Open reduction and bone plate stabilization, compared with closed reduction and external fixation, for treatment of comminuted tibial fractures: 47 cases (1980–1995) in dogs

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Objective—To compare open reduction and bone plate fixation with closed reduction and external skeletal fixation as treatment for severely comminuted fractures of the tibia. Limb alignment, fracture reduction, operating time, hospitalization time, postoperative care, time to unrestricted activity, bone healing, complications, and number of surgical procedures were considered.

Design—Retrospective case series.

Animals—47 dogs with severely comminuted fractures of the tibia treated with open reduction and bone plate application (22 dogs) or closed reduction and external fixation (25 dogs).

Procedure—Medical records of all dogs included in this study were reviewed. Postoperative and follow-up radiographs were evaluated by 2 independent observers.

Results— Differences were not found in hospitalization time, time to unrestricted activity, or time to earliest radiographic evidence of bone healing between dogs with fractures treated with a bone plate and dogs with fractures treated with an external fixator. Fractures treated with an external fixator had more caudal malalignment, and fractures treated with a bone plate had more valgus malalignment. Malalignments were determined not to be related to clinical problems. Dogs with fractures treated with an external fixator had shorter surgery times and more recheck examinations. Dogs with fractures treated with a bone plate had more complications.

Clinical Implications—Open reduction with bone plate fixation and closed reduction with external fixation were both effective for treatment of comminuted tibial fractures. External fixation was associated with shorter surgery time, but dogs required more extensive postoperative care. Bone plate fixation was associated with more complications. (*J Am Vet Med Assoc* 1997;211:1008–1012)

Optimal treatment for comminuted tibial fractures is controversial in human and veterinary medical literature.[1-4] The primary goal of fracture treatment is to achieve a healed fracture with normal bone alignment and function of the affected limb. Additional considerations are minimizing surgery time, hospitalization time, postoperative care, time to unrestricted activity and bone union, complications, and number of surgical procedures. Open reduction with reconstruction of bone fragments with lag screws or cerclage wire and application of a bone plate and screws, or closed reduction with external skeletal fixation, are used successfully to treat comminuted tibial fractures.[2,5-8] The principles of bone plate fixation are anatomic reduction of bone fragments, atraumatic handling of soft tissues, rigid fixation, and early return to function of the limb.[9] The advantage of bone plate fixation is early return to function with minimal aftercare.[9] Recently, less invasive techniques involving minimal disruption of bone fragments with alignment and stabilization of the main segments of the bone have been suggested.[3,8,10,11] Theoretically, this approach causes minimal disruption of fragment vascularity allowing faster incorporation into the callus.[8,10,11] The ultimate application of this concept is closed reduction of the fracture and external skeletal fixation to stabilize the main bone segments and maintain limb alignment.[8] External fixation also permits early return to function but requires more aftercare.[8,11,12]

The purpose of this study was to compare open reduction and bone plate fixation with closed reduction and external skeletal fixation for treatment of comminuted tibial fractures. The effect of each technique on limb alignment, fracture reduction, operating time, hospitalization time, postoperative care, time to unrestricted activity, time to bone healing, number of complications, and number of surgical procedures was determined. Our aim was to identify the advantages and disadvantages of each fixation method.

Criteria for Selection of Cases

All dogs with severely comminuted (> 5 fragments) diaphyseal fractures of the tibia treated with open reduction and bone plate application or closed reduction and external fixation at the University of Illinois Veterinary Medical Teaching Hospital or The Ohio State University Veterinary Teaching Hospital between 1980 and 1995 were included in the study. Preoperative radiographs were reviewed to confirm the severity and location of the fracture.

Procedures

Age, weight, type of fracture (open or closed), method of fracture fixation, surgery time, and hospitalization time were recorded for each dog. The num-

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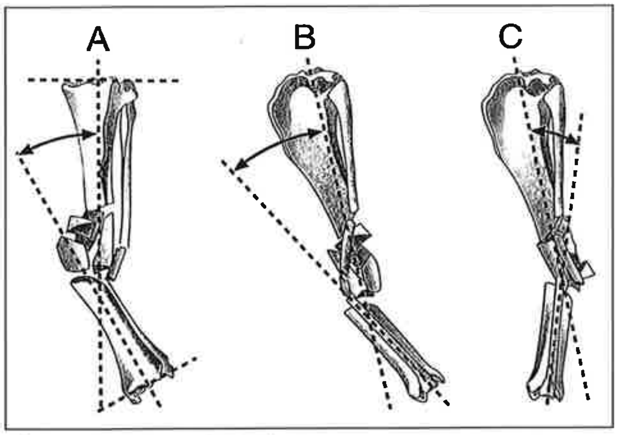

