

Biomechanical Considerations of Fractures and Methods of Fracture Repair

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Adequate and effective fracture repair is predicated on an understanding of the biological properties of bone, the response of bone to trauma, the forces required to cause a fracture, and the mechanics of the devices used to stabilize fractures. The effect of force on bone is dependent on three characteristics - the magnitude, the direction, and the rate of application of the force to the bone. The application of force to bone results in deformation of the bone and the generation of internal forces within the bone. The internal force intensity (force per unit area) at any given point and plane within the bone is called stress. The deformation (change in length per original length) resulting from internal force is called strain.

Biomechanical Considerations

The mechanical behavior of bone and of the implants and devices used for fracture stabilization are related to its stiffness or modulus and its strength. The modulus is a measure of the amount of elastic deformation an object undergoes when subjected to a load. Low-modulus materials deform more than high-modulus materials when subjected to the same load. Strength is related to the amount of load a material can withstand before it fails.

The different loads applied to bone will result in characteristic fractures. Five fracture forces are described; these are **compression, tension, shear, bending, and torsion**. In clinical practice most fractures are the result of a combination of these forces. Compression develops when two forces approach each other through an object on the same plane. When a long bone is loaded in compression the fracture plane is usually at an oblique angle to the applied force. A tensile force occurs when two opposing forces act on an object through one plane. When loaded in tension bone fails with a fracture usually oriented perpendicular to the applied force. Shear stresses act parallel to a surface and tend to angularly deform a structure. Shear is the resistance of one plane of movement on another in opposite directions. Fracture of bone occurs along lines of maximal shear stress. Bending forces subject bone to high compressive stresses on the concave side and high tensile stress on the convex side. Because bone is weaker in tension than compression the fracture plane usually begins on the convex (tension) side of the bone and proceeds transversely to the concave (compression) side. Fractures produced by pure bending forces tend to be transverse or short oblique. Fractures resulting from torsional loads are usually spiral in form. The spiral is created by the combined effects of both shear and tensile stresses.

Adequate fracture stabilization is dependent on effectively neutralizing the inherent forces (compression, tension, shear, bending, and torsion) acting on the bone. Delayed union, nonunion, malunion, and infection may result from a failure to neutralize these forces. Bending loads are present in long bones due to eccentric loading, the shape of the bone, and the spanning of bone by large muscle groups. Bending forces are exaggerated if there is a cortical defect on the compression side of the bone. Bending forces tend to cause an unstable fracture to angulate towards the compression direction.

Compression forces are generated by weight bearing and the muscles surrounding the bone. In some fractures compression contributes to fracture stability. These include transverse and short oblique fractures in which the fragment ends interdigitate. As long as axial alignment is maintained the inherent interfragmentary compression will aid in fracture stabilization. In other fractures, such as short obliques without fragment interdigitation, long obliques, and those that are comminuted, it is a detrimental force. Compressive forces in these fractures tend to create overriding, shortening, and collapse at the fracture site.

Tensile forces lead to distraction of fracture fragments. They are usually seen at the ends of long bone where tendons and ligaments arise and insert. Tensile forces are also present on the convex surfaces of long bones that are undergoing bending deformation and must be neutralized to gain adequate stability. Torsional forces are present in transverse and short oblique fractures in which the ends do not interdigitate. Torsion must also be neutralized in comminuted fractures in which anatomical reduction has not been achieved.

Stability of fracture fixation depends on the stiffness of the fixation device(s), the stiffness of the device-bone interface, and the ability of the device to neutralize all of the disruptive forces acting at the fracture site. Factors influencing the choice of fixation device include the location and type of the fracture, the size and age of the patient, the number of bones and limbs involved, concurrent injuries, the patient's temperament, the owners' likelihood in following post-operative patient care instructions, the intended performance level of the patient, the entire cost of procedure including follow-up care, and the expertise of the surgeon.

Properly applied bone plates are the most stable fixation devices. The plate must be of sufficient length, must be rigidly applied to the bone, must have sufficient contact with the bone, and be applied on the proper bone surface.

Secondary fixation devices are used to augment the primary method of repair. By themselves they are generally not able to neutralize the major forces acting on a fracture. Cerclage wires, hemicerclage wires, skewer pins, interfragmentary screws, and tension band wires are the common secondary fixation devices.

