A PRACTITIONER’S GUIDE TO FRACTURE MANAGEMENT

Part 3: Selection of Internal Fixation Technique

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Fractures occur commonly in both dogs and cats and, therefore, are frequently seen in general practice. This series of articles has been presented in 3 parts, with:

• Part 1 describing fracture biomechanics, classification, and diagnosis
• Part 2 discussing selection of fixation technique, external coaptation, identification of bone healing, and potential complications.

This last article in the series addresses the options for internal fixation, including (Table 1):

- Intramedullary (IM) pins and cerclage wire
- Interlocking nails (ILNs)
- External skeletal fixators (ESFs)
- Bone plates and screws.

Selection of Internal Fixation Technique

Choice of internal fixation method is based on fracture classification, affected bone, concurrent injuries, open versus closed and, of course, the forces being counteracted by the fixation method (Table 2). In addition, consider the ability, or inability, to reconstruct the cylinder of the bone, which affects the choice of fixation type and, ultimately, determines whether the bone can share in load bearing during healing or whether load bearing is done entirely by the implant until healing has occurred.

<table>
<thead>
<tr>
<th>INVASIVENESS &amp; STABILITY</th>
<th>PRIMARY FIXATION</th>
<th>ANCILLARY FIXATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least invasive</td>
<td>External fixation</td>
<td>External coaptation (cast or splint)</td>
</tr>
<tr>
<td>Most unstable</td>
<td>Intramedullary (IM) pin and/or K-wires</td>
<td>Lag screws</td>
</tr>
<tr>
<td>Most invasive</td>
<td>External skeletal fixator (ESF)</td>
<td>Full cerclage</td>
</tr>
<tr>
<td>Most stable</td>
<td>Interlocking nail (ILN)</td>
<td>Hemi cerclage</td>
</tr>
<tr>
<td></td>
<td>Bone plates and screws</td>
<td></td>
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Note: Even though ESF and ILN are listed above bone plates and screws, the last 3 primary fixation methods offer complete stability depending on the fracture configuration; however, in general, ESF and ILN are less invasive than bone plates and screws.
INTRAMEDULLARY PIN WITH CERCLAGE WIRE

IM pin (and/or K-wire) and cerclage wire is probably one of the more common fracture fixation methods used in general practice. While cerclage wires are typically considered a method of ancillary fixation commonly used with IM pins, they can also be used with ESFs, ILNs, and bone plates.

**Indications**

IM pins resist bending loads well, but are poor at resisting rotational forces. For this reason, cerclage wires should always be added to IM pin fixation to help counteract axial and rotational forces. Cerclage wires also provide interfragmentary compression without damaging the blood supply or interfering with healing (unless they become loose). IM pins and cerclage wire fixation is limited to long oblique fractures and spiral fractures of the femur, tibia (Figure 1), and humerus.

**Benefits Versus Risks**

Advantages of IM pin and cerclage wire fixation include:

- Less cost for clients
- Ease of placement.

Disadvantages include:

- Requirement for open fracture stabilization
- Failure of IM pins used alone without cerclage wire
- Limited control of axial loads
- Pin migration or implant failure.

**Technique**

When using IM pins and cerclage wire fixation (see Orthopedic Hardware: IM Pin & Cerclage Wire, page 32):

1. Place IM pins into the medullary cavity of long bones (femur, tibia, or humerus) with either a drill or Jacobs chuck.

2. Insert the pin in either a normograde or retrograde fashion to avoid joint surfaces.

3. With this method of fixation, the IM pin should fill approximately 70% of the medullary cavity:

   - Measure the size of the canal on radiographs and select a pin that is 70% of the cavity or, alternatively, gauge size during surgery if the canal is exposed.

4. Use a minimum of 2 cerclage wires and place them:

   - Approximately 1 cm apart
   - At least 0.5 cm from the beginning and end of the fracture line
   - Perpendicular to the bone shaft.

5. The cerclage wires must be tight to provide adequate interfragmentary compression.

**Cautions**

When attempting IM pin and cerclage wire fixation of the tibia:

- Avoid the proximal articular surface and potential damage to the insertion of the cranial cruciate ligament; cerclage wire is also difficult to use around the tibia due to its triangular shape, which prevents placing appropriately tight cerclage.

