



An In-Depth Look:

INTERLOCKING
NAIL FIXATION

Intramedullary Interlocking Nail Fixation in Dogs and Cats: Clinical Applications*

Jason L. Wheeler, DVM, MS
Daniel D. Lewis, DVM, DACVS
University of Florida

Alan R. Cross, DVM, DACVS
Georgia Veterinary Specialists, Atlanta

W. Preston Stubbs, DVM, DACVS
Alameda East Veterinary Hospital,
Denver, Colorado

Robert B. Parker, DVM, DACVS
Animal Medical Center, New York, New York

ABSTRACT:

Although the use of interlocking nails was once limited to larger dogs, the development of smaller-diameter nail systems now allows application in smaller dogs and cats. Although interlocking nails can be inserted in closed fashion, most are inserted using a traditional open or limited open approach. The largest-diameter nail that can be accommodated by the medullary canal should be selected. Large oblique or spiral fracture fragments or segments can be anatomically reduced and stabilized using cerclage wires before advancing the nail into the distal fracture segment. In more highly comminuted fractures, intermediate fragments often remain undisturbed while the nail is placed in buttress fashion. Uncomplicated union rates as high as 96% have been reported with interlocking nail stabilization, with up to 90% of animals regaining good to excellent limb function. Complications associated with interlocking nail fixation include malposition of interlocking screws, nail or screw breakage, and delayed union or nonunion.

*A companion article on biomechanics and instrumentation appears on page 519.

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The use of intramedullary interlocking nail fixation to stabilize diaphyseal long bone fractures in dogs and cats is increasing. This article discusses indications and general techniques for intramedullary interlocking nail application, specifically for nail stabilization of diaphyseal fractures of the femur, tibia, and humerus.

