The nature, incidence and response to treatment of injuries to the distal limbs in the racing Greyhound

“Thesis submitted in accordance with the requirements of the Royal College of Veterinary Surgeons for the Diploma of Fellowship by Michael James Guilliard”

August 2012

INDEX

ABBREVIATIONS

RF = right fore (thoracic) limb
LF = left fore (thoracic) limb
RH = right hind (pelvic) limb
LH = left hind (pelvic) limb

Carpus:
ACB = accessory carpal bone
C2 = second carpal bone
C3 = third carpal bone
C4 = fourth carpal bone
FCU = flexor carpi ulnaris

Tarsus:
CTB = central tarsal bone
T2 = second tarsal bone
T3 = third tarsal bone
T4 = fourth tarsal bone

Metacarpus:
MC2 = second metacarpal bone
MC3 = third metacarpal bone
MC4 = fourth metacarpal bone
MC5 = fifth metacarpal bone

Metatarsus:
MT2 = second metatarsal bone
MT3 = third metatarsal bone
MT4 = fourth metatarsal bone
MT5 = fifth metatarsal bone

Foot:
P1 = first phalanx
P2 = second phalanx
P3 = third phalanx
MC/P and MT/P = metacarpophalangeal and metatarsophalangeal joints
P1/P2 = proximal interphalangeal joint
P2/P3 = distal interphalangeal joint
UCO = ungual crest ostectomy
ESF = external skeletal fixator

INTRODUCTION

The first Greyhound racing track in the United Kingdom (UK) opened in 1926 in Manchester and was followed by many more across the country. These were either governed by the rules of a national authority that is now the Greyhound Board of Great Britain, or were independently run.

The track design is oval with two straights connected by two 180 degree bends. The radius of the bends varies from 23 to 33 metres in the UK and Ireland, and up to 45 metres in the United States of America (USA) and Australia. The bends are banked at variable degrees to decrease the amount of leaning in the turns.

The racing surfaces have in the past been of grass or a combination of grass and sand. In recent years all tracks in the UK are of sand that generally comes from one geographical location to ensure consistency. The speed at which the dogs run is determined by the firmness of the track surface. Sand grains are held together by the surface tension of the water content and ideal conditions are akin to the hard sand on the beach exposed as the water ebbs.

Track preparation involves regular harrowing followed by levelling and uniform compaction. Water is applied to the track to obtain ideal surface consistency.

In the UK and Ireland there are six dogs in each race and up to nine in the USA and Australia. The dogs are placed into individual starting boxes and then chase an artificial lure running around the outside of the track. Some individual dogs always run close to the inside track rail while others close to the outside rail. It is the responsibility of the racing manager to place the dogs in the starting boxes appropriate to their style of running to avoid collisions.

The standard racing distance of about 500 metres is covered in around 30 seconds, the speed of a dog of average ability being 58 kilometres per hour (36 miles per hour).

Dogs are graded according to their racing times allowing each race to contain dogs of equal ability. Graded races are designated as A1 being the fastest, to A9 the slowest. Many professional trainers are attached to only one licensed track and consequently their dogs will only run in graded races at that track. Races open to any Greyhound, designated “open races”, attract the fastest dogs from any licensed tracks.

Greyhounds begin their racing careers from about 15 months of age and can race until their fourth or fifth year.

The racing Greyhound is an elite athlete that has been selectively bred for speed. The pelvic limbs provide the propulsion and the thoracic limbs the direction of travel.

Racing injuries are common and are often specific to the breed. In the majority of cases external trauma is not a factor in the aetiology but injury is caused by a failure of the musculoskeletal structures to withstand the forces developed during a race. Specific injuries are often over-represented in one limb.

As Greyhounds always run in the same direction around the bends the forces vary between the left and right limbs and the physiological response is to strengthen the structures affected by increased force. This is called asymmetric adaptive remodelling and it affects both the skeleton and the soft tissues (Bukowiecki and others 1987, Johnson and others 2000). The response is slow to occur and requires regular training and racing over a period of time (Piras and Johnson 2006).

