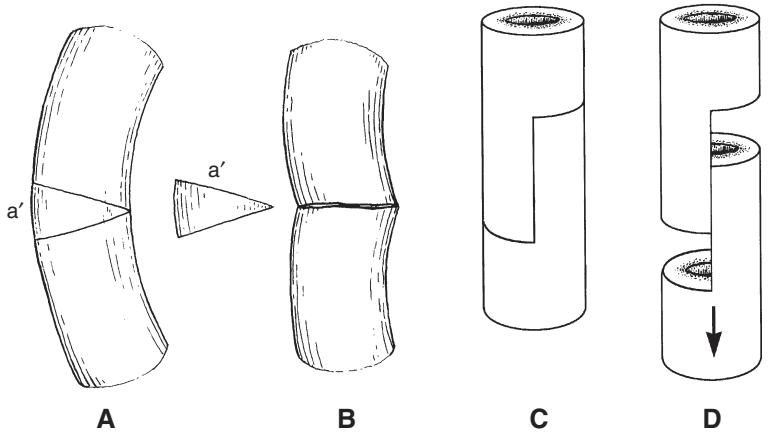


FIGURE 23-2. **A** and **B,** Cuneiform osteotomy, closing wedge type. A predetermined-size wedge of bone *(a′)* is removed from the point of maximal deformity. **C** and **D,** Lengthening osteotomy. The sagittal osteotomy is twice as long as the desired lengthening in order to provide good bone contact for healing.

Surgical Principles of Corrective Osteotomy

1. Because corrective osteotomy is an elective procedure, there is no urgency. The animal must be in optimal condition to undergo anesthesia and surgery; the procedure should be well planned; and all equipment and implants necessary should be available.
2. Plan the procedure by obtaining radiographs of the bone in two planes, 90 degrees apart, usually craniocaudal and mediolateral. Tracings of these films allow the osteotomy to be preplanned to some degree (see Figure 23-17). Because rotational changes cannot be adequately appreciated radiographically, a certain amount of error is introduced that must be compensated for at surgery. Nevertheless, it is useful to have a plan preoperatively, even if it is not on paper.
3. For angular deformity, the osteotomy must be done as close as possible to the point of maximum angular change (see Figure 23-17) while still allowing room for implant stabilization. This will minimize the overall cosmetic deformity induced by the osteotomy. Make the osteotomy parallel to the joint surface to be realigned.
4. When practical, make the osteotomy so the cut surfaces will fit together. Although this is useful to minimize the amount of bridging callus necessary, it is often not possible, as in the oblique osteotomy (see Figure 23-7). It is more important to minimize the osteotomy gap in diaphyseal locations than in metaphyseal areas. It is also more important to minimize the osteotomy gap in adult dogs than in juvenile dogs that have rapidly healing bone.
5. Axially align the proximal and distal joints relative to the shaft. The animal should be draped in a manner that will allow good visualization of the distal limb because the final alignment is done visually.
6. An open approach is carried out to expose the operative bone area. In skeletally immature dogs, a longitudinal incision is made through the periosteum, which is peeled back as a layer using the osteotome or periosteal elevator. The bone is osteotomized using a powered bone saw, Gigli wire, or osteotome. With the power saw, constant irrigation is necessary to dissipate the heat generated in the cutting process. The osteotome should not be used as the

primary cutting instrument in the diaphysis because there is undue risk of splintering the bone. Instead, a row of closely spaced holes is drilled on the osteotomy line with a Kirschner wire or 1.5- to 2.0-mm drill, and a narrow osteotome is used to connect the holes. This is a very good method, since it produces an irregular surface that tends to lock together, unlike the smooth surface of the power saw or Gigli wire cut.

7. Autogenous cancellous bone graft is added at the osteotomy site in diaphyseal osteotomies (see Chapter 3). It is not needed in metaphyseal osteotomies in skeletally immature patients.
8. Fixation appropriate to a similar fracture pattern in the same bone is applied, and the surgical area is closed in layers.
9. Aftercare is as for a similar fracture pattern in the same bone.

TREATMENT OF PREMATURE PHYSEAL GROWTH ARREST

Salter-Harris type V injury to the growth plate can result in temporary delay in growth, altered growth, or premature closure and cessation of growth.[1] The entire growth plate or a localized eccentric region within the growth plate may close prematurely. This is recognized radiographically by replacement of the radiolucent growth plate with uniform bone density, known as *bone bridging*. In paired bones the premature closure may involve one or both bones, resulting in partial or complete growth impairment. The degree of alteration of growth is proportional to the growth potential remaining at the time of injury. Frequently, the immediate resultant pathology may be too insignificant for clinical observation, but with time (1 week to several weeks) angular and/or rotational deformities begin to appear. The most common injuries involve the distal radial and ulnar physes in medium-sized to large canine breeds.

Clinical characteristics of premature partial or complete closure of the physes include lameness, shortened limb, angular deformity, valgus or varus (Figure 23-3), rotation, discomfort, crepitation, and restricted range of movement. Radiography should include both limbs, with special attention to the physis, the adjacent metaphysis, and the joints above and below the growth arrest. This radiographic study should determine (1) length of bone or bones, (2) width of the joint space at either end of the shortened bone, (3) direction of diaphyseal bowing, (4) angulation of the foot, (5) range of movement, and (6) extent of pathological changes in the joints

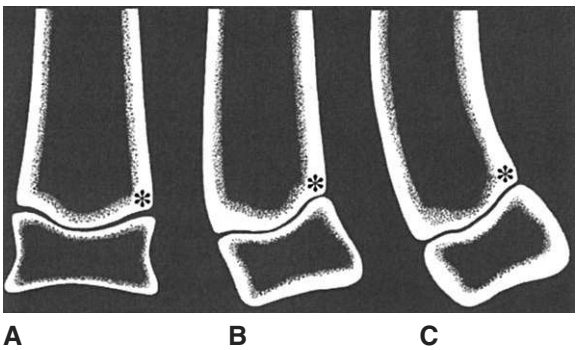


FIGURE 23-3. A, Eccentric injury to the physeal growth plate (*) can result in complete cessation or reduction in rate of bone formation in that part of the physis. **B** and **C,** Diaphyseal angular deformity and varying degrees of subluxation of the adjacent joint follow because of a greater amount of bone growth on the uninjured side. (From O'Brien T, Morgan JP, Suter PF: *J Small Anim Pract* 12:19-35, 1971.)

above and below the physeal injury. O'Brien and colleagues[2] provide an excellent description of the radiological changes of forelimb growth disturbances.

The treatment of pathological changes in Salter-Harris type V injury presents more complex problems when paired bones are involved (e.g., radius and ulna, tibia and fibula). The most common problems involve the radius and ulna; each bone must grow in a synchronous manner to promote normal growth and maintain congruency of their common articular surfaces. The *ulna* grows from two growth plates. The *proximal* ulnar physis, which closes between approximately 187 and 222 days, contributes only to olecranon length and is usually not significant relative to premature physeal closure anomalies. The *distal* ulnar physis, however, is responsible for 100% of the longitudinal growth distal to the elbow joint and must equal the combined growth of the proximal and distal radial physes. The *radius* grows from both the *proximal* radial physis (40%) and the *distal* radial physis (60%) and provides the major weight-bearing surface of the elbow joint (75%-80%). Closure of these physes ranges from about 220 to 250 days (7-8 months).[3] Abnormal development from asynchronous growth between the radius and ulna can result from retarded growth of the distal ulnar physis, distal radial physis, or proximal radial physis. Resultant dysplasias are common orthopedic problems and vary depending on the physis or physes involved, the age of the animal at time of involvement, and the span of time since injury.

Two cardinal considerations in planning corrective surgery are that (1) the operative procedure should increase or at least maintain length because closure of the physis always results in a shorter bone (limb), and (2) corrective surgery should be carried out early to avoid or to at least minimize irreversible pathological changes in the adjacent joints. In this discussion of surgical treatment, the following criteria are used:

- **Skeletally immature.** Two to 3 months of growth potential remaining: giant breeds less than 8 months of age, large breeds less than 7 months, and small breeds less than 4 months.
- **Skeletally mature.** Growth plates not necessarily totally closed, but little lengthening remaining: giant breeds over 8 months of age, large breeds over 7 months, and small breeds over 4 months.

Distal Ulnar Physis Closure

Premature closure of the distal ulnar physis and subsequent deformities are the most common complications of forelimb physeal injuries, accounting for 83% of forelimb growth disturbances in 39 dogs in one study.[2] The conical shape of the distal ulnar physis is unique to the dog. In all other animals, the radial and ulnar physes are flat and predisposed to shearing fractures, and after reduction, the prognosis for uninterrupted growth is usually good. The canine distal ulnar physis is unable to shear because of the conical configuration, and thus shear forces are transformed to compressive forces and injury to germinal cartilage.[4] Significant retardation in growth of the distal ulnar physis results in a shortened ulna, which, because of the interosseous ligamentous connections between the bones, acts as a "bowstring" to restrict longitudinal growth of the radius.

Clinical and Radiographic Signs

Retardation of ulnar growth produces varying degrees of cranial and lateral bowing of the distal radius, radial shortening, valgus deformation and external rotation (supination) of the foot, elbow subluxation, and degenerative joint disease in the

carpal and elbow joints (Figures 23-4 and 23-5). Measurement of carpal valgus and cranial bowing can be done from the radiograph, as shown in Figure 23-6. With cessation of growth of the ulnar diaphysis and continued growth of the radius, the humeral condyle is forced proximally relative to the ulna. In normal straight-limbed dogs, this usually results in subluxation of the humeral condyle and damage to the anconeal process. The most severe lesion occurs in the distal half of the trochlear notch, resulting in degenerative cartilage changes, fracture of trabeculae in the subchondral bone, and alteration in joint morphology. Another effect is seen at the distal radial physis, where the compression of the physis laterally can cause eccentric slowing or complete cessation of growth and further carpal valgus and cranial bowing deformities. In chondrodystrophic breeds the radial head usually subluxates laterally and rests on the lateral edge of the humeral condyle articular surface, where it causes mechanical damage to both the radial head and the humeral condyle. Because the radius is released from some of the compression force, there may be less carpal valgus and cranial bowing.

Lameness is usually the first clinical sign of premature closure of the distal ulnar growth plate. Elbow subluxation may be accompanied by regional pain. Beginning radiographic changes are usually visible at this time. If taken at the time of injury, radiographs often reveal a fracture line in the region of the growth plate.

Surgical Correction

Skeletally Immature

Early corrective surgery is indicated to avoid or to at least minimize subsequent changes. It is important to decide if the distal radial physis has bridged laterally or caudolaterally; if this is seen radiographically, see the later description for combined ulnar and distal radial physeal closure.

Carpal Valgus Less Than 25 Degrees. *Partial ulnar ostectomy* of the distal ulna is required to remove the bowstring effect and to allow radial remodeling. The distal

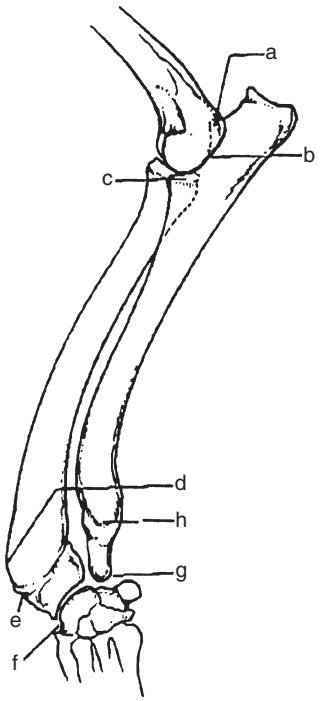


FIGURE 23-4. Radiographic changes characteristic of premature closure of the distal ulnar physis. With a cessation of growth of the ulna and continued growth of the radius, there is remodeling of the anconeal process with sclerosis *(a)*, elbow subluxation with flattening of the trochlear notch *(b)* and distal displacement of the styloid process *(c)*, anterior bowing of the radius *(d)*, opening of distal radial physis *(e)* with increased angulation of the radiocarpal joint *(f)*, and secondary arthritic changes. There is proximal relocation of the ulnar styloid *(g)* because of the shortened ulna. The distal ulnar physis is closed *(h)*.

