# Tarsal fractures: part 1

While fractures of the tarsal bones may not be common in non-racing dog and cat populations, an awareness of these injuries and the gold-standard treatment thereof remains important. Failure to diagnose these fractures and pursue appropriate treatment can have devastating consequences for long-term limb use; racing dogs may fail to return to racing and potentially be condemned to euthanasia while non-racing dogs may go on to suffer debilitating osteoarthritis. For many tarsal fractures, surgical stabilisation is indicated and in order to plan this, an accurate diagnosis must be made. While various radiographic views may assist in achieving this diagnosis, computed tomography is more sensitive for detection and classification of tarsal fractures. Fractures of the talus are generally classified as articular fractures of the body or non-articular fractures of the head or neck. Treatment of talar fractures depends on the site of the fracture and degree of comminution, with intra-articular and certain extra-articular fractures necessitating anatomical reconstruction with a lag screw or multiple K-wires. The prognosis is variable depending on fracture type and accuracy of reduction, but following articular fracture management, most patients will suffer from clinically relevant osteoarthritis later in life. https://doi.org/10.12968/coan.2019.0054

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The tarsus acts as a shock absorber and lacks support and protection from surrounding muscle, which makes it prone to injury (Jaegar and Canapp, 2008). However, with the exception of the calcaneus, tarsal fractures are not common in the pet population. Conversely, fractures of the tarsus are seen commonly in working breeds, most commonly involving the calcaneus, the central tarsal bone, the numbered tarsal bones and the talus (Dee, 2005). Many fractures of the tarsal bones are managed surgically as the gold standard of treatment, and a fundamental prerequisite to this is achieving an accurate diagnosis, which can be challenging in the absence of advanced imaging techniques. Surgery of the tarsal bones that is well planned and technically well executed is often associated with an excellent prognosis; unfortunately, surgeries that fall short of these standards may be disastrous for limb function (Dee, 2005). In this, the first part of a two part series, the surgically-relevant anatomy of the tarsus is reviewed, the diagnostic imaging techniques commonly used are evaluated and the diagnosis and treatment of talar fractures are discussed.

## Anatomy

The canine tarsus is a complex anatomical structure composed of seven tarsal bones. The term also applies collectively to the several joints between the tarsal bones, as well as the region between the crus and the metatarsus (Evans, 1993). The outer layer of the tarsal joint capsule extends from the distal end of the fibula and tibia to the proximal ends of the metatarsals. It attaches to the bone surfaces and the ligaments and forms the inner wall of the tarsal canal housing the flexor hallucis longus tendon and sheath. The synovial lining divides into three lateral and four medial joint sacs, the largest of which is at the tarsocrural articulation (Vaughan, 1987).

The tibia's distal articular surface has two almost-sagittal grooves separated by an intermediate ridge; the shape accommodates the proximal trochlea of the talus. The medial part of the tibia, forming the medial malleolus, extends slightly distal to the articular surface. The medial and lateral malleoli together assist in stabilising the tarsocrural joint. A groove in the medial side of the medial malleolus houses the long digital extensor tendon, while caudally another groove houses the flexor hallucis longus tendon. The lateral malleolus is formed by the distal end of the fibula, and articulates with the tibia and the talus. A groove caudally on the lateral malleolus contains the lateral digital extensor tendon and the fibularis brevis tendon (Vaughan, 1987).

The seven tarsal bones are arranged in two rows: two in the proximal row (calcaneus and talus) and four in the distal row (first, second, third and fourth) (Vaughan, 1987). The central tarsal bone separates the proximal row from the small first, second and third tarsal bones. The large fourth tarsal bone, which completes the distal row laterally, is as long as the third and central tarsal bones combined, and lies against these (Evans, 1993).

The five main articulations of the tarsus are the tarsocrural joint (between the tibia/fibula and the talus), the talocentral joint (between the distal talus and the central tarsal bone), the calcaneoquartal joint (between the distal calcaneus and the fourth tarsal bone), the centrodistal joint (between the central tarsal bone and the first, second and third tarsal bones) and the tarsometatarsal joint (between the metatarsus and tarsal bones one to four). The tarsocrural joint is the high-motion joint of the hock that accounts for the majority of flexion and extension; the remaining joints are low-motion joints, with minimal flexion and extension possible (Voss et al, 2009).

