Bone is essentially the frame that supports locomotion. It’s an amazing tissue with complex properties that are a series of lever arms that act to counteract the forces of gravity while constraining and directing the forces of muscle. In general bone follows Wolff’s law in that it adapts to loads under which it is placed. Essentially, bone is shaped for the greatest strength while at the same time minimizing bone mass that would contribute to excessive weight. Bone is considered both viscoelastic and anisotropic. Viscoelastic implies that the strength of bone depends on the rate upon which it is loaded such that a bone is stronger when loaded rapidly versus slowly. Technically, bone becomes stiffer the more rapidly it is loaded; however, if the rate of loading exceeds the yield point a bone will fracture. The anisotropic property of bone says that its strength is dependent on the direction in which it is loaded, and thus bone is stronger when loaded longitudinally versus transversely. This makes sense in that while a patient is walking bone is loaded longitudinally; however, in many cases bone fractures occur due to a transverse load.

Bone in general is subjected to many forces. A fracture occurs when the sum of the forces is greater than the ultimate strength of the bone. The 5 main forces that bone is subjected to and thus must be overcome are tension, torsion, bending, shearing, and compression. Tensile forces are a type of axial force that acts to lengthen the bone while compressive forces are a type of axial force that acts to shorten the bone. The anisotropic nature of bone suggests that it is stronger when loaded in compression versus tension. Shearing forces are difficult to conceptualize with respect to bone; however, it is a common force present within bone. Shearing forces acts parallel or tangential to the bone. Torsion acts to twist bone about its long axis. This creates a shear stress in the bone (where tension and compression are seen in oblique planes). Bending forces (also referred to as moments) makes bone convex on one side and concave on the other side. The convex side is undergoing tensile forces while the concave side is undergoing compressive forces. Understanding the forces that act on bone are important as these are the very forces that must be overcome when choosing the appropriate fracture fixation method.

Fractures occur when the sum of the forces to the bone are greater than the ultimate strength of the bone. This can occur due to trauma and the force exceeds that of normal bone, or it can occur pathologically when the bone is weakened and therefore the force does not have to be as great to allow a fracture (abnormal bone). In a load deformation curve when bone is loaded there will be slight deformation. As long as the load remains in the elastic region then failure will not occur and the shape of the bone will revert back to normal. However, if the load continues past a certain point known as the yield point then bone will cross over to the plastic region, which will result in permanent deformation. If the load continues the breaking point then the bone will fracture.

Once a fracture occurs, the goal is to allow the bone to heal with restoration of normal function with acceptable cosmetics. There are certain factors that must be taken into consideration for a bone to heal such as the biologic factors (blood supply, location of the fracture, and concurrent soft tissue injuries) and the mechanical factors (such as the degree of stability at the fracture site). The afferent blood supply to the bone is supplied through the nutrient artery, where the blood flow is centrifugal in that it progresses from the medullary cavity to the periosteum. Therefore, blood flow is from the nutrient artery to the metaphyseal arteries, and then the peristomal arteries. After a fracture the medullary circulation is disrupted, therefore we get an enhancement of existing normal blood supply. Temporarily, there is a transient extraosseous supply from the soft tissues. It is very important to preserve this blood supply and be kind to the tissues during surgery. As the bone heals the medullary circulation is reestablished. From a mechanical standpoint the fixation must counteract the forces acting on the bone while preserving the blood supply. Healing will also depend on the fracture gap and the stability.