**TABLE 2. Selection of an Internal Fixation Technique**

<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>INDICATIONS</th>
</tr>
</thead>
</table>
| Intramedullary pin + cerclage wire | • Long oblique fractures  
                                 | • Spiral fractures of femur, tibia, and humerus                          |
| Interlocking nails       | Fractures in which:  
                                 | • The bone cannot be reconstructed (eg, comminuted fractures)  
                                 | • Limited bone length is available proximally or distally  
                                 | • Very rigid repairs are required that counteract all forces and are entirely load bearing |
| External skeletal fixators | Open contaminated fractures in which:  
                                 | • The open wound requires wound therapy and bandage changes  
                                 | • Concern exists that placing implants, such as plates or IM pins, may lead to infection, osteomyelitis and, eventually, explantation |
| Bone plates & screws     | Any fracture in which there is enough bone length proximal and distal to the fracture to allow placement of 3 screws in each fragment, engaging a minimum of 6 cortices |

**FIGURE 1. Example of IM pin and cerclage wire for fixation of a long oblique tibial fracture in an immature dog.**
**Orthopedic Hardware: IM Pin & Cerclage Wire**

IM pins and Kirschner wires (K-wires) are made from 316L stainless steel. The difference between pins and K-wires is mainly diameter: IM pins—also referred to as Steinmann pins—are between 1.5 mm (1/16 inch) and 6.5 mm (1/4 inch) in diameter, while K-wires are 0.9 to 1.5 mm (0.035, 0.045, 0.062 inches) in diameter.\(^1\)

The most common pointed ends for IM pins are 3-sided trocar tips or 2-sided chisel tips: trocar tips are better suited for penetration of cortical bone, while chisel tips can be braced against the endosteal surface of the bone’s cortex or lodged in cancellous bone.\(^2\) Some IM pins may be partially threaded; however, when placed in the medullary cavity, partially threaded IM pins do not have any better holding power than standard smooth threaded pins (see **Cautions**).

Cerclage wire comes in various sizes, ranging from 0.635 mm (22 gauge) to 1.02 mm (18 gauge). The correct size must be used based on patient size: \(^1\)

- Cats and very small dogs: 20 to 22 gauge
- Small, medium, and large breed dogs: 18 to 22 gauge
- Giant breed dogs: 16 gauge.

**Never place IM pins into the radius due to high likelihood of joint penetration into the carpus or articular surface of the radial head.**

**Avoid stack pinning**—placing multiple small pins to replace one large pin—and threaded pins—those with a threaded endface; stack pinning does not provide any additional rotational support and threaded pins tend to fail at the thread pin interface.\(^1\)

**INTERLOCKING NAIL**

An ILN is similar to an IM pin, but is secured to the bone by bolts or screws that are placed proximal and distal to the fracture, passing through pre-existing holes in the nail. ILNs are similar to IM pins with regard to placement; however, they are superior for preventing rotational and shearing forces (due to the bolts/screws) and countering bending and compressive forces.

**Indications**

ILNs are useful for fractures in which the bone cannot be reconstructed, such as highly comminuted fractures. This fixation method typically results in very rigid repairs that can counteract all forces and are entirely load bearing until bone healing has progressed to callus formation. ILNs are also helpful when limited bone length is available proximally or distally, as their corresponding bolts do not require much available bone length for placement.

**Benefits Versus Risks**

Benefits of ILNs include placement with a minimally invasive technique, allowing the fracture hematoma to remain untouched. This principle of minimal disruption at the fracture site allows for healing to progress undisturbed, optimizing the biological environment for healing.

However, some of the same limitations seen with IM pin placement must be considered when placing ILNs: the articular surface must be carefully avoided during placement; thus, placement in the radius is not advisable and, while placement in the tibia is possible, it is slightly more challenging.

**Technique**

ILNs are locked in place with bolts or screws that penetrate the cortex and thread through pre-existing holes at the proximal and distal aspects of the nail. Depending on nail type and number of holes distally and proximally, the number of screws or bolts placed varies. During surgical placement, a jig must be used to ensure that the bolts appropriately line up with the holes in the nail.

A newer, angle-stable ILN (I-Loc, biometrix.com) was developed to overcome the concerns of instability in bending and torsion that is seen with traditional ILNs. It has a novel hourglass shape that provides increased strength due to a larger diameter...
at each end; furthermore, the hourglass shape allows for increased vascularity of the diaphyseal medullary canal. In multiple studies, this newer, angle-stable ILN was shown to be stronger and result in faster healing compared with traditional ILNs (Figure 2).