On either side of the tarsal joint lie the collateral ligaments which, in dogs, comprise long and short parts. The long part of the medial collateral ligament runs from the medial malleolus to the first tarsal bone and first and second metatarsals; it also has attachments to the talus and the central tarsal bone. The short medial collateral ligament attaches to the long. It divides as it passes underneath the long ligament, with one section inserting onto the talus and one onto the first tarsal and metatarsal bones. The long part of the lateral collateral ligament extends from the lateral malleolus to the base of the fifth metatarsal bone, with additional attachments to the calcaneus and fourth tarsal bone. The short part has one band that attaches to the tuber calcanei and a second band that attaches to the talus. There are many other ligaments both dorsally and on the plantar aspect; the plantar ligaments are particularly distinct and thick (Vaughan, 1987).

### Cat-specific details

Unlike dogs, cats do not have long collateral ligaments, only short ones, and the medial and lateral short collateral ligaments consist of straight and oblique branches. The oblique branch of the medial collateral ligament is known as the tibiotalar portion and is partially hidden, deep to the medial malleolus. The straight branch of the medial collateral ligament is the tibiocentral ligament and inserts on the dorsomedial process of the central tarsal bone. The lateral collateral ligament has an oblique talofibular ligament, the origin of which is deep to the lateral malleolus. The calcaneofibular ligament of the lateral collateral ligament has a straight and oblique branch (Voss et al, 2009).

## Imaging

Untreated or improperly treated tarsal injuries can result in life-long consequences for the patient, including osteoarthritis and lameness (Jaegar and Canapp, 2008). Additionally, for racing greyhounds, dogs with comminuted type IV or V central tarsal bone fractures have a poorer prognosis for return to racing, and many with severe tarsal bone fractures are euthanased (Dee et al, 1976; Boudrieau et al, 1984a; Hercock et al, 2011). Therefore, correct detection and diagnosis of fractures is crucial to developing the correct treatment plan for the patient. However, diagnosing fractures of tarsal bones can be problematic, because of the compound nature of the joint.

### Radiography

Radiographic evaluation of the tarsus is challenging and may require stress radiographic views (Gielen et al, 2002; Hudson and Pozzi, 2012; Beever et al, 2016). Disadvantages of using radiographs to interpret complex joints include the superimposition of overlaying structures and relatively low contrast resolution (Gielen et al, 2001; Hercock et al, 2011; Stieger-Vanegas et al, 2015). This superimposition can produce radiolucent lines that could be misinterpreted as a fracture and complicate fracture identification (Hercock et al, 2011). Additionally, small fractures in the tarsal bones may not be detected if the X-ray beam does not pass parallel to the fracture plane (Henry, 2013).

Various radiographic views, in addition to the standard dorsoplantar and mediolateral views, have been suggested to be helpful in identifying different tarsal pathologies. Dorsolateral-plantaromedial oblique; dorsomedial-plantarolateral oblique; flexed mediolateral; flexed dorsoplantar; and stressed radiographic views including dorsoplantar flexed laterally stress, dorsoplantar flexed medially stress, dorsoplantar extended laterally stress and dorsoplantar extended medially stress views, are often recommended to enable comprehensive assessment of the tarsal bones and collateral ligaments. However, a recent study indicated that even with an experienced evaluator, there was little improvement in detecting fractures of the canine tarsus with ten-view compared to two-view radiographic studies (Butler et al, 2018).

### Computed tomography

It is widely accepted that computed tomography (CT) is the method of choice in evaluating tarsal joint pathology, when it is available (Saxena et al, 2000; Gielen et al, 2001; Johnson et al, 2006; Galateanu et al, 2011). The use of CT to evaluate complex joints has several advantages compared to radiography (Drost et al, 1996; Gielen et al, 2001; Hercock et al, 2011; Stieger-Vanegas et al, 2015). The tomographic nature of CT generates two-dimensional transverse images (*Figure 1*) eliminating the superimposition of the tarsal bones (Drost et al, 1996). Compared with radiography, CT also has a higher contrast resolution that can result in better