Bone healing parallels that of most other tissue in the body such as soft tissues. It will progress through the typical inflammatory, reparative, and remodeling phases. For bone to adequately heal there has to be a stable environment in that the interfragmentary strain is <2%. This is the deformation occurring at the fracture site relative to the size of the gap, which influences the type of tissue that will form in the gap. Secondary bone healing is considered the normal course of bone healing and is how all bones healed prior to the advent of open reduction and internal fixation (ORIF). Essentially this occurs through callus formation by progressively stiffer tissue as bone healing moves through the various phases. Initially when the bone is fractured a hematoma develops. This hematoma provides no strength but is very important in that it releases lots of growth factors. The next stage is the formation of granulation tissue, which adds very slight strength. After the formation of granulation tissue, connective tissue develops followed by cartilage formation, cartilage mineralization, and finally woven bone formation. With ORIF primary bone healing can occur which allows “skipping” of the initial secondary phases. For this to occur once again the interfragmentary strain has to be <2% and the interfragmentary gap must be <1 mm. Thus, even with ORIF if the bone ends are not touching it will proceed through secondary bone healing, but in a quicker time since the fracture will be stable. The 2 types of primary bone healing are gap and contact bone healing. Gap bone healing occurs when the gap is <1 mm. Granulation tissue forms first with its blood supply, then lamellar bone follows.
without the cartilage phase. Initially the lamellar bone is oriented transverse to the to long axis of the bone (think like “caulk” filling in the gap). Haversian remodeling allows new lamellar bone to be oriented longitudinally. Contact bone healing occurs when the fracture fragments are in direct contact and there is no interfragmentary motion. There is no lamellar phase, but rather Haversian remodeling occurs directly by bridging the fracture with longitudinally oriented osteons known as cutting cones. Many bones are fractured as a result of trauma. Always remember that if there is enough force to cause a bone to break then there is certainly enough force to cause soft tissue damage. It’s important to triage these patients by checking and stabilizing vitals (such as treating hypovolemic shock). A thorough physical/orthopedic exam and a neurologic exam are needed. It does no good to repair a femoral or pelvic fracture if the sciatic nerve is transected. Baseline diagnostics including chest and abdominal radiographs, TFAST, and AFAST should be completed. Any life-threatening issues need to be addressed which may mean delaying surgery. I love fixing fractures, but I want the patient to live more. Fractures in and of themselves are not emergencies. Analgesia is imperative as fractured bones hurt, and thus the pain will lead to a systemic cascade so controlling this is important. Pure mu opioids are recommended such as morphine, hydromorphone, or fentanyl. Unfortunately, butorphanol does not typically provide adequate analgesia. Once the patient is stable then go back and obtain a thorough history, it is important to separate traumatic from pathologic fractures. Evaluate PE/Ortho/Neuro findings. Common signs of fractures include pain, swelling, reluctance to bear weight, crepitus, or angulation deformities. And as previously mentioned if the patient is non-ambulatory it is very important to evaluate for neurologic deficits such as with the radial or sciatic nerves. The traditional AO classification system I have found to be confusing and not many people classify fractures based on this. Each bone has a number, then there are 3 zones, and finally the fracture is classified into the morphology and severity. More commonly fractures are classified by the anatomical location, severity, configuration, displacement, contamination, and if they are a growth plate fracture or not.

Fractures can be classified by the anatomical location such that they are articular which requires complete anatomical reconstruction with rigid internal fixation, epiphyseal, physeal (which have their own Salter Harris classification), metaphyseal, or diaphyseal. Furthermore, in particular areas special terms can be used such as condylar (as seen with distal femoral or distal humeral fractures), supracondylar (meaning above the condylar region), trochanteric (as seen around the greater trochanter), or subtrochanteric. The severity is described as incomplete meaning the fracture is only through one cortex (sometimes called a “greenstick” fracture in immature patients). There is a small fissure noted but the fracture is not complete. A complete fracture involves a fracture through both cortices. Also, please note that the term “compound fracture” is not used to describe any fracture in either human or veterinary medicine. A comminuted fracture is one with multiple fragments. A segmental fracture is one with two or more separate fractures of the same bone. Avulsion fractures are classified as an enthesis fracture, which is one that occurs at the attachment of a joint capsule, or an apophysis fracture, which is one that occurs at the origin or insertion of a tendon or ligament. The configuration of a fracture can be transverse in that it is perpendicular to the axis of the bone and the fracture equals the diameter of the bone. Or the configuration can be considered oblique. A short oblique fracture is one where the fracture is less than two times the diameter of the bone versus a long oblique where the fracture is greater than two times the diameter of the bone. A spiral fracture is a long oblique with a twist. The displacement is based on the degree of displacement of the distal segment in relation to the proximal segment. You have to have orthogonal radiographs to describe this. One can’t simply have only a lateral or only an AP, but must have both. The degree of contamination is used to classify open fractures. Type I open fractures are those with <1 cm puncture wounds where the fragment briefly penetrated the skin. A type II open fracture is one where there is >1 cm puncture wound with evidence of external trauma. A type III open fracture has extensive wounds with significant soft tissue damaged or absent. It is further subclassified into IIIa where there is adequate skin to close the wound, IIIb where there insufficient skin to close (aka degloving injuries), or IIIc where there is compromised vascular supply to the skin.