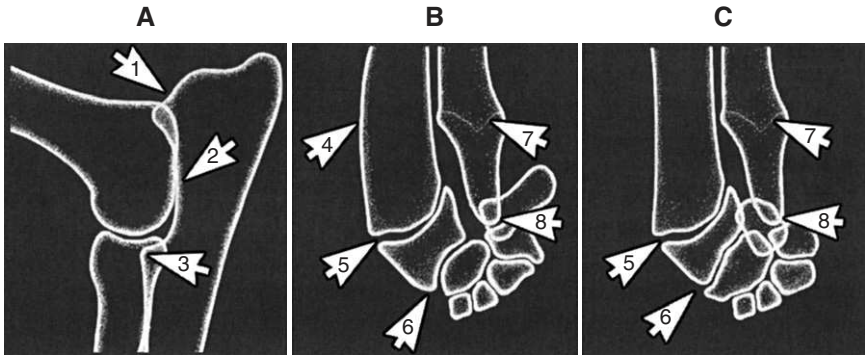


FIGURE 23-5. Common bony changes seen radiographically after premature closure of the distal ulnar physis. **A,** Elbow region. *1,* Sclerotic and remodeled anconeal process with decrease of the distance between the process and the radial head; *2,* trochlear notch shallow and subluxation of the humeroulnar joint; *3,* distal displacement of the coronoid processes. **B** and **C,** Region of the distal radius and ulna. Lateral view (**B**) and dorsopalmar view (**C**): *4,* cranial bowing of the radial diaphysis and metaphysis; *5,* open distal radial growth plate; *6,* cranial and medial subluxation of the distal radius with increased angulation of the antebrachiocarpal joint and secondary degenerative joint disease; *7,* closed distal ulnar growth plate; *8,* proximal location of ulnar styloid process resulting from shortened ulna. (From O'Brien T, Morgan JP, Suter PF: *J Small Anim Pract* 12:19-35, 1971.)

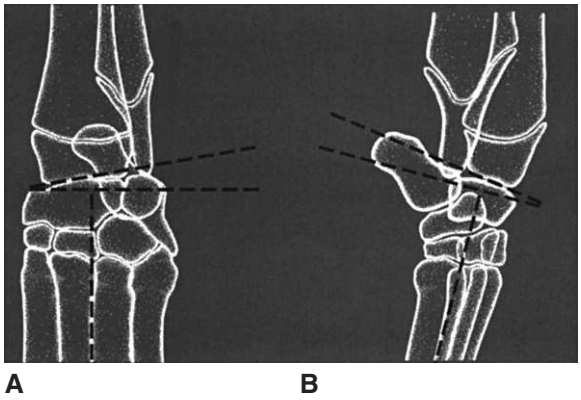


FIGURE 23–6. **A,** Lining method for determination of angulation of the carpus from dorsopalmar radiographs; 0 to 10 degrees is normal. **B,** Lining method for determination of angulation of the carpus from lateromedial radiographs; 0 to 8 degrees is normal. (From O'Brien T, Morgan JP, Suter PF: *J Small Anim Pract* 12:19-35, 1971.)

ulna is approached laterally, and the lateral digital extensor muscle is retracted.[5] The easiest section to excise is just proximal to the physis. The length of the excised ulnar segment should be about 1.5 times the bone diameter, and it is critical that it be exposed extraperiosteally so that no periosteum is left to cause rapid bony bridging. Cutting of the bone is done with a power saw, Gigli wire saw, or osteotome, which can be used here because the bone is still quite soft at this age. Care must be exercised to avoid severing the radial artery on the caudal side of the radius. A fat graft placed in the defect will discourage bone bridging.[6] The fat can be collected from the falciform ligament or the subcutaneous gluteal region. It should be collected in a single block and handled gently to avoid necrosis. The fat should be large enough to fit tightly in the available space, and soft tissues are closed to secure it. A firm padded bandage is maintained for 7 to 10 days postoperatively. If bilateral procedures are done, the limbs should be lightly splinted for 2 weeks to avoid motion at the graft site, which interferes with incorporation of the graft.[6] Moderate malalignment of the

elbow will correct after distal ostectomy as the ulna is pulled proximally by triceps brachii muscle forces. More severe malalignment accompanied by elbow pain requires proximal dynamic proximal ulnar osteotomy and is described later (see Figure 23-9).

The original report on partial ulnar ostectomy concluded that partial correction of the radial deformity was obtained.[6] No mention was made of the exact amount of carpal valgus preoperatively. A later report found the procedure to be effective only in young dogs (median age 5 months) with less than 25 degrees of carpal valgus or in older animals (median age 6.5 months) with less than 13 degrees of valgus.[7] This further reinforces the urgency of early surgical treatment.

Carpal Valgus Greater Than 25 Degrees. Corrective osteotomy of the radius to realign the foot should be performed at the same time as the partial ulnar ostectomy (as previously described). Use of the external fixator is usually the preferred method of fixation. Type I external fixators can be used (Figure 23-7, *E*), as well as type II (Figure 23-7, *C* and *D*). Because the osteotomy is in the metaphyseal area in an immature animal, healing is rapid; the fixator can usually be removed by 6 weeks postoperatively.

The type II fixator is preferred by the author because of the ease of final alignment. The proximal full pin is placed in the frontal plane of the proximal radius; this will be perpendicular to the humerus when the elbow is flexed 90 degrees. The distal full

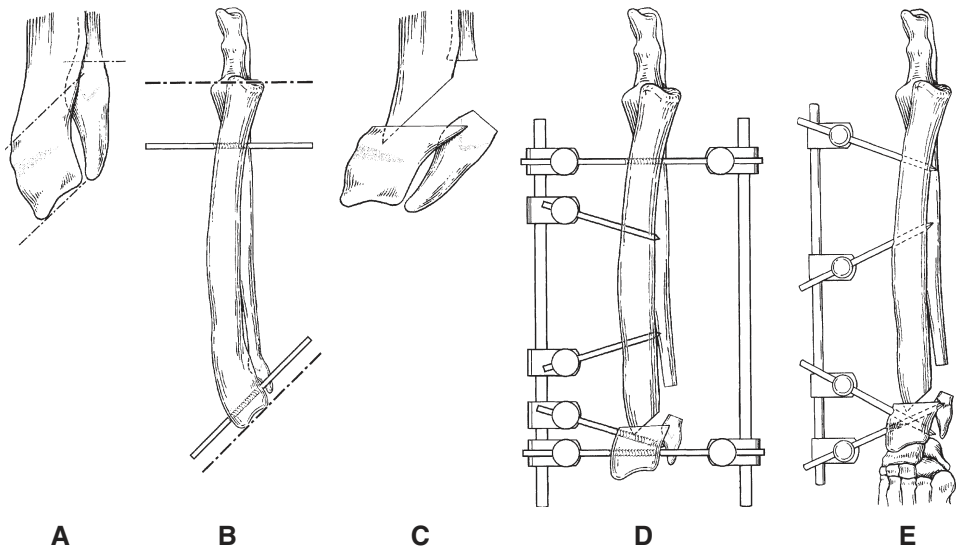


FIGURE 23-7. Oblique osteotomy of the radius for correction of angular deformity caused by premature arrest of the distal ulnar growth plate. **A** and **B,** The osteotomy line is drawn parallel with the antebrachiocarpal joint surface at the area of greatest radial curvature. A transverse osteotomy of the ulna is planned at or slightly proximal to the radial osteotomy. Center-threaded fixation pins are placed proximally and distally in the radius, parallel to the adjacent joint surfaces. The distal pin is also positioned to keep it in the frontal plane of the rotated carpus/metacarpus. These pins are placed before the osteotomy is done. **C** and **D,** The pointed proximal segment of the radius is reduced into the center of the distal segment. Connecting bars and clamps are loosely positioned on the fixation pins, and the foot is derotated and held so that it is in a straight line with the proximal portion of the radius and ulna and its frontal plane is continuous with the plane of the proximal segment. The two full pins should be approximately parallel to each other and in the same frontal plane at this point. The connecting-bar clamps are tightened and the half pins driven through the empty clamps to complete the type IIB fixator. **E,** The type IA fixator can also be applied. As above, the proximal and distal fixation pins are placed before the osteotomy is done.

pin is placed as close to the joint as is practical. A small hypodermic needle is used to probe for the joint space and is left in place to mark the distal end of the radius. This pin is placed in the frontal plane of the distal radius, carpus, and metacarpus. It will be perpendicular to the paw when the carpus is flexed 90 degrees. Because of possible supination of the distal radius, the pins will be in different planes as viewed from the distal end of the limb.

The ulnar osteotomy is performed first from a lateral approach, as described earlier. The osteotomy is done at or distal to the proposed radial site; if cut too proximally, the cut end will protrude laterally after angular correction. The radial osteotomy site is approached cranially with separation and retraction of the carpal and digital extensor tendons.[5] Periosteum is incised longitudinally and elevated from the bone and the osteotomy performed as previously described. Connecting bars and clamps are positioned loosely, with three empty clamps on the medial bar.

The distal segment is aligned first by placing the pointed end of the radius within the medullary canal and rotating the full pins until they are in the same plane, then angulating the distal bone until the pins are parallel to each other in the frontal plane. The foot should be in axial alignment with the proximal radius. Rotational alignment is checked by flexing the elbow and the carpus; the paw should be aligned with the humerus. It is often difficult to reduce the cranial bowing completely because of contracture of the flexor apparatus. If insufficient correction of cranial bowing or valgus deformity is achieved after oblique osteotomy of the radius, a closing wedge osteotomy of the radius may be performed to enhance angular correction. Slight bone shortening will occur with this procedure. At this point, the four clamps on the full pins are tightened, and a half pin is driven through the distal empty clamp into the distal fragment and the clamp tightened. Two more half pins are then driven into the proximal segment to complete the fixation. Bone grafting is not necessary, and closure is routine.

Type I fixators are applied in a similar manner, with the proximal and distal pins inserted first and the remaining pins driven after realignment (Figure 23-7, *E*). Prognosis for satisfactory function is good, regardless of degree of deformity, when performed at this skeletally immature age.[7] Some limb shortening can be expected in most animals.

Figure 23-8, *A* and *B,* shows a healed fracture of the radius with premature closure of the distal ulnar physis in a 5-month-old Afghan hound. Treatment originally consisted of application of a Mason metasplint. The radiographs taken 3 weeks after the injury revealed a clinically healed radius, leg shortening of 10 mm, premature closure of the distal ulnar growth plate, moderate valgus deformity of the foot, and early signs of incongruency of the elbow joint.

The primary objectives were to restore congruency of the elbow joint and to correct the cranial bowing of the radius and valgus deformity of the foot. Removal of a 1½-inch section of the ulna (including periosteum) corrected the bowstring effect, and in most cases (with minor deformity) the proximal ulna will readjust in position and make the correction needed for congruency at the elbow joint. An oblique osteotomy of the radius at the fracture site was used to derotate the foot and straighten the radius. In Figure 23-8, *C,* the type I external fixator is in place, following partial ulnar ostectomy and corrective osteotomy of the radius. At 4½ weeks postoperatively, the radius was healed, and the elbow joint was congruent and had a full range of movement (Figure 23-8, *D*). The external fixator was removed at this time.