Cautions

Bolts are superior to screws, which are more likely to break due to a stress riser—a location in an object where stress is concentrated—between the head and neck of the screw. Earlier generation ILNs have also been shown to have a higher rate of breakage or bending compared to newer, angle-stable ILNs.¹

EXTERNAL SKELETAL FIXATION

External skeletal fixation involves transcutaneous placement of threaded pins or wires into fracture fragments; these pins or wires are then stabilized externally with clamps and rods or epoxy.

- Linear external fixators are created by using...

Linear ESF configurations can be classified based on pin and rod placement, including the number of planes the pins pass through in space, and how many skin surfaces are penetrated (Table 3).

- Pins should be positive profile pins—those with threads rolled onto the core diameter of the pin, creating an inner diameter of the threaded region equal to the shaft diameter and eliminating a stress riser effect.
- Avoid negative profile pins—in which the thread is machine cut into the pin shaft creating an inner diameter of the threaded region smaller than the shaft diameter—due to their considerable weakness at the pin thread interface.
- Avoid smooth pins—those with no threads—which have considerably less holding power. If smooth pins must be used, they should be angled at least 70° to the bone to improve holding power.

Table 3.
Classification of ESF Configurations

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CONSTRUCT</th>
<th>HARDWARE</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>Type Ia</td>
<td>Unilateral uniplanar</td>
<td>1 connecting bar Half pins</td>
<td>Least rigid construct available but sometimes appropriate for puppy greenstick fractures (Figure 3A)</td>
</tr>
<tr>
<td>Type Ib</td>
<td>Unilateral biplanar</td>
<td>2 connecting bars Ila: Full pins IIb: Half &amp; full pins</td>
<td>Increased stability relative to Type Ia due to additional pins across 2 planes (Figure 3A)</td>
</tr>
<tr>
<td>Type IIA</td>
<td>Bilateral uniplanar</td>
<td>3 connecting bars Ila: Full pins IIb: Half &amp; full pins</td>
<td>At least 2 pins that pass fully through the bone, with connecting rod on each end (Figure 3B)</td>
</tr>
<tr>
<td>Type IIB</td>
<td>Bilateral biplanar</td>
<td>4 connecting bars Full pins</td>
<td>At least 2 pins passing fully through the bone, but not all pins penetrate the skin adjacent to the far (trans) cortex (Figure 3B)</td>
</tr>
</tbody>
</table>

Figure 3. ESF classification: Differences between Types Ia and Ib (A) and Types IIA and IIB (B), and depiction of Type III (C).
transfixation pins or K-wires that are attached to a linear connecting bar using a clamp (Figure 3, page 33).

- **Circular external fixators** or ring external fixators allow the wires to engage the bone, with full or partial ring structure support, which consequently allows engagement of the bone circumferentially. This type of ESF can be very useful when available bone fragment size is small or short in length.

- **Hybrid fixators** can be created by combining ring and linear fixator components and are used to address, for example, distal tibial fractures or angular limb deformity of the distal tibia (Figure 4).

**Indications**

External skeletal fixation is diverse in its use and can be applied in a variety of fracture scenarios. It is an especially useful technique in patients with open contaminated fractures in which the open wound over the fracture requires local wound therapy and bandage changes. Another reason external skeletal fixation is often chosen to treat open fractures (and eventually removed altogether once the fracture has healed) is due to concern that placing implants, such as plates or IM pins, in a contaminated fracture may lead to infection of the implant and osteomyelitis, with eventual need for explantation.

**Benefits Versus Risks**

A benefit of ESFs is the ability to segmentally destabilize them over time as the fracture begins to heal, allowing more load bearing by the bone itself in a slow, controlled manner. Once the fracture has been assessed by radiographs and determined completely healed, the construct is removed entirely. However, caring for ESFs can be challenging for owners because the constructs are often bulky and may damage furniture or get caught on household items.

**Technique**

Regardless of construct, an ESF requires placement of at least 2 pins proximally and 2 pins distally. However, it is ideal to place at least 3 pins proximally and 3 pins distally, engaging a total of 6 cortices on either side.
of the fracture. See Orthopedic Hardware: Linear ESF (page 33) for further details on using linear ESFs.