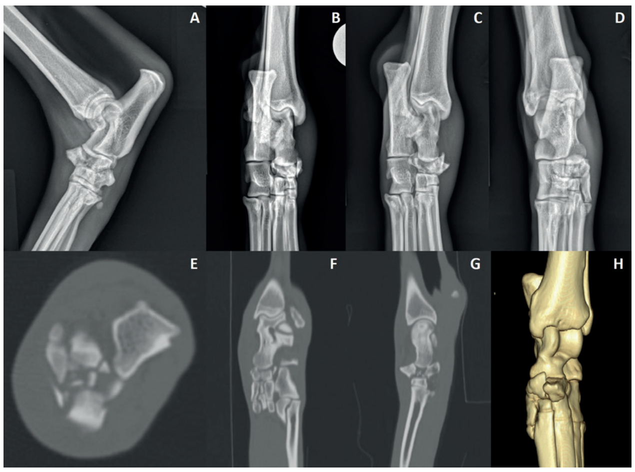


*Figure 1. Mediolateral (A), plantarodorsal (B), plantaromedial-dorsolateral oblique (C) and plantarolateral-dorsomedial oblique (D) views of the tarsus of an 18-month-old German Shorthair Pointer that presented with an acute onset pelvic limb lameness after running on a trail. Radiographs demonstrated a comminuted fracture of the central tarsal bone with the largest fragment being dorsally displaced. A small linear fragment is mildly displaced medially with an additional fragment displaced slightly laterally. The third tarsal bone is displaced slightly proximally and the soft tissues are mildly thickened. A computed tomography scan was performed to give more information and to ascertain whether surgical repair was feasible. Axial (E), coronal (F), sagittal (G) and three-dimensional reconstruction (H) images demonstrated several smaller, angular fragments of the central tarsal bone with mild-to-moderate displacement, rendering accurate reconstruction of the articular surface impossible to achieve.*

detection of subtle pathological variations in tissues (Henry, 2013; Stieger-Vanegas et al, 2015). Furthermore, both bone and soft tissue structures can be evaluated in high and medium frequency algorithms by varying the greyscale window and level and with multiplanar reconstructed views (Drost et al, 1996; Gielen et al, 2001). Computed tomography has been shown to be more sensitive for the detection of tarsal fractures than ten-view radiographic studies (Butler et al, 2018).

## Fractures of the talus

The talus is the second largest bone in the canine tarsus and one of the main weightbearing bones, by virtue of its articulation with the tibia (McCartney and Carmichael, 2000). It is composed of a head, neck and body. The body contains medial and lateral trochlear ridges that articulate with the distal tibia and fibula (Welch, 1993). The head articulates with the central tarsal bone while the neck is extra-articular (Carlisle and Reynolds, 1990; Welch, 1993).

Isolated fractures of the talus are not common and are generally classified as either articular fractures of the body or non-articular fractures of the head or neck (Houlton, 2005). Fractures of the neck are generally accompanied by complete luxation of the fracture fragment at the talocentral joint, whereas fractures of the head and body are often associated with mild subluxation of the talocalcaneal articulation (Welch, 1993; Beale, 1998). Fractures of the trochlear ridges are rare (Miyabayashi et al, 1991; Welch, 1993; Beale, 1998; Piermattei et al, 2006).

Treatment of fractures of the talus depends on the site of the fracture and the degree of comminution. Some extra-articular fractures of the talus (body and neck) can be managed by conservative methods, especially if treated early (Newton, 1985; Brinker et al, 1990). In contrast, intra-articular fractures and certain extra-articular fractures require anatomical reconstruction with a lag screw or multiple Kirschner (K)-wires (Brinker et al, 1990; Denny, 1993). Most talar fractures can be exposed by the appropriate plantarolateral or plantaromedial approach, but proximally located fractures may require an osteotomy of the appropriate malleolus. Some authors have also reported using a dorsal or dorsomedial approach (Boudrieau et al, 1984b; Dee, 2005; Guilliard, 2005). Severely comminuted fractures of the talus may necessitate arthrodesis (Dee, 1977; Early and Dee, 1980). Intra-articular fractures that are only chip fractures can be removed, but carry a guarded prognosis because of resultant osteoarthritis (Brinker et al, 1990).

**Talar ridge fractures** are generally of unknown aetiology, although occasionally owners report a fall or a jump that preceded the clinical signs (Piermattei et al, 2006). They are typically associated with acute-onset moderate to severe lameness, hock effusion and pain on hock extension (Miyabayashi et al, 1991; Piermattei et al, 2006; Maley et al, 2010).

