An Analysis of Common Calcaneal Tendon Disruption in Canids

Sophie Foster

HONR 499: Senior Honors Thesis

Colorado State University

December 13th, 2024

Outline

I. Introduction

II. Anatomy of the Common Calcaneal Tendon

III. Types of Injuries

IV. Prevalence

V. Signs and Symptoms

VI. Diagnosis

  A. Radiography

  B. Computed Tomography (CT)

  C. Ultrasonography

  D. Magnetic Resonance Imaging

VII. Treatment

  A. Three-Loop Pulley Suture vs. Two Locking-Loop Sutures

  B. Novel Synthetic Fiber Implant

  C. Single Ring Transarticular Fixator

  D. Stem Cell Therapy

  E. Platelet Rich Plasma Therapy

  F. Extracorporeal Shockwave Therapy

VIII. Conclusion

Introduction

Small animals are prone to muscular trauma throughout their life. A common trauma these animals experience includes disruption of their Achilles tendon, better known anatomically as the common calcaneal tendon. Trauma to the common calcaneal tendon can present in many different ways, but in many cases, it involves the tendon detaching from the calcaneal tuber of the calcaneus bone located in the tarsus. Ruptures of the tendon may be partial or complete. A partial rupture is when one or a few of the muscle tendons are torn, while a complete tear is when all of the muscle tendons that are a part of the common calcaneal tendon are torn. In both cases, the gastrocnemius and superficial digital flexor tendons are most frequently affected because they are the two most prominent muscle tendons in the common calcaneal tendon (Harari, 2020). However, this does not mean they always rupture together when injury occurs. While disruption of the common calcaneal tendon is seen in many species, it is prevalent in working, athletic dogs (Harari, 2020). There are several clinical signs of a damaged common calcaneal tendon, including lameness, hyperflexion of the tarsal joints, and an altered stance that results in a plantigrade stance rather than a normal digitigrade stance. Affected animals will likely experience pain and swelling as well (American, n.d.). Trauma to the common calcaneal tendon can be diagnosed with a series of imaging techniques and can be surgically repaired with a variety of different options. While the prognosis is variable based on several factors, a successful outcome is often observed (American, n.d.).

Anatomy of the Common Calcaneal Tendon

The common calcaneal tendon is a group of muscle tendons that extend from the proximal pelvic limb to the calcaneal tuber, a bony prominence on the calcaneus bone. The components of the common calcaneal tendon consist of the gastrocnemius, superficial digital flexor, biceps femoris, gracilis, and semitendinosus muscle tendons. The gastrocnemius muscle is a tarsal extensor and digital flexor. It originates on the medial and lateral supracondylar tuberosities of the femur and attaches to the calcaneal tuber. The superficial digital flexor is also a tarsal extensor and digital flexor muscle. It originates from the lateral supracondylar region of the distocaudal femur and attaches to the calcaneal tuber and middle phalanges of digits II through V. The biceps femoris muscle is a hip extensor and stifle flexor. It originates from the sacrotuberous ligament and ischiatic tuberosity, a bony prominence on the ischium of the pelvis. It attaches to the patella, patellar ligament, the tibial crest of the tibia bone, and the calcaneal tuber via the fascia lata and fascia of the leg on the lateral aspect of the limb. The gracilis muscle is a limb adductor, stifle flexor, and hip and tarsal extensor. It originates from the pelvic symphysis and attaches to the cranial border of the tibia and calcaneal tuber. The semitendinosus muscle is a hip and tarsal extensor and stifle flexor. It originates from the ischiatic tuberosity and attaches to the medial body of the tibia and calcaneal tuber via the fascia of the leg (Magee, 2022). Gross images of the gastrocnemius and superficial digital flexor muscle tendons can be seen in Figures 1 and 2, highlighting the majority of the common calcaneal tendon.

Types of Injuries of the Common Calcaneal Tendon

There are two main types of injuries that can occur in the common calcaneal tendon: traumatic and atraumatic. Traumatic injuries are caused by lacerations, blunt force trauma, or extreme stretching and pulling. Atraumatic injuries can result from repetitive injury, hypothyroidism, hyperadrenocorticism (formerly known as Cushing's disease), or immune-mediated polyarthritis (American, n.d.), all of which can lead to muscle degeneration. Muscle degeneration weakens the muscle tendons, leading to an increased risk of injury to the common calcaneal tendon. Trauma to the common calcaneal tendon results in a partial or complete tear of one or more muscle tendons confined within the common calcaneal tendon. A partial tear is when one or two of the muscle tendons are torn, while a complete tear is when all of the muscle tendons are torn. The tendon may also be entirely or partially detached from its bony insertion. The gastrocnemius and the superficial digital flexor muscle tendons are the two structures of the common calcaneal tendon most frequently affected because they are the most prominent, meaning they are the two largest muscle tendons that are part of the common calcaneal tendon (Harari, 2020). A diagram showing a normal, partially torn, and completely torn common calcaneal tendon can be seen below in Figure 3.

Prevalence of Common Calcaneal Tendon Disruption

Any breed of dog can experience trauma to their common calcaneal tendon. However, working, athletic dogs are at a higher risk for injury (Harari, 2020). This is because they use their muscles at a much higher level, posing a greater risk of stretching or pulling the common calcaneal tendon too far. More active dogs also have a higher chance of experiencing trauma to the common calcaneal tendon simply because of the environments they are exposed to. Once an athletic working dog experiences an injury to their common calcaneal tendon, they can return to their normal activities. However, they may not perform at the same level they did before the injury. If an athletic dog continues to participate in increased activity levels, they will likely experience another tear to their common calcaneal tendon.

