A PRACTITIONER'S GUIDE TO FRACTURE MANAGEMENT

Part 2: Selection of Fixation Technique & External Coaptation

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Fractures occur commonly in both dogs and cats and, therefore, are frequently seen in general practice. It is important for veterinarians to understand:

- Fracture biomechanics, classification, and diagnosis
- Selection of correct fixation method
- Identification of bone healing and complications (if they occur).

In Part 1 of this series, fracture biomechanics, fracture classification and diagnosis, and selection of proper fixation technique were addressed. In this article, selection of fixation technique is further discussed, along with the specifics of external coaptation, identification of bone healing, and potential complications. The last article in this series will address several different internal fixation methods.

SELECTION OF FIXATION METHOD

Components to Consider

When approaching fixation selection, the following components should be evaluated:

1. Potential fixation methods (**Table 1**)
2. Patient, client, fracture, and veterinarian factors (**Table 2**, page 24)
3. Pros and cons of each method
4. Whether opposing forces (**Table 3**, page 24) can be counteracted with a particular fixation method.

Approaches to Fixation

In the past, fracture fixation has been approached in 2 ways:

1. Anatomic reconstruction with rigid internal fixation ("the carpenter")
2. More recently, minimal reconstruction to preserve blood flow to the fracture site ("the gardener").

TABLE 1.
Fracture Fixation Methods

INVASIVENESS & STABILITY	PRIMARY FIXATION	ANCILLARY FIXATION
Least invasive Most unstable ↓ Most invasive Most stable	**External Fixation**	
	External coaptation (cast or splint)	
	Internal Fixation	
	Intramedullary (IM) pin and/or K-wires	Lag screws
	External skeletal fixator (ESF)	Full cerclage
	Interlocking nail (ILN)	Hemi cerclage
	Bone plate and screws	

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.*

TABLE 2.
Factors to Consider When Choosing Fracture Fixation Method

Patient	Size, age, body condition, breed, activity level
Client	Finances, compliance, husbandry
Fracture	Configuration, location, forces, contamination
Veterinarian	Understanding of biomechanics and healing, knowledge of particular implants, experience and skill level, implant availability

TABLE 3.
Five Main Forces That Act on Bone

The most common forces acting on bone, and those that MUST be counteracted with bone fixation, are:

1. Bending
2. Compression
3. Shearing
4. Tension
5. Torsion

Ideally, a middle ground for fixation should be identified that:

- Stabilizes the fracture site to allow bone healing, but is not so rigid that fixation delays bone healing
- Preserves blood flow to the fracture, and does not disrupt the blood clot at the fracture site during surgery.

Choosing Between External & Internal Fixation

Counteracting Forces
External coaptation can effectively counteract *bending* and *rotational* forces, provided the joints above and below the fracture are immobilized. However, fractures subjected to *compression*, *shearing*, and/or *tensile* forces require internal fixation. Furthermore, comminuted and long oblique fractures are not ideal for external coaptation.

Fracture Reduction
When external coaptation is chosen, fracture reduction greatly increases the chances for primary fixation healing. The "50/50 rule" applies, and states that *fracture ends should have at least 50% contact to expect fracture healing*. Unfortunately, this rule also states that *50% reduction is the absolute minimum for bone healing to be possible, not probable*. If the fracture cannot be reduced appropriately, then some type of internal fixation should be pursued instead.

EXTERNAL COAPTATION

External coaptation is defined as *the use of bandages, splints, casts, or other materials to aid in stability and support for soft and osseous tissues*. Furthermore, external coaptation can help manage wounds and control edema.

Indications

External coaptation can be used as either:

- Primary fixation for a fracture
- Ancillary fixation to provide additional support (ie, after bone plating a radius/ulna fracture), or
- Temporary fixation for an open fracture and/or until definitive surgical correction can take place.

External coaptation should only be used in fractures distal to the elbow and stifle, as correct application requires immobilization of the joints above and below the fracture. Certain splints, such as spica splints, can help immobilize more proximal injuries (humerus and femur); however, given the location of these fractures, external coaptation may create a fulcrum effect with the bandage.

Fracture Alignment

Fracture alignment is imperative to limb function. Once the bandage/splint has been applied, assess both reduction and rotational alignment with radiographs. Joint stiffness is common after immobilization; therefore, place and develop the bandage/splint to achieve maintenance of a neutral standing position.

