Fractures occur commonly in both dogs and cats. While typically fractures occur after a traumatic incident, such as being hit by a car or falling from a height, some fractures occur following a pathologic weakening of the bone, which is seen with certain neoplastic conditions, such as osteosarcoma.

Since fractures are frequently seen in general practice, it is important for veterinarians to understand fracture biomechanics as well as how to:

- Classify and diagnose fractures
- Choose the correct fixation to ensure proper bone healing
- Identify bone healing
- Address complications, if they occur.

In Part 1 of this 2-part series, fracture biomechanics, fracture classification and diagnosis, and factors to consider when selecting a fixation technique are discussed. In Part 2, selection of fixation technique and specific techniques, identification of bone healing, and potential complications will be addressed.

**Fracture Biomechanics**

Bone is an amazing tissue with complex properties that allow it to adapt to its environment but typically conserve its general structure and shape. By following Wolff’s law, bone adapts and changes in areas of high stress, while minimizing changes in areas of low stress. Basically, bone is shaped for the greatest strength while, at the same time, minimizing bone mass that would contribute to increased weight of the animal.

**Qualities of Bone**

Bone is considered both viscoelastic and anisotropic:

- The viscoelastic property of bone states that the strength of bone depends on the rate upon which it is loaded. For example, bone is stronger when it is loaded rapidly versus slowly (ie, the more rapidly bone is loaded, the more inflexible it becomes). However, once any bone reaches a failure point of loading, it will fracture.

- The anisotropic nature of bone suggests that bone strength is dependent on the direction in which it is loaded. For example, bone is stronger when loaded longitudinally versus transversely, which explains why bone is more likely to fracture with sudden high impact placed transversely upon the bone.

**Fracture Forces**

Bone is subject to many forces; a fracture occurs when the sum of these forces exceeds the ultimate strength of the bone. Therefore, understanding the forces placed upon bone is crucial to counteracting these forces when stabilizing a fracture.

**TABLE 1.**

<table>
<thead>
<tr>
<th>Five Main Forces That Act on Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>The most common forces acting on bone, and those that MUST be counteracted with bone fixation are:</td>
</tr>
<tr>
<td>1. Bending</td>
</tr>
<tr>
<td>2. Compression</td>
</tr>
<tr>
<td>3. Shearing</td>
</tr>
<tr>
<td>4. Tension</td>
</tr>
<tr>
<td>5. Torsion</td>
</tr>
</tbody>
</table>
The 5 main forces that act on bone are listed in Table 1.

- **Tensile (tension) forces** act to lengthen the bone, while **compressive forces** shorten the bone.
- **Shearing forces** are typically parallel or tangential to the bone, while **torsional forces** act to twist bone about its long axis.
- **Bending forces** create a convex side of the bone (bone loaded in tension on the convex side) and a concave side (bone loaded in compression on the concave side). Bending forces are typically referred to as moments.

**FRACTURE DIAGNOSIS & CLASSIFICATION**

**Patient Stabilization**

Because most fractures result from trauma, it is important to ensure patient stability prior to focusing on the fracture. Ideally, for any patient that presents after a traumatic event:

1. Check and stabilize vitals (temperature, pulse quality and heart rate, respiration rate, blood pressure, pulse oximetry), if needed.
2. Perform thorough physical, orthopedic, and neurologic examinations.
3. Pursue initial diagnostics, including blood analysis, thoracic and abdominal radiographs, and an AFAST ultrasound.
4. Resolve any life-threatening issues, which means that surgery may need to be delayed for several days due to conditions, such as pulmonary contusions or hypovolemia.
5. Administer proper analgesia as soon as possible: Ideal analgesics are pure mu opioids, such as:
   - Morphine: Dogs, 0.5 to 2 mg/kg; cats, 0.05 to 0.4 mg/kg; IV or IM Q 6 to 8 H
   - Hydromorphone: Dogs/cats, 0.05 to 0.2 mg/kg IV or IM Q 6 to 8 H
   - Oxymorphone: Dogs/cats, 0.05 to 0.2 mg/kg IV or IM Q 6 to 8 H
   - Methadone: Dogs, 0.05 to 0.3 mg/kg; cats, 0.1 up to 0.3 mg/kg; IV or IM Q 6 to 8 H
   - Fentanyl: Dogs/cats, 2 mcg/kg loading dose followed by 2 to 10 mcg/kg/H CRI (caution with cats).

Other opioids, such as butorphanol, do not typically provide adequate analgesia.

**Post Stabilization Diagnostics**

Once the patient is deemed stable:

1. Obtain a thorough history: It is important to separate traumatic from pathologic fractures by determining the cause of the fracture, such as hit by car or fall from a height.
2. Evaluate physical examination findings: Signs of fractures include pain, swelling, reluctance to bear weight, crepitus, and/or angulation deformities.
3. If the patient is nonambulatory on the affected limb, perform a complete neurologic examination to rule out any neurologic defects, such as:
   - Radial nerve damage—seen with distal humeral fractures
   - Sciatic nerve damage—seen with ilial fractures.

Radiographs are the mainstay for determining fracture type and location. Key radiographic projections are orthogonal views, including lateral, craniocaudal, and oblique (if needed) views. If only a lateral view is taken, some fractures, such as T-Y humeral fractures that involve both the articular surface of the distal humeral condyle and the supracondylar region, will be missed (Figure 1).

**Fracture Classification**

To improve communication between veterinarians and clients, and between veterinarians themselves,
Fractures must be correctly identified and classified. Fractures are initially classified by anatomic location, such as articular, physeal, epiphyseal, metaphyseal, or diaphyseal (Figure 2). Certain fractures are further subclassified based on anatomic locations, such as condylar, supracondylar, trochanteric, or subtrochanteric.