Fracture Classification

Fractures are classified and described based on the severity of the fracture, whether it communicates (or had communicated) with the "outside" through the skin, the shape of the fracture line(s), and the anatomical location of the fracture within an individual bone.

An **incomplete fracture** is one in which the bone has not lost complete continuity with only one cortex being disrupted. A greenstick fracture, which is most common in young animals, resembles the break that results when a supple green branch of a tree is bent and breaks incompletely. Fissure fractures exhibit fine cracks in one cortex beneath usually intact periosteum. Bones may have single or multiple fissure lines of any configuration. A **depression fracture** represents an area in which multiple fissure lines intersect with the affected area depressed from the direction of the traumatic force. These fractures are most often seen in the calvarium, frontal bone area, and maxilla.

Complete fractures of the long bones are indicated by loss of bony continuity and are classified by the shape of the fracture line(s). A **transverse fracture** is a fracture line that is transverse (perpendicular) to the long axis of the bone. An **oblique fracture** has a fracture line that is at an angle to the long axis of the bone with the two cortices of the bone involved being in the same plane without spiraling. Oblique fractures are further described as being either short or long. The line of a **spiral fracture** twists around the long axis of the bone; they tend to be long with sharp points. **Comminuted fractures** have at least three fracture fragments the lines of which interconnect. The individual fracture lines may be transverse, oblique or spiral. A **multiple fracture** of one long bone is one in which there are three or more fracture fragments of the bone. Unlike a comminuted fracture the fracture lines do not interconnect. This type of fracture is also referred to as a segmental fracture. A **compression fracture** is one in which the bone collapses on itself, primarily in areas containing cancellous bone. Compression fractures are seen most often in vertebral bodies.

A **closed fracture** is one in which the affected bone remains encased within its overlying musculature and skin. The broken bone does not or has not communicated with the outside environment. An **open fracture** is just the opposite; it does or has communicated with the outside environment and will be associated with a skin wound. In older terminology open fractures were called compound fractures.

For further clarification fractures are also described by their location within a long bone. Fractures are termed **midshaft** if they occur near the axial center of the diaphysis. For other diaphyseal fractures the diaphysis is divided into equal thirds. So a fracture can be said to occur in the proximal, middle or distal third of the diaphysis. An example would be a closed, long oblique fracture of the middle third of the diaphysis of the left femur. Any fracture of the metaphysis is referred to as a **metaphyseal fracture**. An example would be a closed oblique fracture of the right distal femoral metaphysis.

Epiphyseal fractures occur in immature animals during the time the physis remains active and “open”. These fractures occur through the zone of hypertrophied cartilage. **The Salter-Harris** system of description, originally developed to describe these fractures in children, is commonly used for animals as well.

Type I – epiphyseal separation with displacement of the epiphysis from the metaphysis

Type II – the fracture line extends through a portion of the metaphysis and then along the physis with the epiphysis separated from the metaphysis

Type III – the fracture line passes through a portion of the epiphysis and then along the physis; the metaphysis is unaffected

Type IV – the fracture line extends through the metaphysis, across and/or through the physis, into the epiphysis

Type V – impaction across the physis with the metaphysis driven into the epiphysis

Condylar fractures affect the distal ends of the femur and humerus and the proximal end of the tibia. They are described as being medial or lateral. If both condyles of the femur or humerus are fractured from the shaft as a unit the fracture is called a **supracondylar fracture** because the fracture line will be immediately above the condyles. If both condyles are fractured from the shaft and from each other the fracture is described as

supracondylar/intercondylar and may be further described as a “V”, “Y”, or “T” fracture depending upon its shape.

An **articular fracture** involves the articular cartilage and the underlying subchondral bone; the term intra-articular fracture may also be used to describe this type of fracture. An avulsion fracture usually involves a bony prominence that arises from centers of ossification separate from the bone to which they are attached. A ligament, muscle, or muscle group attaches to the prominence. **Avulsion fractures** occur at prominences such as the greater trochanter of the femur, the tibial tuberosity, the medial and lateral malleoli of the tibia, etc.