There are a number of different types of splints available, ranging from spoon splints to tongue depressors (as used with small puppies and kittens). We prefer to use fiberglass, which allows a custom-made molded splint to be created. These can be placed either palmar or lateral in the forelimbs or lateral in the hindlimbs.

Temporary Fixation

Temporary fixation with external coaptation can help improve patient comfort, reduce swelling, and provide a protective covering for open fractures prior to definitive fixation and/or surgical correction.

If external coaptation is used:

1. Attempt to reduce the fracture prior to applying external coaptation.
2. If there is an open fracture, immediately flush the wound and debride dead tissue.
3. After appropriate wound care, cover the exposed

bone and/or wound with a sterile dressing.

4. Apply temporary fixation, which may include only a soft padded bandage, such as a Robert Jones bandage, or a splint, such as a fiberglass, spoon, or plastic splint, incorporated into the Robert Jones bandage.
5. After bandage/splint placement, take a radiograph to ensure alignment.
6. With open fractures, change the temporary bandage daily to allow for wound care prior to definitive fixation.

Unfortunately, since external coaptation is only recommended for fractures distal to the elbow and stifle, temporary stabilization of humeral and femoral fractures should not be attempted. In these cases, hospitalization with confinement to a crate (along with analgesic relief) may be ideal while awaiting definitive fixation.

Primary Fixation

Ideal fractures for primary fixation using external coaptation include incomplete diaphyseal tibial fractures in young dogs, sometimes referred to as "greenstick fractures." These fractures are often incomplete, minimally or nondisplaced, and have an intact fibula that increases stability overall.

Benefits versus Risks. Benefits of external coaptation for primary fixation include avoidance of a surgical procedure and less cost for the client. The risks, however, include:

- Potential fracture instability, resulting in poor healing (delayed, nonunion, or malunion)
- Frequent bandage changes, especially if the bandage becomes wet or soiled
- Limb stiffness from lack of mobility and/or osteoarthritis from joint immobilization
- Cast sores (63% morbidity with external coaptation[1]) (**Figure 1**).

Another risk is eventual need for surgery if healing fails to progress, which is especially of concern in small breed dogs with radius/ulna fractures. Although these fractures may be minimally displaced and appear to lend themselves to external coaptation, in small breed dogs the blood supply in the distal radius is decreased compared with large breed dogs, putting small breed dogs at a higher risk for healing complications.[2] In small and toy breed dogs, 83% of distal radius/ulna fractures addressed with external coaptation alone result in malalignment or nonunion.[3,4] Therefore, internal fixation is recommended for these fractures in small and toy breed dogs.

Technique. Ideally, sedate or anesthetize the patient for fracture alignment and splint placement. Then apply a soft padded bandage and fiberglass splint made specifically for the patient. The splint should span the joint above and below the fracture, and be padded enough to prevent pressure sores and prevent movement of the limb within the bandage. Radiographs should be obtained after bandage application to confirm appropriate fracture reduction.

Follow-Up. Initially, the bandage may need to be changed every 1 to 3 days, especially if a wound is present that requires ongoing management. Otherwise, change the bandage a minimum of every 10 to 14 days to assess the limb for pressure sores or other bandage complications, such as contracture, rotational malalignment, or dermatitis. Instruct the client to keep the bandage clean, dry, and intact as well as to monitor the patient's toes for any evidence of swelling or pain.

In puppies with greenstick fractures, radiographs can be obtained as soon as 2 to 4 weeks after the injury due to rapid bony healing. A bony callus, spanning a minimum of 3 cortices on orthogonal

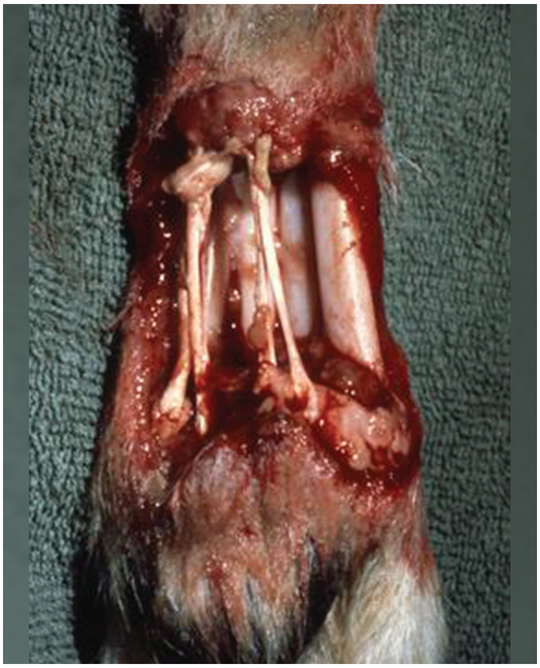

FIGURE 1. Morbidity associated with external coaptation: The end of the bandage became wet, but the bandage was not changed. The result was a moist dermatitis that led to tissue sloughing and significant soft tissue trauma. Not only did the fracture still need to heal, but the lesion required extensive wound management and reconstruction.