Dynamic Proximal Ulnar Osteotomy. If there is marked incongruency of the elbow, with or without distal changes, a proximal ulnar osteotomy allows the proximal end to shift proximally and reestablish congruency as well as possible with the

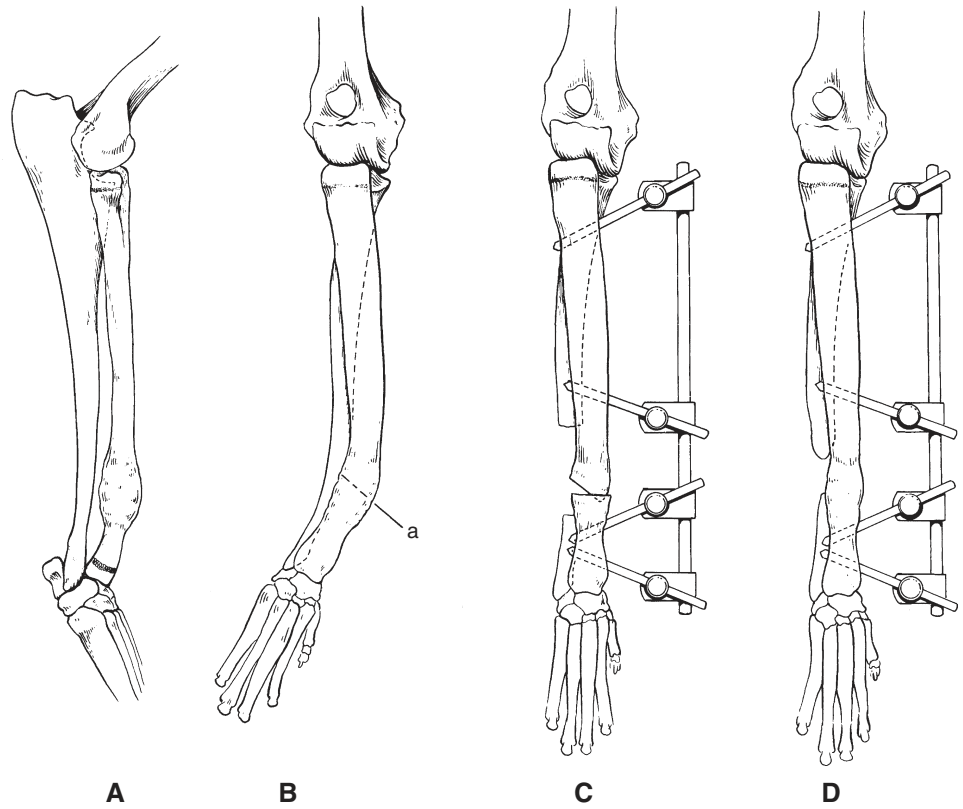


FIGURE 23-8. **A** and **B,** Healed fracture of the radius with premature closure of the distal ulnar physis in 5-month-old Afghan hound. Preoperative lateral and craniocaudal views. **C,** A 1½-inch section of the ulna (including periosteum) was removed; the oblique cut *(a)* in the radius was made at the point of greatest curvature; the point of the radius was inserted into the medullary cavity of the distal radial segment; the foot and distal section of radius was held so that it was in line with the proximal end of the leg; and the external fixator was applied on the medial surface. **D,** At 4½ weeks postoperatively, healing of the radius has occurred, and the elbow joint is congruent with a good range of motion; the external fixator was removed at this point.

deformed articulating surfaces[8] (Figure 23-9). A caudal approach to the proximal ulna exposes the ulna and the humeroulnar joint,[5] which can be inspected for fibrous tissue invasion and osteophytes; these are removed as indicated. The osteotomy is made slightly distal to the coronoid process. In most cases the bone will spring apart after cutting, but in some cases a periosteal elevator is needed to break down the interosseous and annular ligaments. A small, smooth Steinmann pin driven normograde is used for stabilization. In immature dogs a fat graft, as described earlier, is used to prevent premature osseous bridging.

Skeletally Mature

After cessation of most long-bone growth, there is no hope of meaningful correction of carpal valgus by eliminating the bowstring effect of the short ulna, and all attention should be directed toward correcting angular and rotational deformities and in reestablishing elbow congruity. Angular and rotational deformities are eliminated by corrective radial osteotomy, as previously described. Bone plate fixation is possible only with moderate angular deformity and little or no rotational component. A closing

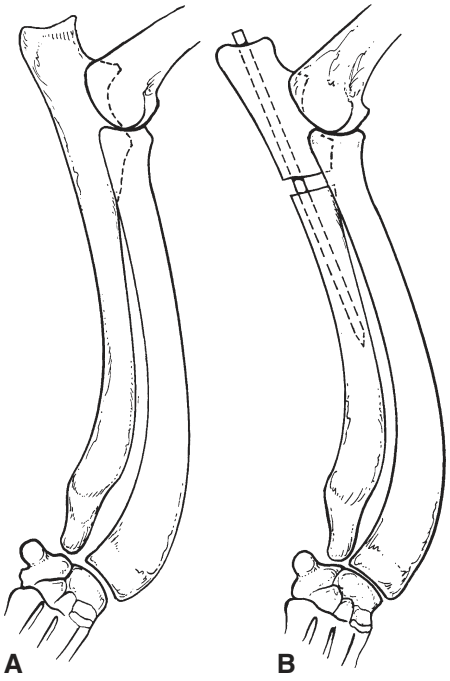


FIGURE 23-9. A, Incongruency and subluxation of the elbow joint caused by shortening of the ulna. **B,** Dynamic proximal ulnar osteotomy of the ulna just distal to the coronoid processes allows the ulna to move into physiological reduction because of muscle and weight-bearing forces. A smooth Steinmann pin or Kirschner wire is used for stabilization.

wedge osteotomy is advisable when using plate fixation, which further shortens the limb. If the elbow incongruity is minor, it will correct itself after the distal ulnar osteotomy. However, if the incongruity is marked and accompanied by pain in the elbow region, the dynamic proximal osteotomy just described will provide more rapid and complete realignment.

Distal Ulnar and Eccentric Distal Radial Closure

The primary injury in this situation most likely is distal ulnar physis closure. The bowstring effect of the short ulna can create a compression of the lateral or caudolateral region of the distal radial physis that can cause complete shutdown of the growth plate in this region and replacement by a bone bridge. As the medial side of the physis continues to grow, the valgus angulation of the distal radius continues, even after the ulna is sectioned, and probably accounts for some of the failures of ulnar ostectomy alone to correct radial deformities. If the bridging involves primarily the caudolateral aspect of the physis, increased cranial bowing accompanies the lateral deviation. Careful inspection of fine-detail screen or nonscreen radiographs is necessary to verify the bone bridge, which has the same density as surrounding bone, compared to the radiolucent active physis.

Surgical Correction

Skeletally Immature

In distal ulnar and eccentric distal radial closure, simple partial ulnar ostectomy will fail because the radial bone bridge will prevent radial correction. Ulnar ostectomy should be accompanied by resecting the bone bridge to free its restriction to radial remodeling[9] (Figure 23-10).

A skin incision is made over the craniolateral region of the radial physis, and fascia is incised to expose the epiphysis. A small-gauge hypodermic needle is used to probe for the growth plate, beginning medially and working laterally. The needle easily

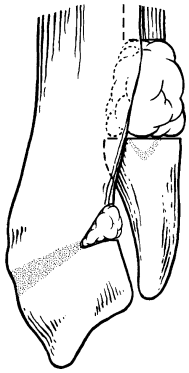


FIGURE 23-10. Premature closure of the distal ulnar growth plate accompanied by lateral closure and bone bridge of the radial growth plate (see also Figure 23-7, *A*). A partial ulnar ostectomy of the distal ulna is accompanied by resection of the lateral bone bridge in the radius. Both bone defects are packed with fat grafts to discourage bone healing.

penetrates the cartilage of the active physis and is used to locate the medial limits of the bone bridge. A curette, fine-nose rongeur, osteotome, or power saw is then used to create a generous V-shaped bone defect corresponding to the location of the original growth plate and extending medially into the active physeal cartilage. The point of the V should be in the active growth cartilage. It is important to be sure that the bone bridge is completely removed. A fat graft (see previous discussion) is collected from the gluteal region and placed into the defect, and soft tissue is sutured over it. The partial ulnar ostectomy is then completed as described earlier.

There seems to be little published regarding the outcome of this surgery. One case available for follow-up by Vandewater and Olmstead[9] returned to normal, and the author's experience has been encouraging. As with the other techniques that depend on bone remodeling, the earlier they are done, the better the prognosis.

Skeletally Mature

Correction at this age is corrective osteotomy, as described for distal ulnar physis closure.

Retained Cartilaginous Cores in Distal Ulnar Physis

This condition is seen in growing large and giant breeds of dogs and is caused by delayed endochondral ossification of a zone of distal ulnar metaphysis, resulting in cores or "candlesticks" of hypertrophied cartilage cells rather than bony trabecula[10] (Figure 23-11, *A*). This cartilage core slows distal ulnar lengthening, and the ulnar styloid is seen to not extend distally to the ulnar carpal bone. This results in some loss of lateral support for the carpus, and mild carpal valgus deformity ensues. The distal radius may also respond to the ulnar shortening by cranial bowing (Figure 23-11, *B*), although lateral deviation or elbow incongruity has not been seen.

The cause of retained cartilage cores is unknown, although some think it is a form of osteochondrosis.[11] Although the role of hypernutrition and accelerated growth remains to be proved, when presented with a 3- to 4-month-old puppy with these changes, we advise decreasing the plane of nutrition to slow growth. Corrective osteotomy is occasionally indicated in a mature dog with functional problems resulting from deformity.

Proximal or Distal Radial Physis Closure

Less common than premature closure of the distal ulnar physis is premature closure of either the proximal or the distal radial physis. Of all cases of forelimb growth



A B

FIGURE 23-11. **A,** Four-month-old female Great Dane with painful forelegs. Note the "candlestick" core of cartilage extending from the ulnar epiphysis into the metaphysis. **B,** Five-month-old male Saint Bernard with increased valgus angulation of the carpus and pain elicited on palpation of the carpus. Note the "candlestick" formation in the ulna and cranial bowing of the radius with secondary thickening of the caudal cortex (Wolff's law).

arrest, there was an 11% incidence of distal closure and a 6% incidence of proximal closure.[2] Premature closure of either physis results in shortening of the radius, although the leg may remain straight if the distal closure is symmetrical. Asymmetrical distal closure usually results in some degree of angular deformity, either varus or valgus.

Clinical and Radiographic Signs

Proximal Closure

As the ulna grows, the shortened radius is pulled distally by the radioulnar ligament, bringing about an increase in joint space between the radial head and humeral condyle[2] (Figures 23-12 and 23-13, *A*). As discrepancy of growth between the radius and ulna continues, the medial and lateral collateral ligaments of the elbow impinge the humeral condyle on the coronoid processes, with subsequent displacement and an increase of humeroulnar joint space, elongation of the articular notch, and sometimes fragmentation of either coronoid process[2,12,13] and degenerative joint disease (DJD). Shortening of the limb usually occurs.

Distal Closure

Several variables determine the types of abnormality seen.[14] Because ulnar growth usually continues, elbow malarticulation develops as described for proximal closure. With complete *symmetrical* closure, the limb usually remains straight and shortened, but carpal varus has been reported.[15] There are also changes in the antebrachiocarpal

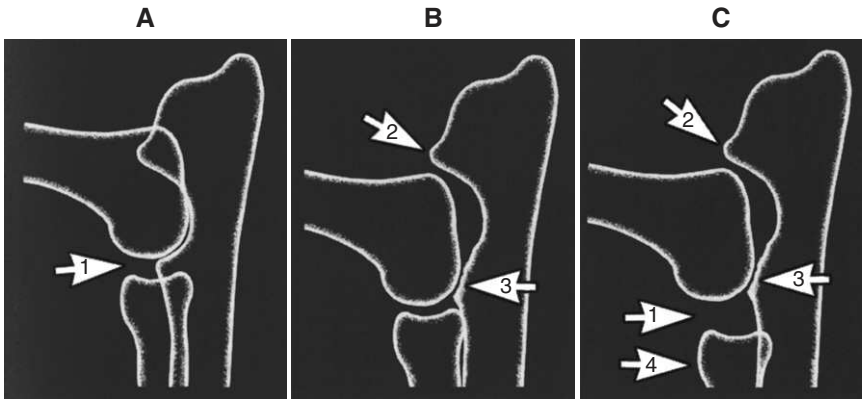


FIGURE 23-12. Common bony changes seen radiographically after premature closure of the proximal or distal radial physis. *1,* Increased space at the humeroradial joint, resulting in subluxation of the entire elbow joint. *2,* As a result of the increased distance between the anconeal process and radial head, the anconeal process appears displaced proximally. *3,* Sclerosis and remodeling of the coronoid processes, accompanied by varying degrees of degenerative joint disease. *4,* Displacement of the radial head caudally and laterally. (From O'Brien T, Morgan JP, Suter PF: *J Small Anim Pract* 12:19-35, 1971.)

joint, which may include an increase in joint space and later DJD. A caudal bowing of the radius and ulna may occur in some cases. *Asymmetrical* distal closure is more common, and *lateral* closure results in valgus deformity and external rotation (supination) of the paw similar to that seen with distal ulnar closure. Indeed, some degree of closure of the distal ulnar physis may be concurrent. *Medial* closure of the radius is less often seen and causes varus angular deformity and inward rotation (pronation) of the paw. In some cases, particularly with lateral closure, caudal closure is more pronounced than cranial, resulting in caudal angulation of the antebrachiocarpal joint.