Principles of Fracture Fixation

Early ambulation and complete return to function are the goals of fracture fixation. The major principles are anatomic reduction of fracture fragments, especially in articular fractures; stable fixation; preservation of the blood supply to the bony fragments and surrounding soft tissues; and, early active pain-free mobilization of the muscles and joints adjacent to the fracture.

The concept and principles of fracture repair have gradually changed over the years. The idea of perfect anatomic reduction of non-articular fractures with rigid fixation is now being replaced with the concept of **biological fixation**, also called **bridging osteosynthesis**. In this scenario total anatomic reconstruction of all fracture lines is only employed for articular fractures or shaft fractures treated by interfragmentary compression. Instead, shaft fractures are treated by leaving the fragments undisturbed to protect their blood supply. The fracture is spanned by a bridging plate attached to the ends of the bone or stabilized by an external fixator or interlocking nail. Other fixation methods may also be used including a combination of an intramedullary (IM) pin and a bone plate and an IM pin and an external fixator. In this circumstance anatomic reduction means restoring axial alignment, eliminating torsional deformity, and restoring or maintaining bone length. Manipulation and reduction of each bone fragment is not done. With bridging osteosynthesis the fixation only needs to be as strong as necessary to maintain alignment and length and to allow callus formation.

Methods of fixation have been classified as: **limb splintage**, to include casts and splints; **bone splintage**, to include IM pins, interlocking nails, external fixators, and bone plates; and **compression**, to include lag screws, cerclage/interfragmentary wire, tension band wire, and tension band/compression plates.

Casts

External casts (and bandages and splints) are often called **coaptation devices**. Properly applied casts transmit stabilizing forces to the bony structures of a limb by means of the interposed soft tissues. This pressure must be uniformly distributed beneath the cast to avoid circulatory stasis and tissue swelling. Casts are molded tubular structures that should conform to the shape of the limb to which they are applied. The most commonly used casting material is resin/binding materials impregnated into rolls of knitted fiberglass tape. The resin is activated by immersion in warm water and then immediately applied to the limb. Prior to application of the fiberglass cast material soft cotton cast padding is placed on the limb. Casts are applicable for closed stable fractures below the elbow and below the knee. A full cylinder cast is the most rigid form of external coaptation. Properly applied a full cylinder cast neutralizes only bending and rotational forces. To be effective the cast must

conform to the limb, immobilize the joints immediately above and below the fracture, and be of sufficient strength to withstand normal weight bearing loads. Fixation by external coaptation reduces but does not eliminate motion at the fracture site. Fracture healing usually occurs by development of an external callus.

External Fixators

External skeletal fixation devices are widely used and are extremely versatile. They may be used on all of the long bones, the mandible, and for bridging joints. They have also been used in conjunction with other devices to stabilize spinal fractures and dislocations. Common indications for their use include stable and unstable fractures, open fractures, and corrective osteotomies. Stability is achieved through the use of multiple percutaneous transcortical pins interconnected externally to form a rigid frame. Factors influencing the stiffness of external skeletal devices include the geometry of the frame, the number, size, design and spatial orientation of the fixations pins, the length of the pin between clamp and bone, the distance between the clamps, the number and length of the connecting rods, and the method of pin insertion.

Most fixation frames are secured to the bone by stainless steel fixation pins that should penetrate both cortices of the bone. Partially threaded pins which are either threaded on their ends or in their centers may be used to increase the strength of the pin-bone interface. Positive threaded pins, those on which the threads are raised, have a greater holding power than negatively threaded pins. These pins are then connected via clamps to external connecting bars. Connecting bars made of acrylic-filled tubes are also used, especially for mandibular fractures and those in which the fixations pins are placed in a variety of different planes and still must be attached one to the other.

There are several different types of external fixators that use fixation pins and external connecting bars. The major difference is the design of the clamp used to attach the pins to the connecting bar. In veterinary use external fixators are commonly referred to as a Kirschner-Ehmer (K-E) splint or modified K-E splint or device. The interface between the fixation pin and the bone is subject to very high stress loads. This can lead to bone resorption around the pins thus causing loosening of the pins and a weakening and loss of stiffness of the fixation device. Increasing the number of pins from the minimum of two per fragment increases the area of pin-bone interface, decreases the stress applied to each pin, and therefore reduces the incidence of bone resorption.