If you are presented with an open fracture cover it immediately. When any open fracture arrives in our hospital I cover it as soon as they come in the door with a sterile covering. This can be as simple as a sterile huck towel with vet-wrap around it. Trust me, the bacteria in your hospital will be much worse then the environmental bacteria the bone may have come in contact with. Once the dog is stable then remove your dressing and flush the wound with lots of fluid. In severely contaminated wounds I have used tap water, but typically will use either saline or p-lyte. I’m not a fan of combing iodine or chlorhexidine to my flush solutions because if you are not measuring out the specific concentrations correctly you could be killing viable cells. Once I have flushed and debrided the area then I will cover the wound with a more stable covering. We then have to make the decision about fixing the fracture as well as addressing the wound and dealing with any evidence of infection. Physeal fractures are classified by the Salter Harris (SH) classification scheme. SH I fractures are through the physsis itself, while SH II fractures are through physsis and into metaphysis. SH III fractures are through physsis and into the epiphysis and are considered intra-articular. SH IV fractures are through physsis and into metaphysis and epiphysis as well as being considered intra-articular. SH V are compression fractures though the physsis, while SH VI are compression fractures though only a portion of the physsis, which results in angulation deformities.
To aid in ease of communication amongst veterinarians we need to list the bone involved (remember left or right), the location, configuration, displacement, and contamination if present. This will allow the veterinarian or surgeon on the receiving end to create a visual image of the fracture to begin to decide on how best to fix the fracture. Radiographs are mainstay for diagnosing fractures. However, one must take orthogonal views to determine and evaluate the extent of the fracture. This includes at least a lateral and AP radiographs to tell the whole story. CT scans can be helpful especially with sacral fractures, spinal fractures, and articular fractures.

In summary to be able to fix a fracture requires one to be able to correctly diagnosis and classify a fracture. Remembering bone characteristics, biomechanics, and healing all play in decision making for fracture fixation. In terms of classification it is important to describe the fracture with the anatomical location, severity, configuration, displacement, contamination, and if and what type of growth plate fracture may be present. The biggest piece of advice with fracture diagnosis is to take orthogonal radiographs to create the full picture.
The Roadmap to Fracture Management: Part II: Selecting a Fixation Technique and External Coaptation

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In part I we discussed the classification and diagnosis of fractures as well as basic bone healing. Once an understanding of the appropriate classification of fractures is understood then it is important to understand the approach and selection of fixation. Unfortunately, there is no “orthopedic cookbook” in regards to selecting the appropriate fixation for a fracture. Each fracture needs to be addressed to the individual patient by different factors.