Based on radiographs, fractures are classified by severity, such as:

- **Incomplete**: Fracture through only one cortex
- **Complete**: Fracture through both cortices
- **Comminuted**: Multiple fragments (Figure 3)
- **Segmental**: Two or more separate fractures.

The term *compound fracture* is no longer used for fracture classification.

Typical fracture patterns consist of:

- **Transverse**: Fracture is perpendicular to axis of the bone and is the diameter of the bone
- **Oblique**: Fracture is diagonal to axis of the bone
  - Short oblique: Fracture is < 2× the diameter of the bone
  - Long oblique: Fracture is > 2× the diameter of the bone (Figure 4).
- **Spiral**: Oblique fracture with a twist
- **Avulsion**: Fractures classified as either:
  - Enthesis: Fracture at attachment of a joint capsule
  - Apophysis: Fracture at origin or insertion of a tendon or ligament; an example of an apophysis fracture is an olecranon fracture (Figure 5).
- **Growth plate**: See Salter Harris Fractures.

Displacement should also be recognized when classifying fractures; full orthogonal radiographs are needed to fully characterize displacement. This property is based on the degree of displacement of the distal segment in relation to the proximal segment. An example is caudoproximal displacement, which is seen with most distal diaphyseal femoral fractures.

Further classification of fractures should incorporate level of contamination—whether the fracture is closed (intact skin) or open. Open fractures are further subclassified as:

- **Type I**: < 1 cm puncture; fragment briefly penetrated the skin

---

**Figure 2.** Anatomic classification of long bones helps describe fracture location.

**Figure 3.** Lateral radiograph of mid-diaphyseal right comminuted femoral fracture due to trauma associated with a bullet (A). Cranio-caudal radiograph of same femoral fracture (B). When both views are compared, caudoproximal and medial displacement can be seen. Note markers indicating right or left are not present; they were cropped out for magnification purposes, but should always be included in radiographs.

**Figure 4.** Classification of transverse, short oblique, and long oblique fractures of a femur.
Salter Harris fractures (SH) are growth plate (physeal) fractures in immature animals. They are classified based on the prognosis for continued physeal growth (with type I less likely and type VI more likely to have long-term effects on mature bone length):

- **SH I fracture**: Involves a fracture through the physis itself (Figure 6)
- **SH II fracture**: Involves the physis and extends into the metaphysis
- **SH III fracture**: Involves the physis and extends into the epiphysis; considered an intra-articular fracture
- **SH IV fracture**: Involves the physis and extends into both the metaphysis and epiphysis; considered an intra-articular fracture
- **SH V fracture**: Compression fracture through the physis
- **SH VI fracture**: Compression fracture through only a portion of the physis that typically results in angulation deformities after maturity.

<table>
<thead>
<tr>
<th>Table 2: Fracture Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bone</td>
</tr>
<tr>
<td>2. Location</td>
</tr>
<tr>
<td>Articular, physeal, epiphyseal, metaphyseal, diaphyseal</td>
</tr>
<tr>
<td>Subclassification: Condylar, supracondylar, trochanteric, subtrochanteric</td>
</tr>
<tr>
<td>3. Configuration</td>
</tr>
<tr>
<td>Severity: Incomplete, complete, comminuted, segmental</td>
</tr>
<tr>
<td>Pattern: Transverse, oblique (short or long), spiral, avulsion (enthesis or apophysis), growth plate</td>
</tr>
<tr>
<td>4. Displacement</td>
</tr>
<tr>
<td>5. Contamination</td>
</tr>
<tr>
<td>Closed, open</td>
</tr>
<tr>
<td>Subclassification of open: Type I, type II, type III</td>
</tr>
</tbody>
</table>

In summary, fracture classification provides an accurate description that is important when determining fixation approach (Table 2). For example, the fracture in Figure 7 (page 22) is classified as a right closed mid-diaphyseal comminuted femoral fracture; there are multiple pieces but, in general, caudoproximal and medial displacement are present.

**FIXATION FACTORS**
Several options exist for fracture stabilization, and several factors must be considered when deciding on an appropriate fixation method:

- Patient factors: Size, age, weight, breed, activity level
- Client factors: Finances, compliance, husbandry

**Salter Harris Fractures**

**FIGURE 6.** Salter Harris I fracture of the proximal right humeral growth plate.

**FIGURE 5.** An olecranon fracture is an example of an apophysis fracture. In this radiograph, the pull of the triceps is causing proximal displacement of the fracture fragment (arrow). Fixation for this fracture would involve counteracting the force of the triceps, such as a tension band fixation.

**FIGURE 5.** An olecranon fracture is an example of an apophysis fracture. In this radiograph, the pull of the triceps is causing proximal displacement of the fracture fragment (arrow). Fixation for this fracture would involve counteracting the force of the triceps, such as a tension band fixation.
Fracture factors: Configuration, location, forces, contamination

Veterinarian factors: Understanding of biomechanics and healing, knowledge of particular implants, implant availability.

The goal is to select the appropriate fixation method for each individual fracture based on these described factors. For example, even though an intramedullary pin set and cerclage wires are available, this does not mean that every fracture should receive this fixation.

In addition, when we approach fixation selection, we always evaluate the list of fixation methods (Table 3), pros and cons of each method, and previously described factors. In addition, we determine whether all the opposing forces (Table 1) can be counteracted with a particular fixation method.

**WHEN TO REFER**

An important concern when addressing fractures is to understand when to refer the patient to an orthopedic surgeon, based on consideration of the type of fracture, patient comorbidities, availability of appropriate fixation techniques, client resources, and the practitioner’s experience.

SH = Salter Harris

**Reference**