Signs and Symptoms of Common Calcaneal Tendon Disruption

An animal with an injury to their common calcaneal tendon will present with pain, lameness of the affected limb, swelling around the injury, and hyperflexion of the tarsus. Hyperflexion of the tarsus results from the extensor muscles of the tarsus being torn (Harari, 2020) and affects the canine's stance. Normally, quadrupeds have a digitigrade stance, meaning they are weight-bearing on their digits. When the muscles responsible for holding the digitigrade stance are injured and can no longer support the animal, they will succumb to a plantigrade stance in which they are weight-bearing on their entire pes, similar to humans. Injury may also cause the digits to continuously flex due to excessive pull on the superficial digital extensor muscle tendon. This effect is depicted in Figure 3 when the tendon is completely torn and in Figure 4, which compares a normal tarsus to a dropped tarsus. Walking with a plantigrade stance can negatively impact the animal by causing luxation, or dislocation, of the tarsal joints and other joints throughout the pelvic limb.

Diagnosis of Common Calcaneal Tendon Disruption

Injury to the common calcaneal tendon is diagnosed using a series of techniques. First, a physical exam is done to assess the animal and potentially localize the injury. An essential part of completing a physical exam on a canine suspected of having a common calcaneal disruption is performing a posture and gait analysis to assess their stance and how they are walking. If a dog appears flat-footed or limping when they walk, this could indicate injury to the common calcaneal tendon. After completing a physical exam, various imaging techniques can be used to further assess the extent of the injury. Radiography can be used as an indirect form of imaging due to the limited visibility of tissues (Abako, 2021). The visibility of soft tissue is limited when taking radiographs because of its low density compared to bone. Rather than using radiographs to assess the quality of the muscles and associated tissues, they can be used to evaluate the state of the surrounding bones, such as the calcaneus bone. Often, injury to the common calcaneal tendon will result in an alteration to the associated bones, which will appear on a radiograph and can be used to further diagnose injury to the tendon. Some animals may also have arthritis in their tarsus or calcaneus, which affects the quality and strength of the structures and can be visualized on a radiograph. Radiographs can also show mineralization of tissue and swelling of nearby tissues, indicating damage to the common calcaneal tendon. (Abako, 2021). Radiographs demonstrating injury to the common calcaneal tendon can be seen below in Figures 5 and 6.

Computed tomography (CT) can also be used to identify pathologies of the common calcaneal tendon. Unlike radiographs, CT provides better visualization of soft tissues and sectional images, creating a clearer picture and preventing the superimposition of structures as seen with regular radiography (Abako, 2021). Nonetheless, CT is still considered an indirect imaging method due to the limited visibility of the tissues associated with the common calcaneal tendon. When using CT, veterinarians should still look for damage to the associated bones and attachment points, such as the calcaneal tuber, and swelling of surrounding structures. A CT image of a common calcaneal tendon can be seen below in Figure 7, highlighting the mineralization of the tendon. A reconstructed 3D CT image is also included below in Figure 8 to provide a clear picture of the mineralization one should look for when diagnosing injury to the common calcaneal tendon. Compared to radiographs, CT scans are much more expensive and not as widely used throughout the country, making them less accessible to the general public.

Another standard and accessible imaging method used to diagnose a common calcaneal disruption includes ultrasonography, which can be used to obtain a more direct view of the common calcaneal tendon. The structures that make up the common calcaneal tendon, such as the gastrocnemius, superficial digital flexor, biceps femoris, gracilis, and semitendinosus muscle tendons, are easily visible with ultrasound. The superficial digital flexor tendon is the easiest to visualize because it is the most superficial muscle tendon within the common calcaneal tendon. The best view of the tendon can be achieved via a caudal-plantar angle in the longitudinal and transverse planes (Abako, 2021). Rupture of the common calcaneal tendon appears as a break in the continuity of the structures seen on the ultrasound, often accompanied by a hematoma between the broken ends of the tendon (Abako, 2021), as seen in Figure 9. In addition to diagnosis, ultrasonography can also be used to monitor the healing process of a treated common calcaneal injury; however, it cannot be used to determine how long the tendon has been damaged or how long it will take to heal (Abako, J).

A less common but much more effective imaging technique that can be used to diagnose injury to the common calcaneal tendon is magnetic resonance imaging (MRI). MRI provides high-resolution, multiplanar images, allowing for clear visualization of the structures (Abako, 2021). An MRI of a ruptured common calcaneal tendon can be seen below in Figure 10. It is important to note that while magnetic resonance imaging would be the ideal method of diagnosing a common calcaneal injury, MRI machines are not widely used in average veterinary practices. Magnetic resonance imaging is also costly, not just for the veterinary businesses but for the clients, and often requires sedation of the animal, making it a less affordable and less common option for diagnosis.