Racing injuries are documented with their incidences in various surveys (Walpole 1944, Gannon 1972, Prole 1976, Agnew 1992, Bloomberg and Dugger 1998). Response to treatment is evidence-based in a few retrospective studies but many reports are anecdotal.

The aims of this prospective and retrospective study are to further classify some injuries and to report the response to specific treatments.

LITERATURE REVIEW

History

Greyhound racing in the United Kingdom, chasing an artificial lure around a track, began in 1926 and rapidly gained popularity. Specific racing injuries and treatments were then reported (Walpole 1944, Bateman 1950, Bateman 1958, Bateman 1960).

Greyhound racing was also popular in Australia and the United States of America and further publications followed (Davis 1967, Gannon 1972, Hickman 1975). In 1977 and in 1983 the Post-graduate Committee in Veterinary Science at the University of Sydney ran courses entitled “Refresher course on Greyhounds” with the proceedings published in a 750 page tome, many of the results and observations of injury being anecdotal.

With the development of novel orthopaedic implants and techniques, treatment and understanding of the causes of the common fractures improved resulting in a number of landmark publications. Fractures of the accessory carpal bone and the tarsal bones were classified and specific internal fixation techniques described (Boudrieau and others 1984a, Boudrieau and others 1984b, Johnson 1987, Johnson and others 1988, Johnson and others 1989).

There were publications on metacarpal and metatarsal fractures (Bellenger and others 1981), calcaneal fractures (Ost and others 1987), acetabular fractures (Wendelburg and others (1988), and dorsal carpal chip fractures (Ferguson 1986, Boemo 1993).

Treatment of phalangeal fractures and instabilities can be found in various text books (Dee 1981, Dee and others 1984, Dee and Dee 1985, Dee and others 1990, Earley 1990, Eaton-Wells 1998). A novel treatment for phalangeal instabilities using external fixation was described (Guilliard 2003a).

Pathogenesis of injury

Distal limb injuries are often specific to one limb. Tarsal fractures are found almost exclusively in the right pelvic limb (Boudrieau and others 1984a, Ost and others 1987, Guilliard 2010) and fractures of the accessory carpal bone are found mainly in the right thoracic limb (Johnson and others 1988).

Many fractures occur without any obvious external trauma and are classified as stress or fatigue fractures (Davis 1971, Gannon 1972, Bellenger and others 1981). Remodelling of the fifth metacarpal bone with 5mm thickness of new bone on the craniolateral aspect was described as an adaptation to running on a circular track in one direction (Kidd 1983).

This change was described as adaptive remodelling and was found to occur in many of the distal limb bones (Emmerson and others 2000, Johnson and others 2001, Lipscombe and others 2001, Hercock and others 2008a).

Adaptive remodelling of bone occurs when bones are subjected to cyclic asymmetrical loading (Johnson and others 2000). Microfractures appear in the bone leading to bone resorption followed by new bone formation, indicated by increases in bone mineral density with a consequent increase in strength to adapt to the new workload. The adaptive response is relatively slow and a sudden overload can cause fracture (Piras and Johnson 2006).

Adaptive changes to the soft tissues also occur with ligaments responding to higher loading rates by becoming stiffer and stronger. Bone is even more strain-rate sensitive and gets stronger and stiffer when loaded quickly (Frank and others 1985). The strengthening effect of physical exercise on ligaments has been described by several authors (Laros and others 1971, Noyes and others 1974, Bukowiecki and others 1987).

The strength of the suspensory ligament in horses was compared in animals that had been heavily exercised and those that had been rested (Bukowiecki and others 1987). It was found that with exercise the ligamentous parts of the suspensory apparatus responded faster to training than the sesamoid bones, resulting in fractures being more common in the trained group and ligament rupture more common in the untrained group.

Accessory carpal bone fracture is an injury almost exclusively seen in Greyhounds and other athletic types, but in companion animals carpal hyperextension injuries often result from midsubstance ligament rupture rather than an avulsion fracture of the attachments (Johnson 1987). It is suggested that this difference may be due to the strengthening effect of exercise on ligaments (Johnson and others (1989).