There are several classification systems used to describe the configurations of veterinary external fixators. Most commonly, the terms Type I, Type II, and Type III are used. One can correctly assume that a Type III configuration is more complex and stronger than a Type I configuration.

A Type I configuration, also called a half-pin splint or unilateral frame, is one in which the pins only pass through one skin surface (on the same side of the bone) but penetrate both cortices. There are a minimum of two pins per fragment and they are attached to the same connecting bar. In some cases the pins are extended through the clamps on the first connecting bar to clamps on a second connecting bar that is parallel to the first bar. This double connecting bar configuration is stronger than the single bar construct. Because the

external connecting bar(s) are only on one side of the bone (usually its lateral surface) a Type I construct can be applied to all of the long bones.

In a Type II configuration, also called full pin splintage or a bilateral frame, the pins pass through the skin, both cortices, and through the skin on the opposite side of the leg. The pins are attached to connecting bars on each side of the leg. This construct is very strong, but is limited to the radius/ulna and the tibia because the medial connecting bar will interfere with the patient's comfort if applied to the humerus or femur. In a common modification of a Type II construct the most proximal and distal pins are applied in the through & through standard manner while other pins are connected to only one bar. Centrally threaded pins will add stability to this type of frame.

A Type III configuration is also called a three dimensional or two-plane bilateral frame. It consists of a Type II splint with a half splint applied to the anterior side of the bone at 90 degrees to the full pin splint. While this configuration is the strongest of the three types it is rarely used because of the complexity of application.

A ring fixator, such as that described by Ilizarov, is now being used in veterinary surgery. This frame uses small diameter, flexible Kirschner wires as fixation pins. Stiffness of the frame is created by placing the wires under tension as they are attached to metallic rings that circle the limb. The rings are connected one to the next by several threaded connecting bars. This construct is used for limb lengthening procedures because the rings can be moved along the threaded connecting bars while their corresponding fixation wires remain in the bone. Ring fixators are also used for corrective osteotomies and multiple piece fractures.

Intramedullary Pins

A single intramedullary (IM) pin is effective only in neutralizing bending forces. They lack the ability to resist rotational, compressive, shear and torsional forces. The ability of an IM pin to resist bending forces is directly proportional to the ratio of the diameter of the pin and the diameter of the intramedullary space at the fracture site. As the medullary diameter increases in comparison to the pin diameter, it becomes more mechanically difficult for the pin to control bending forces. Rotation is not effectively controlled with a single IM pin. Multiple pinning can significantly resist rotational forces due to increasing the multiple points of fixation in the proximal and distal fragments. It is the rare fracture that can be appropriately stabilized with a single IM pin. Ancillary fixation methods such as external fixators, tension band devices, interfragmentary wires, lag screws, and cerclage wire are frequently used with IM pins to counteract rotational, torsional, shear, and compressive forces.

The two most common pins in use in veterinary surgery are the Steinmann pin and the Kirschner wire also called a K-wire. Both are round on cross-section. The diameter of a Steinmann pins ranges from 1/16 of an inch (1.5 mm) to ¼ inch (6.5 mm). Pin length is either 9 or 12 inches. K-wires come in three diameters, 0.035, 0.045, and 0.062 inches, and are 9 inches long. These pins can be obtained with a trocar, chisel, or threaded trocar points. The most common is the three-sided trocar point on each end of the pin.

IM pins are used often in conjunction with cerclage and/or hemicerclage wire, transfixation pins, external fixators, and bone plates. The use of more than one IM pin is referred to as

stack pinning. IM pins are used in the humerus, ulna, femur, and tibia. Small pins or K-wires may be used in the metacarpal/metatarsal bones. They are rarely used in the radius because the shape of the bone does not allow for easy access to the medullary cavity. IM pins are placed in long bones by either a normograde or retrograde manner. Retrograde placement involves starting the pin in the medullary cavity at the fracture site, driving it out one end of the bone, and then with the fracture reduced driving the pin across the fracture site into the opposite fragment. Normograde placement is where the pin is started at one end of the bone into the medullary cavity, across the fracture site, and into the opposite fragment.

