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Tibial fractures in the dog and cat: options for management

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Introduction

Tibial fractures are common and may present in a variety of forms. Because there is little soft tissue covering over the craniomedial aspect of the tibia, open fractures are common. Tibial fractures have the highest rate of non-union after those of the radius (25% and 60% of all non-unions, respectively). The majority of fracture complications come as a result of poor decision-making by, rather than poor technical expertise of, the attending veterinary surgeon. Pre-operative assessment of the fracture and planning the repair helps to limit complication rates of tibial fractures.

Figure 1: Cross-section of the right proximal tibia.

Figure 2: Cranial aspect of the left tibia. A; tibial crest, B; Gurdey's tubercle, F; medial tibial condyle, G; lateral tibial condyle, H; medial malleolus.

Figure 3: Lateral aspect of the left tibia. A; tibial crest, B; Gurdey's tubercle, C; muscular groove (of the long digital extensor tendon), G; lateral tibial condyle.

The location and anatomy of the tibia provides several advantages to the surgeon:

• as it is superficial, it is easy to approach medially, with only one neurovascular bundle present. Also, minimal muscle elevation is necessary;

• it is a relatively 'familiar' surgical site;

• the proximal tibia is a relatively 'powerful biological' site, with good muscle attachment on the proximal lateral aspect (**Figure 1**) and a low cortical:cancellous bone ratio which leads to relatively rapid bone healing.

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Fractures of the tibia also create several potential difficulties for the surgeon:

• as the tibia is superficial, open fractures are common;

• the tibia is an irregular shape (**Figures 1, 2** and **3**). In the proximal third it is triangular in cross-section. It is much wider proximally than distally and tapers to an isthmus in the distal diaphysis. The tibia also has a sigmoid shape in both a craniocaudal and mediolateral plane and has approximately 10-15° of torsion (twist) along its length. The distal half of the bone is torsed medially relative to the proximal half;

• unlike the femur, the tibia has articular surfaces proximal and distal

Figure 4: Cross-section of the distal third of the right tibia.

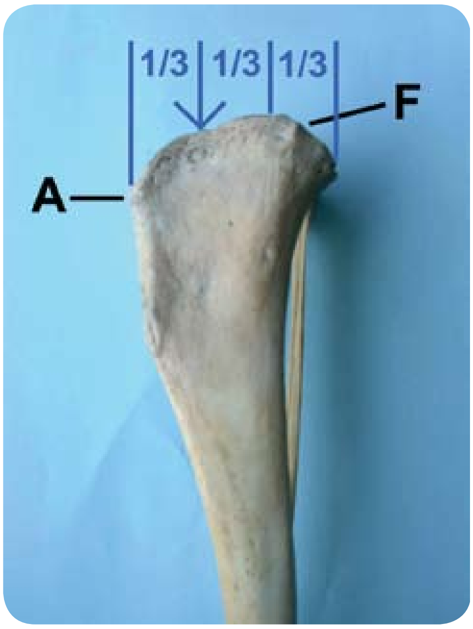

Figure 5a: Site for intramedullary pin insertion. Medial view of the proximal right tibia. A; tibial crest, F; medial tibial condyle

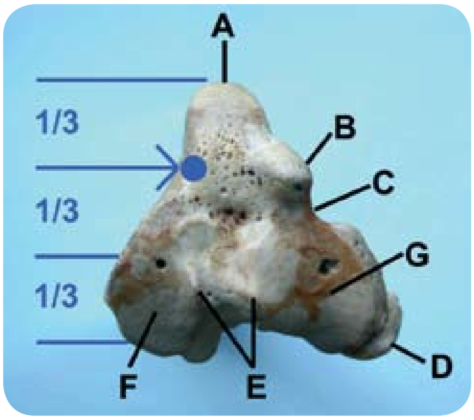

Figure 5b: Site for intramedullary pin insertion. Dorsal view of the tibial plateau of the right tibia. A; tibial crest, B; Gurdey's tubercle, C; muscular groove (of the long digital extensor tendon), D; Fibular head, E; intercondylar eminences, F; medial tibial condyle, G; lateral tibial condyle.