The first clinical sign of closure is a gradual onset of lameness and pain in the elbow region. Radiographic changes are present at this time, and early surgery is indicated to check or minimize joint changes.

Surgical Correction

Skeletally Mature

The most pressing problem is restoration of congruency of the elbow joint because degenerative changes occur rapidly. A choice must be made regarding the existing radial shortening: the ulna can be shortened by partial ostectomy, or the radius can be lengthened by osteotomy to achieve contact of the radial head with the humeral condyle. The ideal choice would always be radial lengthening, but technical and economic considerations often prevent employing this method. Shortening the ulna is technically much easier, and good results can be anticipated.[15] If limb length is sufficient for reasonably good function, ulnar shortening is probably the preferred method. If distal angular and rotational deformity is present, it generally must be corrected by osteotomy. There is also the possibility with eccentric distal closure for resection of the bone bridge and achieving correction in younger animals.[14] Corrective ostectomy could be done later if the deformities persist.

Dynamic Partial Ulnar Ostectomy. For cases in which the radial shortening is minimal and the animal is nearly mature, the surgeon can remove a short section

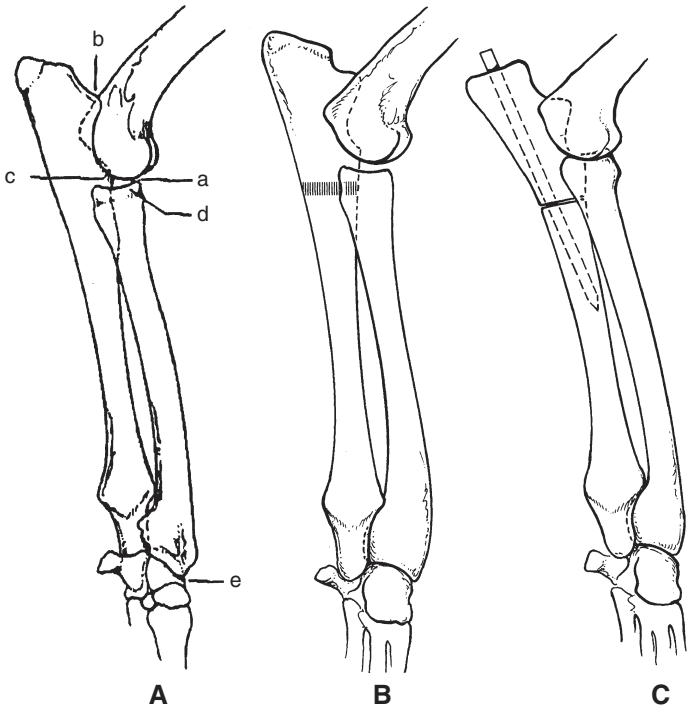


FIGURE 23-13. **A,** Bony changes characteristic of premature closure of the distal or proximal radial physis (also see Figure 23-12). With a cessation of growth of the radius, there is increased width of the humeroradial joint space *(a),* proximal displacement of the anconeal process *(b),* remodeling of the trochlear notch and coronoid process *(c),* and development of secondary degenerative joint disease. There is caudal and lateral displacement of the radial head *(d).* Angular deformity may or may not be present; however, there is usually some increase in radiocarpal joint space *(e)* and evidence of radial physis closure. **B,** If lengthening of the radius is not possible, the ulna is shortened by dynamic proximal ulnar ostectomy, removing a section of ulna *(shaded area)* slightly longer than the distance between the humeral condyle and radial head. The ostectomy is immediately distal to the coronoid processes. **C,** Shortening of the ulna caused by weight-bearing and muscular forces results in physiological reduction of the humeroradial joint. A smooth Steinmann pin or Kirschner wire is used for stabilization.

(ostectomy) of the ulna to restore congruency of the radial head with the humeral condyle[8] (Figure 23-13, *B* and *C*). The proximal ulna and elbow joint are approached from a caudal incision.[5] The ulnar segment removed should be slightly longer than the observed gap between the humeral condyle and radial head. A small Steinmann pin is used for stabilization. Muscular forces and weight bearing will cause the ulna to shorten by sliding on the smooth pin until the radial head contacts the condyle. Fragments of the lateral coronoid process can be removed from the same caudal approach to the proximal ulna, but those of the medial coronoid will probably require a separate medial approach.[5] Analgesic and antiinflammatory agents are given to encourage early postoperative weight bearing.

The advantage of this approach over a static shortening ostectomy with rigid fixation is that the radial head will find its own position relative to the humeral condyle and thus will form a more physiological joint. This procedure is often combined with a distal corrective osteotomy of the radius and ulna to correct angular and rotational defects[15] or with resection of the bone bridge of the distal physis.

Bone Bridge Resection. When the distal radial physis closure is eccentric, resection of the bone bridge can allow varying degrees of angular and rotational correction because of continuing growth of the remaining growth plate.[14,15] This is most applicable to younger patients with considerable bone growth remaining and is usually combined with partial ulnar ostectomy. The technique is explained in the previous section Distal Ulnar and Eccentric Distal Radial Closure (see Figure 23-10).

Dynamic Lengthening Osteotomy of the Radius. Progressive spreading of a radial osteotomy has the potential for elongating the radius to match the ulna and thus reduce the elbow incongruity. This process is termed *distraction osteogenesis* and creates new bone at the site where the osteotomy callus has been slowly distracted. Although the conventional external fixator applied with threaded connecting rods or the Charnley apparatus has been employed to lengthen the radius, correction of angular deformity is restricted to one plane. The advent of the Ilizarov-type circular-frame fixator and linear and hinged distraction motors (see Figure 2-35, *E*) offers the possibility of simultaneous lengthening with angular and rotational correction.[14,16,17] Such an apparatus is now commercially available for veterinary use in North America (IMEX Veterinary, Inc., Longview, Texas; Jorgensen Laboratories, Inc., Loveland, Colo) and in Europe.

The circular-frame (ring) fixator is usually assembled before it is applied. Appropriate size and number of rings are selected for the deformity present and the size of the dog. The average large-breed dog 4 to 6 months of age requires three rings of appropriate diameter with approximately 2 cm between the ring and the skin. One ring will be distal to the proposed osteotomy of the radius and two proximal. If the dog is of sufficient size, two rings should be used on either side of the osteotomy. Number of rings and ring diameter, wire diameter and tensioning, and configuration of the wires and threaded rods on the circular frame will affect the axial stiffness of the fixator construct and therefore the quality of distraction osteogenesis.[18-22]

After the surgical approach, osteotomies of the radius and ulna are performed as previously described. Angular and rotational deformities are realigned and the osteotomies reduced to the extent possible. The previously assembled circular-frame fixator is applied to the leg. Two small pins (1.0-1.6 mm) are driven through connecting bolts for each ring of the circular frame and are tensioned, to increase stiffness, to 30 to 60 kg for an average, growing, large dog.[19]

Careful examination and radiographs are used to assess surgical results. After a latency period of 2 to 4 days, distraction of the osteotomy is begun. One-millimeter daily spreading of the osteotomy divided into two to four increments is continued until the elbow is reduced. The distraction period may be as short as 10 to 14 days for a simple, small, humeroradial space or may be protracted up to 4 to 6 weeks in cases with severe deformity and shortening of the limb. Frequent radiographic evaluation is necessary to monitor the progress (Figure 23-14). After the distraction phase is complete, the fixator is left in place for another 4 to 6 weeks to allow solidification of the distracted callus. In cases of severe deformity where acute correction of angulation is difficult to achieve, an additional useful method is to add hinges and an angular distraction motor to the circular frame for a dynamic correction of the angular deformity.[20,21]

If only the proximal physis is closed, or if there is no angular deformity with distal closure, simple axial lengthening is sufficient. This can be accomplished with the Ilizarov apparatus, the Charnley apparatus (Synthes, Ltd., Paoli, Pa), or a slightly modified, conventional Kirschner-style apparatus applied in type IIA configuration. Threaded 3/16-inch (3.2-mm) rods (available at hardware outlets) are substituted for normal connecting rods. There are two methods for providing the sliding motion

necessary for distraction. In the first, conventional medium clamps are attached to the two distal fixation pins, and these are tightened to the rod in the normal manner. The proximal pin clamps are modified by drilling or filing the connecting-rod hole to 3/16-inch diameter with a fixation pin in the bolt and the nut tightened (modified clamps are available from IMEX Veterinary, Inc., Longview, Texas). This allows the clamps to slide on the threaded rod, and they are secured to the rod by a normal nut on each side of each clamp. Distraction is accomplished by loosening the nuts on the proximal side of the clamps and tightening the distal clamps. The second method is to divide the connecting rods in the middle area and connect each pair of rods by a



FIGURE 23-14. Limb lengthening with a ring (Ilizarov) fixator. The patient was a 4-month-old greyhound with a deformed left antebrachium. **A** and **B,** Premature closure of the distal radial physis and malunion of a distal radial metaphyseal fracture. Varus deviation of the distal limb and cranial bowing of the radius. The elbow joint is stable and congruent. **C** and **D,** Postoperatively, after transverse radial osteotomy and segmental ulnar ostectomy. The angular deformity and cranial bowing have been corrected with the ring fixator. Distraction was started 10 days later at the rate of 0.25 mm four times daily. E and F, At 20 days postoperatively, and after 10 days of distraction, new bone formation is evident in the osteotomy gap. The elbow joint has become incongruent.

Continued



FIGURE 23-14. *Continued* **G** and **H,** Approximately 5 cm of lengthening has occurred at 8 weeks postoperatively. Regenerate new bone appears as axially oriented striations, and the elbow has realigned. **I** and **J,** Distraction has been discontinued at 4 months postoperatively, and approximately 8 cm of length has been gained. The fixator was left in place an additional 6 weeks to allow maturation of new bone formation. **K** and **L,** Eleven months postoperatively and 5½ months after removal of the fixator. The limb is 5 mm longer than the opposite, and function is normal. There is good axial alignment, and the elbow appears normal. The quality of the regenerate bone is excellent. (Photos and case material courtesy Dr. Erick Egger.)

threaded turnbuckle. Rotation of the turnbuckle causes the rod to lengthen. The distraction procedure is managed as previously described.

Static Lengthening Osteotomy of the Radius. Bone lengthening with plate fixation or conventional external fixators is also possible. For animals older than 5 to 6 months of age, one lengthening will usually be sufficient. For those under this age, the procedure may need to be repeated in 6 to 8 weeks to restore length and congruency. If the closure is accompanied by angular deformity, corrective osteotomy for this defect may be delayed until the lengthening osteotomy is almost healed.

Figure 23-15 shows premature closure of the distal growth plate of the radius, with shortening and early secondary incongruency of the articular surfaces in the

elbow joint in a 4-month-old large-breed dog. The animal had started to favor the leg 2 weeks before presentation. The leg appeared to be straight from both lateral and cranial views. The objective was to restore approximately normal length to the radius and thus restore congruency to the articular surfaces of the elbow joint. Because the animal had approximately 4 months of growth left, the surgical procedure was expected to be repeated to maintain a good elbow joint.