Diagnosis of talar ridge fractures using standard plain view radiography is challenging because of anatomical complexity and superimposition (Carlisle and Reynolds, 1990; Miyabayashi et al, 1991; Gielen et al, 2005; Piermattei et al, 2006; Liuti et al, 2007). On both flexed and extended mediolateral views, the lateral trochlear ridge is superimposed over portions of the medial trochlear ridge, the calcaneus and the distal tibia and fibula (Miyabayashi et al, 1991). While studies assessing the radiographic characteristics of normal trochlear ridges assert that the lateral ridge is visible as the larger, more distinct and more proximally superimposed ridge, abnormalities within the ridge are obscured by overlap (Carlisle and Reynolds, 1990; Miyabayashi et al, 1991). On the dorsoplantar view, the calcaneus overshadows the lateral trochlear ridge (Miyabayashi et al, 1991). Oblique views may be of diagnostic benefit (Carlisle and Reynolds, 1990; Gielen et al, 2005). While supination of the hock increases overlap of the proximodorsal lateral trochlear ridge, the plantarolateral dorsomedial projection provides adequate visualisation of the distodorsal lateral ridge (Carlisle and Reynolds, 1990; Gielen et al, 2005). The plantaromedial-dorsolateral view is obtained by pronation; in this view, the tuber calcanei shifts so that it is no longer superimposed over the lateral trochlear ridge; however, the malleoli continue to overlap and obscure the ridge (Carlisle and Reynolds, 1990). The flexed dorsoplantar (skyline) view may be obtained by placing the patient in dorsal recumbency, flexing the stifle and elevating the tarsus so that the angle between the radiographic beam and the metatarsals is 10–15 degrees (Miyabayashi et al, 1991). This view is often helpful in diagnosis, as it provides optimal visualisation of the middle and distal aspects of the lateral trochlear ridge; however, the proximal aspect of the ridge may remain obscured (Miyabayashi et al, 1991; Gielen et al, 2005).

Overall, for diagnosis of talar ridge fractures, plain radiography probably delivers a less than optimal sensitivity. While there are no studies evaluating radiographic examination for fracture diagnosis, multi-view radiography is only 78% sensitive in diagnosis of lateral trochlear ridge osteochondritis dissecans (OCD) lesions (Gielen et al, 2005).

Computed tomography provides unparalleled diagnostic assistance in the detection of trochlear ridge fractures and the surgical planning of their repair (Gielen et al, 2001; 2005) *(Figure 2)*. While there are no published studies evaluating the sensitivity of this tool with regard to these fractures, there are studies that indicate the CT is 100% sensitive in the diagnosis of OCD lesions in the same location (Gielen et al, 2005).

Talar ridge fractures must be differentiated from OCD lesions, as different treatment options may be considered. Patient signalment; size, orientation and location of the fragment; and the presence or absence of degenerative changes within the joint may assist with differentiation. Fragment removal has been attempted in cases where the fragment is deemed too small to fix, or where OCD is suspected rather than traumatic fracture, but the success rate of this is low because of the intra-articular nature of the lesions (Gielen et al, 2001; Piermattei et al, 2006). Anatomical reduction and rigid fixation are essential in order to optimise outcome postoperatively.

Talar ridge fractures often require an osteotomy of the appropriate malleolus in order to gain sufficient exposure for accurate fracture reduction, because of their proximal location (Dee, 2005). Lateral talar ridge fractures are approached via a distal fibular osteotomy with retraction of the lateral malleolus. Predrilling the screw holes that will be required for the repair of the osteotomy is advisable and will ensure accurate reduction of the articular surface (Dee, 2005). The distal fibula is osteotomised