Follow-Up
Since constructs can damage, or get caught on, household items, the ESF frame should be bandaged, which requires checks every 7 to 10 days to evaluate the frame and change the bandage. In addition, while the implants are in place, during each check the skin–pin interface should be monitored and cleaned regularly to prevent superficial infections or draining tracts.

BONE PLATES & SCREWS
Bone plating is ideal for preventing many of the potential forces that will be imposed on the fracture, including compression, shearing, rotation, and bending. The plate–bone construct is weakest in regard to bending forces; therefore, the plate is always placed on the tension side of the bone. An IM pin can be combined with a plate to enhance bending strength (Figure 5).

Indications
Bone plates can be used for almost any fracture type if there is enough bone length proximal and distal to the fracture to allow for placement of 3 screws in each fragment, engaging a minimum of 6 cortices. This general rule can be used to determine the length and type of plate that should be applied in any given situation.

A bone plate used in a buttressing fashion is designed for metaphyseal fractures to prevent collapse of the area adjacent to an articular surface due to compressive forces. A plate used in a bridging fashion (in old terminology used interchangeably with buttressing) is designed to act as an internal splint to maintain the correct length and normal axial alignment when fracture ends cannot be anatomically reconstructed. More simply, this placement bridges the fracture site to hold the bones in reduction and alignment, allowing the bone to heal.

Technique
Bone plates (see Orthopedic Hardware: Bone Plates & Screws, page 36) can be placed in bridging, buttressing, or compressing fashion, depending on the fracture type.

• Bridging and buttressing fashion: Used for fractures that cannot be readily reconstructed or for long bone fractures in which the length of bone must be restored and maintained in the face of comminution and bone loss.

• Compressing fashion: Used when the bony column can be reconstructed and the ends of the fracture fragment can be compressed together, which allows the bone to share in load bearing during the healing process.

Screws are placed in either neutral or compressing fashion dependent on planned use of the plate. Additionally, independent of use in the plate, screws can be placed in lag fashion to apply compression across a fracture line—a method commonly used with humeral or femoral condylar fractures (Figure 6):

• The near (cis) cortex is drilled to the same diameter of the screw threads (glide hole), while the far (trans) cortex is drilled slightly smaller than the core diameter of the screw.

A screw used in a neutral fashion (also known as a plate screw) is placed in the center of the screw hole only to hold the plate in place.

A screw used in a compression fashion allows movement of the bone fragment relative to the plate as it is tightened, leading to compression of the fracture. Screw holes in compression plates have an oval shape (rather than the round shape seen in noncompression plates) that allows the screw to be placed at one end of the oval.
Screws used to secure bone plates may be traditional or self-tapping, and are typically:
- **Cortical screws** for diaphyseal bone: Designed to engage cortical bone, with smaller pitch and less depth of the thread
- **Cancellous screws** for metaphyseal bone: Designed to engage metaphyseal or epiphyseal bone, with larger outer diameter, deeper thread, and larger pitch.

Several plate types exist, including:
- **Traditional plates**, such as the dynamic compression plate and limited contact dynamic compression plate
- **Locking plates**, such as PAX plates (seuros.com), ALPS plates (Kyon.ch), Synthes LCP (us.synthesvet.com), and string of pearls plates (orthomedinc.com) as well as others.

With **traditional plates**, screws hold the plate in close contact with the bone, creating friction between the bone plate and bone and securing the construct. The axial load through the bone actually creates a shearing force at the screw–bone interface. Therefore, to minimize screw and plate failure, it is important that the plate be well contoured and fitted to the bone, with no soft tissue between the plate and bone.

With **locking plates**, the screw heads thread into the plates, creating a locked fixed-angle system that behaves more like an ESF and does not require friction between the bone and plate. In addition, the axial force through the bone creates a compressive force at the screw–bone interface.

In theory, locking plates create a stronger and stiffer construct compared with traditional plates and potentially reduce the number of cortices needed for engagement to create an acceptable stable construct, eliminating the need to engage the trans cortex. However, if possible, bicortical screws should always be placed to:
- Increase strength of the construct
- Decrease likelihood for screw back out
- Resolve need for perfect plate contouring and removal of soft tissue.

Other specialized plates exist for use in specific anatomic regions, such as T-shaped plates for the proximal tibia or distal radius, L-shaped plates for the distal femur, and curved plates designed specifically for acetabular fractures.

**References**

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