Unfortunately, as is the case with human beings, it is not uncommon that dogs and cats break a bone at some point in their lives. Whether accidental or intentional in nature, many fractures require some form of repair in order to provide the best chance for full return to function. Traditionally, fracture repair in both humans and animals has focused on precise anatomic reconstruction of bone and rigid internal fixation to provide the most direct path to fracture healing. In recent years, however, there has been an increasing appreciation of the importance of the surrounding soft tissues in the healing process, and the focus is shifting from a purely mechanical approach to fracture repair to more of a biological approach.

Fracture Biology and Biomechanics

Obviously, bones can break a number of different ways. The energy and the specific forces that are responsible for a fracture ultimately dictate the fracture configuration. Low energy fractures (resulting from falls, blunt force trauma, etc.) tend to be simple; higher energy fractures (hit by car, gunshot wounds, etc.) are more often comminuted and have more significant damage to the surrounding soft tissues. The specific forces responsible for fractures include: axial compression (oblique fractures), bending (transverse fractures), and torsion (spiral fractures). Combinations of these forces can produce various, unique patterns.

Once a fracture has occurred, the bone and surrounding soft tissues will naturally try to heal themselves through a process of secondary bone healing. Secondary bone healing, often thought of as the natural, or “normal,” course of bone healing, results in formation of a callus of progressively stronger tissue types. Initially, hemorrhage from ruptured blood vessels forms a hematoma. As capillaries and fibrous tissue invade, granulation tissue forms over a period of several days, providing the first bit of stability at the fracture site. The fibrous tissue radiates outward from the site, providing a gradual increase in stability. As strain decreases over several weeks, fibrocartilage begins to form, followed thereafter by cartilage. Once local strain is reduced to under 2%, woven bone can form. Over a period of months to years, the woven bone then remodels to form normal, lamellar bone.

Although a surprisingly high percentage of fractures will heal without any medical or surgical intervention, few will heal in a manner that allows normal function. In an effort to improve the functional outcome of patients with fractures, the AO (Arbeitsgemeinschaft für Osteosynthesefragen) philosophy of fracture fixation was adapted to companion animals in the late 1960s. This philosophy consisted of 4 key principles:
Anatomic reduction and rigid fixation of a fracture has the benefit of allowing immediate load sharing between the implant and the bone. Additionally, this approach to fracture repair can minimize the requirement for callus and allow for primary bone healing, through which lamellar bone formation and Haversian remodeling occur directly. There are 2 physical requirements for primary bone healing to occur: less than 2% interfragmentary strain and an interfragmentary gap of less than 1mm. If these conditions can be met, lamellar bone formation may occur more quickly and reduce complications (such as nonunion, malunion, or “fracture disease” of the soft tissues) that can occur with secondary bone healing.

**Biological Osteosynthesis: A Paradigm Shift**

You can imagine that achieving the conditions necessary for primary bone healing is difficult, if not impossible, in many clinical situations. In the case of an interfragmentary gap of 1mm, maintaining less than 2% interfragmentary strain equates to having less than 2/100mm of movement at the fracture site. If this is ever actually feasible in the clinical situation, it requires perfect anatomic reconstruction of the fracture fragments (i.e., no comminution can be present) and rigid internal fixation. Open reduction of fracture fragments and application of internal fixation require significant disruption of the soft tissues associated with the fracture site. This iatrogenic damage inevitably damages the intrinsic blood supply to the area and impedes healing to various degrees.

Over the past two decades or so, there has been an increasing appreciation of the contribution of soft tissues to bone healing. Additionally, surgeons have noted that while mature lamellar bone forms more quickly through a process of primary bone healing, functional healing of the bone (i.e., the point at which the bone can support the full load of the limb without the need for coaptation) actually occurs more quickly through a process of callus formation. Therefore, the true necessity of perfect reduction of bone fragments and absolute stability of fixation in cases of non-articular fractures has come into question. Instead, focus has shifted to creating less disturbance of the fracture site and iatrogenic damage to the soft tissues in an effort to encourage callus formation and expedite secondary bone healing. This has become known as biological osteosynthesis.

Similar to the AO philosophy, biological osteosynthesis also has 4 main principles:

1. Indirect fracture reduction with limited surgical approaches and minimal, if any, disturbance of the fracture hematoma
2. Stabilization using bridging osteosynthesis rather than anatomic reconstruction and rigid fixation

3. Limited reliance on secondary implants (e.g., cerclage wires, Kirschner wires)

4. Limited, if any, use of bone grafts

Biological Osteosynthesis: Technique and Implants

Biological osteosynthesis differs from traditional open reduction and internal fixation in two main aspects: the invasiveness of the surgical approach and the function of the implants applied to stabilize the fracture.