to the line of the shaft, making intramedullary pin placement difficult;
• the insertion of the patella tendon on the tibial crest can produce high tensile and bending loads on repairs to fractures of the proximal tibia;
• the limited muscle attachments to the distal tibia and the high cortical:cancellous bone ratio of the distal third of the tibia (**Figure 4**) result in a relatively slow rate of bone healing compared to the proximal tibia. Blood supply to a healing fracture comes initially from the surrounding muscle attachments through the periosteal blood vessels, the so-called extraosseous blood supply of healing bone;
• concurrent fissure fractures are common in tibial fractures, particularly of the distal third.

All of the fracture repair modalities (bone plates, external skeletal fixators, interlocking nails, intramedullary pins, external coaptation) may be used on the tibia. It is essential to consider the strengths and weaknesses of each fracture repair method when making an assessment of any fracture and planning which method of repair to use.

Intramedullary pins

Intramedullary (IM) pins are only suitable for relatively simple tibial fractures. Normograde pin placement is the only suitable method in the tibia. Tibial fractures should never have an IM pin placed by a retrograde method because the pin will pass into the articular part of the stifle joint. In these instances the pin commonly damages the cruciate ligaments, menisci and articular cartilage resulting in pain, lameness and, ultimately, degenerative joint disease.

For normograde IM pin placement, make a 1-2cm skin incision over the medial tibial condyle at the junction of the cranial and middle thirds (**Figures 5a** and **5b**). The pin should be driven distally entering the medial ridge of the tibial plateau at that location. The fracture is held in reduction while the pin is driven into the distal fragment. Judge the correct depth of insertion by measuring with a second pin of identical length. It is essential to remember that the medial malleolus extends distally past the location of the talocrural joint (**Figures 2** and **6**). As the IM pin is being driven distally, it is important to remember this, it will help to prevent the pin from penetrating the talocrural joint. The base of the medial malleolus, rather than the tip, is the distal extent of maximum pin insertion. Flex and extend the hock joint to ensure that the pin has not been driven too far distally and penetrated the joint.

Tibial pins should not be too large (they are usually 50 to 60% of the medullary diameter at its narrowest point); they need to curve slightly as they pass down the shaft of the tibia. Once seated, the pin must be cut short enough so that it will not touch the femoral condyles at full extension of the stifle joint. The reduced pin size means a consequent reduction in stability. Therefore, IM pins should only be used for tibial fractures where significant compressive and rotational forces are not present.

Cerclage wire

It is technically very difficult to place an effective cerclage wire around the tibia. Unlike the case of femoral fractures, cerclage wire does not provide reliable additional support to IM pin repair, due to the shape of the tibia. Fractures of the distal third are an exception where, for a short length, the tibial diameter is uniform (**Figures 2** and **3**). This location has little soft tissue covering thus loop cerclage, rather than twist cerclage, wires must be used to prevent the wire protruding through the skin.

The shape of the tibia results in a compromise of three principles of cerclage wire application:

1. The wire must be tight and directly against the bone with no entrapped soft tissue. However, the proximal half of the tibia is triangular in cross section (**Figure 1**) which prevents application

of the wire directly against the bone. When the wire is tightened it contacts only the three points of the triangle. In addition, the numerous muscle origins (popliteus, medial and lateral heads of the deep digital flexor, caudal tibial) from the caudal aspect of the proximal half of the tibia makes effective muscle elevation for passage of cerclage wire difficult. The location of the popliteal/cranial tibial artery and the tibial nerve further complicates tissue elevation in this region;

2. If using twist cerclage rather than loop cerclage, to prevent loss of tension after placement, it is important that the knots are not cut less than three twists (cutting less than three twists can lose up to 20% tension) and that the twists are not bent over (bending the twists over to lie flat against the bone can result in up to 70% loss of tension). Lack of soft tissue on the craniomedial aspect of the tibia means that placement of twist cerclage via the standard craniomedial approach requires bending of the twists to lie flat and consequently knot tension is usually not maintained. Use of loop cerclage rather than twist cerclage will overcome this problem and is strongly recommended;

3. Avoid, if possible, placement of cerclage wire on a conical diaphysis (e.g., the proximal half and distal one-fifth of the tibia, **Figures 2** and **3**). Placement of the wire proximal to a transverse K wire or placement as a hemicerclage wire is needed to prevent slippage though probably does not maintain effective tension.