Treatment of Common Calcaneal Tendon Disruption

Once the injury is localized and evaluated, a treatment plan can be curated for the animal. Treatment options for an injury to the common calcaneal tendon depend on the severity of the injury and the means that are available to both the veterinarian and the client. In most cases, the common calcaneal tendon ruptures can be surgically repaired. Surgically repairing a ruptured tendon often involves using sutures or grafts to reattach healthy ends of the tendon(s) back together. In more severe cases, implants can aid the reattachment of a damaged tendon. External tendon protection is also needed after surgery to ensure the repair is not damaged and heals effectively. Forms of protection include casts, splints, and temporary screws. Patients are limited to restricted activity for 6-12 weeks after surgery and are required to keep the external support on until the injury is completely healed, which can take 9-12 months. Adjunct therapies may also be recommended to help manage symptoms and regain appropriate motion of the tarsal joint. The surgery success rate for repairing damage to the common calcaneal tendon is high, and the prognosis is usually really good. More than 70% of dogs will regain normal function after an injury (American, n.d.).

There are two standard suturing techniques that are used to surgically repair common calcaneal ruptures: the Three Loop Pulley suture and the Two Locking-Loop sutures. In a Three Loop Pulley suture pattern, six strands of suture material cross the site of anastomosis, while only two strands cross the anastomosis in the Locking-Loop suture pattern (Moores et al., 2004). Diagrams depicting these two suturing patterns can be seen in Figure 11 below. A greater amount of sutures crossing the anastomosis site increases the strength of tendon repairs (Moores et al., 2004), meaning the Three-Loop Pulley system should be deemed the better repair method. A study conducted by Moores et al. compared the tensile strength of the Three-Loop Pulley suture pattern and Two Locking-Loop sutures. As expected, the results showed that the Three-Loop Pulley pattern is significantly more resistant to gap formation when exposed to tensile loading. In addition, the study found that the Three-Loop Pulley suture pattern was quicker to place than the Locking-Loop sutures, resulting in less tendon substance distortion. It is worth noting that if three Locking-Loop sutures were placed (instead of two) and compared to the Three-Loop Pulley pattern, the results of the study may have differed, producing similar outcomes since the same amount of suture strands would be crossing the anastomosis, providing the same amount of strength. However, as mentioned, placing the Locking-Loop sutures takes longer, so placing three of them will only prolong the surgical procedure, posing more risk to the patient. For both of these suturing methods, slowly absorbable suture material would be ideal to allow enough time for the tendon tissue to regenerate and eliminate the need for suture removal in the future.

Another available surgical treatment for repairing an injury to the common calcaneal tendon includes using a novel synthetic fiber implant. Most cases of surgical repair involve reattaching two broken or damaged ends of the torn tendon. However, there are some cases in which reattachment is more complex. For example, the tendon may be torn off from its insertion on the calcaneal tuber, making it extremely difficult to reattach the tendon to the bone, especially if it is damaged. Additionally, degeneration of the muscle tendons can cause the formation of scar tissue and may lead to muscle atrophy, which would leave less tissue to work with when trying to reconstruct the tendon (Buttin et al., 2020). In these cases, an implant can be used to assist with the repair of the tendon. The novel synthetic fiber implant is composed of braided grad-medical Ultra-High Molecular Weight Polyethylene (UHMWPE) fibers, which is a biocompatible material that is used in many medical applications, such as cruciate implants (Buttin et al., 2020). The implant has two parts, one of which is designed to be proximally sutured to the tendon and distally sutured to the site of bone insertion, and the other which is a puller wire that is used to insert in bone tunnels for stabilization (Buttin et al., 2020). A picture highlighting the different parts of the implant can be seen below in Figure 12. A study performed by Buttin et al. used the synthetic implant for surgical repair in three different cases: (1) a complete avulsion, or unattachment, of the common calcaneal tendon from the insertion point on the calcaneus bone, (2) a chronic patellar tendon rupture, in which case the patellar tendon was ruptured between the patella and its attachment point on the tibial tuberosity, and (3) a chronic avulsion (rupture) of the triceps tendon. In all three cases, the implant was used to repair the injury successfully. It is worth noting that using synthetic implants can pose risks of infections. Therefore, the implant should not be placed in an area of infection or an open wound where infection could occur, and proper asepsis should be performed before and during surgery. Nonetheless, using an implant is an effective technique to repair injury to the common calcaneal tendon, especially in more complicated instances that make simple reattachment much more difficult.

As mentioned above, immobilization of the tarsocrural joint is often required after surgical repair to ensure proper healing of the common calcaneal tendon. Immobilization is attained by an external device to prevent movement of the joint, such as a cast, splint, or temporary screws. A device known as a single-ring transarticular fixator can also be used. This device is made up of a metal ring with a specific diameter based on the size of the tarsus it is being placed around, a wire that is placed through the calcaneal tuber and tibia, and Kirschner wires that are placed in the distal tibia to help stabilize the fixator. Figure 13 provides a clear picture of the device. In a study performed by J.C. Norton et al., the use of a single-ring transarticular fixator in ten different canine patients that presented with a partial or complete common calcaneal tendon disruption was observed. Results of the study found that eight out of the ten cases developed complications, with the most common complication being swelling of surrounding tissues. Only two of the cases required surgical intervention after the device was placed. One case resulted in the formation of a seroma, an accumulation of fluid under the skin, which required a drain to be placed. The other case that required surgical intervention was due to severe swelling that led to the transarticular fixator needing to be removed. Despite these complications, the study concluded that all the repairs led to a successful outcome and improved the lameness seen in each patient at the time of injury. The single-ring transarticular fixator is still considered a beneficial means of immobilizing the talocrural joint, especially when comparing its complication level to other means of immobilization. To explain, casts, splints, and screws can lead to pressure sores, skin infections, splint breakage, and secondary fractures. While it is known that complications can occur with any external immobilization method, the transarticular fixator presents the least amount of complications, making it a safe and effective immobilization method after surgical repair of a common calcaneal injury.