radiographic views, typically confirms radiographic healing of the fracture. The callus should span the fracture gap on 3 of the possible 4 cortices: medial, lateral, cranial, and caudal.

Ancillary Fixation

External coaptation can be used as ancillary fixation to provide additional support in patients with radius/ulna fractures that, for example, have already undergone bone plating. As mentioned earlier, distal radius/ulna fractures, especially those in small and toy breed dogs, addressed with external coaptation alone commonly result in malalignment or nonunion.

Schroeder-Thomas splints are *never* recommended for fracture stabilization. Schroeder-Thomas splints are traction devices constructed of wire frame and soft bandage material. Since the splint does not adequately immobilize the shoulder or hip joint, it is considered contraindicated in humeral and femoral fractures.

IDENTIFICATION OF BONE HEALING

While a complete description of the physiology of bone healing is beyond the scope of this article, in general, bone healing of a stable fracture occurs through direct bone healing as opposed to indirect bone healing, which is seen with unstable fractures or certain fractures addressed with external coaptation as a primary means of fixation.

Direct (Primary) Bone Healing

Direct bone healing tends to take one of 2 forms:

1. Contact healing
2. Gap healing.

Contact healing occurs when the defect between the bone ends is less than 0.01 mm. With contact healing, cutting cones—an osteoclastic tunneling process—develop, resulting in direct formation of lamellar bone oriented in the normal axial direction of the bone.

Gap healing occurs when the bone ends are less than 0.8 mm to 1 mm apart. With gap healing, the initial fracture site undergoes intramembranous bone formation, with lamellar bone oriented perpendicular to the axial direction of bone. Due to the perpendicular direction of bone formation, the fracture site remains relatively weak. Haversian remodeling begins 3 to 8 weeks after fracture fixation, allowing bone to develop in a more longitudinal fashion.

In a more general sense, bone union and remodeling occur simultaneously with contact healing; with gap healing, they are instead sequential steps.[5]

Indirect (Secondary) Bone Healing

Indirect bone healing occurs in unstable fractures or fractures treated with external coaptation as a primary means of fixation.

The most characteristic feature of indirect bone healing is formation of an intermediate callus prior to bone formation. As the bone heals, the tissues pass through different stages of increasing stiffness and strength. In general, the amount of callus is related to the amount of instability present at the fracture site; the greater the instability, the greater the amount of callus.

Much like wound healing, indirect bone healing has 3 overlapping phases:

1. **Inflammation:** This phase traditionally lasts 3 to 4 days or longer, and is characterized by a fibrin-rich clot at the fracture site. This clot releases growth factors to simulate bone healing and potentially acts as a scaffold for migration of inflammatory and reparative cells.
2. **Repair:** During this phase, the clot is slowly replaced by granulation tissue, which adds slight mechanical strength. As collagen fibers become more abundant, granulation tissue is replaced by connective tissue and, after formation of connective tissue at the fracture site, resident mesenchymal cells differentiate into chondrocytes to form cartilage. With the help of growth factors, such as bone morphogenic proteins, the cartilage begins mineralizing to form woven bone.
3. **Remodeling:** This phase is characterized by a slow adaption of the bone to regain its original function and strength. It is a very slow process (up to 6–9 years in humans) that represents 70% of the fracture's total healing time. The action of osteoclastic resorption and osteoblastic deposition is guided by Wolff's law.[5]

Radiographic Evidence

Radiographic evidence of bone healing is noted by the general disappearance of the fracture line.

Radiographic Signs of Normal Indirect Bone Healing

Following is a typical timeline for radiographic signs of normal indirect bone healing:

- **5 to 7 days after trauma:** Widening of the fracture gap and "smudging" of the fracture edges
- **10 to 12 days:** Appearance of a bony callus
- **Within 30 days:** Disappearance of the fracture line
- **90 days after repair:** Complete remodeling of the callus

Adapted from Johnson A, Houlton J, Vannini R. AO Principles of Fracture Management. New York: Thieme Medical Publishers, 2005.