A transverse midshaft osteotomy of the radius was performed (Figure 23-15, *B*). The bone segments were wedged apart 15 mm with a bone spreader, and a semitubular plate was inserted for fixation. Congruency of the elbow joint was restored. At the 3-month reexamination, the osteotomy area was filled with bone. Shortening of the radius and incongruency of the elbow were again evident. Lameness returned about 3 weeks before this reexamination. Discrepancy between the coronoid process of the ulna and the articular surface of the radius was evident (Figure 23-15, *C*). The bone plate was removed, and the radius was again osteotomized and lengthened by 10 mm. A semitubular plate was applied for fixation (Figure 23-15, *D*). At the 2-month follow-up, the leg was straight, the elbow joint range of motion appeared

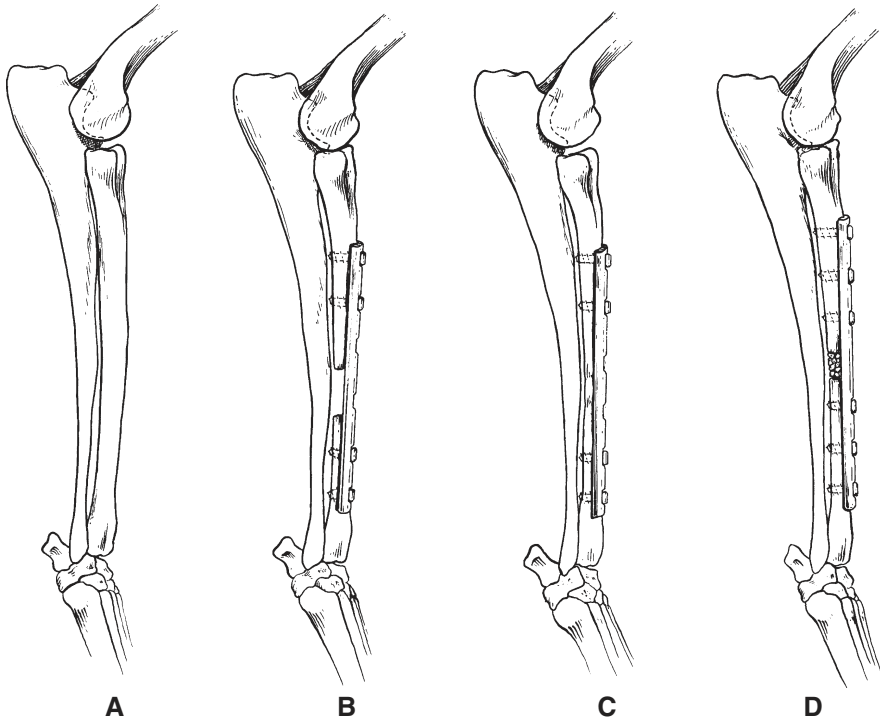


FIGURE 23-15. **A,** Premature closure of the distal physis of the radius with shortening and early secondary incongruency of the articular surfaces in the elbow joint in a 4-month-old dog. **B,** Transverse midshaft osteotomy of radius was performed. Bone segments were wedged apart 15 mm, and a semitubular plate was inserted for fixation. Congruency of elbow joint was restored. **C,** At the 3-month follow-up, osteotomy area is filled with bone. There is evidence of shortening of the radius and incongruency of the elbow; lameness has returned. Note the discrepancy between the coronoid process of the ulna and the articular surface of the radius. **D,** The bone plate was removed, the radius again osteotomized and lengthened 10 mm, and another semitubular plate applied for fixation. The osteotomy area deficit was filled with autogenous cancellous bone.

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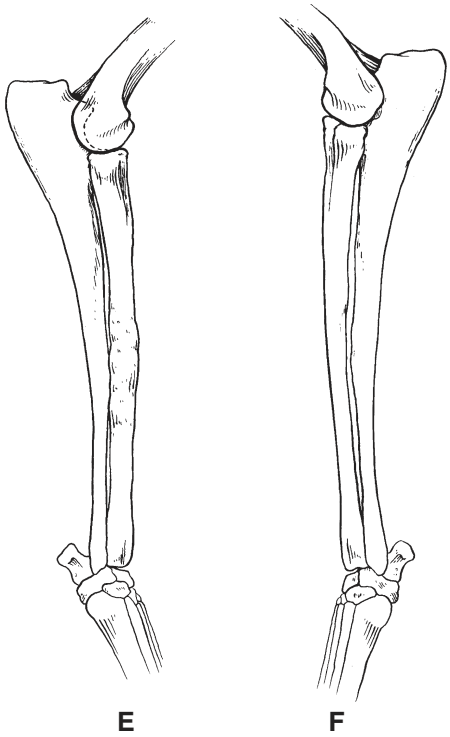


FIGURE 23-15. *Continued* **E,** At the 2-month follow-up, the leg is straight, the elbow joint's range of motion appears normal; overall length compared with the opposite leg is 16 mm shorter, although this is not evident when the animal moves or stands. The plate was removed. **F,** Normal opposite leg.

normal, and function was good (Figure 23-15, *E*). The overall length compared with the opposite leg was 16 mm shorter; however, this was not evident on standing or moving (Figure 23-15, *F*).

Figure 23-16 illustrates partial or complete premature closure of the distal and proximal radial physes in the same limb. For this condition, the objectives of corrective osteotomy were to restore congruency of the elbow joint and realign the foot. Because the leg was already shorter than the opposite leg, a lengthening procedure was planned. The 6½-month-old Doberman had sustained a foreleg injury approximately 8 weeks before being treated. Lameness was intermittent at first but became continuous and progressive during the 3 weeks before surgery. Radiographs revealed premature closure of the proximal radial physis, shortening of the radius, and incongruency of the elbow joint (Figure 23-16, *A* and *B*). There was also evidence of damage to the distal radial physis with altered growth, resulting in some valgus deformity and outward rotation of the foot, which was becoming more pronounced. The first objective was to restore radial length and elbow congruency; the second objective was to correct the angular deformity and external rotation of the foot at a later date.

A transverse osteotomy was performed, and the segments were wedged apart by 11 mm using a bone spreader; this restored length to the radius and congruency to the articulating surfaces of the elbow joint. A semitubular plate (buttress plate) was applied for fixation (Figure 23-16, *C*). In 1 month, healing at the osteotomy site was well under way, and the elbow appeared stable. Leg function had greatly improved. At this time, the ulna and radius were again osteotomized, angulation and rotation were corrected, and an external fixator was applied for fixation (Figure 23-16, *D* and *E*).

In 7 weeks the osteotomy sites were well healed; the bone plate and external fixator were removed (Figure 23-16, *F*). When the animal was rechecked at 1 year of age, good functional use of the leg was evident (Figure 23-16, *G* and *H*). The leg appeared straight from both lateral and cranial views. There was a 10-degree loss of flexion at the elbow joint; however, it was not discernible at the walk or running. The affected radius was slightly shorter than the opposite normal radius. The animal adjusted by slightly increasing extension at the shoulder and elbow joints; this was not evident on standing or moving.

Skeletally Mature

The objectives of treatment of mature animals are identical to those previously detailed for immature animals, and the same procedures are applicable, with the exception of resection of physeal bone bridges. The elbow joint may need to be explored to resect fibrous tissue and osteophytes and to remodel bone deformity.[14] Partial ulnar ostectomy alone or combined with distal corrective osteotomy for

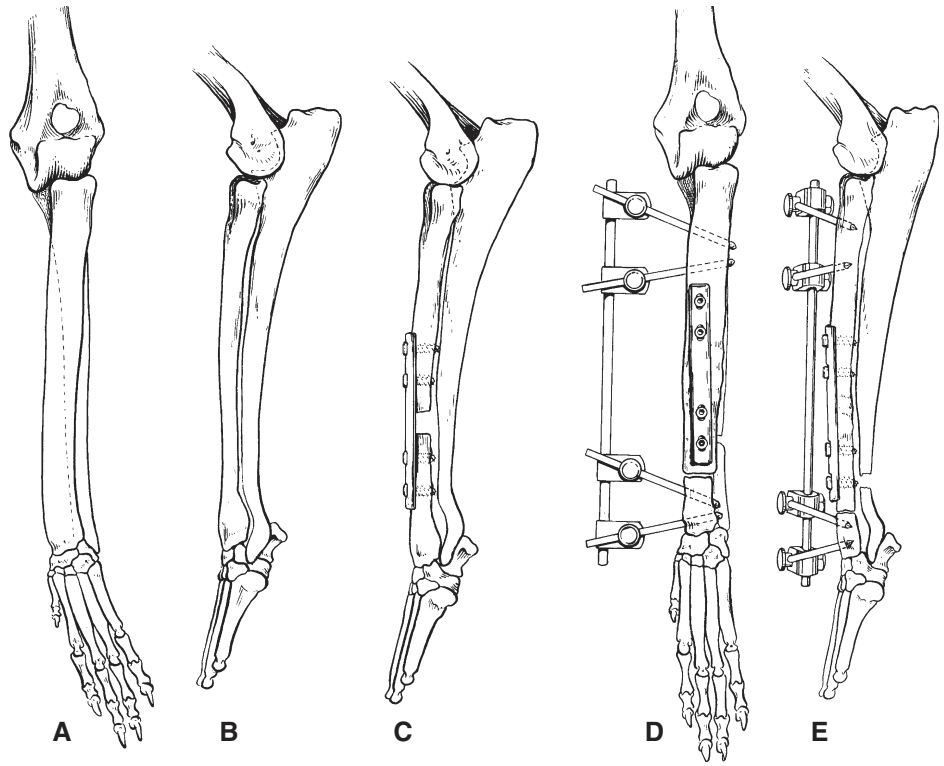


FIGURE 23-16. Growth plate injury with closure of the proximal radial physis and partial closure of the distal radial physis. **A** and **B,** Eight-week-old foreleg injury in a 6½-month-old Doberman with progressive lameness, shortening of the radius, and incongruency of the elbow joint. Damage to the distal radial physis with partial closure resulted in some progressive valgus deformity and outward rotation of the foot. **C,** Lateral view after transverse osteotomy. The segments were slowly wedged apart 11 mm by exerting constant pressure with a bone spreader, restoring length to the radius and congruency to the elbow joint. A semitubular buttress plate was applied. In 1 month, healing at the osteotomy site was nearly complete, the elbow joint appeared congruent, and leg function had greatly improved. **D** and **E,** The ulna and radius were osteotomized, derotation and straightening of the foot were carried out, and an external fixator was applied to the medial surface of the radius.

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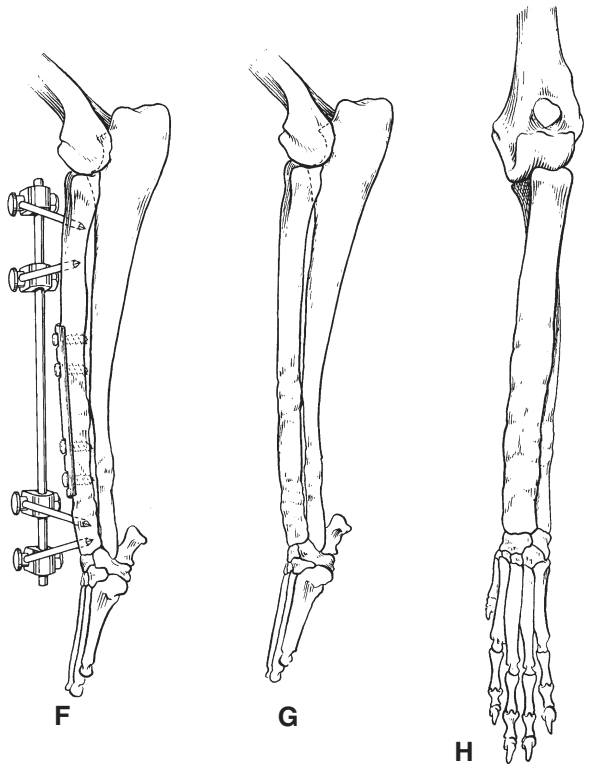


FIGURE 23-16. *Continued* **F,** After 7 weeks, both osteotomy sites were well healed, and the plate and external fixator were removed. **G** and **H,** At 1 year the leg was straight when viewed laterally and cranially. There was a 10-degree loss of flexion at the elbow joint, the elbow joint appeared congruent, the affected leg was slightly shorter than the opposite normal leg, and function was good.

angular and rotational deformity are the most common procedures. Static lengthening of the radius by stair-step osteotomy is simpler than in the growing animal because only one procedure is needed. Because of the degenerative changes present due to elbow incongruity, the prognosis for function is not as good as in animals treated early in life.

Distal Tibial Deformity

Deformity as a result of disturbed growth of tibial physes is very rare. Trauma involving the proximal tibia totaled 3.7% of 135 cases and the distal physis 3% in one report; none of these developed any deformity.[23] As in the radius/ulna, however, premature closure of the distal fibula is possible in a two-bone system, with resulting valgus deformity of the tibia, as reported in at least one case.[24] Premature closure of the medial side of the distal tibial growth plate without traumatic injury may be an inherited condition in the dachshund, termed "pes varus" by Johnson and coworkers.[25] Lameness of the affected limbs before skeletal maturity was seen in both types of cases.

Surgical Correction

Valgus Deformity

Either an opening wedge or closing wedge[24] osteotomy can be performed according to the principles described earlier. A closing wedge method is illustrated in Figure 23-17.