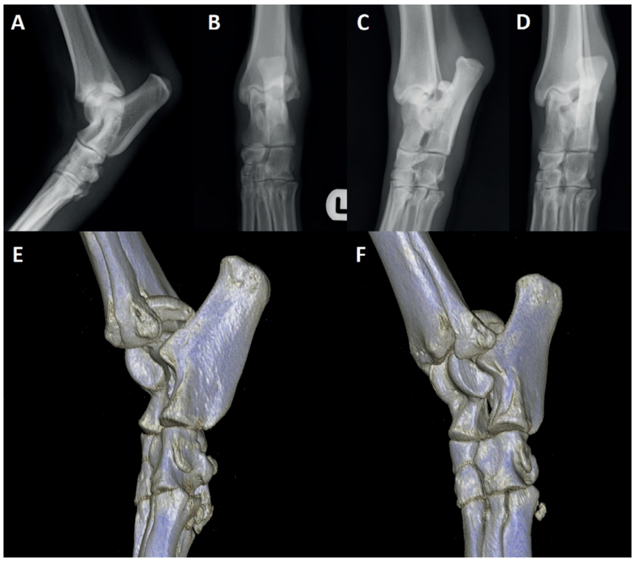


*Figure 2. Mediolateral (A), plantarodorsal (B), plantaromedial-dorsolateral oblique (C) and plantarolateral-dorsomedial oblique (D) views of the tarsus of a 3-year-old mixed-breed dog that presented with acute onset pelvic limb lameness following jumping for a ball. Radiographs demonstrated a fracture of the lateral trochlear ridge and a computed tomography scan, three-dimensional reconstructions of which are shown here (E and F) was performed to assess for evidence of comminution and to assess fragment size more accurately, allowing appropriate screw dimensions to be selected for stabilisation.*

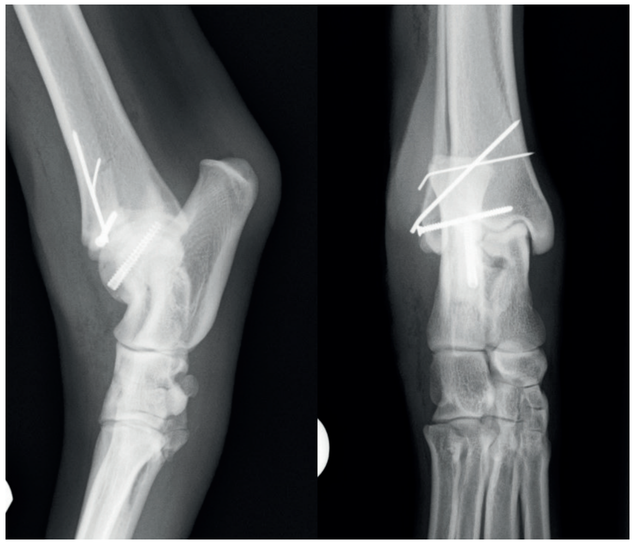

*Figure 3. Mediolateral and plantarodorsal views of the tarsus of the same dog as in* Figure 2*, following fracture stabilisation. The fracture was approached via an osteotomy of the lateral malleolus. The fracture was reduced and stabilised using an Acutrak Mini screw from Acumed; these screws incorporate a variable thread pitch into their fully-threaded, headless, cannulated, tapered design. The lateral malleolar osteotomy was then repaired using a position screw and two K-wires. Anatomic reduction was obtained at the articular surface.*

just proximal to the lateral malleolus (Goring and Beale, 1990; Piermattei et al, 2006). Following reduction and stabilisation of the fracture, the osteotomy site is then stabilised using a pin and tension band, or position screws (Goring and Beale, 1990; Dee, 2005; Piermattei et al, 2006). Alternatives to fibular osteotomy include less-invasive dorsolateral and plantarolateral approaches (Goring and Beale, 1990). While there are no reports describing their use in fracture repair, these approaches reportedly provide complete exposure to the lateral trochlear ridge and minimise risk for damage to the tendons of the peroneus longus, peroneus brevis and extensor digitorum longus (Goring and Beale, 1990).

The recommended method for internal fixation of simple fractures of the trochlear ridges is placement of small K-wires (0.9 or 1.1 mm) or lag screws (1.5 or 2.0 mm) across the fracture site (Goring and Beale, 1990; Piermattei et al, 2006). Lag screw fixation is preferred in cases where fracture fragments are large enough to support screw placement (Goring and Beale, 1990; Piermattei et al, 2006) (*Figure 3*). It is important to remember that when implants are placed on an articular surface they must be countersunk beneath the cartilage (Goring and Beale, 1990; Piermattei et al, 2006). Stabilisation with lateral splinting is recommended for the first 4 weeks postoperatively, with application of a padded bandage being recommended for an additional 2 weeks after removal of the splint (Goring and Beale, 1990; Piermattei et al, 2006). Exercise should be restricted for at least 10–12 weeks postoperatively in total (Piermattei et al, 2006).

The prognosis for these intra-articular fractures is variable depending on the accuracy of reduction of the fracture fragments. Unfortunately, most patients will suffer from clinically-relevant osteoarthritis later in life (Gielen et al, 2001).