One such factor is the patient. Issues such as size, is this a big dog or a little dog? The age, as younger dogs may heal quicker and may require implant removal versus older dogs, which may take longer to heal and thus need a more robust type of fixation. Activity level certainly plays a role, as a less active dog may not require as robust of a fixation versus a dog that is very active or is a canine athlete. Client factors play a role, as they are the ones making decision. I always find it nice to give them options, as finances will play a role in what they are able to do versus what they are not able to do. I will also never commit to a certain type of fixation as my plan may change intra-operatively so I will go over all the available options that may be possible so that if something needs to change in surgery there are no surprises for the owner. Their compliance will play a big role in my selection of fixation. For example if the dog is aggressive or the owner is unable to care for an external fixator then a bone plate with screws may be a better option. The fracture itself as discussed in part I of this series is certainly a factor. The configuration will dictate what type of fixation can be used, for example an IM pin and cerclage wire is not the best option for a transverse fracture. Remember the 5 forces that need to be counteracted with fixation. The degree of contamination will dictate as well what type of fixation may be best. For example a severely contaminated fracture may be better suited for an external fixator rather than bone plates and screws. Another large factor is of course your own ability. Having the understanding of biomechanics and healing as discussed in part I is very important. Knowledge of particular implants will help decide what type of implant will be best suited for that particular type of fracture. Experience and skill level should be considered. Always ask yourself “can I fix this fracture, and should I fix this fracture” Meaning if you have experience and skill to fix it along with available implants. “Should I fix this fracture” means if you don’t have the experience should you refer it rather than attempting the unknown. Implant availability will play a role as far as what you have in your clinic to repair a fracture. It is helpful if you do lots of fractures that you have different types of implants available, as an IM pin and cerclage fixation is not an option for every fracture. If you don’t do many fractures then know the limitations of the implants you have.

In the past fractures were approached from the “carpenter” standpoint, which means absolute anatomic reconstruction with rigid internal fixation. This will disrupt the fracture hematoma and blood flow and requires significant tissue dissection. This type of approach is needed for articular fractures and for fractures that require anatomical reconstruction. Recently, a more biologic friendly way to fix fractures has been described at the “gardener” (biologic osteosynthesis) standpoint. This approach uses minimal reconstruction and rigidity to preserve blood flow. This is accomplished by indirect fracture reduction through limited approaches such as the “open but do not touch” method meaning the fracture area is approached but no manipulation of the fracture is performed or a minimally invasive plate osteosynthesis (MIPO) approach. This is accomplished through a few stab incisions and everything is done in a closed manner. When approaching these fractures there should be minimal to no disturbance of the fracture hematoma. Bridging osteosynthesis rather than rigid fixation is typically elected with limited reliance on secondary implants such as k-wires, cerclage wires, etc. In a perfect world we need to try to find the balance between the carpenter and the gardener. The fixation needs to be something that stabilizes the fracture to allow bone healing but that it is not too rigid to delay bone healing. The fixation should preserve the blood supply to the fracture and not disrupt the fracture hematoma. Furthermore, of extreme importance is to maintain joint alignment and allow early return to function.

After consideration has been given to the various factors, we then need to consider the individual factors of the various implants themselves. I have a chart that I run through in my head (see below) for every fracture I am presented with. As I run through this chart I begin to go through the pros and cons of each type of fixation until I decide on the one or two best options for that particular patient.

Kapler M. Dycus DL. A practitioner’s guide to fracture management: Part II: Selection of Fixation Technique and External Coaptation. Todays Veterinary Practice, September/October;23-30, 2015.

### Table: Fracture Classification

<table>
<thead>
<tr>
<th>Invasiveness &amp; Stability</th>
<th>Primary Fixation</th>
<th>Ancillary Fixation</th>
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<tbody>
<tr>
<td>Least invasive/ Most unstable</td>
<td>External Fixation</td>
<td>Lag screws</td>
</tr>
<tr>
<td>Internal Fixation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most invasive/ Most stable</td>
<td>IM pin and/or k-wires</td>
<td>External skeletal fixator (ESF)</td>
</tr>
<tr>
<td></td>
<td>Interlocking nail (ILN)</td>
<td>Bone plate and screws</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.
External coaptation

External Coaptation is defined as the use of bandages, splints, casts, etc. to aid in the stability and support for soft and osseous tissues. It is useful for the management of wounds, edema reduction, and fracture management. The central theme for any patient with external coaptation is comfort and function. External coaptation for fracture management can be as the primary fixation, temporary fixation, and ancillary fixation. For primary fixation the bandage and splint will be the sole means of fixation where as with temporary fixation the bandage/splint may be used to cover open fractures or stabilize a fracture until definitive surgical correction. Ancillary fixation with external coaptation is useful for additional support such as after bone plating to prevent implant breakdown as seen with distal radius and ulna fractures.