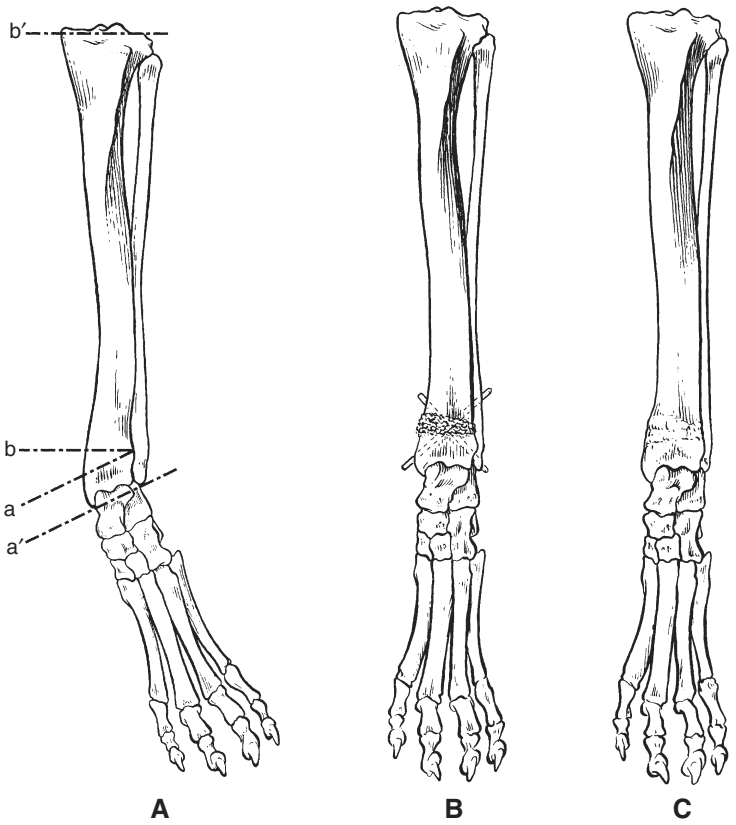


FIGURE 23-17. Cuneiform closing wedge osteotomy used for correction of an angular deformity caused by partial premature closure of the distal tibial physis. **A,** Preoperative craniocaudal view. To plan the size of wedge to remove, a paper tracing is made from the radiogram. *Line a* is drawn parallel to the distal joint surface, *line a′*, and intersects the medial cortex at the apex of the curvature. *Line b* is parallel to the proximal joint surface, *line b′*, and connects to *line a* at the lateral cortex. Because angular deformities and rotation encompass more than one plane, final adjustments will need to be made before application of fixation. **B,** Because the distal segment was relatively short, cross pins were used for fixation at the osteotomy site. The removed wedge of bone was cut into small pieces and laid in the area as a bone graft. The fixation was further stabilized with a coaptation splint. **C,** Clinical union was present at 7 weeks, and the splint and pins were removed.

In addition to the fixation shown in Figure 23-17, *C,* an external fixator similar to that described next for varus deformity could be employed (see Figure 23-18). Bone plate fixation may be applicable if the osteotomy can be made proximally enough to allow at least two plate screws in the distal fragment.[24] The veterinary cuttable plate (VCP) (Synthes, Ltd., Paoli, Pa) is helpful in this situation if 2.7-mm screws are suitable for the size of animal (see Figure 2-75).

Varus Deformity

Opening wedge osteotomy and type II external fixators were used in a series of five cases for correction of pes varus in dachshunds (Figure 23-18).[25] As these authors note, the proximal and distal tibial articular surfaces are usually not parallel in the dachshund, so careful study of craniocaudal radiographs of the normal tibia is necessary to determine the angular correction needed. The method of application of the

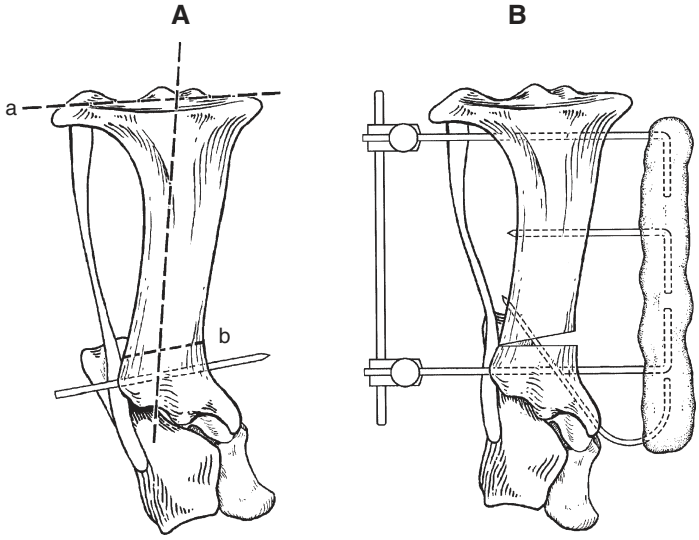


FIGURE 23-18. Opening wedge osteotomy for pes varus in the dachshund. **A,** Preoperative planning is complicated by the fact that the plane of the proximal joint, *line a,* is not perpendicular to the sagittal plane of the tibia. Radiographs of the normal limb are essential to understanding the correction needed. The planned osteotomy, *line b,* is parallel to the distal joint surface at the point of maximum curvature of the tibia. The distal full fixation pin is parallel to *line b* and is placed before the osteotomy is completed. **B,** The proximal fixation pin is placed perpendicular to the sagittal plane of the tibia. The wedge is opened by lateral angulation of the distal segment until the full pins are parallel to each other, at which point the lateral connecting bar is attached and clamps tightened. A 0.062-inch (1.5-mm) Kirschner wire is driven through the medial malleolus and across the osteotomy into the medial cortex, and a second pin is placed in the proximal segment. A molded acrylic connecting bar simplifies connecting the fixation pins medially. (From Johnson SG, Hulse DA, Vangundy TE, Green RW: *Vet Surg* 18:373-379, 1989.)

external fixator illustrated here allowed the osteotomy to be made very distally, at the point of maximum curvature. Because the fixation pin in the medial malleolus was only 0.062 inch, methyl methacrylate acrylic bars were used instead of conventional clamps.

MALUNION

Malunion may be described as a fracture healed or healing in malalignment. Function of the part is disturbed to a variable degree depending on the type of deformity induced. Minor degrees of malalignment are well tolerated by animals, for which the veterinary orthopedist should be grateful. When function is interrupted, however, corrective surgery is advisable.

Malunion can be caused by lack of fracture treatment or inappropriate treatment. Recognition of a developing malunion during fracture healing, while the callus is still plastic, provides an opportunity for treatment by augmenting the fixation after closed reduction of the deformity. Closed application of external skeletal fixation works well in most diaphyseal fractures. Kaderly[26] has proposed the following classification:

1. *Overriding:* long diaphyseal fragments pulled past each other by muscular forces but still axially aligned.
2. *Angular:* diaphyseal fragments in end-to-end contact with axial angular deformity.

3. *Rotational:* diaphyseal fragments in end-to-end contact with torsional deformity.
4. *Intraarticular:* malalignment of articular surfaces.

Most clinical cases exhibit a mixture of these types. A secondary effect of most malunions is that joints may become malaligned and subsequently undergo DJD. Ligamentous tissues are abnormally stressed, and joint instability can follow. Soft tissues adjacent to involved bones may become impinged by the bone. Valgus and external rotation seem to be more poorly tolerated by the limb than do their opposites. Bowing in the craniocaudal direction causes limb shortening, but this is relatively well tolerated because joint surfaces remain parallel to each other and to the ground plane.

Surgical correction by osteotomy is the preferred method of treatment when the malunion is well healed and is producing significant functional, as opposed to cosmetic, problems. Consideration must be given to the extent of the soft tissue shortening when the angular deformity is severe. It may not be possible to achieve significant straightening of the limb in a single procedure without endangering soft tissue vascularity. This situation requires either multiple procedures or gradual lengthening, such as previously described for correction of bone growth abnormalities. The choice of an appropriate osteotomy technique will depend on the type and location of deformity and the age of the patient. Adequate internal fixation is imperative for uninterrupted healing and generally is identical to that required for a type A fracture of the bone, as described in previous chapters. It would be tragic to convert a malunion into a nonunion because of poor choice of fixation.

Clinical Considerations in Common Malunions

Femur

Malunion of the femoral shaft can be disastrous because of the complexity of the resulting changes. The proximal femur and neck undergo anteversion and valgus angulation, especially in immature animals. Both changes destabilize the hip joint and lead to dysplasia-like changes. Proximal femoral intertrochanteric varus and derotational osteotomy may be needed to correct the hip changes. Severe degenerative changes in the hip probably warrant total hip replacement or excision arthroplasty.

Torsional and angular changes in the shaft also can predispose to patellar luxation, usually lateral. Conventional patellar stabilization techniques may suffice if the structural changes are minor, but diaphyseal osteotomy may be necessary in more severe cases. Closing wedge techniques are usually preferred because of their inherent stability and because loss of length is rarely a problem.

Marked overriding of fragments results in severe shortening of the quadriceps and hamstring muscles. Lengthening osteotomies may be difficult to perform as a result of these soft tissue changes. Sciatic nerve entrapment and hyperextension of the stifle are potential problems associated with femoral malunions and must be dealt with appropriately.

Other Long Bones

Malunion of the tibia and radius/ulna typically result in tarsal/carpal valgus and external rotation. Treatment of humeral malunion, as with fractures of this bone, requires identification and protection of the radial nerve.

Pelvis

Pelvic malunion may affect the rectum and the hip joint. Chronic constipation results from narrowing of the pelvic canal. Treatment is pubic osteotomy, followed

by spreading to enlarge the canal (see Chapter 15) or by triple pelvic osteotomy (see Chapter 16). Malarticulation of the hip joint caused by pelvic fracture can result in severe DJD. If treated early, triple pelvic osteotomy may stabilize the joint. After severe DJD is present, only excision arthroplasty or total hip replacement offers relief.

Mandible

Mandibular malunions may result in poor mastication and wear of the teeth. They are usually handled better by extraction of the involved teeth than by osteotomy of the mandible.

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24

Disease Conditions in Small Animals

PANOSTEITIS

Panosteitis is a common condition of the long bones in large breeds of young dogs, especially the German shepherd and basset hound. The condition is also called eosinophilic panosteitis, osteomyelitis, enostosis, fibrous osteodystrophy, juvenile osteomyelitis,[1] and "eo pan" or "long-bone disease" by breeders.

Although this disease causes severe lameness, it is self-limiting, and there is no permanent impairment. Therefore, intensive investigations of the various stages of this disease have been lacking. Many contradictions exist as to its clinical features.

The etiology of panosteitis is unknown, although infection, metabolic disease, endocrine dysfunction, allergy, autoimmune mechanisms, parasitism, and hereditary factors have been postulated.[1] Viral infection appears the most probable cause of panosteitis.[2] In their review of this condition, Muir and colleagues[3] reported no new information as to its cause.[3]

Clinical Signs

The clinical picture is that of a healthy dog with lameness of acute onset but no history of trauma. Males are affected four times more often than females.[4] The lameness may be marked, and often the dog will "carry" or favor the limb. This lameness may last a few days to several weeks.[4] In about 53% of cases, other limbs have become involved, thereby characterizing the condition as causing a "shifting leg lameness."[5] These recurring bouts usually subside by the time the animal reaches 2 years of age.[1] However, dogs up to 5 years of age have developed panosteitis.[5,6]

Examination

Gentle palpation along the distal, middle, and proximal areas of long bones may elicit exquisite pain when the involved area is reached, even in stoic animals. This reaction may consist of crying out, wincing, pulling the leg away, or occasionally, snapping at the examiner. When palpating, the clinician's fingers should push aside muscle bundles (especially of the humerus and femur) so that bone is reached before squeezing. This avoids misinterpretation resulting from hurting normal muscle tissue trapped in the palpation.

Depending on when thorough veterinary attention is sought and how elaborate the workup, other factors may be present, such as fever,[1,4] muscle atrophy,[4] eosinophilia,[1,4] decreased activity, and inappetence. Others have disclaimed the occurrence of fever, muscle atrophy,[6] and eosinophilia.[6] Eosinophilia has been reported to be seen only in the first 2 days of clinical signs.[1]

Radiographic Signs

Radiographically, panosteitis may be separated into three stages.[6] Often the clinician sees the case in the middle phase and learns about the other stages only during extensive studies of this condition.

Early Phase

Although the limb may be asymptomatic, radiographic changes may be detected during a survey of all the long bones. These consist of blurring and accentuation of trabecular patterns, best seen at the proximal and distal ends of the diaphysis (Figure 24-1). The contrast between the cortex and medullary canals is diminished. In some cases, a few granular densities are seen.