The use of stem cells is also a newer, innovative method of repairing injury to the common calcaneal tendon. Stem cells are unspecialized cells that can differentiate into different cell types and be used to treat several different conditions. There are two types of stem cells: embryonic and adult stem cells. Embryonic stem cells are found in blastocysts during development, while adult stem cells are found in most tissues of an animal's body. In the case of a common calcaneal tendon injury, adult stem cells are taken from either bone marrow or adipose (fat) tissue and placed into the tissue of the torn tendon to enable the repair of the damaged tissue by regenerating new cells. The procedure for introducing stem cells into the damaged tissue involves some form of anesthesia and an injection of the stem cells into the damaged tissue (Durzi et al., n.d.). In a study performed by Case et al., a 4-year-old spayed female Border Collie presenting with lameness and injury to the gastrocnemius tendon was treated with autologous mesenchymal stem cells. The stem cells were taken from bone marrow from the proximal aspect of the right humerus and transplanted into the tissue of the patient's torn gastrocnemius muscle tendon. A custom cast was used to immobilize the tarsus and facilitate proper healing. After a series of repeated examinations, the study found that the patient's lameness had resolved significantly. However, ultrasonographic images showed improved but incomplete restoration of the gastrocnemius muscle tendon. This study suggests that stem cell therapy is a potentially viable and minimally invasive method of treating injuries such as common calcaneal disruptions and managing associated symptoms. However, more research will need to be done to determine how effective stem cell therapy can be.

An additional therapy that can be used to help manage the healing process and symptoms of a common calcaneal tendon injury includes platelet-rich plasma. Platelet-rich plasma treats inflammation in the body and promotes the healing of damaged tissues. The platelet-rich plasma is obtained by removing red blood cells from a whole blood sample collected from a patient. This plasma is then directly injected into the affected site of a patient experiencing inflammation, where its growth factors will attract macrophages to the wounded area and activate fibroblasts and endothelial cells to repair wounded and inflamed tissue. The growth factors present in platelet-rich plasma include vascular endothelial growth factor (VEGF), platelet-derived growth factor (PDGF), fibroblast growth factor 2 (FGF-2), and transforming growth factor-β (TGF-B) (Durzi, n.d.). In the case of a patient with a common calcaneal tendon disruption, the platelet-rich plasma would be injected into the tarsal joint to minimize inflammation. Patients will need multiple injections for this therapy to be effective. Other than possible pain, irritation, or bleeding at the injection site, side effects of platelet-rich plasma therapy are minimal since the sample is obtained from the patient's own blood (Durzi, n.d.). Although more research is needed to define platelet-rich plasma as a mainstream therapy, studies have shown it to be an effective and reasonably low-cost option for patients experiencing inflammatory conditions.

Extracorporeal shockwave therapy (ESWT) uses sound waves to create energy that will form changes in the tissues. The process involves a rapid change in pressure that causes sound waves with a very high velocity and pressure to be released from a trode, or the handheld device used to deliver the treatment. As the sound waves pass through layers of skin, fascia, tissue, and muscle, they will produce enough energy to influence tissues at the cellular level, ultimately relieving pain, decreasing inflammation, and facilitating healing (Williams, n.d.). ESWT requires a series of treatments to see effective results. The frequency of treatments depends on the condition that is being treated. For most conditions, patients should receive a minimum of two shockwave treatments every 2-3 weeks. While ESWT is effective in patients with a common calcaneal tendon injury, ESWT should not be used in patients with infected joints, discospondylitis (infected intervertebral discs), neurologic deficits, or immune-mediated joint disease (Williams, n.d.). It is worth reiterating that immune-mediated joint disease can lead to a common calcaneal tendon disruption, so it is imperative to pay attention to the underlying conditions a patient may be experiencing when considering treatment with ESWT if they have a common calcaneal tendon disruption. ESWT should also not be used in dogs that are still growing to prevent the risk of affecting the growth process. In addition, EWST should not be applied to the lungs, brain, spinal cord, or large vessels due to complications such as pneumothorax, nerve damage, or internal bleeding, respectively. Minimal side effects of EWST include minor bruises, temporary swelling, and some discomfort. Therefore, pain medications may be prescribed for a short amount of time during treatment to relieve these side effects (Williams, n.d.). Nonetheless, studies have shown that EWST is an effective therapeutic technique for relieving symptoms of musculoskeletal injuries such as common calcaneal tendon disruptions.