To utilize external coaptation for primary fixation one must be able to stabilize the fracture a joint above and below the fracture. This leaves only fractures that are distal to the elbow or stifle amendable for external coaptation. Thomas-Schroeder splints are never recommended. These are traction devices that are constructed of a wire frame and soft bandage material. The splint does not adequately immobilize the shoulder or hip, and; therefore, is considered contraindicated in humeral and femoral fractures. The advantages external coaptation for fracture management are that it does not disturb the fracture site, there is minimal risk of contamination, no risk of implant break down, it is easy to apply and there may be a decreased expense. However, there are associated costs for frequent rechecks and bandage changes which tend to add up very quickly especially if complications develop. The disadvantages for using external coaptation for primary fixation are that it is limited to fractures that are distal to the stifle or elbow. External coaptation wont counteract all the forces on a fracture and there is the possible need for eventual surgery if the fracture fails to heal. If there is fracture instability this could result in delayed, nonunions, or malunions. Frequent bandage changes will be needed which will require cost and frequent visits by the owner. Furthermore limb stiffness can occur from prolonged immobilization, which can lead to disuse atrophy and fracture disease. Probably the biggest reason I really don’t like bandages and splints is just by placing a bandage there is a 63% morbidity associated with it, which will lead to costs to the owner and potential delays in fracture healing. When determining if external coaptation is an option certain patient factors need to be considered. For example ideal candidates for external coaptation are younger animals with green stick fractures. These are fractures that are often incomplete, minimally or non-displaced and have an intact fibula or ulna which will increase stability. Breed and confirmation are very important as chondrodystrophic breeds and obese patients can be challenging to incorporate an appropriate splint. Patients that have suffered poly-trauma may not be the best candidates, as they may need internal fixation to promote early limb use. Concurrent diseases need to be considered, as immuno-suppressed patients may take longer to heal and thus require longer immobilization. Temperament needs to be considered such as aggression. If the patient is going to require multiple bandage changes then this may prove challenging. Another consideration is patient assessment. Breed is a consideration such that small and toy breed dogs with radial/ulna fractures are not a good candidates for external coaptation. The blood supply when compared to large breed dogs is decreased and there is a higher risk of complications. In fact in small breed dogs with radius and ulna fractures treated with external coaptation are at an 83% chance of malalignment or nonunion. Another consideration when choosing external coaptation, as a primary means of fixation is fracture assessment. External coaptation will counteract bending and rotational forces as long as the joint above and below are immobilized. The goal with external coaptation is once the splint is applied orthogonal radiographs need to be taken to assess the fracture. Try to follow the 50/50 rule which states that cortical positioning of the fracture ends should have 50% contact to expect fracture healing. Note that this is for fracture healing to be possible, not probable. The goal should be for 100% reduction. Furthermore, rotational alignment is imperative meaning the joint above and below the fracture is aligned and there is no rotational issue that may lead to angular limb deformities or gait abnormalities or progression of OA. If these goals are not met then external coaptation should not be used and internal fixation should be considered.

External coaptation when used as a temporary means of fixation can help improve comfort and reduced swelling while the patient awaits definitive repair. It can also act as a protective covering with open fractures. No matter how clean your hospital is, hospital bugs are much worse than what the bone was exposed to in the environment. I tend to use extreme caution placing a temporary splint on humeral and femoral fractures, as it is very hard to fully stabilize it. Furthermore, the splint can act as a fulcrum and cause worsening pain or malignment of the fracture. I tend to keep these in a crate with analgesic relief while awaiting fixation. External coaptation for ancillary fixation is designed to add additional support. I tend to use this with splint management following radius/ulna fractures. Along with additional support it will also help minimize cycling of the implants to help prevent premature breakdown.