The indications for the use of a single Steinmann pin without any ancillary fixation is limited to stable fractures in small dogs and cats that will not have a tendency for axial shortening or rotation. Usually these fractures are two-piece, diaphyseal, transverse (or nearly so) and have jagged edges that will interlock when the fracture is reduced. When using an IM pin as the primary means of stabilization the pin must be of an appropriate size in relation to the diameter of the bone. Factors to consider in choosing the appropriate pin size are the location and shape of the fracture in the bone and the shape of the bone. The time honored goal has been to select a pin that will fill approximately 95% of the medullary cavity at the fracture site. Others have stated that filling 60 – 75% of the medullary cavity for midshaft fractures is sufficient. When an IM pin is used with an external fixator or a bone plate a pin smaller in diameter than that which would be used as the primary fixation device must be used. This will allow the fixations pins of the external fixator or the bone screws to be placed with interference from the IM pin.

Other intramedullary devices have been used in the past but are very rarely used today. Some of these include Rush pins or Kuntscher nails.

Interlocking Nails

Interlocking nails (IN) are a relatively new fixation device in veterinary surgery. An IN is a large diameter “pin” that is placed in the medullary cavity of a fractured bone and then locked in place with screws placed perpendicularly through the bone, the pin, and then into the bone of the opposite cortex. The screws are placed in the proximal and distal aspects of the bone. An IN is effective in neutralizing bending, shear, compressive, rotational and torsional forces. They are most applicable to fractures of the femur, humerus, and tibia. In selected fractures IN have been used with success.

Bone Plates

Properly applied bone plates and their corresponding screws provide one of the most stable forms of fracture fixation. However, the fracture configuration can clinically affect the plate’s mechanical behavior. Each of the long bones is eccentrically loaded as the animal walks normally. Because of the eccentric loading one side of the bone is under more compression and one side is under more tension. Bone plates should be applied to the tension side of a bone. Clinically these surfaces are the lateral side of the femur, medial or cranial surface of the tibia, cranial or lateral surface of the humerus, and the craniomedial or cranial surface of the radius. While this is not always possible, it is the general principle that allows plates to provide maximum stability. When properly applied, bone plates are capable of neutralizing the disruptive forces acting on a fracture: compression, tension, shear, bending and torsion.

The bending stiffness of a plated bone is related to the length of the plate; the longer the plate the greater the stiffness. This is due to a better distribution of stresses over a greater length of the loaded bone. Filling all screw holes with screws (when possible) improves the strength and stiffness of a plate. Open screw holes, especially those located at or near a fracture line, act as a stress riser, predisposing the plate to fatigue failure. If fracture gaps exist, especially on the compression side of a long bone, the plate is susceptible to bending stresses that could result in fatigue failure of the plate. The use of wider and/or thicker plates can enhance a plate's ability to counteract the disruptive forces to a certain degree.

There are many designs and manufacturers of bone plating systems. The ASIF (Association for the Study of Internal Fixation, Synthes, Ltd.) is the most commonly used system in veterinary surgery. The terminology used to describe bone plates is a combination of the type (design) of the plate, its length, its width, the size of the screws used to secure the plate to the bone, and its function. Plates used in small animal surgery accept 1.5, 2.0, 2.7, 3.5, and 4.0 mm screws. An example of terminology would be a midshaft, multiple piece fracture of the femur stabilized with a 3.5 mm, 9 hole dynamic compression plate applied as a neutralization plate.

Dynamic Compression Plate (DCP)

A plate applied to a bone so that it is under tension and the fracture fragments are under compression is referred to as a compression plate or a tension band plate. A DCP is a plate that has specially designed screw holes that allow compression of the bone to be developed if the screw is inserted. This is referred to as an eccentrically placed or loaded screw. As the screw is tightened the fragment into to which it is being placed is displaced toward the fracture line and the center of the plate. By alternate tightening of "loaded" screws on each side of a fracture line the fragments are compressed. If the screw is placed in the center of the screw hole it will secure the plate to the bone without producing compression. DCP's come in different lengths and several sizes depending upon the size of the screws to be used. In the narrow DCP the width of the plate is just slightly greater than the screw holes and the holes are arranged in a straight line. In a broad DCP the plate is considerably wider than the screw holes; the holes may be in a straight line or staggered, and the plate is thicker than a narrow DCP. A limited contact DCP is one in which the underside of the plate (the side applied to the bone surface) is such that not all of the surface of the plate is in contact with the bone.