**Talar neck fractures** appear to be more common in cats than in dogs. These fractures are presumed to be traumatically induced, although the definitive cause often remains unknown. It has been postulated that cats may be predisposed to fractures of the talar neck, and that this may be the most common fracture of an individual tarsal bone in this species (McCartney and Carmichael, 2000). This may reflect the higher degree of mobility in the hock area in cats when compared to dogs. Therefore, the talus may experience more significant combined loading forces such as torsion and tension (McCartney and Carmichael, 2000).

In dogs these fractures are normally accompanied by luxation of the body and head of the bone (Houlton, 2005), but this may be seen less commonly in cats (McCartney and Carmichael, 2000). While minimally displaced talar neck fractures can be managed using external coaptation (Denny, 1993; Houlton, 2005), the degree of displacement in many cases renders reduction and internal fixation the optimal course of treatment. Reduction of these fractures generally requires dorsiflexion of the proximal intertarsal joint and placement of the foot in a valgus position. The reduction can then be maintained using Vulsellum forceps placed dorsally and on the plantar aspect. In dogs, the most common method of repair involves placement of a position screw between the body of the talus and the calcaneus, traversing the tarsal sinus. The repair is then protected using a cast or splint for a period of 4–6 weeks (Houlton, 2005). Generally, fractures of the neck of the talus are associated with a good prognosis (Houlton, 2005).

Screw fixation of feline talar neck fractures can be used, as in dogs, but is technically difficult because of the small size of the bones (McCartney and Carmichael, 2000). The use of external skeletal fixation (ESF) has been reported in the management of five cats with talar neck fractures (McCartney and Carmichael, 2000), and this may represent a preferable treatment option, particularly where fragments are very small rendering screw placement difficult. In four of the five cats the ESF was placed closed and was used as the only method of fixation. Threaded pins were placed in the distal tibia and metatarsals through stab incisions and were connected with clamps to an ESF connecting bar contoured to 125 degrees. The hock was manipulated in traction until reduction of the fracture was achieved, then the clamps were tightened. In one case the fracture was approached medially and stabilised using a 2.7 mm lag screw from the tarsal neck to the calcaneus before placement of the ESF. The ESF was removed once at least 70% of the fracture gap was deemed to have filled with new bone radiographically, and the average time that the ESF remained in place was 10 weeks. Clinical outcome was deemed to be excellent in all cases, with no lameness or stiffness reported (McCartney and Carmichael, 2000). The authors postulated that an ESF applied with the hock under traction may represent a superior method for treatment of feline talar neck fractures, because of stability, soft tissue preservation, simplicity, patient tolerance and the option of disassembling the fixation (McCartney and Carmichael, 2000).

## Conclusions

When tarsal fractures are encountered, achieving an accurate diagnosis is imperative as the first step in making a treatment plan and determining a prognosis. Taking multiple radiographic views may assist in the evaluation of this compound joint, but CT offers increased sensitivity and facilitates visualisation of all fracture lines as well as appreciation of small fragments which may otherwise be missed. Fractures of the talus that may be encountered include talar ridge fractures and talar neck fractures. Talar ridge fractures are articular, therefore open reduction and internal fixation represents the treatment of choice. Despite this, however, many patients will develop clinically-relevant osteoarthritis in the future. Talar neck fractures often necessitate open reduction and internal fixation also, because of the degree of fragment displacement; however, the use of ESF has also been reported to result in an excellent prognosis for these injuries in cats. In the second part of this series, calcaneal fractures, central tarsal bone fractures, fractures of the numbered tarsal bones and malleolar fractures will be covered. CA

## KEY POINTS

- Radiographic evaluation of the tarsus is challenging. Even experienced evaluators with a ten-view radiographic study do not detect all fractures. Computed tomography is more sensitive for the detection and characterisation of tarsal fractures.
- Many tarsal fractures are intra-articular and therefore mandate anatomical reconstruction and rigid stabilisation.
- Fragment removal is generally not recommended and carries a guarded prognosis because of subsequent osteoarthritis development.
- Talar ridge fractures must be differentiated from osteochondritis dissecans lesions as different treatment options will likely be considered.
- Cats may be predisposed to fractures of the talar neck.