Middle Phase

Patchy, mottled, sclerotic-looking densities appear, especially around the nutrient foramen in the early stages (Figure 24-2). In some cases the entire diaphysis is involved; in others there may be only pea-sized lesions (Figure 24-3). In a third of panosteitis cases, the periosteum becomes involved. Initially, a subtle roughening appears that becomes more dense within 1 or 2 weeks and eventually becomes as dense as the cortex (see Figures 24-2 and 24-3).



FIGURE 24-1. Early stage of eosinophilic panosteitis in the humerus of a 9-month-old male German shepherd. Granular densities are seen.

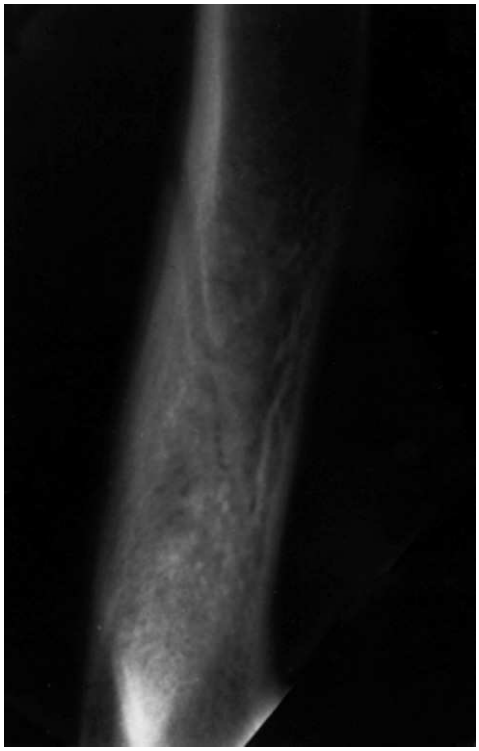


FIGURE 24-2. Middle stage of eosinophilic panosteitis, with increased densities around the nutrient foramen in a 6-month-old male Great Pyrenees. Note the periosteal thickening caudal to the foramen.



FIGURE 24-3. Middle stage of eosinophilic panosteitis showing a small sclerotic area in the distal humerus of a 6-month-old German shepherd. Note the thickened caudal cortex adjacent to the sclerotic patch.

Late Phase

In the process of recovery, the medullary canal attains normal density while the coarse trabecular pattern remains. In about a third of cases, the cortex remains thicker than normal. A few granular densities may be present. It may require several months for these changes to disappear completely. In general, the lesions affect the central part of the radius, the proximal third of the ulna, the distal and central parts of the humerus, the proximal third of the tibia, and the central and proximal parts of the femur.

Histopathology

Histopathological findings[6] of the lesions consist of accentuation of osteoblastic and fibroblastic activity in the periosteum, endosteum, and marrow. Fibrosis occurs in the marrow. There is no evidence of either acute or chronic inflammation or malignancy. In highly mature lesions, the cortical thickening consists of thickened lamellar bone with haversian systems, whereas in immature lesions, cellular fiber bone is present with many osteoblasts and osteoclasts.

Differential Diagnosis

Differential diagnosis includes osteochondritis dissecans (OCD), fragmented coronoid process, ununited anconeal process, hip dysplasia, cruciate disease, coxofemoral luxation, and fractures. When there is a shifting leg lameness, other conditions, such as rheumatoid arthritis, systemic lupus erythematosus (SLE), and bacterial endocarditis, must be considered. The diagnosis of panosteitis is determined by palpation and radiography.

Treatment

Treatment is symptomatic to relieve pain by using aspirin, corticosteroids, and other agents. None of these has been documented to hasten the resolution of panosteitis.[1,3]

NUTRITIONAL DISORDERS

Although nutritional problems affecting bone and muscle are beyond the scope of this text,[1,7-11] this section discusses some clinical situations that may confront the orthopedist.

Clinical Problems

We see three main clinical problems in our practice: obesity, consequences of the all-meat diet, and oversupplementation in large and giant breeds of dogs.

Obesity

Although obesity has not been proved to cause osteoarthritis, at least in mice,[12] common sense tells us that excessive weight on injured or congenitally deformed joints or spinal conditions can affect musculoskeletal performance. Prevention of obesity is accomplished more readily than treatment. Interesting clinical studies in people have shown that obesity precedes and increases the risk of osteoarthrosis of the knee (especially in women)[13,14] and probably results from mechanical stresses.[15] In addition, other studies suggest that weight loss can both prevent the onset of

symptomatic osteoarthrosis of the knee[16,17] and alleviate pain when present.[16] If the veterinary clinician observes patients gaining weight, or if an animal has a potential for arthritis or back problems or becomes neutered, the client should be warned to watch the animal's weight carefully and to cut back food intake before weight gain becomes unmanageable. In known periods of inactivity (e.g., winter months, cessation of hunting season), food intake should be diminished.

If an animal is obese, the endocrine system, especially the thyroid, should be examined. For a "diet," we usually recommend cutting the total daily caloric intake by one third to half to reduce the animal's weight. Canine vitamin supplementation may be administered to alleviate the owner's apprehension concerning dietary restriction. Often, if the owner is sincere and conscientious, decreasing the current amount of food by one third to half is all that is necessary. Owners (even those who are overweight themselves) seem to understand and accept that "the more weight your pet carries, the more it abuses its bad joint, which could hasten joint destruction, requiring surgery or leading to a painful life." When this does not seem to be effective, prescribed weight reduction diets may be tried. Our usual goal is to achieve a conformation in which there is an observable indentation or "waist" along the flank region and the presence of individually palpable ribs. Some clients may need to be told, "Your dog needs to lose 4 pounds," instead of these guidelines. For a lighter-weight breed, the owner may monitor progress using a bathroom scale at home.

The All-Meat Diet

Publicity concerning all-meat diets has been widespread enough that the syndrome is rarely seen today. Low in calcium and high in phosphorus, this diet has the tendency to cause *secondary nutritional hyperparathyroidism* (SNH), a condition in which the parathyroid glands are stimulated to secrete parathormone. This hormone increases the resorption of calcium from bone to maintain proper serum levels. In the young animal the result may be loss of skeletal density and thinning of the bone cortex. Lameness or pathological fracture may result (Figure 24-4). In an adult animal that is fed an all-meat diet, the process is slow and can result in osteopenia. Treatment involves feeding the animal a balanced commercial diet, as well as supplementation with calcium.

Hypernutrition and Oversupplementation

The most perplexing nutritional problem facing the orthopedist is presented when a breeder asks the veterinary clinician to test serum calcium and phosphorus levels in a young dog of large or giant breed that has poor bony conformation. Although it may appear that improper nutrition is the cause, this may or may not be the answer. A few points are worth emphasizing in this regard. In giant breeds the phosphorus may be twice as high in the dog 3 to 6 months old as in the adult (8.7 mg/100 ml vs. 4.2 mg/100 ml). The calcium may be slightly higher in a younger animal (11.1 mg/100 ml vs. 9.9 mg/100 ml for an adult).[7] In those dogs with known dietary excesses or imbalances of calcium and phosphorus, the serum calcium and phosphorus levels usually are in the normal range as a result of the dog's homeostatic mechanisms, if the parathyroid gland is working properly. More sensitive indicators of dietary imbalance are the quantities of calcium and phosphorus excreted in the urine over 24 hours and the creatinine clearance ratios.

Most commercial dry dog foods contain the proper quantities of and balance between calcium and phosphorus. People owning large breeds believe that this commercial diet may be good for the normal "run-of-the-mill" dog, but not for their dog, which is going to be large. Often the owner feeds a mixture of foods suggested



FIGURE 24-4. Five-month-old male Gordon setter with pathological fracture of the tibia from secondary nutritional hyperparathyroidism. Note the thin cortices of the femur. This dog was fed a balanced home diet by a breeder using eggshells (which are not absorbed in the canine intestine) for the calcium source.

by the breeder, for whom the diet produced champions. These mixtures include vitamins, dicalcium phosphate, bone meal, high-protein cereals, meat, milk, cottage cheese, eggs, wheat germ, and other nutrients. This highly palatable diet may lead to an ingestion of excessive quantities of nutrients, which can lead to a nutritional imbalance. Young Great Danes fed a balanced diet ad libitum (as desired) had accelerated bone growth, sinking of the metacarpophalangeal joints, lateral deviation of the forepaws (valgus deformity of the carpus), cow-hocked rear limbs, enlargement of the distal radial and ulnar metaphyses, enlargements of the costochondral junctions, pain, arched backs, and inactivity. Those dogs fed two thirds of the quantity of protein and calories of the other group had slower bone growth and better conformation, and they were more active and playful.[9] It is therefore wise for the veterinarian to discuss diet with the owners of these large breeds. The importance of slow bone growth should be stressed, and the owners should be warned not to push their dogs nutritionally.

Signs of overnutrition may be mistaken for "rickets" and therefore improper acceleration of the plane of nutrition prescribed. Rickets is extremely rare and has been seen usually only under starvation or research conditions.

The valgus deformity of the carpus may correct itself when the diet is changed while the dog is still growing. Severe deformities, however, may require corrective osteotomy after skeletal maturity is complete.

RETAINED CARTILAGINOUS CORES

Retained cartilaginous cores (RCCs) or retained hypertrophied endochondral cartilage in the ulnar metaphysis may give an outward appearance of valgus deformity of the carpus (abduction of the foot).



FIGURE 24-5. Four-month-old female Great Dane with painful forelegs. Note the "candlestick" core extending from the ulnar epiphysis into the metaphysis.

These cores may extend 3 to 4 cm into the metaphysis of the ulna and on radiographs appear similar to "candlesticks" (Figure 24-5). The cores are composed of hypertrophied hyaline cartilage cells rather than bony trabeculae.[18] This cartilage core retards the overall length of the ulna. The styloid process does not extend to the ulnar carpal bone. Therefore the lateral support of the carpus is lost, and the foot abducts. Because the ulna is shortened, the normal sliding of the radius on the ulna during growth is altered, and the distal radius is then bent caudally, resulting in cranial bowing of the radius (Figure 24-6).

The cause of RCCs is unknown. Whether this condition is a form of osteochondrosis[12] or whether hypernutrition or accelerated body growth plays a role remains to be proved. When these changes are seen in the puppy, it may be advisable to decrease the plane of nutrition if it is on the high side. If the dog is mature and the deformity is severe, corrective osteotomy may be indicated.

HYPERTROPHIC OSTEODYSTROPHY

Hypertrophic osteodystrophy (HO), also called vitamin C deficiency, metaphyseal osteodystrophy, or scurvy,[19] is a syndrome seen in young dogs of medium-sized and giant breeds (Great Danes, Irish setters, boxers, Labrador retrievers). The condition is characterized by grossly observable swellings of the distal metaphyses of the radius, ulna, and tibia. This disorder has been misinterpreted by some clinicians as "joint swellings." The etiology is unknown.

Clinical Signs

Often the dog with HO appears to show systemic involvement, with pyrexia, anorexia, pain, arched back, and reluctance to move,[1] and has a history of diarrhea



FIGURE 24-6. Five-month-old Saint Bernard with increased valgus angulation of the carpus and pain elicited on its palpation. Note the "candlestick" formation of the ulna and cranial bowing of the radius with secondary thickening of the caudal cortex (Wolff's law).

the preceding week.[19] Cranial bowing of the forelegs and a valgus deformity of the carpus may occur.[5] The acute phase may last 7 to 10 days[1]; however, recurrences have been seen.[19]

Radiographic Signs

Radiographically, the initial finding in HO is a thin, radiolucent line in the metaphysis parallel to the epiphyseal plate, especially of the radius. Secondarily, there is an extraperiosteal cuff of calcification along the metaphysis (Figure 24-7). The lucent line disappears and is replaced by an increased radiodensity. If relapses occur, a new radiolucent line appears between the physis and the radiodense region.[20] As the dog matures, these extraperiosteal thickenings often regress (Figures 24-8 and 24-9) but may leave a permanently thickened metaphysis.[21]

Pathogenesis

The scurvy theory arises from the radiographic similarity to scorbutic changes seen in children.[1] Whether HO and scurvy are the same disease, or whether vitamin C deficiency is involved at all, remains to be proved.[19] The mean value of serum ascorbic acid in 18 dogs with HO was only slightly below the mean of serum ascorbic acid in 28 normal, young, large breeds of dogs.[19] Because serum ascorbic acid levels vary with exercise, food intake, and stress, these values may be meaningless because dogs with HO are under stress and anorexic. Circumstantial evidence suggests that the canine distemper virus may be involved with HO, especially after vaccination. Virus has been detected in bones of some dogs with HO.[22]

Treatment

This disease appears to improve with whatever treatment is undertaken. In one study, 24 dogs with HO were managed by one of these methods: no treatment;



FIGURE 24-7. Six-month-old male Great Dane with extraperiosteal proliferation and calcification of the distal radius and ulna.