In the authors' opinion, cerclage wire has limited indications as an adjunct to the repair of tibial fractures for both biological and biomechanical reasons. Lag screws will provide superior interfragmentary compression with usually less soft tissue damage. Cerclage wire may be of use in distal tibial fractures where longitudinal fissures are present. In fractures of this nature the placement of cerclage wire to prevent further fractures during reduction and manipulation of the fractured tibia is often useful.

External coaptation

The use of external coaptation is only suitable in relatively simple tibial fractures. Full casts are reasonably good at preventing bending and rotational forces of low magnitude, which occur in simple transverse fractures in small or medium sized animals.

External coaptation is unsuitable for use in fractures where bending and rotational forces of high magnitude (such as in large breed or very active dogs) are expected. External coaptation is also unsuitable in comminuted fractures or in long oblique fractures as it cannot prevent collapse and overriding of the fracture fragments.

Bone Plates

Bone plates are very useful for the repair of tibial fractures (**Figure 6**). They can be used for grade I open fractures although for more severe open fractures such as grade 2 or 3 fractures, external fixators are preferable. Bone plates are applied to the medial aspect of the tibia. The use of the plate-rod technique is possible for the tibia although this procedure is technically more difficult than when applied to the femur (the narrowest part of the tibia is in the distal half and the limited widening in the distal tibial metaphysis makes distal screw placement more difficult).

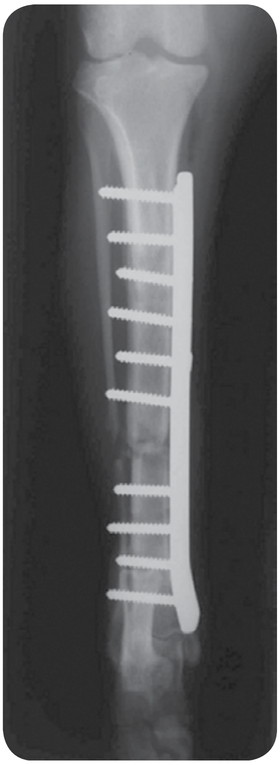

Figure 6: Radiograph of an 11-hole, 3.5mm broad dynamic compression bone plate applied as a buttress plate to the medial aspect of the right tibia, to repair a minimally comminuted fracture.

Tips on application of bone plates to the tibia

- Make a skin incision on the cranial aspect of the crus for the medial approach to the tibia. This approach will simplify closure and prevent the skin being closed directly over the plate. Wound breakdown over the distal tibia is a problem if this is not done.

- Intraoperative contouring of the bone plate, prior to application to the bone, is necessary due to the sigmoid shape of the tibia in a mediolateral and craniocaudal plane.
  - o The use of aluminium bending templates greatly simplifies contouring and they are a useful (and inexpensive) investment;
  - o When viewed from a medial aspect, the plate is applied to the line of 'best fit' and typically requires placement along the caudal edge of the proximal third;
  - o Bending of the plate can be done with either a bending press, bending pliers or bending irons;
  - o Slight twisting of the plate is usually necessary if the plate is applied to the full length of the tibia, to account for the 10-15° of tibial torsion. Whether twisting of the plate is necessary will be apparent from using a plate template and needs to be done with bending irons.