Conclusion

To conclude, the common calcaneal tendon is a group of five muscle tendons that extend from the proximal pelvic limb to the calcaneal tuber of the calcaneus bone located in the tarsus. Traumatic or atraumatic injuries can occur to the common calcaneal tendon, leading to a partial or complete tear. Injuries are most common in working, athletic dogs because of their increased activity levels and muscle usage. Patients presenting with a common calcaneal disruption will display signs of pain, lameness, swelling, hyperflexion of the tarsus, and a plantigrade stance rather than a digitigrade stance. Multiple imaging techniques, such as radiography, computed tomography (CT), ultrasonography, and magnetic resonance imaging (MRI), can be used to diagnose a common calcaneal tendon disruption. Of these imaging methods, radiography and ultrasonography are the most accessible. However, magnetic resonance imaging (MRI) would be the ideal method of diagnosis because it provides the clearest picture. Treatment of common calcaneal tendon disruptions often involves surgical repair to reattach the torn ends of the tendon, which can be accomplished with the use of sutures. A variety of suture patterns can be used, such as the Three-Loop Pulley suture pattern or two Locking-Loop sutures. Studies have shown the Three-Loop Pulley suture pattern to be the most effective. Following surgical repair, immobilization of the tarsal joint is needed to ensure proper healing. Immobilization can be attained using a cast, splint, external screws, or more complex devices such as a single-ring transrticular fixator that minimize the risk of further complications. In addition to surgical repair and immobilization, adjunct therapies such as stem cell therapy, platelet-rich plasma, and extracorporeal shockwave therapy can also be used to help manage symptoms and facilitate healing. Common calcaneal tendon disruption is a prevalent condition seen in veterinary medicine but has many different diagnostic and treatment options that make it a treatable condition, allowing canines to recover effectively from injury. More research is being done to determine additional therapies that can be used to help treat and manage this condition.

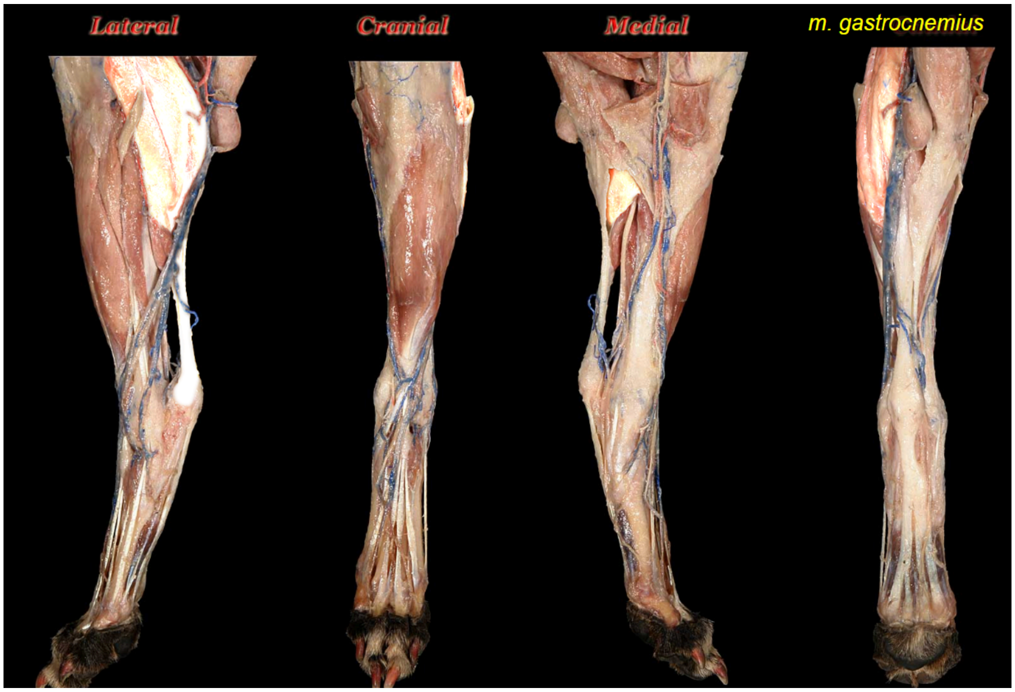

Figure 1: Gastrocnemius m. (Image from Virtual Canine Anatomy, all rights reserved).