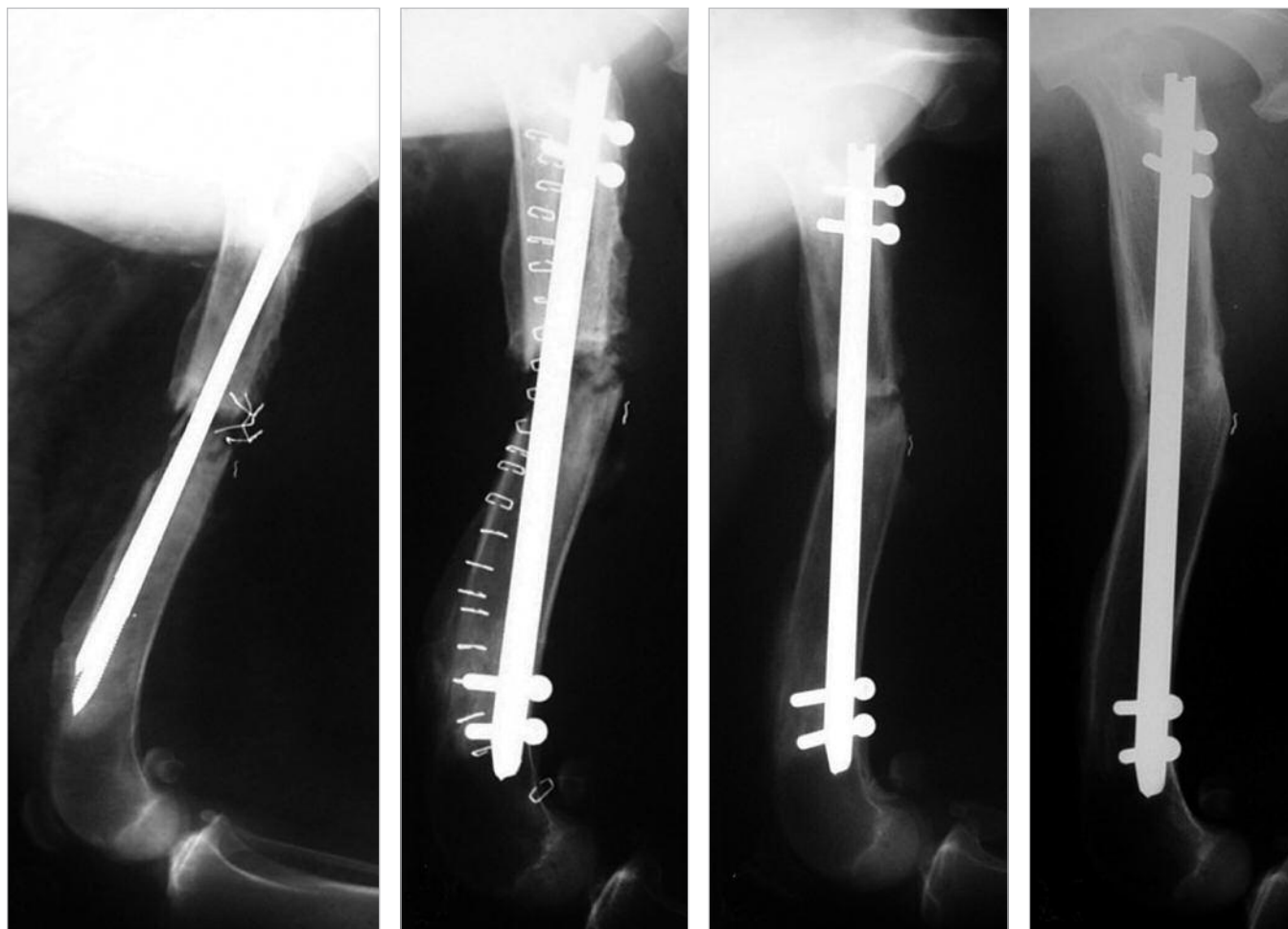
GENERAL INDICATIONS AND APPLICATION TECHNIQUE

Interlocking nails were developed to treat diaphyseal fractures of the femur, tibia, and humerus.¹ Applicable fracture configurations can vary from simple to highly comminuted. Although interlocking intramedullary nails are most frequently used to stabilize closed fractures, using the nails to manage open and contaminated fractures is also justified.²⁻⁹ Interlocking nails provide suitable axial, rotational, and bending stability to allow infected and/or nonunion fractures to obtain union.^{3,6,7} We and others have successfully used interlocking nails to treat infected and/or nonunion fractures in dogs^{3,6,7} (Figure 1). Placing an interlocking nail simplifies axial alignment of the major proximal and distal bone segments, which can be particularly difficult to accomplish when applying a bone plate to stabilize a nonunion fracture. Interlocking nails can also be used to stabilize cortical allografts in treating highly comminuted fractures and in limb-sparing procedures. Healing and incorporation of cortical allografts in sheep were found to be similar when grafts were stabilized with either an interlocking nail or a 3.5-mm broad dynamic compression plate.¹⁰

Intramedullary interlocking nail fixation has many advantageous biologic and biomechanical properties for stabilizing diaphyseal femoral, humeral, and tibial fractures.

Because of the introduction of the 4- and 4.7-mm-diameter nail series, most diaphyseal fractures of the femur, tibia, and humerus in dogs and cats can be stabilized with interlocking nail fixation^{3-5,7,9}; we have even used interlocking nails to stabilize fractures that have extended into the metaphyseal region. Obtaining radiographs of the contralateral intact bone before surgery is often helpful to determine the appropriate nail diameter and length. Acetate overlays are available to assist surgeons in determining the correct nail diameter and length. The largest-diameter nail that can be inserted into the medullary canal should be selected. The nail should be long enough to ensure that the screw holes will not be positioned over or immediately adjacent to the fracture site. The nail should be slightly shorter than the bone to be stabilized so that the proximal end of the nail will not protrude from the bone following implantation.

Although interlocking nails can be inserted in closed fashion, most are inserted using a traditional open or limited open approach. After exposing the fracture, the selected nail should be inserted into the medullary canal and advanced toward the isthmus of the bone to confirm that the nail is the appropriate diameter. Making a pilot hole simplifies advancement of the interlocking nail into the medullary canal of the proximal fracture segment. The interlocking nail must be inserted in normograde fashion to accommo-

Figure 1. Lateral radiographs of a femoral fracture.

The infected, nonunion fracture repaired 6 months before the patient presented with inadequate fixation.

The fracture immediately after surgery following fracture debridement, cancellous bone grafting, and stabilization with an interlocking nail.

One-month follow-up showing resolving osteomyelitis and early fracture healing.

Three-month follow-up showing uncomplicated osseous union.

date attachment of the drill jig. A twist drill bit or Steinmann pin should be used to drill a pilot hole in normograde (for the femur and tibia) or retrograde (for the humerus) fashion. It is advisable to begin this process with a relatively small-diameter or twist drill bit and then sequentially enlarge the diameter of the pilot hole with successively larger-diameter twist drill bits. Four-, 4.7-, 6-, or 8-mm intramedullary reamers can be used to enlarge the pilot hole to the same diameter as the nail to be implanted.

The appropriate nail extension should be secured to the selected interlocking nail and then the insertion tool attached to the extension. The interlocking nail should

then be inserted into the pilot hole in normograde fashion and advanced down the medullary canal until the tip of the nail protrudes from the proximal fracture segment at the fracture site. If the nail is difficult to advance, the power adapter, which can be secured in the chuck of a pneumatic or electric drill, can be attached to the extension in place of the insertion tool.