When racing the limbs are subjected to compressive, tensile, bending, shear and torsional forces. In the carpus and tarsus the dorsal aspects are naturally in compression and the palmar or plantar aspects in tension. In addition if the dog has a carpal valgus then the medial aspect will be in tension and the lateral aspect in compression. The centrifugal force generated when running around the bends causes the dog to lean into the bend resulting in the aspect of the limbs closest to the inside of the bend to be subjected to compressive forces with the contralateral aspect to tensile forces.

This effect will supplement intrinsic compressive and tensile forces potentially leading to bone fracture or ligament failure (Guilliard and Mayo 2000a, Guilliard 2010). The lean explains why certain injuries are almost exclusively limb specific as the dogs always run in an anticlockwise direction.

Abnormal loading of the limbs also occurs with interference from another dog leading to a sudden change in direction, braking, stumbling or falling. The incidence of mishaps or falls per race ranges from 25% to 83% (Bloomberg and Dugger 1998).

It has been suggested that leading with the wrong limb can lead to an increased risk of injury (Bateman 1960, Hickman 1975).

Humans sprinting around banked bends change the duration of foot contact to spread the time over which the load is applied. Greyhounds do not change foot contact timings and so have to withstand up to a 65% increase in limb forces (Usherwood and Wilson 2005).

Track design

The influence of the track on greyhound injuries has been widely recognised (Walpole 1944, Gannon 1972, Prole 1976, Poulter 1984, Johnson and others 1988, Johnson and others 1989). Greyhound tracks in the United Kingdom are oval in shape with two straights connected by two 180 degree bends and the racing surface is sand.

In the past the surface material has consisted of turf, sand or a combination of turf and sand. A comparison of the two running surfaces was made in favour of sand as it was more easily maintained and allowed all-year racing (Layton and others 1987). In the UK the change from grass to fine-washed silica sand has produced a notable reduction in racing injuries (Poulter 1981).

Greyhounds are subjected to centrifugal, gravitational and frictional forces when racing around circular curves (Ireland 1998). The radius of the curve and the degree of banking on the curves determines how much the dog has to lean into the inside of the bend to overcome the centrifugal forces and maintain speed. The degree of lean influences the strain on the supporting limbs. The musculoskeletal system places a limit on the maximum amount of lean available and if this maximum is reached then the greyhound will either slow down or will run wide to search for a greater radius. Either course of action can cause interference with the other runners (Ireland 1998).

Comparing five tracks in the USA one track with a significantly higher injury rate had a decreased length of straight to the first bend, a narrower radius on the second part of the bend and increased banking compared with other tracks. Injuries were most likely to occur at the first bend (Sicard and others 1999).

Two track injury surveys reported that 74% of injuries occurred on the bends (Bloomberg and Dugger 1998).

The texture and condition of the racing surface is paramount to ensure safety and consistency in the race times. The moisture content, permeability and coefficient of friction must be such that the surface maintains compressive and shear strengths (Ireland 1998). In addition the drainage needs to be consistent across the racing surface, especially on the bends.

Many factors increase the risk of injury during a race. In a survey of injuries at five racing tracks in the USA, speed, race distance and track design were significant factors that influenced the injury rate. Temperature, body weight, race number and type of trauma had no significant effect on injury rate (Sicard and others 1999). A higher incidence of injury was also noted in the higher grades of races (Bloomberg and Dugger 1998).

It has been shown that in wet years there are fewer injuries compared to dry years with faster running conditions (Prole 1976). A seasonal variance was also found with fewer injuries in the wet winter months.

Injury surveys

A number of surveys of racing injuries have been published (Walpole 1944, Gannon 1972, Prole 1976, Agnew 1992, Bloomberg and Dugger 1998).

A survey of two London tracks, both with grass racing surfaces, showed 70% of the injuries occurring in the distal limbs (Prole 1976). In another survey of two provincial UK tracks, one with a sand and grass surface and the other all sand, the incidence of distal limb injuries was only 50% (Agnew 1992). At 18 race tracks in the USA 73% of injuries were in the distal limbs (Bloomberg and Dugger 1998).