Special Plates

These include C-shaped plates for dorsal acetabular fractures; T-shaped plates have a variety of applications including distal radial fractures and certain types of arthrodeses; and cuttable plates. The cuttable plate has found use in the repair of long bone fractures in cats and small breeds of dogs. They can be cut to the specific length needed and can be stacked one on the other if additional strength is needed. A leg lengthening plate is solid in its center (does not have screw holes) and its screw holes are not of the DCP design.

Plate Function

In addition to functioning as a compression plate, plates are also applied as a neutralization plate or a buttress plate. A neutralization plate is applied to the tension side of a fractured bone. For a plate to have neutralization function the fracture must be anatomically reconstructed so that the load points exist throughout the length of the bone and the main

fragments are rigidly fixed, usually with lag screws. Longitudinal compression is not applied to the bone. A buttress plate is also applied on the tension side of the bone. A buttress plate is used to shore up a fragment of bone, thus maintaining length and functional angle, as in epiphyseal or metaphyseal fractures where joint congruity must be maintained. The term buttress plate, or bridging plate is used when the plate is placed to span or bridge a fracture area to maintain length when fragments are left unreduced or are missing and replaced with a cancellous bone graft. Thus, a DCP can be applied as a compression plate, a neutralization plate, or a buttress plate.

Plate Application

Plates are placed on the tension side of a long bone and secured to the bone with bone screws. As a general rule a minimum of 3 to 4 screws (6 to 8 cortices) must be placed on each side of a fracture for a compression, neutralization or bridging plate. In most cases the screws are placed so they engage both cortices of the bone. The minimum distance between a screw and a fracture line should be between 4 and 5 mm. As previously mentioned, a long plate is more effective than a short plate in neutralizing forces disruptive forces. The ideal in most cases is to use a plate that is just short of the entire length of the bone. For a plate to function properly it must be in contact with and conform to the shape of the bone to which it is being applied. Plates are bent or twisted so that they can fit the contours of a bone. The bends and twists must be placed between the screw holes.

Bone Screws

As with plates, screws are described by their design and by their function. There are two basic types of bones screws, cortical screws and cancellous screws. Screws are also described in millimeters by the diameter of their core and by their length, also in millimeters. Cortical screws are designed to be used primarily in dense diaphyseal bone. They are fully threaded and have more threads per length than cancellous screws. In addition the threads are shallower and have less of a pitch than the threads of a cancellous screw. Cancellous screws are used in the less dense bone of the metaphyseal and epiphyseal areas of bone. They are partially or fully threaded. In contrast to cortical screws they have less threads per length, the threads are deeper, and the pitch of the threads is greater. In practice, the metaphyseal and epiphyseal areas of bone of dogs and cats are more dense than in humans, therefore cortical screws are used quite frequently in these areas.

To place a screw in bone a hole of appropriate size is first drilled with a drill of the proper diameter, usually through both cortices. The depth (length) of the hole is then measured with a depth gauge and noted in millimeters. A tap is then placed in the hole and used to cut threads in the bone. The threads being cut will match those of the screw that will be inserted in the hole. The screw of proper size and length is then placed in the tapped hole and tightened.

In addition to securing plates to bone, screws are used to provide static interfragmentary compression by means of the lag screw principle. To function as a lag screw the screw head engages the first (near) cortex and the treads engage bone only on the opposite side of the fracture line in the second cortex. As the screw is tightened the threads engage the bone on the far cortex and compress the fracture line. For the lag principle to work, threads cannot engage bone on the near side of the fracture line. If screw threads engage bone on both sides of the fracture line compression will not occur. To provide interfragmentary compression

using a fully threaded screw, the screw hole in the near cortex must be created such that when tapped threads will not be cut in the bone. Partially threaded screws act as compression screws or lag screws if all of their threads are on the opposite side of the fracture line. Fully threaded screws provide compression between a plate and a bone because the threads do not engage the plate and are secured in the cortices of the bone.