FIGURE 24-8. Same dog as shown in Figure 24-7, now 9 months old.



FIGURE 24-9. Gross specimen of the ulna shown in Figure 24-8.

antibiotics; antibiotics and corticosteroids; or antibiotics, corticosteroids, and vitamin C. There was no statistical difference in the rates of recoveries among these treatments.[19] Most dogs recovered from systemic signs in 7 to 10 days,[1,19] whereas bony changes have required several months for resorption.[21] In severe cases, if bacteremia has been verified by blood cultures, broad-spectrum antibiotics are indicated.[20] Death has been reported in some cases.[19] Generally, analgesics and antidiarrheal medications are indicated.

RENAL OSTEODYSTROPHY

Although renal osteodystrophy, or "renal rickets," is infrequently seen by the orthopedist, it can occasionally produce pathological fractures or present the appearance of generalized skeletal demineralization on radiography. With renal disease, phosphorus is retained, which causes secondary hyperparathyroidism similar to that caused by nutritional imbalances or excesses of phosphorus.

When an adult dog spontaneously fractures a leg or jaw or experiences minimal trauma, such as falling down two stairs, particular attention should be paid to the density of the bone on the radiograph. It is only with chronic severe kidney disease that the bone will show obvious demineralization, and usually the client would have sought veterinary attention because of the problems related to uremia.

HYPERTROPHIC PULMONARY OSTEOPATHY

Hypertrophic pulmonary osteopathy (HPO) has been known as hypertrophic pulmonary osteoarthropathy (HPOA)[23] and hypertrophic osteoarthropathy (HOA).[24]

HPOA is a misnomer because the joints are not really involved, and some prefer HOA because the lung occasionally is not involved.[24]

Clinical Signs

This syndrome is characterized by lameness, reluctance to move, and firm swellings of the distal limbs. The lungs usually are involved. In a study of 60 cases, 30% showed thoracic disease signs before musculoskeletal signs.[24] Lung disease was eventually seen in 95% of the cases. The cause of the thoracic disease was cancer in 91%. *Spirocerca lupi* infestation of the esophagus and dirofilariasis can also cause HPO.

Radiographic Signs

The classic radiographic signs of HPO consist of extensive, rough periosteal formation beginning in the distal phalanges, metacarpal bones, and metatarsal bones (Figure 24-10). Other bones may become involved (Figure 24-11). In peracute cases with swollen limbs, the radiographs may not show the extensive periosteal changes, but such changes will be apparent within a few days.

Pathogenesis

The pathogenesis of these periosteal changes is speculative. Some theories include chronic anoxia, obscure toxins,[1] and autonomic neural vascular reflex mechanisms mediated by afferent branches of the vagus or intercostal nerves.[2,25] When HPO is diagnosed, a thorough diagnostic workup, especially of the thorax, is indicated. The probability of finding a nonlethal cause is low. Lung lobectomy may allow regression



FIGURE 24-10. Phalanges, metacarpus, radius, and ulna affected with hypertrophic pulmonary osteopathy in a 5-year-old female collie mix with metastatic carcinoma to the lungs from the ovaries or uterus.



FIGURE 24-11. Gross appearance of an 8-year-old German shepherd with hypertrophic pulmonary osteopathy affecting the vertebrae, pelvis, long bones, and metacarpal and phalangeal bones.

of bony lesions until death occurs or until additional lung cancer intercedes.[2,24,26] Bony changes may take 3 to 4 months to regress after lobectomy.[26] With possible nonlethal causes (i.e., *S. lupi* infestation, dirofilariasis), removal of the inciting cause may or may not bring about regression of HPO signs.[23,24]

CRANIOMANDIBULAR OSTEOPATHY

An uncommon proliferative bone disease, craniomandibular osteopathy (CMO), commonly called "lion jaw," usually involves the mandibular rami and the tympanic bullae in Scottish, cairn, and West Highland white terriers.[27] Other breeds that occasionally experience this condition include the Boston terrier, Labrador retriever, Great Dane, Doberman pinscher,[28] German shepherd, boxer, and a mongrel.[22] Other bones of the head and some long bones have occasionally been involved. In some animals, only the mandibles are involved, whereas in others only the tympanic bullae seem affected.

Occurrence

The occurrence of CMO is infrequently reported in the literature. At the small animal clinic at Michigan State University, only seven cases were seen in 9 years (1970-1979), and during that time, a total of 130,000 admissions had been recorded. In a literature review, Watson and colleagues[22] reported on collated data from 81 dogs and discussed information on an additional 13 cases.

Clinical Signs

The signs of CMO usually relate to persistent or intermittent pain around the mouth in growing male and female puppies 4 to 7 months of age. Mild cases may be asymptomatic and are discovered by palpation or radiography. If the angular processes of the mandible and tympanic bullae are involved, jaw movement is diminished, even

under anesthesia. Temporal and masseter muscle atrophy is apparent. Nutrition may become inadequate if the condition is so severe that the dog cannot drink liquids. The mandibular thickening may be palpable, and there may be intermittent fever. Exacerbations may recur every 2 to 3 weeks.[28] However, once skeletal maturation nears (11-12 months of age), the pain disappears and the exostoses may even regress.

Diagnosis

Diagnosis of CMO is made based on breed, signs, physical findings, and radiography.

Radiographic Signs

Radiography helps to document the condition. Changes consist of beadlike osseous proliferations of the mandible or tympanic bullae (Figures 24-12 and 24-13). When the exostoses stop proliferating and eventually regress, the roughened borders become quite smooth. With early lesions, however, swellings may not be very radiopaque.

Histopathological Appearance

Histologically, normal lamellar bone is replaced by an enlarged, coarse-fiber (woven) bone. The bone marrow is replaced by a fibrous-type stroma and some inflammation.[27] Inflammatory cells at the periphery of the invading bone have been documented and would seem to make CMO an inflammatory disease. However, others claim that CMO is a noninflammatory, nonclassifiable disease,[5,28,29] based on earlier histopathological literature that may or may not have had sufficient case material to offer adequate study of the disease in various stages. Although the cause of CMO is unknown, Riser and colleagues[27] suggested possible infection (arising from the fever and histological inflammation at the periphery of the lesion), with a genetic influence, because of its occurrence in the terrier breeds. Others have postulated an autosomal recessive trait.[30] Watson and co-workers[22] suggested that the



FIGURE 24-12. Open-mouth radiograph of a 6-month-old female West Highland white terrier with canine mandibular osteopathy. Note the bilateral roughened proliferations of the mandible.



FIGURE 24-13. Proliferation of the tympanic bullae of a 7-month-old male Scottish terrier.

canine distemper virus may be involved, similar to that suggested for hypertrophic osteodystrophy.

Treatment

Treatment is usually aimed at decreasing pain and inflammation with medication, such as aspirin, cortisone, and other agents. Signs may wax and wane spontaneously, and the disease is self-limiting, which makes treatment responses in sporadic cases difficult to assess.[22] Surgical excision of the exostoses has resulted in regrowth within 3 weeks in one documented case.[29] Rostral hemimandibulectomy in one dog unable to move its jaws allowed better food intake, resulting in weight gain.[22] Feeding highly nutritious fluids would be important in dogs with minimal ability to open the mouth. Euthanasia may be necessary in a very few cases.

SYNOVIAL CHONDROMETAPLASIA

Synovial chondrometaplasia (SCM) is a condition in which nodules of sclerosis, fibrocartilage, and even bone form in the synovial layer of the joint capsule, causing chronic lameness in the dog.[31] We have also seen SCM in a cat, as well as several more cases in the dog. SCM has been reported in the shoulder, stifle, and hock of dogs and in the tendon sheath and bursae of horses.[31-34] SCM affects the large joints in humans.[35]

The cause of the spontaneous nodular formation is unknown, but secondary SCM can be stimulated by traumatic, degenerative, or inflammatory conditions in humans.[35]

The diagnosis is made by radiography and histological examination of the joint capsule. On joint exploration, synovial biopsy should be performed when the synovial lining appears nodular. Differential diagnoses include synovial sarcoma, immune-mediated inflammatory joint disease, and infection. Multiple (10-100) "joint mice" seen radiographically, as well as nodular formation seen histologically, are diagnostic of the condition (Figure 24-14). Surgical removal of loose bodies and partial synovectomy have resulted in marked improvement in most cases.[31]



A B

FIGURE 24-14. Anteroposterior (**A**) and lateral (**B**) radiographic views of a hock of a 1-year-old golden retriever with synovial chondrometaplasia. Note the severe soft tissue swelling and the multiple concentric loose bodies ("joint mice") caudal to the distal tibia (in flexor hallucis longus tendon sheath) and the talocrural joint.

SURGICAL ASPECTS OF LONG-BONE NEOPLASMS

Appendicular bone tumors may be separated into the following three categories:

1. Primary bone tumors (osteosarcoma, chondrosarcoma, or fibrosarcoma).
2. Secondary metastatic tumors (arising most often from the mammary gland, lung, and prostate).
3. Local invasion from soft tissue tumors (e.g., synovial cell sarcoma).

All are malignant and carry a grave prognosis. Osteosarcoma is the most common tumor type seen in a dog's bone.

Often the presenting sign is lameness with or without systemic signs such as lethargy and anorexia. Neoplasia should be suspected and ruled out in the older dog with a rapidly progressive lameness (2-4 weeks) as well as swelling. Palpation may reveal muscle atrophy, swelling, and increased heat and sensitivity. Neoplasia should also be suspected in dogs sustaining fractures following minimal or no trauma. Careful scrutiny of good-quality radiographs is required in such cases.

Fine-detail radiography is often the best diagnostic tool to use in finding bone neoplasia, but it may be inappropriate to predict histological type based on radiographs.[36] However, often the radiograph is very characteristic and therefore diagnostic of osteosarcoma. Biopsy in such cases is sometimes misleading because of the lack of tumor cells in small biopsy samples. Biopsy should be used, however, on uncharacteristic lesions, especially if potentially curable conditions exist (e.g., infection, cysts,

undifferentiated carcinoma, lymphomas, transmissible venereal tumor, plasma cell myeloma). Biopsy is also helpful when an owner wants a more knowledgeable answer as to the probable life expectancy of the pet. Chondrosarcoma and fibrosarcoma are slow growing, allowing slower progression until natural death.

Limb amputation is the most frequent surgical treatment in the dog and cat, with or without chemotherapy. It improves the quality of life, but 85% of dogs still die within 8 months after amputation.[37,38]

Recent advances in treatment of osteosarcoma in humans have increased overall survival rates to 60% to 70% in patients with nonmetastatic osteosarcoma.[39] However, 80% to 90% of human patients do not have gross evidence of metastatic disease in the bone at the time of osteosarcoma diagnosis.[39] This is in contrast to our canine patients, in which 85% to 90% have metastatic disease when the primary tumor is removed.[38] Treatments in people include various chemotherapy regimens, pulmonary resection of metastases (often multiple surgeries), and limb salvage procedures. The goals of limb salvage procedures are to remove the tumor completely and to avoid local recurrence while reconstructing a functional extremity.[39] Endoprostheses may be inserted (metal, allografts, or autoclaved autograft of resected tumor). However, the overall survival rates have not differed from those seen with amputation.[39] Ten percent of dogs undergoing amputation or limb sparing alone will survive 1 year.[40]

Limb salvage in dogs has been used in selected cases and includes tumor resection and stabilization using whole cortical allografts and bone plates.[38,41] The use of cisplatin has shown improved survival rates, with more than 50% of dogs living 1 year after treatment.[38] If limb sparing or amputation is combined with cisplatin, 35% to 50% will survive 1 year.[42] Newer immunotherapeutic regimens are being investigated,[4] but at this time the prognosis remains poor for long-term benefit. Exact statistics about survival rates are difficult to obtain because of euthanasia intervention. In oncology centers, increased survival rates may result from owners' persistence in continuing treatment options.

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