The quick and dirty technique for external coaptation is to sedate or anesthetize the patient for fracture reduction and alignment. I prefer to use custom made fiberglass splints rather than preformed plastic ones as I feel that the comfort is better improved if the splint follows the patient’s anatomy. The splint is typically applied to the lateral aspect for the hind limb and either the lateral or palmar aspect for the front limb. Remember to splint a joint above and below the fracture. It’s important to provide enough padding to prevent pressure sores and movement. Leave the middle two digits exposed. To encourage weight bearing and to minimize trauma to the articular cartilage from prolonged immobilization it is important to splint them in a functional standing angle. As has been previous mentioned take orthogonal radiographs after splint application to evaluate the reduction and alignment.
In terms of radiographic healing ideally we will consider it completely healed with disappearance of the fracture line. Technically we want 3 of the 4 possible cortices to show evidence of bridging before returning the patient to normal activity. Ideally, within about 5-7 days there will be slight widening of the fracture gap; this is normal as the bone tries to maintain interfragmentary strain. There may be some evidence of “smudging” of the fracture edges. Around 10-12 days we can see the early stages of a bony callus beginning to form. In some cases around the 30-day mark there is the beginnings of disappearance of the fracture line, then around 90 days there is complete healing and remodeling of the callus. This is the time point when many can return to normal activity.

Complications with any type of fracture fixation or implant as much as they suck, happen to everyone, even the best. The big 3 are infection, implant failure, and poor bone healing. The easiest thing to do is blame someone else. Don’t be quick to blame the owner, the dog, or the particular plate. Many times the reason for the issue is standing right in front of you if you were to look in a mirror.

Infection can occur due to hematogenous spread, direct inoculation from an open fracture or surgical contamination or less commonly direct spread from a focal soft tissue infection. In the acute phase after a bone has fractured the vascular channels are comprised which results in ischemia. Bone ischemia is a major predisposing factor for osteomyelitis. Around the bone ischemia is a reactive hyperemia that is associated with an increase in osteoclast production. Along with increased osteoclast production there is also periosteal irritation that leads to periosteal reaction. The aggressiveness of the infection is noted to parallel that of the periosteal reaction seen on radiographs. The damage and ultimately the response to treatment of bony infections are dependent on the viability and stability of the fixation, the virulence and antibiotic sensitivity of the organism and the condition of the soft tissue envelope. The most common type of osteomyelitis is from direct inoculation, which is also known as post-traumatic osteomyelitis. The staph species dominate with S. intermedius being the most common. Some gram-negative bacteria can be associated with osteomyelitis. Fungal organisms are usually due to hematogenous spread. For an infection to occur the bacteria must contaminate and colonize the bone and surrounding tissues. Its important to note that a stable fracture will heal in the face of infection, an unstable fracture will not heal in the face of infection and will perpetuate the persistence of infection.

Poor bone healing is broken into delayed union, non-union, or malunion. Delayed union is healing of a bone that takes longer than expected to heal. The normal healing time frame for a bone is 8-12 weeks versus a nonunion, which is where the bone fails to heal regardless of healing time or if a delayed union is not addressed. A malunion is characterized by a healed fracture in an improper alignment. This may be noted as shortening of a limb, malalignment of the joint surfaces, rotational abnormalities, or varus and valgus deformities. Nonunions are further broken down into viable and nonviable. Viable nonunions can be classified as hypertrophic where there is considerable callus formation but no bone healing, this is sometimes referred to as an “elephants foot”, or it can be moderately hypertrophic where there is a lesser degree of callus known as a “horses foot”. Both types of hypertrophic viable nonunions are typically caused from motion in the fracture site; therefore more rigid fixation is needed. An oligotrophic viable nonunion is hard to distinguish from a nonviable nonunion due the fact there is no radiographic evidence of healing. Its cause is due to lack of cellular activity which are typically due to loose implants in the area of the fracture such as loose cerclage wires. Nonviable nonunions can be classified as dystrophic where there is nonviable bone on either side of the fracture, necrotic where there is an infected section of bone such as a sequestrum, defect where there is a gap at the fracture site that is too large to heal, or atrophic where there is removal of dead bone by the host with no healing and often times resorption of the bone.

References
The decision in choosing internal versus external fixation is dictated by many factors that have been discussed in parts I and II. After considering the various factors such as the fracture configuration/classification, patient, client, and veterinarian factors then remember to run through the below chart in deciding on external fixation (as discussed in part II) versus internal fixation. If internal fixation is chosen then the decision has to be made as to which type.