Bone screws may also be used to hold bone fragments in a fixed position without interfragmentary compression. These screws are referred to as position screws. Screw threads engage the bone on both side of the fracture line.

Orthopedic Wire

Orthopedic wire is a flexible monofilament stainless steel wire used to provide interfragmentary compression or temporary stabilization of fracture fragments. The wire comes on spools and is available in several gauges; the larger the gauge designation the smaller the wire. Twenty-two gauge wire is used in toy breeds and cats, 20 gauge for medium size dogs, 18 gauge for larger breeds, and 16 gauge for giant breeds. Stainless steel suture must never be used to replace orthopedic wire. The term cerclage means to wrap-around or encircle. Cerclage wire then refers to orthopedic wire that completely encircles a bone. Hemicerclage wire refers to orthopedic wire that partially encircles a bone. These wires are used as ancillary fixation devices in conjunction with IM pins, external fixators, and bone plates, they should not be used as the sole means of fracture fixation. They are used most often on long oblique, spiral and certain comminuted or multiple fractures. Cerclage wire fixation of fracture fragments should be reserved for those fractures in which the length of the fracture line is at least twice the diameter of the bone. In addition, cerclage wire should only be applied to areas of a bone in which the bone cylinder can be anatomically reconstructed; in most cases this means there should not be more than two fracture fragments and two fracture lines in the transverse plane to be encircled by the wire. In general, cerclage wire for the fixation of fracture fragments should be placed approximately 5mm from the ends of the fragment and 1cm from each other. The wire must be placed as tightly as possible around the bone and not entrap soft tissue (muscle, nerve, vessels) between the wire and the bone. Loose wire will not provide a stable fixation and will disrupt the periosteal vascularity needed for fracture healing.

There are two primary methods of tightening cerclage wire. A specially made cerclage wire has a preformed eyelet in one end. The wire is passed around the bone, through the eyelet, tightened with a special device putting tension on the wire, and then bent back 90° over the eyelet. The end of the wire is then cut with a wire cutter.

In the twist method of tightening orthopedic wire the wire is again placed around the bone. The two free ends of the wire are inserted into a special wire tightener or grasped with the jaws of special pliers and twisted. It is very important that tension be applied to the wire as it is being twisted. This ensures that the wires wrap around each other equally, rather than one wire being wrapped around the other. The wire may be cut seven to eight twists from the bone and then back back, or it can be cut three to four twists from the bone and left in place. The latter method preserves the tension in the wire better, but the end of the wire may cause irritation to the overlying soft tissue.

Interfragmentary Wire

Interfragmentary wire is used primarily to prevent rotation of short oblique or transverse fractures, to secure bone fragments, and to stabilize certain fissure fractures. Holes are drilled in the bone on each side of the fracture, the wire is passed through each of the holes, the fracture is then reduced and the wire tightened (twisted) to hold the fragments in place. In some cases K-wires or small IM pins are used as transfixation pins which are passed from one side of the fracture to the other penetrating both cortices; orthopedic wire is then passed in a figure-of-eight pattern around the tips of the protruding pins and tightened. The wire adds compression while the pins maintain the fragments in position.

Tension Band Wire

A tension band wire, or tension band device, is used to counter the distracting forces placed on certain bones and bony prominences. When properly applied the device functions by converting the forces of distraction to those of compression. It is used primarily to repair fractures or osteotomies of the olecranon process, trochanter major, and fractures of the tuber calcis, medial and lateral tibial maleolli, and a detached tibial tuberosity. The device consists of orthopedic wire and two K-wires. The K-wires neutralizes shear forces; the tension band wire neutralizes bending loads and distraction forces and converts them to compressive forces. The fracture or osteotomy is reduced and the K-wires are passed through the fragment, across the fracture line and into the main portion of the bone. The K-wires should be as parallel to each other as possible. A transverse hole is then drilled through the diaphysis of the bone distal to the fracture. The hole is drilled such that a figure-of-eight wire will cross at or just distal to the fracture line. The orthopedic wire is then passed through the hole and around the protruding tips of the K-wires in a figure-of-eight pattern. The wire is tightened by twisting each side of the figure-of-eight to compress the fracture line. Alternatively, transverse holes are drilled above and below the fracture and the wire again placed in a figure-of-eight pattern and tightened.