## References


Beale BS. Surgical treatment of talus fractures. In: Bojrab MJ (ed). Current Techniques in Small Animal Surgery. 4th edn. Baltimore (MA): Williams and Wilkins; 1998:1264–1267

Beever LJ, Kulendra ER, Meeson RL. Short and long-term outcome following surgical stabilization of tarsocrural instability in dogs. Vet Comp Orthop Traumatol. 2016;29(2):142–148. https://doi.org/10.3415/VCOT-15-05-0083

Boudrieau RJ, Dee JF, Dee LG. Central tarsal bone fractures in the racing greyhound: a review of 114 cases. J Am Vet Med Assoc. 1984a;184(12):1486–1491

Boudrieau RJ, Dee JF, Dee LG. Treatment of central tarsal bone fractures in the racing greyhound. J Am Vet Med Assoc. 1984b;184(12):1492–1500

Brinker WO, Piermattei DL, Flo GL. Fractures of the tarsus, metatarsus and phalanges. In: Handbook of Small Animal Orthopaedics and Fracture Treatment. 2nd edn. Philadelphia (PA): WB Saunders; 1990:156–169

Butler D, Nemanic S, Warnock J. Comparison of radiography and computed tomography to evaluate fractures of the canine tarsus. Vet Radiol Ultrasound. 2018;59(1):43–53. https://doi.org/10.1111/vru.12558

Carlisle CH, Reynolds KM. Radiographic anatomy of the tarsocrural joint of the dog. J Small Anim Pract. 1990;31(6):273–279. https://doi.org/10.1111/j.1748-5827.1990.tb00806.x

Dee JF. Noncompound traumatic hock injuries. Am Anim Hosp Assoc Proc. 1977;44:311–314

Dee JF. Fractures of the tarsus. In: Johnson AL, Houlton JEF, Vannini R (eds). AO Principles of Fracture Management in the Dog and Cat. Davos: AO Publishing; 2005:349–357

Dee JF, Dee J, Piermattei DL. Classification, management, and repair of central tarsal bone fractures in the racing Greyhound. J Am Anim Hosp Assoc. 1976;12(3):398–405

Denny HR. The hindlimb. In: Denny HR. A Guide to Canine and Feline Orthopaedic Surgery. 3rd edn. Oxford: Blackwell Scientific Publications; 1993:284–293

Drost WT, Love NE, Berry CR. Comparison of radiography, myelography and computed tomography for the evaluation of canine vertebral and spinal cord tumors in sixteen dogs. Vet Radiol Ultrasound. 1996;37(1):28–33. https://doi.org/10.1111/j.1740-8261.1996.tb00808.x

Early TD, Dee JF. Trauma to the carpus, tarsus, and phalanges of dogs and cats. Vet Clin North Am Small Anim Pract. 1980;10(3):717–742. https://doi.org/10.1016/S0195-5616(80)50063-X

Evans HE. Tarsus. In: Evans HE. Miller's Anatomy of the Dog. 3rd edn. Philadelphia (PA): Lea & Febiger; 1993:212–215

Galateanu G, Aizenberg I, Hildebrandt TB, Apelt D. Computed tomographic demonstration of central tarsal bone plantar process occult fracture in a dog. Vet Rec. 2011;169(17):442–443. https://doi.org/10.1136/vr.d4760

Gielen IM, De Rycke LM, van Bree HJ, Simoens PJ. Computed tomography of the tarsal joint in clinically normal dogs. Am J Vet Res. 2001;62(12):1911–1915. https://doi.org/10.2460/ajvr.2001.62.1911

Gielen I, van Bree H, Van Ryssen B, De Clercq T, De Rooster H. Radiographic, computed tomographic and arthroscopic findings in 23 dogs with osteochondrosis of the tarsocrural joint. Vet Rec. 2002;150(14):442–447. https://doi.org/10.1136/vr.150.14.442

Gielen IM, Van Ryssen B, Van Bree H. Computerized tomography compared with radiography in the diagnosis of lateral trochlear ridge talar osteochrondritis dissecans in dogs. Vet Comp Orthop Traumatol. 2005;18(2):77–82. https://doi.org/10.1055/s-0038-1632935

Goring RL, Beale BS. Exposure of the medial and lateral trochlear ridges of the talus in the dog. Part II: Dorsolateral and plantarolateral surgical approaches to the lateral trochlear ridge. J Am Anim Hosp Assoc. 1990;26(1):19–26