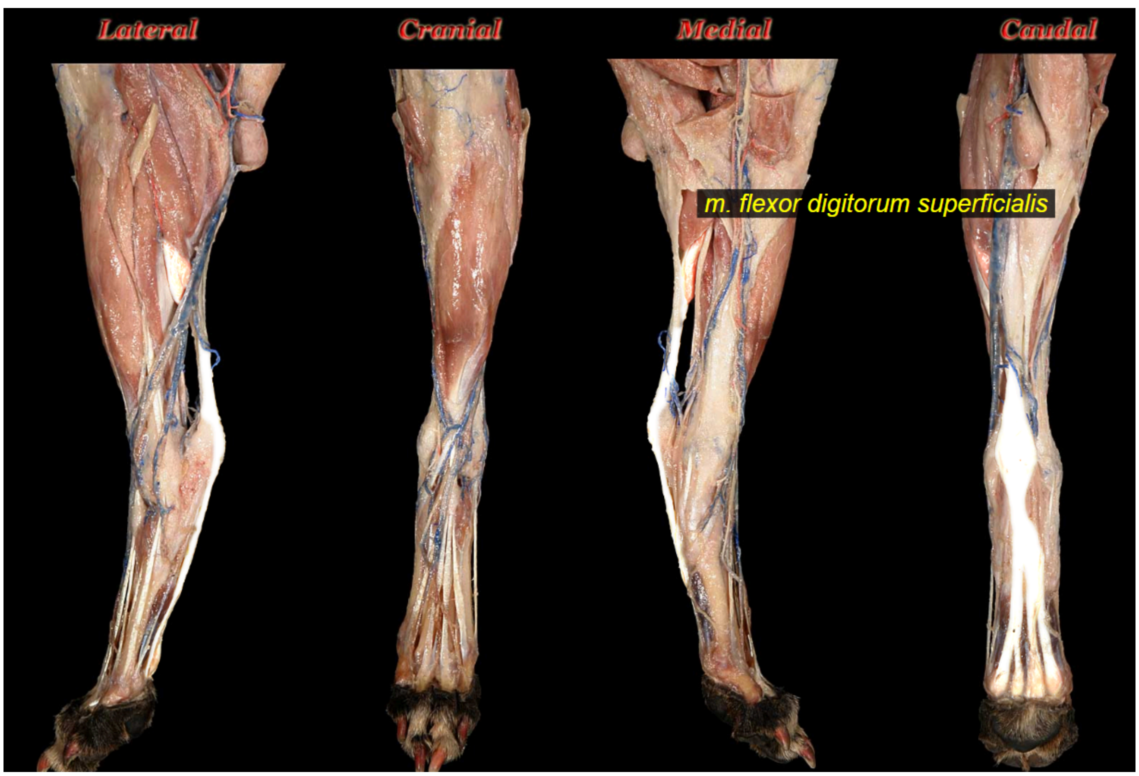

Figure 2: Superficial Digital Flexor m. (Image from Virtual Canine Anatomy, all rights reserved).

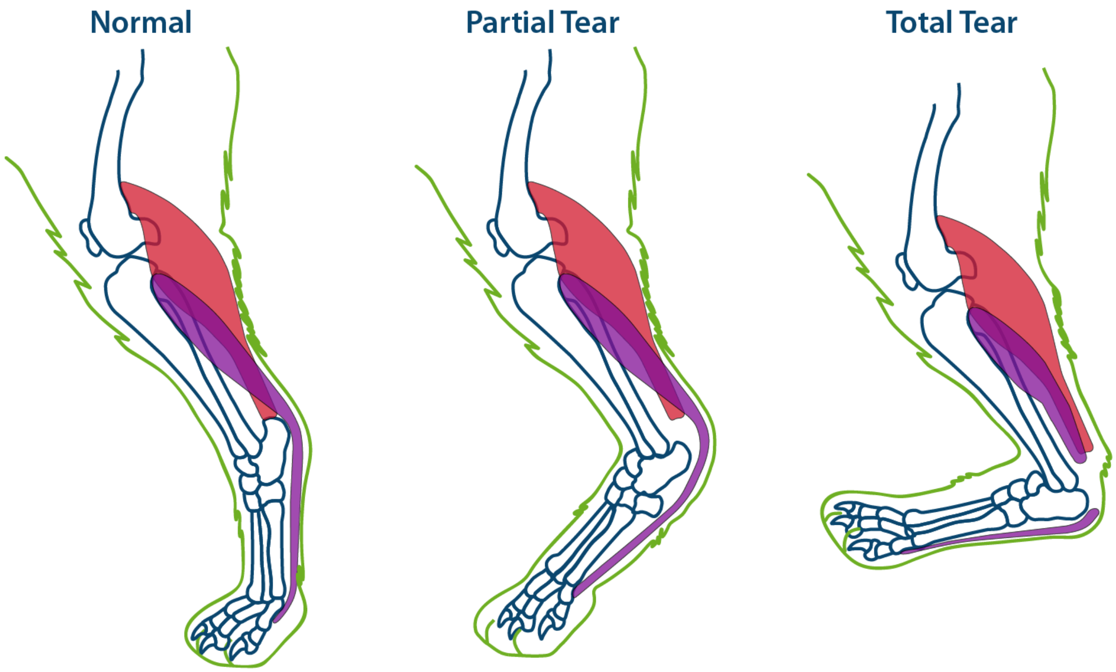

Figure 3: Comparison of a Normal, Partially Torn, and Completely Torn Tendon (Dog, n.d).