With **direct bone healing**, formation of an external callus and resorption of the fracture ends should not be present; however, the cutting cones across the fracture gap may create a loss of radiopacity in the area.

With **indirect bone healing** (as seen with external coaptation or unstable fracture fixation):

- Initial resorption of the fracture ends is noted radiographically by loss of radiopacity and widening of the fracture gap; this process can be noted around 5 to 7 days after the injury.
- Callus formation is not noted radiographically until it becomes mineralized; however, there is typically some phase of tissue healing present in the fracture site, such as a hematoma, granulation tissue, and connective tissue, which are all components of indirect bone healing.
- The callus is noted first as a collar around the fracture site (the periosteal component), which may be seen as early as 10 to 12 days after repair (**Figure 2**).
- As healing progresses, the callus becomes more identifiable, the fracture ends become more radiopaque, and the fracture line begins to disappear (**Figure 3**).

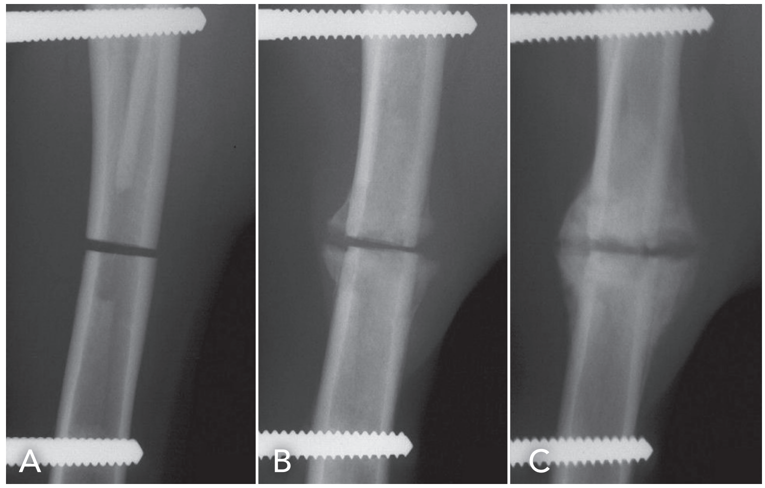

FIGURE 2. Example of indirect bone healing in an experimentally created fracture in a research study: Note the initial sharply marginated fracture ends (**A**); over time there is slight resorption, with the beginning of callus formation (periosteal component) (**B**), and between the fracture ends there would be some phase of tissue healing. As the fracture continues to heal, the callus formation becomes larger (**C**). *Courtesy* Journal of Bone & Joint Surgery

FIGURE 3. A right radius/ulna fracture in a 10-month-old boxer puppy that was treated by external coaptation (note that primary fixation is indicated in this case), showing secondary bone healing at 4 weeks (**A**), 8 weeks (**B**), and 12 weeks (**C**) after injury. Note that over time the ulnar fracture develops a slight callus formation. As the tissues in the fracture gap are slowly transitioning into bone, the fracture line begins to slowly disappear. Due to using external coaptation, there is thinning of the cortical diaphysis of the ulna resulting from immobilization.

Wolff's law

—a theory developed by German anatomist and surgeon Julius Wolff—states that bone in a healthy person or animal will adapt to the loads under which it is placed or, more simply, bone adapts to pressure, or a lack of it.

COMPLICATIONS

Numerous complications can occur with bone healing and fracture repair.

Infection

With open fractures or surgical site contamination, infection is a potential risk that can lead to implant infection, osteomyelitis, and potential sequestrum formation.[6]

