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TISSUE HEALING TIMELINES

Bone

Bone is one of the few tissues that can undergo healing to 100% tensile strength. Its healing may be understood according to two categories – **primary** and **secondary** bone healing. Primary healing occurs when there is very little space in the fracture of the bone, so that they remain rigid and stable, and healing can proceed via **contact** or **gap** healing. Contact healing involves bone formation across a gap of less than 0.1mm, and occurs through the haversian canals. If the gap is bigger than 0.1mm and less than 0.5mm, gap healing occurs. The body will form lamellar bone from the medullary cavity and periosteum to fill the void. The process is then the same as in contact healing. Secondary bone healing occurs when the fracture is greater than 0.5 mm wide and the fracture is less stable. This healing is characterized by **callus formation**. The degree of callus formation depends on the degree of instability of the fracture.

Inflammatory	The primary and secondary inflammatory phase both start immediately and last for 72 hours after injury.
Reparative	In secondary healing, radiographic callus formation occurs at 10-12 days, and the fracture line disappears in 30 days. Primary bone healing takes a bit longer.
Remodeling	Woven bone develops over callus, with complete remodeling after 90 days in a simple fracture. Primary bone healing will produce less early stability and will require that stabilization implants remain in place for longer.
Characteristics of healing	Regains **100% tensile strength** due to regeneration. Healing and an improvement in tensile strength occurs **faster** in secondary healing than in primary, with the rate of healing depending on the presence of interfragmentary strain, the age of the animal and the location of the fracture. Fractures will heal faster in areas of more dense, cancellous bone and a highly vascularized marrow. The rate of healing will depend on concurrent diseases and the fixation method used. **General bone healing timelines in puppies:** Younger than three months: Healing will occur in 2-4 weeks. Between 3-6 months: 4-12 weeks. Between 6-12 months: 5 weeks – 5 months. **Adult dogs:** From 7 weeks up to 12 months.

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Muscle

Muscle can be injured in a variety of ways – lacerations, contusions, ruptures, ischemia and strains. A strain is an injury to the muscle or tendon that tends to occur near the **myotendinous junction**, and is graded from 1-4, depending on the severity. Grade 1 is simply a disruption of a few fibers, while grade 4 is a complete rupture of the muscle belly. The cause of these injuries is usually a **forceful contraction** while the muscle belly is being stretched. Muscle injuries vary from acute to chronic, and from very mild to very severe.

Inflammatory	Immediate to 72 hours
Reparative	Type III collagen starts forming a scaffold after three days, while normal collagen will start coming into place after 6 weeks.
Remodeling	Functional muscle fibers will compete with fibrous scar tissue for deposition space. How much fibrous scar tissue forms is very dependent on the grade of the lesion or the size of the gap.
Characteristics of healing	Normal myofiber healing is important for a return to full function and tensile strength. Myofiber healing will be determined by the **stress** and degree of **movement** at the site of injury during the healing process, as well as the size of the gap or amount of fiber disruption that has occurred. The injured muscle should be immobilized through the inflammatory and early reparative phase, with gentle stress starting in the late reparative and early remodeling phase to allow correct **alignment** of myofibers. If too much stress is placed on the muscle, the gap will widen and **fibrous tissue** will predominate during the remodeling phase. Controlled activity should continue for at least 4-6 weeks before starting a gradual return to functional activity. In a partial lesions you may have regained 60-80% of tensile strength after 12 weeks.

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Tendon

Tendons are classified into two categories that determine how they will heal. **Vascular** tendons lack a synovial sheath and can receive blood supply from the tissue surrounding the tendon. During healing, these tendons receive blood from the surrounding tissue, resulting in the 'one wound-one scar' phenomenon. **Avascular** tendons are surrounded by a synovial sheath and receive blood from the musculotendinous junction, the osseous point of insertion and the adjacent muscle and paratenon. In these tendons, healing takes a little longer as it is dependent on the **intrinsic** blood supply and inflammatory response within the tendon. **Immobilization** is essential in the initial period to reduce gap formation and allow adequate healing.

Inflammatory	Immediate to 72 hours
Reparative	Collagen will orientate itself randomly in a scaffold by day 5. Collagen production then progressively increases for four weeks and decreases by day 60.
Remodeling	Collagen fibers start to align according to the stress placed on them from 28 days after injury, and tendons will resume a normal appearance from day 112.
Characteristics of healing	At six weeks, 56% of tensile strength may be restored, and from one year onwards, only 79% of tensile strength will be restored. **Surgical repair** of an acute gap formation is necessary for optimal healing at six weeks; tendons with a gap of more than 3mm have a lower tensile strength. Vascular tendons will heal faster than avascular tendons, which always require more time.

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Ligament

There are currently many unknowns and unanswered questions when it comes to ligament healing. The ability of a ligament to heal varies greatly, and seems to have a connection to its **location** – for example a collateral ligament on the edge of the joint capsule has a relatively good ability to heal, while the cranial cruciate ligament in the very center of the joint seems to have almost no healing capacity. Ligaments seem to follow the same pattern of healing as other tissues.

Inflammatory	Immediate to 72 hours
Reparative	The repair phase starts on day 2-3 and lasts until about 6 weeks after injury. Collagen fibers at this stage are mostly type 1.
Remodeling	This phase may take more than 12 months to complete, if it completes at all.
Characteristics of healing	Ligaments may regain 50-70% of tensile strength after a year of healing, depending on the grade of injury and the location of the ligament. The **factors** that will affect ligament healing include the location of the ligament, nutritional status, endocrine imbalances, degree of injury, blood supply and the stress placed on the ligament during the healing period.

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Cartilage

Cartilage is divided into three zones – the tangential zone, the intermediate zone and then the largest zone which is the radial zone. The radial zone imbeds into the **subchondral bone**. These zones have no direct blood supply, which affects the ability of cartilage to heal. If an injury extends into the subchondral bone, a **vascular** response will occur, coming from the subchondral bone, and a normal healing pattern will follow. If the injury does not extend into the subchondral bone and remains in the superficial layers of the cartilage, there will be no vascular response and healing will be **limited**.

Inflammatory	In a superficial injury, there is no inflammatory response. In a deep injury, the inflammatory response will come from the marrow bone and last for 3-5 days.
Reparative	In a superficial wound the chondrocytes will initiate a mitotic response that may partially fill the wound. This response is very limited and only lasts for 1 week after injury, rarely filling in the whole gap. In the event of a deep wound repair starts from about 5-7 days and lasts until 2 months after the injury.
Remodeling	In a superficial injury the lack of an inflammatory response means that proper gap closure doesn't occur, and this can remain the case for up to a year after the injury. In the event of a deep wound remodeling occurs in 2-6 months. The repaired tissue remains fibrous and is not comparable to hyaline articular cartilage in nature or quality.
Characteristics of healing	Healing is dependent on the age and size of the patient as well as the **location** of the injury. That being said, it is very rare for hyaline articular cartilage to fully heal, and **degeneration** of the joint over time is a reality. Another very important consideration is the **immobilization** of the joint, as immobilization will greatly **impair** the biomechanical and biochemical healing ability of the joint – early and continuous PROM is essential.