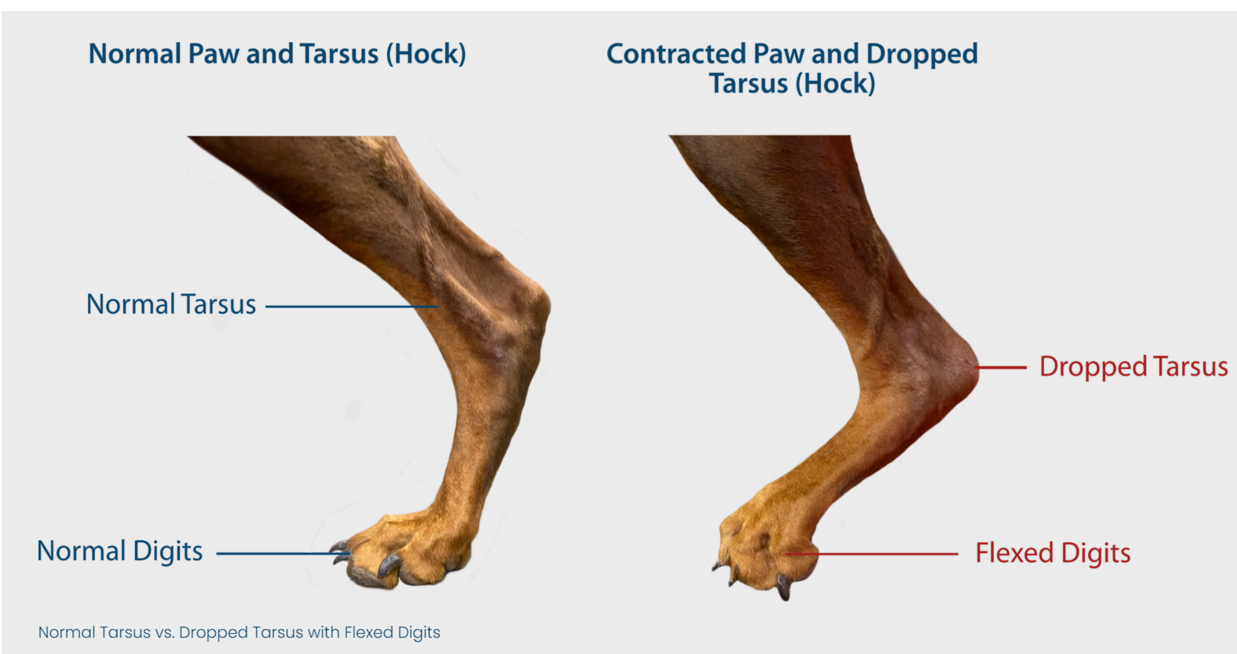

Figure 4: Normal Tarsus vs. Dropped Tarsus and Flexed Digits (Dog, n.d).

Figure 5: Radiograph of an Injured Common Calcaneal Tendon (Abako, 2021).

Figure 6: Radiographic image of the total common calcaneal tendon rupture. The focus of tendon mineralization is shown (red arrow) (Abako, 2021).

Figure 7: CT of the mineralization of the common calcaneal tendon (red arrow) (Abako, 2021).

Figure 8: 3D CT reconstruction of the mineralization of the common calcaneal tendon (red arrow) (Abako, 2021).

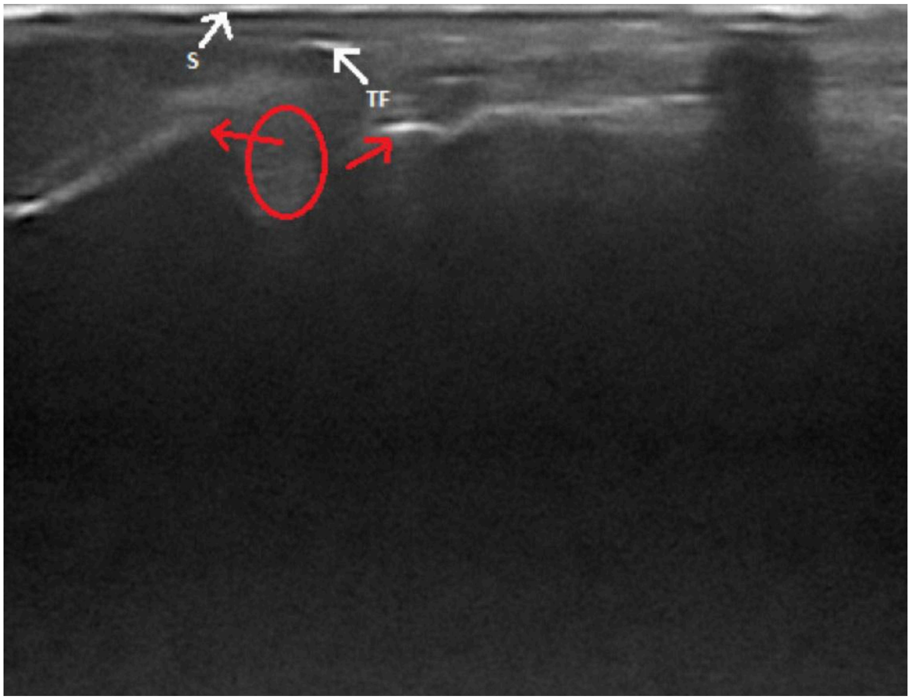

Figure 9: Ultrasonographic image of total Achilles tendon rupture. Ends of the torn tendon (red arrows), a hematoma (circle), a fragment of a tendon (TF), and the skin surface (S) are shown. (Abako, 2021).

Figure 10: MRI image of a partial common calcaneal tendon rupture (red circle) (Abako, 2021).

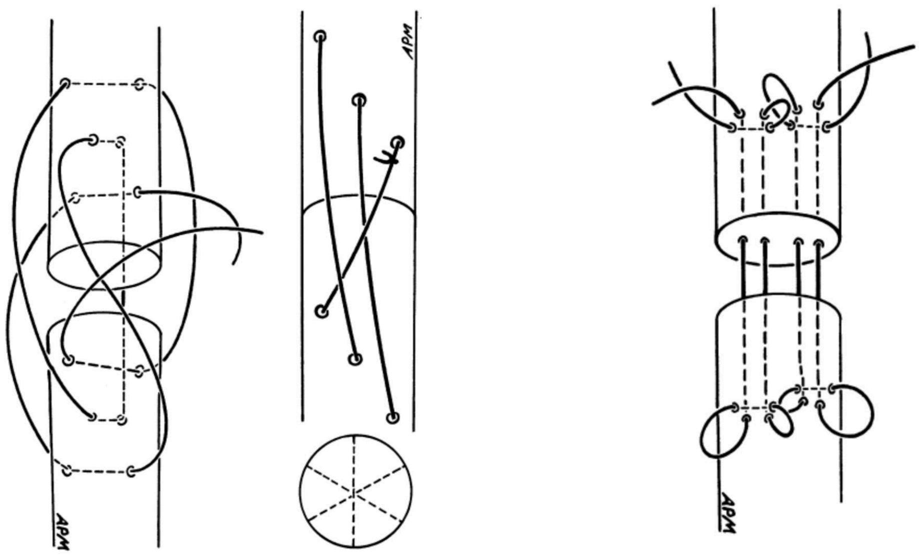

Figure 11: 3-loop pulley suture (two diagrams on the left) vs. two locking-loop sutures (right) (Moores, 2004).