There are 2 general categories of surgical approaches that are compatible with the practice of biological osteosynthesis:

1. The bone is only approached at each end in order to manipulate the fracture fragments and apply the chosen implants at a location distant from the fracture site. No approach is performed to access the actual site of the fracture. This is referred to as Minimally Invasive Osteosynthesis (MIO). MIO is subcategorized based upon the implants applied – for example, Minimally Invasive Plate Osteosynthesis (MIPO) or Minimally Invasive Nail Osteosynthesis (MINO). Because there is no direct visualization of the fracture site, MIO often requires intraoperative fluoroscopy to visualize the alignment of the fracture fragments and position of implants.

2. The soft tissues are approached and opened in a traditional manner, but there is a heavy focus on complete lack of disturbance of the fracture site. No small bone fragments are touched, manipulated, or removed; no suction is applied to the site of the fracture in order to prevent disturbance of the fracture hematoma; and no secondary implants are placed at the fracture site for stabilization (see principle #3 above). This approach is referred to as Open But Do Not Touch (OBDNT). OBDNT may be beneficial in cases where appropriate reduction of the primary fracture fragments is difficult to achieve, or when there is difficulty passing an intramedullary implant (pin or nail) without direct visualization. If intraoperative fluoroscopy is not available, conversion from MIO to OBDNT is frequently necessary.

Because no attempt is made to perfectly reduce fracture fragments when performing biological osteosynthesis, implants are applied in bridging fashion, and no load sharing between the bone and the implant can be expected during the initial phases of bone healing. Therefore, it is important that the implants used with this technique be strong enough to support the entirety of the patient’s weight and resist all of the forces acting upon the fracture site (see Fracture Biology and Biomechanics above). Implants used for biological osteosynthesis include: plate-rod constructs, locking plates, and interlocking nails.
Plate-rod constructs have a significant strength advantage over plates alone. For every 10% increase in the diameter of an intramedullary pin, plate strain is reduced by 20% and construct strength increases by 35%. When a plate and an intramedullary pin are used in combination, ideal construct strength is achieved when the pin occupies approximately 35-40% of the diameter of the medullary canal.

Locking plates are designed such that the screws used to apply them to the bone engage both the plate and the bone. Thus, they are effectively “internal fixators” and serve to link the plate to the bone rather than simply compressing the plate to the bone, as is the case with traditional bone plates. This feature of locking plates provides two distinct advantages over compression plates:

1. Locking plates are much less susceptible to fatigue failure than traditional plates because the screws cannot individually back out from the bone.
2. Locking plates do not need to be contoured exactly to the bone surface, which shortens the length of the surgical procedure and spares the periosteal vasculature, thereby serving to improve the healing potential at the fracture site.

In order to limit plate strain, there are several principles of application of locking plates in human medicine, which have been adapted to veterinary medicine as well:

1. Plate length greater than 3 times the length of the fracture site
2. Screw density (fraction of plate holes filled) of less than 0.5
3. At least 3 plate holes left empty over the fracture site

Interlocking nails may be the ideal implants for use in biological osteosynthesis. In addition to being relatively straightforward to apply in a minimally invasive manner, interlocking nails as a sole implant are capable of resisting all of the relevant forces acting on a fracture site. Nails have a strength advantage over plates because of their cylindrical shape – the AMI (area moment of inertia, a measure of strength) of cylindrical implants are proportional to the radius of the implant to the 4th power, which the AMI of rectangular implants are proportional to the height of the implant to the 3rd power. Furthermore, interlocking nails have a mechanical advantage over plates because nails are placed down the medullary canal of the bone, which minimizes the bending moment experienced by the implant. Several types of interlocking nails are available, with the most recent and reliable being an angle stable interlocking nail (which is similar to a locking plate in that the stabilizing bolts engage both the bone and the implant itself).

When deciding whether to treat a fracture by traditional open reduction and internal fixation or using techniques of minimally invasive osteosynthesis, a surgeon must ask 2 questions:

1. CAN the fracture be reduced? If a fracture is comminuted and it is not possible to perfectly replace all of the pieces, then load sharing will not occur and the implant will inevitably be applied in a bridging manner. In this instance, the best chance for rapid healing will be achieved by following principles of biological osteosynthesis.
2. **SHOULD** the fracture be reduced? In other words, is the benefit of achieving load sharing between the implant and the bone worth iatrogenic damage to the blood supply and soft tissues that will be required to achieve this goal? If the answer is yes, then open reduction can be performed. If the answer is no, then again, it makes sense to stick with principles of biological osteosynthesis.