Figure 1—Measurement of varus, valgus, cranial, and caudal limb malalignment after repair of tibial fractures for the dogs of this report. (A) Varus or valgus malalignment was determined by measuring the angle between lines drawn perpendicular to, and bisecting, the proximal aspect of the joint surface and proximal portion of the medullary canal with lines drawn perpendicular to, and bisecting, the distal aspect of the joint surface and the distal portion of the medullary canal on craniocaudal postoperative radiographs of the fractured tibia. (B) Cranial and (C) caudal malalignment were determined by measuring the angle between a line drawn parallel to the proximal fragment and a line drawn parallel to the distal fragment on lateral postoperative radiographs of the fractured tibia.

ber of postoperative examinations and the time to implant removal or time when unrestricted activity was recommended were recorded. Minor complications, such as pin tract lysis, that increased patient morbidity but did not affect clinical outcome, and major complications, such as implant failure, osteomyelitis, and nonunion, that required treatment to achieve a good clinical outcome, were also recorded. For statistical analyses, any dog without follow-up information was considered to have no complications. The total number of dogs in each group, therefore, was used to compare the number of complications between treatment methods. If indicated in the record, the attending clinician's assessment of limb function was recorded. Two independent observers (MD, ALJ) evaluated fracture reduction and limb alignment from immediate postoperative radiographs, using Freedman's technique[13] (Fig 1). While developing the protocol, the observers repeated measurements on sample radiographs and were within 2 degrees of their initial measurements. Varus-valgus alignment was determined from craniocaudal radiographic views by measuring the difference in angulation between a line drawn parallel to the proximal joint surface and a line drawn parallel to the distal joint surface. Craniocaudal alignment was determined from lateral radiographic views by measuring the angle between a line drawn parallel to the proximal fragment and a line drawn parallel to the distal fragment. Torsional malalignment (internal or external rotation) was recorded as evident or not evident. Translational malalignments (displacement) of the distal bone segment relative to the proximal bone segment were determined as a ratio of the maximal displacement to the width of the diaphysis and were grouped as < 10, 10 to 25, 26 to 50, 51 to 75, and 76 to 100%. The greatest distance major bone segments overlapped, and the greatest and least width of fracture gaps also were measured from postoperative radiographs. The time of the follow-up radiographic examination during which 2 independent observers agreed that there was bone bridging of the fracture (earliest radiographic evidence of a healed fracture) was recorded.

Statistical Analysis

Analysis of variance was used to examine possible interactions between type of fracture (open or closed) or method of fixation (bone plate or external fixator) and surgery time, hospitalization time, time to implant removal, time to unrestricted activity, and time to bone bridging. Age and weight were included as covariates. Analysis of variance was also used to examine possible interactions between method of fixation (bone plate or external fixator) and reduction values (displacement, gap, override), and to examine possible interactions between reduction values (displacement, gap, override) and time to bone bridging. Repeated measures ANOVA was used to determine the agreement between angles (cranial, caudal, varus, valgus) measured by 2 observers (repeated measures) relative to the method of fixation (bone plate or fixator). χ^2 Analysis of a contingency table was used to compare the method of fixation (bone plate or external fixator) with the type of fracture (open or closed), the existence of rotation (external or internal), the number of complications, and the number of recheck examinations. χ^2 Analysis of a contingency table was used to compare the type of fracture (open or closed) with the number of complications. For all statistical analyses, significance was set at $P < 0.05$.

Results

Forty-seven dogs met criteria for inclusion in the study. Fractures in 22 dogs were treated with open reduction and application of a bone plate and screws and fractures in 25 dogs were treated with closed reduction and an external fixator. All dogs treated with an external fixator, and 6 dogs treated with a bone plate, underwent surgery at the University of Illinois, and 16 dogs treated with a bone plate underwent surgery at The Ohio State University. Mean age of dogs with fractures treated with a bone plate was 3.2 years (range, 0.4 to 12 years) and mean age of dogs with fractures treated with an external fixator was 4.2 years (range, 1 to 12 years). Mean weight of dogs with fractures treated with a bone plate was 26.8 kg [58.9 lb] (range, 12.7 kg to 53.6 kg [28 to 118 lb]) and mean weight of dogs with fractures treated with an external fixator was 27.5 kg [60.6 lb] (range, 5.5 kg to 51.8 kg [12 to114 lb]). Five (22.7%) dogs with fractures treated with a bone plate and 12 (48%) dogs with fractures treated with an external fixator had open fractures. All open fractures could be classified as Grade IIIA, an open fracture that resulted from high energy trauma but with adequate soft tissue coverage of the bone.[14] Differences were not detected in age, weight, and type of fracture (open vs closed) between dogs with fractures treated with a bone plate and those treated with an external fixator. Thirty-three dogs had documentation of a healed fracture. Twenty-five of these fractures were treated with an external fixator and 8 were treated with a bone plate. The time until earliest radiographic evidence of a healed fracture, regardless of method of fixation, was not affected by age, weight, or fracture type (open or closed).