Large oblique or spiral fracture fragments or segments can be anatomically reduced and stabilized using full cerclage wires before the nail is advanced into the distal fracture segment. This produces a load-sharing construct, which contributes to the stability of the repair.^{11,12} Cerclage wires can also be used to prevent fissures in the

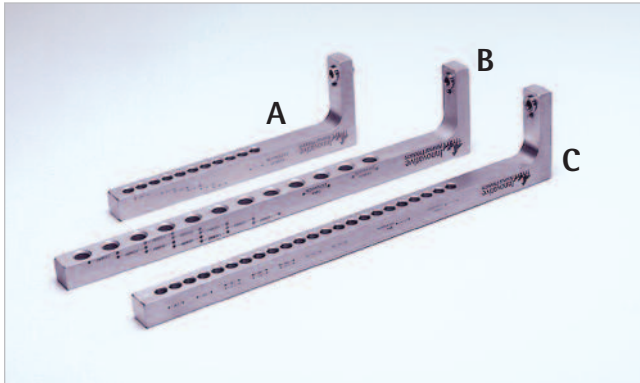


Figure 2. Drill jigs. The 4- or 4.7-mm (A) and 6- or 8-mm (B) jigs of the model 22 series as well as the 6- or 8-mm (C) jig of the model 11 series. The imprinted scale correlates with various interlocking nail lengths.

major bone segments from propagating during nail insertion. In highly comminuted fractures, in which anatomic reconstruction is difficult or impossible, an “open but do not touch” approach should be used.^{13–15} The major proximal and distal fracture segments should be manipulated using bone-holding forceps so that axial, angular, and rotational alignment and normal limb length can be approximated as the nail is inserted into the distal fracture segment. Intermediate comminuted fracture fragments should remain undisturbed, with their soft tissue attachments intact, and a cancellous

drill jig, allowing surgeons to determine which holes in the jig should be aligned with holes in the implanted nail (Figure 2). The first screw is usually placed in the most distal hole in the nail.¹² The guide sleeve and sharp trocar can be inserted into the drill jig and used to separate overlying soft tissues, allowing direct access to the bone. The sharp trocar tip should be used to inscribe a divot on the bone’s surface to help prevent migration of the drill bit. Care must be taken during this process not to apply pressure to the drill jig, which could alter its position with respect to the implanted nail, likely resulting in misplaced screws.

The trocar should then be replaced with the appropriate drill sleeve. A drill bit should be inserted through the drill sleeve and a hole drilled through the *cis*-cortex, transverse cannulation of the interlocking nail, and *trans*-cortex. Surgeons must be careful to keep the drill bit from “walking along” the bone surface before engaging the cortex, or the drill bit may not pass through the cannulation in the interlocking nail.¹² The depth of the hole should be measured and tapped and the appropriate-length screw placed through the bone-interlocking nail construct.

Interlocking bolts should be placed in a fashion similar to that of screws, but tapping the holes is not necessary. The diameter of the insertion holes should be larger for bolts than for screws. For example, transverse holes in an 8-mm nail accepting 3.5-mm interlocking

Interlocking nails should be placed in a normograde fashion to allow attachment of the drill jig via the extension.