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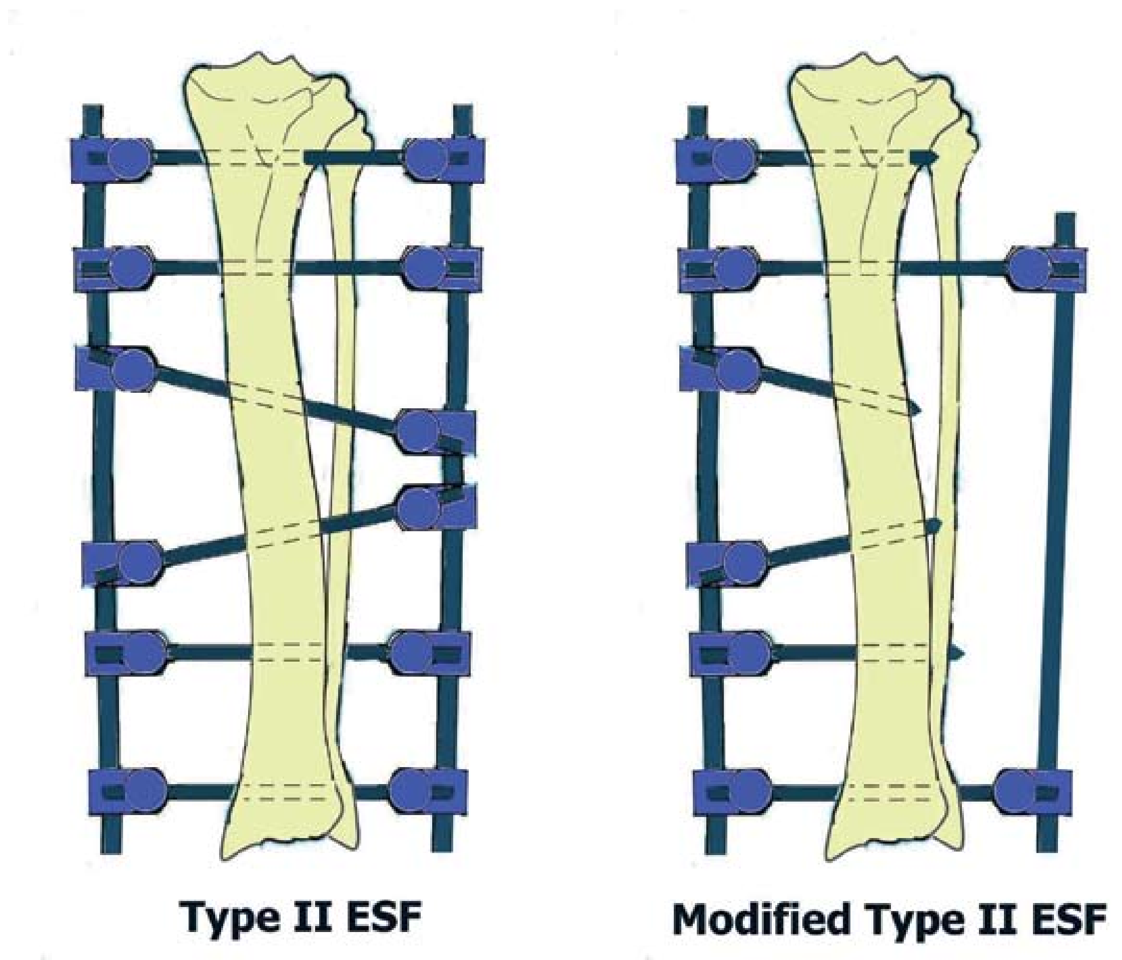

Figure 7: Graphic showing a type II ESF and a modified type II ESF.

Remember when applying bone plates to the distal tibia that the talocrural joint lies proximal to the medial malleolus by 0.5 to1cm. The distal tibial widens or flares at about a 20° angle to the long (saggital) axis of the tibia. If the most distal screw is placed perpendicular to the bone surface, rather than perpendicular to the long axis of the tibia, penetration of the talocrural joint may result.