The mean surgery time of 157 minutes (range, 90 to 285 minutes) for dogs with fractures treated with a bone plate was significantly longer than the mean surgery time of 86 minutes (range, 30 to 180 minutes) for dogs treated with an external fixator. The mean hospitalization time of 6 days (range, 2 to 14 days) for 22 dogs with fractures treated with a bone plate was not significantly different from the mean hospitalization time of 6.8 days (range, 3 to 14 days) for 24 dogs treated with an external fixator.

Varus malalignment was not detected in repaired tibias of any dogs. Twenty-three dogs had valgus malalignment of their repaired fractures; 17 of these were treated with a bone plate and 6 were treated with an external fixator. Mean angle of valgus malalignment of 7.7° (range, 1 to 18°) for dogs with fractures treated with a bone plate was significantly greater than the mean of 3.1° (range, 1 to 10°) for dogs with fractures treated with an external fixator.

Repaired fractures in 8 dogs had measurable cranial malalignment; 6 of these were treated with a bone plate and 2 were treated with an external fixator. Mean cranial malalignment of 1.8° (range, 1 to 4°) for fractures treated with a bone plate was not significantly different from mean malalignment of 3.0° (range, 1 to 6°) for fractures treated with an external fixator. Of repaired fractures in 29 dogs that had measurable caudal malalignment, 7 were treated with a bone plate and 22 were treated with an external fixator. Mean malalignment of 3.6° (range, 1 to 8°) for fractures treated with a bone plate was significantly less than mean malalignment of 9.5° (range, 2 to 22°) for fractures treated with an external fixator.

Significant differences were not found between observers evaluating varus or cranial malalignment of fractures treated with a bone plate or external fixator, valgus malalignment of fractures treated with an external fixator, or caudal malalignment of fractures treated with a bone plate. There was a significant difference between observer measurements evaluating valgus malalignment of fractures treated with a bone plate (a mean difference of 4° between observers) and caudal malalignment of fractures treated with an external fixator (a mean difference of 3° between observers).

Nine fractures treated with a bone plate and 5 fractures treated with an external fixator had external torsional malalignment. One fracture treated with a bone plate and 2 fractures treated with an external fixator had internal torsional malalignment. A significant difference was not found in mean extent of torsional malalignment between treatments.

Displacement measured from radiographs of fractures treated with a bone plate was < 10% in 20 dogs and 10 to 25% in 2 dogs. Displacement measured from radiographs of fractures treated with an external fixator was < 10% in 14 dogs, 10 to 25% in 5, 26 to 50% in 4, and 51 to 75% in 2. There was significantly more displacement in fractures treated with an external fixator. Mean gap measured from radiographs was 1.3 mm (range, 1 to 4 mm) in fractures treated with a bone plate, which was significantly less than the mean gap of 3.54 mm (range, 1 to 10 mm) measured from radiographs of fractures treated with an external fixator. Mean overlap of 0.45 mm (range, 0 to 2 mm) measured from radiographs of fractures treated with a bone plate was not significantly different from mean overlap of 1.0 mm (range, 0 to10 mm) measured from radiographs of fractures treated with an external fixator. Time until earliest radiographic evidence of a healed fracture, as documented for 33 dogs (irrespective of method of fixation), was not affected by displacement, overlap, or gap.