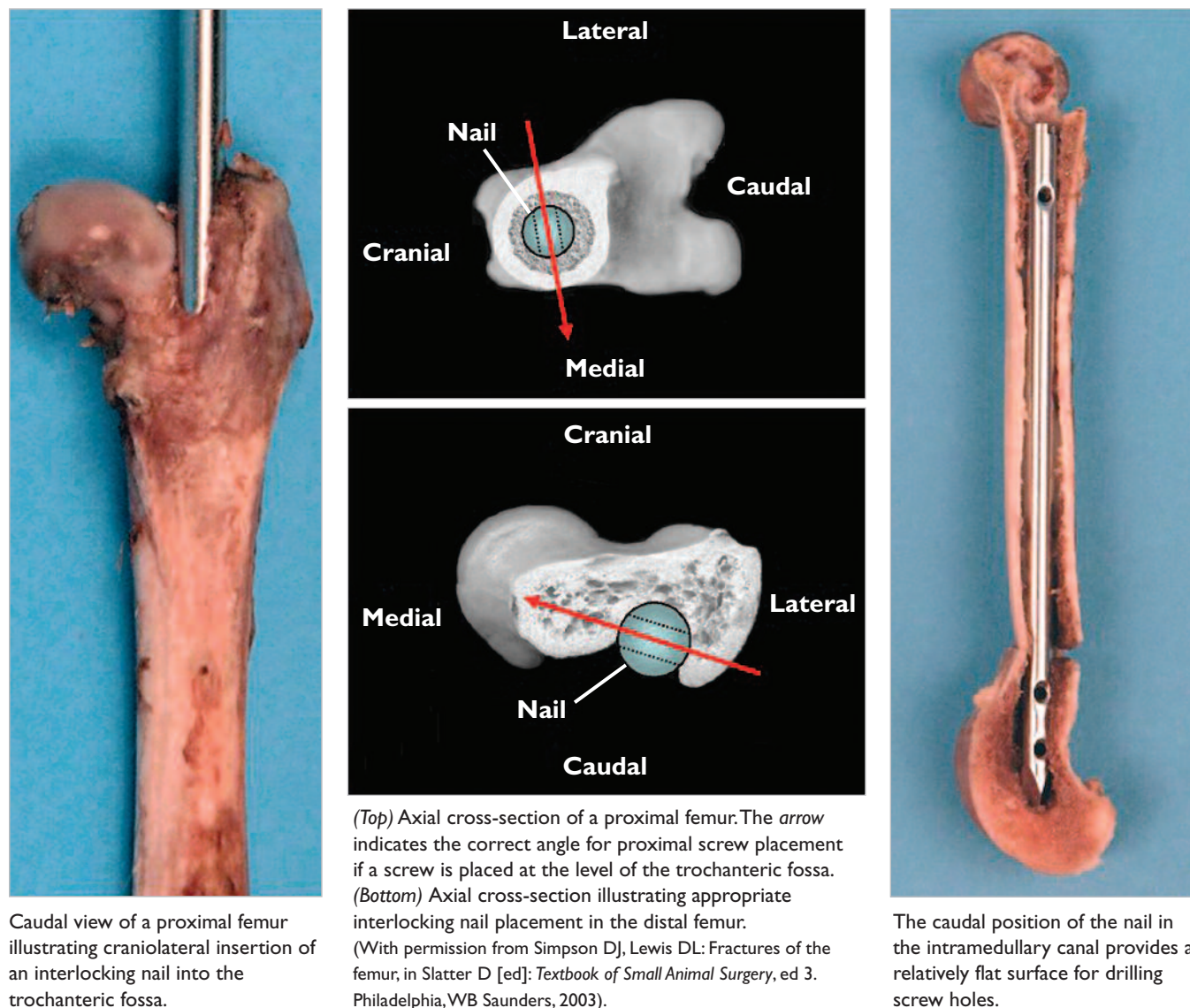
bone graft should be packed into the fracture gap.

An appropriate-diameter reamer can be used to make a pilot hole in the distal fracture segment, which can facilitate proper fracture alignment as the nail is advanced beyond the fracture. Cutting off the trochar tip of the nail with a bolt cutter is often advisable. This prevents the nail from inadvertently penetrating the subchondral bone plate and entering the joint as the nail is seated in the distal fracture segment.

Once the nail is seated in the distal fracture segment, the insertion tool should be removed, the setscrew in the extension retightened, and the drill jig attached to the nail via the extension. The drill jig lies outside the bone and allows surgeons to locate the screw holes in the implanted interlocking nail. A scale is printed on the

bolts should be drilled with a 3.5-mm bit, whereas a 2.5-mm hole should be drilled and tapped for a 3.5-mm screw. Bolts have self-tapping positive profile threads subjacent to the bolt head that engage the *cis*-cortex. Interlocking bolts come in only one length but can easily be cut to the appropriate length with bolt cutters.

Once the first distal locking screw has been placed, the surgeon can rotate the drill jig and the attached interlocking nail within the medullary cavity to confirm that the screw has been placed through the implanted nail. A small amount of rotation should result in an audible and palpable stop as the walls of the transverse cannulation in the nail impinge on the screw. Rotation of the jig should result in an equal amount of rotation of the distal fracture segment. Fracture reduction, particu-

Figure 3. Interlocking nail placement in a femur.

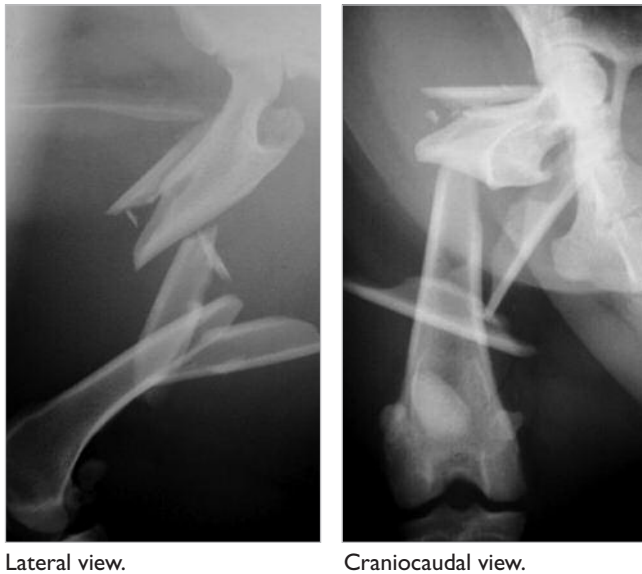
larly proper rotational alignment and axial bone length, should then be reassessed and adjusted if necessary. The remaining interlocking screws should be placed in a distal-to-proximal sequence, after which the drill jig and extension should be detached from the nail.