Guilliard MJ. Centrodistal joint lameness in dogs. J Small Anim Pract. 2005;46(4):199–202. https://doi.org/10.1111/j.1748-5827.2005.tb00312.x

Henry G. Fracture healing and complication. In: Thrall DE (ed). Textbook of Veterinary Diagnostic Radiology. 6th edn. St. Louis (MO): Elsevier; 2013:283–306

Hercock CA, Innes JF, McConnell F et al. Observer variation in the evaluation and classification of severe central tarsal bone fractures in racing greyhounds. Vet Comp Orthop Traumatol. 2011;24(3):215–222. https://doi.org/10.3415/VCOT-10-06-0085

Houlton JEF. The carpus and tarsus. In: Coughlan A, Miller A (ed). Manual of Small Animal Fracture Repair and Management. Cheltenham: BSAVA; 2005:249–256

Hudson CC, Pozzi A. Minimally invasive repair of central tarsal bone luxation in a dog. Vet Comp Orthop Traumatol. 2012;25(1):79–82. https://doi.org/10.3415/VCOT-11-01-0008

Jaegar GH, Canapp SO. Focus on canine sports medicine: carpal and tarsal injuries. 2008. http://vetsportsmedicine.com/includes/storage/brio/files/111/CT-inj-wp.pdf (accessed 8 October 2019)

Johnson PT, Fayad LM, Fishman EK. Sixteen-slice CT with volumetric analysis

of foot fractures. Emerg Radiol. 2006;12(4):171–176. https://doi.org/10.1007/s10140-006-0469-9
Liuti T, Saunders JH, Gielen IM et al. Ultrasound approach to the canine distal tibia and trochlear ridges of the talus. Vet Radiol Ultrasound. 2007;48(4):361–367. https://doi.org/10.1111/j.1740-8261.2007.00257.x
Maley JR, Dvorak LD, Bahr A. Diagnosis and management of a fracture of the lateral trochlear ridge of the talus in a dog. Vet Comp Orthop Traumatol. 2010;23(4):284–288. https://doi.org/10.3415/VCOT-09-07-0077
McCartney WT, Carmichael S. Talar neck fractures in five cats. J Small Anim Pract. 2000;41(5):204–206. https://doi.org/10.1111/j.1748-5827.2000.tb03196.x
Miyabayashi T, Biller DS, Manley PA et al. Use of a flexed dorsoplantar radiographic view of the talocrural joint to evaluate lameness in two dogs. J Am Vet Med Assoc. 1991;199(5):598–600
Newton CD. Fractures and luxations of the tarsus and metatarsus. In: Nunamaker D, Newton CD (eds). Textbook of Small Animal Orthopaedics. Philadelphia (PA): JB Lippincott; 1985:445–452
Piermattei DL, Flo GL, DeCamp CE. Fracture and other orthopedic injuries of the tarsus, metatarsus, and phalanges. In: Piermattei DL, Flo GL, DeCamp CE. Handbook of Small Animal Orthopedics and Fracture Repair. 4th edn. Philadelphia (PA): WB Sanders; 2006:658–686
Saxena A, Fullem B, Hannaford D. Results of treatment of 22 navicular stress fractures and a new proposed radiographic classification system. J Foot Ankle Surg. 2000;39(2):96–103. https://doi.org/10.1016/S1067-2516(00)80033-2
Stieger-Vanegas SM, Senthirajah SK, Nemanic S et al. Evaluation of the diagnostic accuracy of four-view radiography and conventional computed tomography analyzing sacral and pelvic fractures in dogs. Vet Comp Orthop Traumatol. 2015;28(3):155–163. https://doi.org/10.3415/VCOT-14-06-0096
Vaughan LC. Disorders of the tarsus of the dog. I. Br Vet J. 1987;143(5):388–401. https://doi.org/10.1016/0007-1935(87)90016-9
Voss K, Langley-Hobbs S, Montavon PM. Tarsal joint. In: Montavon PM, Voss K, Langley-Hobbs SJ (eds). Feline Orthopaedic Surgery and Musculoskeletal Disease. Philadelphia (PA): Saunders Elsevier; 2009:507–525
Welch JA. The tarsus and metatarsus. In: Slatter DH (ed). Textbook of Small Animal Surgery. 4th edn. Philadelphia (PA): WB Saunders; 1993:2158–2167