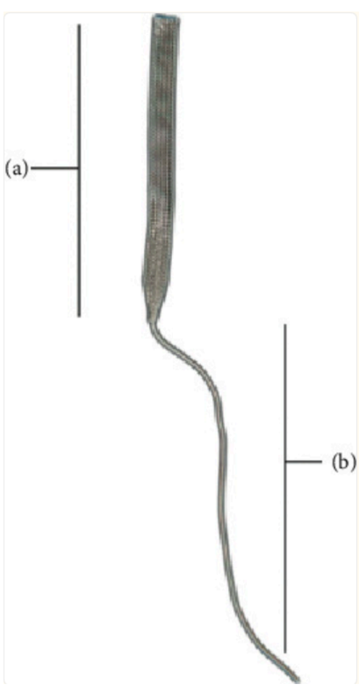

Figure 12: Novel Synthetic Fiber Implant (Buttin, 2020).

Figure 13: A Single-Ring Transarticular Fixator Device (DeCamp, 2009).

Works Cited

Abako, J., Holak, P., Głodek, J., & Zhalniarovich, Y. (2021). Usefulness of Imaging Techniques in the Diagnosis of Selected Injuries and Lesions of the Canine Tarsus. A Review. *Animals: an open access journal from MDPI*, *11*(6), 1834. https://doi.org/10.3390/ani11061834

American College of Veterinary Surgeons. "Achilles' Tendon Injuries - American College of Veterinary Surgeons." *American College of Veterinary Surgeons*, 4 Apr. 2024, www.acvs.org/small-animal/achilles-tendon-injuries.

Alvarez L. (2022). Extracorporeal Shockwave Therapy for Musculoskeletal Pathologies. *The Veterinary clinics of North America. Small animal practice*, *52*(4), 1033–1042. https://doi.org/10.1016/j.cvsm.2022.03.007

Buttin, P., Goin, B., Cachon, T., & Viguier, E. (2020). Repair of Tendon Disruption Using a Novel Synthetic Fiber Implant in Dogs and Cats: The Surgical Procedure and Three Case Reports. *Veterinary Medicine International*, *2020*, 4146790. https://doi.org/10.1155/2020/4146790

Case, J. B., Palmer, R., Valdes-Martinez, A., Egger, E. L., & Haussler, K. K. (2013). Gastrocnemius tendon strain in a dog treated with autologous mesenchymal stem cells and a custom orthosis. *Veterinary surgery: VS*, *42*(4), 355–360. https://doi.org/10.1111/j.1532-950X.2013.12007.x

DeCamp, C., Norton, J., Rooks, R., Yu, J., Use of a single-ring transarticular fixator construct for immobilization of the talocrural joint following common calcaneal tenorrhaphy. Vet Comp Orthop Traumatol 2009; 22(05): 430–435. DOI: 10.3415/VCOT-08-08-0072

Dog Achilles Tendon Injury: Canine Hock: Support Brace. PawOpedic. (n.d.). https://www.pawopedic.com/achilles-tendon-rupture

Durzi, T. (n.d.). *Platelet Rich Plasma*. VCA Animal Hospitals. https://vcahospitals.com/know-your-pet/platelet-rich-plasma

Durzi, T., & Ward, E. (n.d.). *Stem Cell Therapy*. VCA Animal Hospitals. https://vcahospitals.com/know-your-pet/stem-cell-therapy

Harari, Joseph. "Muscular Trauma in Dogs and Cats." *Merck Veterinary Manual*, 2020. 4 Apr. 2024.www.merckvetmanual.com/musculoskeletal-system/myopathies-in-small-animals/muscular-trauma-in-dogs-and-cats#v50523853.

Magee, Christianne., Whalen, Ray., et al. Virtual Canine Anatomy. Colorado State University 2022. https://www.cvmbs.colostate.edu/vca4

Moores, A.P., Owen, M.R. and Tarlton, J.F. (2004). The Three-Loop Pulley Suture Versus Two Locking-Loop Sutures for the Repair of Canine Achilles Tendons. Veterinary Surgery, 33: pp. 131–137. https://doi.org/10.1111/j.1532-950x.2004.04020.x

Sharun, K., Jambagi, K., Dhama, K., Kumar, R., Pawde, A. M., & Amarpal (2021). Therapeutic Potential of Platelet-Rich Plasma in Canine Medicine. *Archives of Razi Institute*, *76*(4), 721–730. https://doi.org/10.22092/ari.2021.355953.1749

Williams, K. (n.d.). *Extracorporeal Shockwave Therapy*. VCA Animal Hospitals. https://vcahospitals.com/know-your-pet/extracorporeal-shockwave-therapy