FEMORAL FRACTURES

Interlocking nail fixation is most frequently used to stabilize femur fractures.⁷ Four- or 4.7-mm-diameter nails are suitable for stabilizing fractures in smaller dogs and cats,⁹ whereas 6-mm nails are generally suitable for dogs weighing approximately 35 to 60 lb (15 to 27 kg), and 8-mm nails are used in larger dogs.⁷ Most femoral

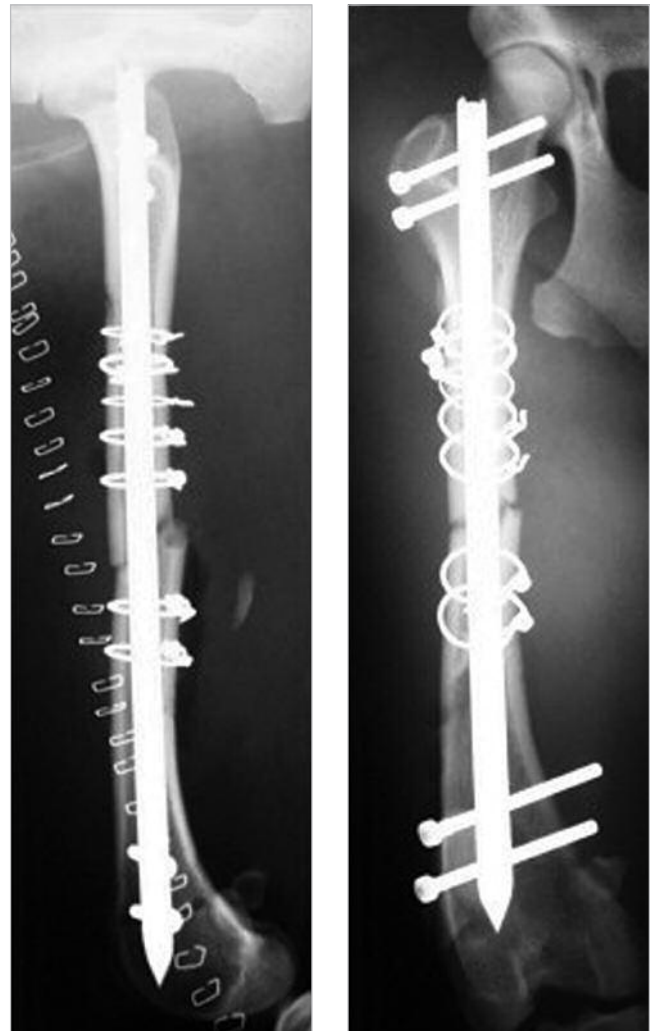
fractures are managed using open reduction. The femur should be approached laterally¹⁶ and its entire length exposed rather than practitioners trying to place the nail and screws via separate, small, limited incisions. The incision should be initiated proximal to the greater trochanter, which simplifies attachment of the drill jig, and extended to include a lateral arthrotomy of the stifle.

Once the fracture has been exposed, the surgeon should slide the nail into the medullary canal of the proximal fracture segment to confirm that an appropriate-diameter nail has been selected. A pilot hole should then be drilled in the proximal femoral segment using a small-diameter twist drill bit. The drill bit should be

Figure 4. Radiographs of a highly comminuted diaphyseal femoral fracture.

“walked” medially off the greater trochanter until the tip of the pin or drill bit falls into the trochanteric fossa. Cranial and lateral pressure should be applied to the drill bit to ensure that it is positioned in the most cranio-lateral aspect of the trochanteric fossa. Before drilling the pilot hole, a guide pin should be placed along the lateral surface of the femur. The guide pin should bisect the proximal diaphysis of the femur and also be parallel to the drill bit, which should be used to make the pilot hole, to ensure that the drill bit can be advanced into the medullary canal. Once the drill bit has been visualized at the fracture site, it should be withdrawn and the pilot hole enlarged, successively if necessary, until the interlocking nail can be placed in the proximal femoral segment (Figure 3).