Twelve dogs with fractures treated with a bone plate were returned for follow-up examination. Mean number of recheck examinations per dog was 1.0 (range, 0 to 6). Mean time until unrestricted activity was allowed was 107 days (range, 71 to 180 days) for 7 dogs with fractures treated with a bone plate. Eight dogs with fractures treated with a bone plate had radiographic evidence of a healed fracture; 4 fractures were not healed at the time of the last radiographic evaluation. Mean time of earliest radiographic evidence of a healed fracture was 87.4 days (range, 41 to 185 days). Mean time to the last recheck examination was 74 days. When clinical function was described in records, all dogs were using the affected limb well. Four dogs treated with a bone plate had the implants removed. Mean time to implant removal was 441 days (range, 150 to 730 days) after the initial surgery. These dogs required a second anesthetic episode and surgery to remove the implant. Four dogs treated with a bone plate had complications. One dog had osteomyelitis and nonunion of the fracture but died of unknown causes before treatment of the nonunion could be addressed. One dog had osteomyelitis and was treated with antibiotics, surgical curettage and removal of a sequestrum, and placement of a Penrose drain but was then lost to follow-up. One dog had osteomyelitis and implant failure and was treated with antibiotics and replacement of the bone plate and was then lost to follow-up. One dog with implant failure was successfully treated to replace a loose screw.

All dogs with fractures treated with an external fixator were returned for follow-up examination. Mean number of recheck examinations/dog was 2.25 (range, 1 to 5), which was significantly greater than the mean number of recheck examinations for dogs with fractures treated with a bone plate. Mean time until unrestricted activity was allowed was 111.5 days (range, 57 to 180 days) for 23 dogs with fractures treated with an external fixator. All dogs treated with an external fixator had radiographic evidence of a healed fracture. Mean time to earliest radiographic evidence of a healed fracture was 69.3 days (range, 35 to 119 days). When clinical function was described in the record all dogs were using the affected limb well. A significant difference was not found between dogs with fractures treated with a bone plate and those treated with an external fixator with respect to time until earliest radiographic evidence of a healed fracture. All dogs with fractures treated with an external fixator had implants removed. Mean time to implant removal of 95.4 days (range, 30 to 165 days) for fractures treated with an external fixator was significantly less than that for fractures treated with a bone plate. None of the dogs with fractures treated with an external fixator required a second surgery in the operating room for implant removal. All fractures treated with an external fixator had radiographic evidence of bony lysis around the pins and some pin tract drainage at the time of implant removal. Osteomyelitis developed in 1 dog with a fracture treated with an external fixator, and was successfully treated with antibiotics, removal of the external fixator and application of a cast for support. The number of major complications was significantly less for fractures treated with an external fixator than for fractures treated with a bone plate.

Discussion

Open reduction and bone plate application and closed reduction and external fixation were successful in fracture repair. Comparisons involving multiple institutions and multiple surgeons of various skill levels are difficult to interpret; however, the standards of care and the skill of the surgeons were similar. The method of repair was chosen on the basis of surgeon preference and was independent of the type (open or closed) or severity of the injury. External fixation has been advocated in human medicine for treatment of severe Grade-IIIB open fractures[15]; however, in that study, bone plate application also resulted in similar healing times. For the dogs of the current report, a difference was not found in time to earliest radiographic evidence of fracture healing between the 2 treatment groups. This result may be confounded because of irregular follow-up times and low rate of return of dogs with fractures treated with a bone plate. Biological fixation strategies of fracture repair involve the attainment of adequate limb length and alignment with minimum disruption to fracture fragment vascularity and surrounding soft tissues.[11] This strategy has been advocated to facilitate fracture healing, especially in comminuted fractures.[11] Indirect open reduction, a method of biological fixation, has resulted in faster healing times in human beings.[10] However, Bach and Hanson did not find a difference in healing times for people when bone plate fixation and external fixation of fractured tibias were compared.[15] Although we detected significantly more fragment displacement and fracture gap width in tibias treated with closed reduction and external fixation, this did not appear to influence healing time. It is possible that the advantages of minimal interference with fragment vascularity are offset by the large gaps between fragments that develop with closed reduction of comminuted fractures.

Use of closed reduction and external skeletal fixation to treat severely comminuted tibial fractures resulted in a markedly shorter surgery time compared with use of open reduction and bone plate application. Closed reduction eliminated time-consuming fracture exposure and fragment reconstruction. An additional benefit is a shorter anesthetic episode for the patient, which may be especially important for severely traumatized dogs.

Valgus malalignment developed more often in tibias treated with bone plates. Most tibial fractures displace in valgus malalignment because of strong forces exerted by contracting lateral musculature, which must be overcome during fracture reduction. The position of the limb during surgical exposure and placement of the bone plate on the medial aspect of the tibia can confound intraoperative determination of the degree of correction of valgus malalignment. Accurately contouring a bone plate to fit a comminuted fracture is difficult unless the fracture can be anatomically reconstructed and secured with screws or wire before the template is applied. Inappropriate bone plate contour will cause malalignment. Precontouring the bone plate to match the contour of the radiographic image of the contralateral tibia is recommended to improve alignment of comminuted fractures. We were unable to determine whether this technique was used during bone plate application in dogs in this study.