### 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.

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<tr>
<td></td>
<td>IM pin and/or k-wires</td>
<td>Full cerclage</td>
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<tr>
<td></td>
<td>External coaptation (cast or splint)</td>
<td>Hemi cerclage</td>
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<td>Most invasive</td>
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IM pin/Cerclage wire

Intramedullary Pins (aka IM Pins) are typically smooth round 316L stainless steel rods. Steinmann pins are most commonly used and they are available from 1/6 to 1/4 of an inch in diameter. They come in either trocar or chisel points and the end may have threads. Note that the threads do not improve holding and in fact have a tendency to fail prematurely because the thread shaft interface creates a point of weakness. K-wires appear just as Steinmann pins but their size if much smaller ranging from 0.035-0.062 inches in diameter. IM pins do a great job of resisting bending forces, but are very poor at resisting rotational forces. They can be used as a primary or ancillary fixation with external skeletal fixation or bone plating. They should never be used alone as the only source of fixation. If using an IM pin for primary fixation then cerclage wires should be added. Cerclage wires are designed to counteract axial and rotational forces while providing interfragmentary compression. Cerclage wires do not damage the blood supply or interfere with healing unless they become loose. Cerclage is French for encircling hoops placed around wooden barrels. It is essentially orthopedic wire that is placed around bone. There are various sizes available from 22 gauge, which is used for small dogs and cats up to 18 gauge, which is used in large dogs. In general cerclage wire is used in conjunction with other fixation methods especially with IM pins. It should only be used alone in non-weight bearing bones such as the mandible. Cerclage wire when used appropriately does not
**External skeletal fixation (ESF)**

ESF involves transcutaneous placement of threaded pins or wires into bone, which are secured by clamps, rods, rings, or epoxy. Linear ESF uses transfixation pins or K-wires that are attached to a linear connecting bar using a clamp. Pins can be placed in one of two ways, either half pins or full pins. Half pins penetrate the skin on one side but go through both cortices of the bone while full pins penetrate the skin on both sides and go through both cortices of the bone. The classification for linear ESF is described as Type I through Type III with a few subtypes. The strength of the ESF is stronger as the types increase. A type Ia is considered unilateral and uniplanar with 1 connecting bar and a half pin. A type Ib is considered unilateral but biplanar such that two type Ia ESF are connected. A type Ia ESF is the strongest of the ESF. A type IIa is considered unilateral and uniplanar such that two type Ia ESF are connected. A type IIb is considered unilateral and uniplanar with 2 connecting bars and full pins. A type IIc is considered unilateral and uniplanar with 2 connecting bars and half pins. A type III ESF is the strongest of the linear ESF in that it is a combination to type I and type II. It is considered bilateral and biplanar consisting of 3 connecting bars and a mix of full and half pins.

ESF is diverse in its use in that it can be applied in a variety of fracture scenarios. It is especially useful in patients with open contaminated fractures. It will allow for concurrent wound management, it keeps implants away from the fracture site, and the implants are removed after the bone has healed thus allowing resolution of infection. Furthermore, ESF is able to counteract all the forces acting on a fracture. They can be used as either primary or ancillary stabilization. It can be used with an IM pin to help control rotation.
The advantages of ESF are that it may be applied in a closed manner thus avoiding disrupting the fracture hematoma and soft tissues. It is good for most fracture configurations being that it is versatile and well tolerated. They are able to be destabilized over time to allow the healing bone to adapt. ESF are relatively easy to apply and remove. There are numerous configurations and types so if you like to construct things then ESF is for you. The disadvantages are pin loosening that happens very frequently, pin tract sepsis, limited function of soft tissues if the pins are passed through large muscle groups. The biggest issue with ESF is the postoperative care of the frame, which will require work on the owner’s part.