For fracture reconstruction, large fracture fragments must be anatomically reduced and secured in place with multiple cerclage wires (Figure 4). However, if the diaphysis will not be extensively reconstructed, the comminuted fragments should remain undisturbed while the nail is applied in buttress fashion and the bone defect is extensively grafted with a cancellous or corticocancellous bone graft. For fractures that are not anatomically reconstructed, it is often advisable to slightly “overreduce” the fracture by levering the distal femoral segment slightly cranially as the nail is advanced into the distal fracture segment (Figure 4). This compensates for the caudal bowing of the distal femur, which is present in most dogs, allowing the nail to be securely seated in the



The fracture was partially reconstructed with cerclage wires and stabilized with an intramedullary interlocking nail. Overreduction of the distal femoral fracture segment allowed the interlocking nail to be seated deep into the condyle.

metaphyseal cancellous bone of the distal femur.¹⁷ Overreduction is typically not necessary in cats because their femurs are relatively straight. A pilot hole can be made in the distal femoral segment to ensure proper seating of the nail. The reamer should contact the cranial cortex of the distal femoral segment at the fracture site and be directed toward the caudal aspect of the distal femoral metaphysis. Once the pilot hole has been reamed, the interlocking nail should be seated in the distal femoral segment.

If a fracture will not be anatomically reconstructed, proper rotational alignment must be obtained. This can

Figure 5. Radiographs of a comminuted diaphyseal tibial fracture repaired with an interlocking nail. The nail was placed using closed reduction, and small medial incisions were used for screw placement.



be done by assessing the position of the femoral head and neck relative to the femoral condyles. The position of the femoral head and neck, which is normally in some degree of anteversion, can be determined by either

proper rotational alignment. Aligning the origin of the adductor magnus muscle along the caudal surface of the diaphysis of the femur on the proximal and distal fracture segments also aids in establishing proper rotational alignment. Once rotational alignment is deemed correct, the interlocking screws or bolts should be placed.

Two screws should be placed proximal and distal to the fracture when possible.¹⁸ Screw placement is dictated by the location and configuration of the fracture as well as the length of the nail implanted. It is ideal to place two screws proximal and two distal; however, if the location or comminution of the fracture does not allow this, only one screw can be used. The proximal end of the nail should not protrude into the trochanteric fossa, and it is preferable to seat the distal end of the nail in the caudodistal aspect of the femoral condyle because the lateral aspect of the stifle provides a relatively flat surface that facilitates accurate screw placement. However, if the distal screws are positioned in the supracondylar region, placing the screws in a slightly craniolateral to caudomedial plane can help keep the drill bit from sliding along the convex surface of the cranial cortex of the diaphyseal-metaphyseal region of the distal femur. The most proximal screws should be positioned at or distal to the third trochanter to avoid placing screws in the trochanteric fossa. If the proximal fracture segment is short, affording limited purchase, or the implanted nail selected is too long, the proximal end of the nail will protrude into the trochanteric fossa. In this situation, it is advisable to place the screws in a slightly caudolateral to craniomedial plane. This allows the screws placed in the greater trochanter to obtain medial purchase in the femoral neck.

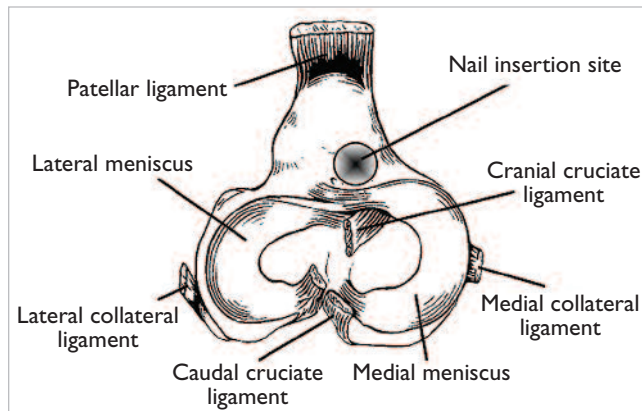
TIBIAL FRACTURES

The sigmoidal shape of the medullary cavity of the tibia can complicate placement of an interlocking nail in

Intermediate comminuted fracture fragments often remain undisturbed, with soft tissue attachments intact, when using an “open but do not touch” approach to fracture management.

direct palpation or placing a Kirschner wire along the cranial surface of the femoral neck. The protruding portion of the Kirschner wire should be angled slightly caudolaterally relative to the femoral condyles when there is

some dogs, particularly chondrodystrophic breeds. Although tibial fractures are more amenable to closed reduction than are femoral fractures, most interlocking nails are placed following reduction via a limited medial

Figure 6. Interlocking nail placement in a tibia.

Proximal tibia showing the correct insertion site for interlocking nail placement immediately cranial to the intermeniscal ligament.



Interlocking nail placement to stabilize a tibial fracture using a limited open approach. A second interlocking nail is used as a guide pin to align drilling of the initial pilot hole.