Tibias treated with external fixation had few valgus deformities. The degree of valgus malalignment in fractures treated with an external fixator can be reduced by use of several strategies.[8] Suspending the affected limb from the ceiling while lowering the surgery table aids in attaining normal limb length and alignment.[8] Once proximal and distal pins are placed, palpation of bony landmarks and intraoperative radiography can be used to assess alignment. After surgery, the external fixator can be adjusted to correct for any residual varus or valgus malalignment.[8]

Caudal malalignment developed more often in tibial fractures treated with an external fixator. When overlapping tibial fragments are reduced, contraction of the cranial tibial muscle must be overcome to regain length and alignment. Bilateral or type-II external fixators do not afford the surgeon mechanical advantage in overcoming caudal bowing caused by contracting muscles when the proximal and distal portions of the metaphysis are distracted by transfixation pins.[8] Type-III external fixation frames or circular external fixators allow application of mechanical forces in a craniocaudal plane and may be more effective in overcoming this deformity during closed reduction of fractures. Tibias treated with bone plates have fewer problems with caudal malalignment. Open reduction and aligning the bone plate along the the medial surface of the bone allow the surgeon to more easily overcome caudal malalignment of the tibia.

Interobserver values agreed when there was minimal deformity, but as deformities became greater, values differed significantly. At greater angles of malalignment, the mean difference between observers was 3° and 4°, which may not be clinically relevant. We did not observe problems with clinical function, nor were problems described in records of dogs with malalignment. To the authors' knowledge, there have been no studies of veterinary patients correlating degree of malalignment with clinical outcome. Malalignment of > 5° in any direction correlates with development of osteoarthritis in human beings.[16]

Dogs with fractures treated with an external fixator were evaluated more frequently than were dogs with fractures treated with a bone plate. All dogs treated with external fixators were evaluated periodically until fracture healing so the external fixator could be removed. Only 8 dogs with fractures treated with a bone plate were evaluated until the fracture healed, and bone plates were removed from only 4 dogs. Use of external fixation ensures that most owners return for follow-up examination and implant removal. In a large study[2] of tibial fractures, 31.79% of dogs and cats included were lost to follow-up. However, in a case series of dogs with fractures treated with external fixation, the percentage lost to follow-up was small.[6] In the current study, all dogs with fractures treated with an external fixator had minor complications of pin lysis and mild drainage that required daily owner care and frequent follow up evaluation. Follow-up examinations and external fixator care take time for the owner and the veterinarian. In certain situations, use of bone plates is advantageous because minimal aftercare is required for uncomplicated cases.

Anatomic reconstruction and rigid fixation with a bone plate and screws requires meticulous alignment of all fracture fragments.[9] When this is achieved, bones heal directly. In severely comminuted fractures, precise reduction may not be possible and, when attained, often causes more surgical trauma.[17] Blood supply to soft tissues and bony fragments may be substantially disrupted. This can lead to delayed healing and complications such as nonunion and infection. These complications, although uncommon, affect clinical outcome. Dogs with fractures treated with a bone plate did have a significantly higher number of major complications compared with those treated with an external fixator. A higher incidence of complications, including osteomyelitis, delayed union, and implant failure, also was seen in human beings with comminuted tibial fractures treated with a bone plate, compared with those treated with an external fixator.[13]

The number of complications for the bone-plated fractures may actually be higher than reported here as any dog without follow-up was considered not to have had complications, and comparisons between the 2 methods were made using the total number of dogs in each group. This assumption was made because it is more likely that a client will return if complications ensue; however, this may not always be the case.

Both methods of fixation can be used successfully to treat comminuted tibial fractures. The advantages of external fixation appear to be a shorter operative time and fewer major complications. The shorter operative time is especially important in traumatized dogs or busy practice settings. The decrease in major complications suggests that in dogs with an increased risk for developing these complications (eg, immunocompromised dogs or dogs with extensive soft tissue damage), an external fixator should be considered. The experience of the surgeon is an important consideration as technical errors in application can be critical in fractures treated with open reduction and bone plate application. Disadvantages of external fixators include the need for more extensive postoperative care to be performed by the owner to ensure pin tracts are kept clean and the greater number of recheck examinations required to be performed by the veterinarian. Bone plates require less postoperative care and fewer recheck examinations, and should be considered if care and follow-up are difficult or impossible (eg, an aggressive patient or a noncompliant owner). Another potential disadvantage of bone plates is that if the implant is removed, a second surgery is required, although few dogs in this study underwent implant removal.

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