When using ESF the goal is to use pins that are about 25-30% of the bone diameter. The pins are inserted though stab incisions and should penetrate both the cis and trans cortex. The minimum to have a stable ESF is to use at least 2 pins above and below the fracture. My mentors always told me that 3 is better and 4 is the best. When inserting the pins try to avoid the fracture line, nerves, and vessels. Furthermore, minimize muscle penetration to cut down on post-operative drainage. When inserting the pins use low speed power insertion to reduce thermal necrosis. Using power insertion will reduce the wobble versus when inserted by hand. Thermal necrosis is a huge contributor to pin loosening. Once finished bandage the frame postoperatively to prevent it from damaging the owners home. Scrub sponges can be used to help with bandaging and they will have some chlorhexidine residue on them. They can also be placed in the freezer and used as post op cold packs around the frame. Don’t use smooth or negative profile pins with ESF. If you must use smooth pins they should be inserted at a 70-degree angle to improve holding power. Negative profile pins have a weakness in the pin at the thread pin interface since the threads are cut into the shaft of the pin, thus the diameter of the threaded region is smaller than the diameter of the rest of the pin. I try to use positive profile pins with ESF. These pins have the threads rolled onto the diameter of the pin, such that the diameter of the pin in the threaded region is the same as the rest of the pin.

**Bone plate and screws**

In the simplest terms using a bone plate and screws involves securing a bone plate to the bone via screws. Depending on the plate type the material may be stainless steel, titanium, etc. There are two big categories of bone plates: locking or non-locking. Bone plates and screws resist all forces a bone undergoes, but is weakest in regards to bending. Because of this the plate is placed on the tension surface of the bone. Non-locking plates allow the plate to be held in close contact with the bone by the screws. Once the patient begins to walk the axial load through the bone creates a shearing force at the screw-bone interface. This shearing force is counter-acted by friction generated at the plate-bone interface. Therefore, for non-locking plates to provide the best stability they must be contoured and applied directly to the bone with no soft-tissue in-between. Locking plates are considered a fixed angle system and behave more like an ESF. It does not rely on the friction between the bone and plate. Rather, the axial force the patient creates when walking is converted to and creates a compressive force at the screw-bone interface. In theory, locking plates are stronger and stiffer. Also, they do not have to be contoured to the bone. Up to 2 mm offset is considered acceptable which may improve biologic osteosynthesis.

Bone plates can be used in 3 primary ways. A neutralization plate is such that the fracture can be anatomically reconstructed and the bone/implant will share the load of the weight. Bridging or buttress plating is where the fracture can’t be anatomically reconstructed and the bone does not share the load, the implant must withstand the forces. Bridging and buttress are commonly used interchangeably; however, buttress plating is technically reserved for metaphyseal fractures to keep articular surfaces from collapsing while bridging plating is reserved for diaphyseal fractures that can be reconstructed. Compression plating is used with specific plates called DCP or LCP plates. Compression plating can be used when the fracture can be anatomically reconstructed to enhance stability.

The two basic screws are cortical and cancellous. As the name implies the screw is designed for the type of bone the screw is placed in. Cortical screws have a smaller pitch and less depth to the thread, which help with engaging the dense cortical bone. Cancellous screws have a larger pitch and more depth to the thread, which are designed to engage the spongy cancellous bone. Furthermore, screws can be self-tapping, or non self-tapping. Self-tapping screws have cutting flutes on them, which cut the thread into the bone and are designed to speed insertion of a screw. While nice to have, they do have less overall surface area of the bone-screw interface so the flutes have to be driven at least 2 mm past the trans cortex. Non self-tapping screws must have the threads cut into the bone prior to inserting the screw. Furthermore, the screw diameter used should be about 25% of the bone diameter. Ideally, one must engage at least 5 cortices on either side of the fracture but try to shoot for 6. Exceptions to this rule can be made on rare occasions such as with young dogs, ilial fractures, or with use of locking plates.

The advantages of bone plates and screws are that they counteract all forces, typically allow early return to function, they can be placed in a minimally invasive way and they come in a variety of sizes and configurations so that most fractures are amenable to bone plating. The disadvantages are that it requires open fixation, there is the risk of infection and thus implant removal. Furthermore, there can be implant breakdown, as well as the cost of the implants and the cost to the owner.