Drill jig application with drill insertion sleeves placed through small separate incisions over the distal medial tibia.

directed slightly caudally to follow the course of the medullary canal (Figure 6). A guide pin should be placed along the medial aspect of the tibia to confirm that the pilot hole will communicate with the medullary canal (Figure 6). Once the drill bit is visible at the fracture site, it should be withdrawn and the pilot hole enlarged sequentially until an appropriate-diameter reamer can be passed.

The interlocking nail should be placed using the tibial extension. The trochar tip of the nail should be cut off before placing the nail. Blunting the tip of the nail prevents inadvertent penetration into the talocrural joint as the nail is seated in the distal tibial segment. Reaming of the distal fracture segment may be necessary, and, in some dogs, a tight-fitting nail may need to be impacted

approach.¹⁶ The nail should be placed in normograde fashion (Figure 5). A separate 3- to 5-cm incision should be made along the medial border of the patellar tendon and the fat pad displaced caudolaterally (Figure 6). A pilot hole should be drilled with a small-diameter twist drill bit. The pilot hole should be initiated just cranial to the intermeniscal ligament and the drill bit

using a mallet. The implanted nail should not protrude above the proximal surface of the tibia and can be countersunk if necessary. Some or all of the screws can often be placed via separate small insertion incisions on the medial aspect of the tibia (Figure 6).

HUMERAL FRACTURES

Humeral fractures are infrequently stabilized using interlocking nail fixation because most of them involve the supracondylar region or condyle.^{3,7} Diaphyseal humeral fractures that are amenable to interlocking nail fixation are usually reduced using an open or limited open lateral approach to the humerus. The radial nerve must be isolated and protected during dissection.¹⁶ If the fracture involves the distal diaphysis, the brachialis muscle can be transected to improve exposure and simplify reduction of the fracture.¹⁹ Once the fracture has been exposed, appropriate nail diameter can be confirmed by sliding the nail into the medullary canal of the distal fracture segment.

The nail should be placed in normograde fashion. Making a pilot hole with a smaller-diameter twist drill bit and then sequentially enlarging the hole to the diameter of the nail is advisable. The pilot hole can be drilled in either normograde or retrograde fashion, but the latter technique is generally used. The pilot hole should exit the proximal fracture segment at or slightly distal to the greater tubercle and should be directed slightly caudomedially down the medullary canal. Although it is preferable to place two screws on each side of the fracture, the distal segment in many humeral fractures is often too short to accommodate two screws. We have found that nail placement (particularly in the distal humerus, but also in selected distal femoral or distal tibial fractures) can be facilitated by cutting off the end of the nail between the most distal screw holes or through the most distal screw hole. This allows the nail to be seated securely in the distal bone segment without leaving an open screw hole at or adjacent to the fracture site. Although the availability of three-hole nails circumvents the need to cut nails through the distal screw hole, cutting the trochar tip off the distal end of the nail before seating the nail in the distal segment prevents the nail from inadvertently penetrating the thin cortical bone in the region of, or just proximal to, the olecranon fossa.

Screws should be placed from the lateral surface of the humerus. If the fracture was reduced using a limited open or closed approach, screws located distant to the

Figure 7. Radiographs of a comminuted diaphyseal humeral fracture stabilized with an interlocking nail. The interlocking nail was placed using an “open but do not touch” approach, and a cancellous bone graft was placed in the fracture site. The trochar tip of the nail has been cut off.



fracture site can be placed through small, separate incisions. The proximal end of the nail should be countersunk several centimeters because the greater tubercle is principally composed of cancellous bone and affords limited screw purchase. If a single screw is used to stabilize the proximal humeral segment, the screw should be placed at the level of the tricipital line to ensure that sufficient cortical bone is engaged to accommodate weightbearing³ (Figure 7).

CLINICAL RESULTS, POSTOPERATIVE CARE, AND COMPLICATIONS

Interlocking nail fixation has been used to stabilize diaphyseal fractures of the femur, humerus, and tibia in dogs and cats with a high degree of success. Results of clinical studies indicate that 83% to 96% of dogs and cats with diaphyseal fractures healed without complications, with 80% to 90% regaining excellent or good limb function.^{3-5,9,13,20,21} Dueland and coworkers⁷ reported that

Figure 8. Radiographs demonstrating complications associated with interlocking nail fixation.



Penetration of the tibiotarsal joint and malposition of the distal screw.



Interlocking nail breakage attributed to placing a nail of inadequate diameter and positioning a screw hole too close to the fracture.



Screw breakage associated with interlocking nail fixation.