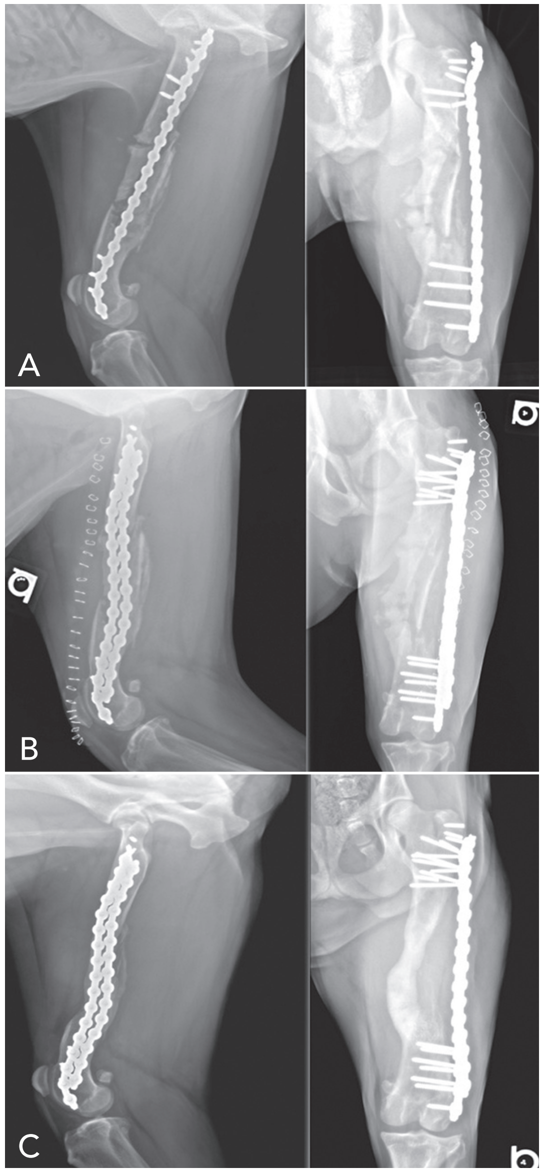

FIGURE 4. Lateral and craniocaudal radiographs after patient presented for sudden onset of right hindlimb lameness approximately 4 weeks after fracture repair (**A**). Note the IM pin was removed approximately 1 week prior to the sudden onset of right hindlimb lameness because it was migrating and causing irritation; on the craniocaudal view, note that all of the proximal screws have broken, leaving the fracture unstable. Immediate postoperative lateral and craniocaudal radiographs (**B**) of a revision that replaced screws in the proximal segment and augmented the fixation with a second plate for additional stability. Four-month postoperative lateral and craniocaudal radiographs (**C**) revealing fracture healing; note that the bone altered its shape during healing; however, due to maintenance of axial alignment, the alteration did not create a clinically significant problem.

Further information

on orthopedic complications is available in the article, **Orthopedic Follow-Up Evaluations: Identifying Complications** (September/October 2014), available at tvpjournal.com.

Implant Failure

Implants are under constant load while the bone is healing and are at risk of implant failure when put through cyclic strain due to excessive motion of fracture fragments, overuse of the limb, or poor confinement of the patient. Implant failure can occur in the form of screw back out or breakage, plate bending or breakage, bending of IM pins, breakage of ILN screws or bolts, breakage or migration of cerclage wire, or loosening of external fixator pins. Implants can also fail due to infection of the implants, or poor healing qualities of the bone (**Figure 4**).

Poor Bone Healing

Poor healing of the bone can lead to delayed union, nonunion, or malunion.[7]

Delayed unions can be caused by too much motion or poor healing properties of the bone at the fracture site, which causes the healing to be prolonged (normal healing is approximately 8–12 weeks).

Nonunions—in which the fracture fails to progress regardless of healing time—occur when delayed unions are not managed appropriately. Based on radiographic evaluation, nonunions can be classified as viable or nonviable.

Viable nonunions are classified as:

- Hypertrophic: Considerable callus and "elephant's foot" appearance on radiographs
- Moderately hypertrophic: Lesser degree of callus formation and "horse's foot" appearance on radiographs
- Oligotrophic: No radiographic evidence of bone healing; hard to distinguish from a nonviable nonunion.

Nonviable nonunions are classified as:

- Dystrophic: Nonviable bone on either side of the fracture
- Necrotic: An infected section of bone, specifically a sequestrum, which is biologically dead
- Defect: Gap at the fracture site that is too large for normal healing to occur
- Atrophic: Nonviable nonunions in which dead bone is removed by the host without a healing response.

Malunions result when fractures heal with the limb in improper alignment and can manifest by shortening of the limb, malalignment of proximal and distal joints relative to each other, rotational abnormalities, and varus or valgus deformities.

IN SUMMARY

The last article in this series, available in an upcoming issue of *Today's Veterinary Practice*, will discuss the various types of internal fixation methods for fracture management.

ESF = external skeletal fixator; ILN = interlocking nail ; IM = intramedullary

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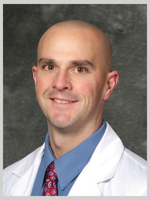

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