External Fixators

External fixators (ESF) are the gold standard in the repair and management of open tibial fractures. The tibia is the easiest bone to which to apply an ESF. It is recommended that surgeons developing their ESF technique should work first on the tibia before repairing fractures of the radius and other long bones using this method.
All types of ESF can be applied to the tibia. The most useful ESF for the repair of tibial fractures are the type II and modified type II ESF (**Figure 7**).

Interlocking Nails

Interlocking nails (ILN) are effective for managing a variety of tibial fractures including comminuted and open fractures. They are the most commonly used method of treatment for tibial fractures in humans because they can be inserted by a closed technique with the use of fluoroscopy. As this imaging modality is not commonly available in veterinary practice, ILN are generally placed via an open or limited-open approach.
Unlike an IM pin, the interlocking nail can neutralise bending, rotational and compressive forces. Compared to a bone plate, the ILN has a similar bending strength although is slightly weaker in resisting torsional loads.
The largest nail that will fit, based on preoperative measurements of the medullary canal made from radiographs of the fractured leg, is used. Usually 8mm diameter ILN are suitable for large dogs, 6mm ILN for medium dogs and 4.7mm ILN for small dogs and cats.
ILN are larger, and therefore more rigid, than IM pins. For this reason, starting the pin medially and making allowance for it to bend as it passes distally is not possible. The ILN is inserted more centrally on the tibial plateau than an IM pin and for this reason must be recessed or countersunk to avoid subsequent damage to the stifle joint. Central placement of the ILN and recession and countersinking is made possible with the customised insertion device of an ILN. This is not possible with IM pin placement.

Tips on ESF application to the tibia

- Preplan the type of ESF you will be applying. Using an acetate sheet trace over the radiograph of the fracture and use this tracing to draw a template of the proposed ESF. This preplanning ensures that you will have enough equipment to apply the planned ESF and also simplifies application of the ESF.

- The type of construct that you will need should be determined on the basis of thorough fracture assessment. Remember that:
  - o Four pins per fracture fragment will provide the maximal stiffness;
  - o Pins should be spread evenly over the length of the fracture fragment (fracture configuration permitting) and the central pins (closest to the fracture line) should be 1-2cm from the fracture to provide maximal stiffness;
  - o Use threaded pins, preferably positive profile pins. They have a resistance to pull out four times greater than smooth pins,decrease the incidence of premature loosening of the pins and double the 'life' of an ESF. The most common complication with ESF, and the main reason for their failure, is loosening of the pins and consequent loss of stability before the fracture has fully healed. Using positive profile threaded pins will decrease the chances of this occuring;
  - o A traditional K-E (Kirschner-Ehmer) type I ESF is weak with mediolateral bending and in torsion. Consequently, type I ESF are only suitable for very simple fractures. More complex fractures require a type II ESF or a newer generation stronger ESF, such as the ImexTM SK, which uses carbon fibre or titanium connecting bars;
  - o A modified type II ESF is much simpler to apply than a full type II although it is less rigid. Application of a full type II requires some type of aiming device or the temporary use of a double connecting bar during drilling and placement of the pins.

- Avoid placing pins into the proximal lateral third of the tibia. This area is associated with a high incidence of loosening of the pins because of the bulk of the cranial tibial muscle and the soft tissue tension which develops from stifle joint movement. Placing half pins on the medial aspect of the proximal tibia and placing the full pin further distally is advisable.

- Use cancellous thread positive profile pins in the proximal tibia.

- Make a cranial skin incision if placing a type II ESF, to avoid having pins near the skin wound.

- Use an 'open-but-do-not-touch' approach for comminuted fractures where the bone column is not being surgically reconstructed.

- Place a bone graft in comminuted fractures. Consider a delayed bone graft in grade II and III open fractures.

- Hanging the leg from a roof bolt or support stand, provided this can be done in a sterile manner, simplifies application of an ESF. Remember that the natural torsion of the tibia means that the fracture will not be anatomically aligned while the leg is hung. It will be necessary to temporarily release the tension on the leg (raise the table or lower the support) to correctly align the fracture.

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