21 of 126 dogs that had fractures stabilized with interlocking nails developed complications, including malpositioned screws that did not engage the nail, nail or screw breakage, and delayed union (Figure 8). Infection

and complications such as sciatic and radial neuropathy have been reported at rates comparable with other fixation methods.^{3,7} Screws that do not engage the nail are typically located in the distal fracture segment and can be attributed to a loose drill jig, bending of the implanted nail, or applying pressure to the jig while drilling holes for screws. To decrease the potential of placing screws outside the nail, the setscrew in the extension should be retightened before attaching the drill jig. Nail breakage can often be ascribed to a surgeon selecting a nail with an inappropriate diameter or positioning a screw hole at or adjacent to the fracture site.⁷ Although modifications in nail design should continue to decrease the incidence of nail breakage, this complication can also be avoided by selecting nails of proper length and configuration with the largest diameter that can be implanted. Screw breakage remains a concern, particularly when only one screw is placed in either major fracture segment. The recent development of

bolts to supplant screws should decrease the incidence of screw breakage.

Implant removal following fracture union is not currently advocated. In evaluating the torsional stiffness of Dueland interlocking nails, no difference was found between intact femoral 8-mm interlocking nail constructs (i.e., two or four screws) and intact femurs. Likewise, there was no difference in maximum torque and intact femoral 8-mm interlocking nail constructs (i.e., four screws) and intact femurs without implants.²² These results imply that the intact femur–nail–screw construct mechanically compensates for the adverse stress riser effect of the screw holes in the bone and that nail removal following fracture healing is probably not warranted or necessary.

CONCLUSION

Interlocking nail fixation has many advantageous attributes for stabilizing long bone fractures in dogs and

Resources

Web

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Search for “interlocking nail”

Instructional Videos

Waltham Forum Video Series: Interlocking Nails (Volume 7, Tape 1, 1995)

By Tass Dueland, DVM

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cats. Interlocking nails have favorable biomechanical characteristics, are relatively simple to apply to a wide range of diaphyseal fractures, and are a relatively economical method of fracture repair. Reported clinical results are promising, and continuing modifications to existing systems should make interlocking nail fixation an even more valuable modality for fracture repair in dogs and cats.

Tips on using interlocking nails and radiographs of actual case studies are available at VetLearn.com/compendiumdownloads.html.

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- Intramedullary interlocking nails have been successfully used**
 - in infected, nonunion fractures.
 - in highly comminuted fractures.
 - to stabilize cortical allografts.
 - all of the above
- _____ involves biologic fracture fixation, in which highly comminuted fractures are stabilized without anatomic reconstruction of the comminuted segment.
 - External coaptation
 - The “open but do not touch” approach
 - External fixation
 - Fracture neutralization
- Intramedullary interlocking nails should be placed**
 - in retrograde fashion.
 - eccentric to the lateral cortical surface of the bone.
 - in normograde fashion.
 - in either retrograde or normograde fashion.
- Intramedullary interlocking nail fixation in small-breed dogs and cats**
 - requires the 4- or 4.7-mm-diameter interlocking nail system.

- b. is not feasible because of implant size limitations.
- c. has a lower success rate compared with its use in large-breed dogs.
- d. is contraindicated because of the development of fracture disease.

5. When placing locking screws in an intramedullary interlocking nail,

- a. the most distal screw should be placed first.
- b. the most proximal screw should be placed first.
- c. overdrilling of the near cortex is advisable.
- d. screws can be safely placed within 5 mm of the fracture.

6. When stabilizing femoral fractures with intramedullary interlocking nail fixation,

- a. nail insertion should begin in the greater trochanter.
- b. nails should not be countersunk to allow removal after fractures heal.
- c. it is advisable to slightly “overreduce” the distal fracture segment.
- d. two screws must be placed proximal and distal to the fracture.

7. Intramedullary interlocking nail fixation of humeral fractures

- a. is typically done in retrograde fashion.
- b. is done via a lateral approach to the humerus.
- c. should be performed only in large-breed dogs.
- d. should be done only in combination with cerclage wires.

8. Which statement regarding intramedullary interlocking nail placement in the tibia is true?

- a. The nail should be inserted just distal to the patellar tendon.
- b. Screws can be placed through separate, small skin incisions on the lateral aspect of the tibia.
- c. The sigmoidal shape of the tibia can limit intramedullary interlocking nail fixation in some dogs.
- d. Countersinking the nail below the level of the proximal tibia is unnecessary and should be avoided.

9. Which of the following is a recognized complication of intramedullary interlocking nail fixation?

- a. malpositioned screws
- b. implant failure
- c. slowed fracture union
- d. all of the above

10. Which statement regarding intramedullary interlocking nails is true?

- a. Implant removal is recommended following fracture healing.
- b. Eighty three percent to 96% of dogs and cats with diaphyseal fractures heal without complication.
- c. Interlocking bolts are manufactured in 2-mm increments from 10 to 40 mm.
- d. Only 42% to 58% of dogs regain good limb function following repair.