SPECIFIC INJURIES

CARPUS

The carpus accounted for 11% (Prole 1976) and 29% (Agnew 1992) of all injuries in two UK track surveys. The injuries were classified as sprains, fractured accessory carpal bone, flexor carpi ulnaris strain, arthritis, cut stopper pad and anterior bursitis (Prole 1976, Agnew 1992).

Fracture of the accessory carpal bone accounts for 1.5 to 13 percent of all carpal injuries (Prole 1976, Agnew 1992). Many authors regarded these fractures as common (Gannon 1972, Hickman 1975, Dee and Dee 1985, Vaughan 1995, Kealy 1987, Johnson 1987, Johnson and others 1989). It is generally accepted that in track greyhounds there is an over-representation of this injury in the right thoracic limb with only one author claiming a higher frequency in the left carpus (Hickman 1975).

Accessory carpal bone fractures are consistent with a sprain-avulsion fracture (Farrow 1977) and theoretical mechanical forces involved in the pathogenesis of these fractures have been documented (Bateman 1960, Davis 1967, Dee 1981, Johnson and others 1988, Johnson and others 1989).

Five types of fracture have been classified (Johnson 1987).

Type I: An avulsion fracture from the distal articular surface.

Type II: An avulsion fracture from the proximal articular surface.

Type III: An avulsion fracture of the distal apical end at the attachment of the two accessorio-metacarpal ligaments.

Type IV: An avulsion fracture at the tendon of insertion of the flexor carpi ulnaris muscle on the proximal apical end.

Type V: comminuted fracture.

A variation of the type I is an avulsion fracture of the lateral articular prominence at the origin of the lateral part of the accessoro-ulnar ligament (Boemo 1994).

Treatment consists of either conservative management or surgery. Conservative management is advised when the injury is more than two weeks old when there is less chance of surgery being successful (Davis 1967). An injection of the sclerosing agent ethanolamine oleate into the site of injury has been recommended for type IV fractures (Yore 1983), and for the highly comminuted type V fracture (Dee 1988).

The first surgical technique described for type I fractures was resection of the abductor digiti quinti muscle (Bateman 1950). This procedure was then incorporated with fragment removal (Bateman 1960, Davis 1967).

Fragment removal is the usual surgical procedure for type I injuries (Bateman 1960, Yore 1983, Vaughan 1985, Johnson and others 1989). Accurate fragment reduction with lag screw fixation of mainly type I fractures gave good results (Johnson and others 1989). A tension band wire technique has also been described (Early 1990).

The prognosis for a successful return to racing was considered poor for conservative management and for resection of the abductor digiti quinti muscle (Davis 1967). The success of type I fragment removal has only been objectively evaluated in one publication where 13 out of 19 dogs returned to racing with nine winning at least one race (Chico 1992). It was considered not to be a highly successful procedure (Vaughan 1985), a success rate of 50-60% is quoted (Yore 1983), and another publication states that less than 50% ever won a race (Brinker and others 1983). A return to racing varied from 45% to 90% dependent on factors including the age of the dog, duration of the injury and the development of degenerative joint disease (Dee and Dee 1985).

Of eleven dogs treated by screw fixation for type I injuries, ten dogs returned to racing but only five won any races (Johnson and others 1989).

Screw fixation of types II and III accessory carpal bone fractures has been described but with type IV fractures the fragment is usually too small to surgically reattach (Johnson and others 1989). Prognosis for all types of accessory carpal bone fracture is considered good with adequate fixation but poor otherwise (Dee and others 1990).

Radial carpal bone fractures
Reported fractures are an oblique fracture through the body of the bone seen on the dorsopalmar radiographic view, an avulsion fracture of the palmar process (Johnson 1998), and a dorsal chip fracture (Boemo 1993).

Conservative management of the oblique fracture is considered unsatisfactory and lag screw fixation can return the dog to racing (Johnson 1998).

Dorsal chip fractures of the carpus have been identified at the origin of the dorsal radiocarpal ligament (Ferguson 1986, Boemo 1993) and on the radial carpal bone and third carpal bone (Boemo 1993). Diagnosis is by radiography with dorsopalmar, mediolateral and oblique extended and flexed views (Boemo 1993). An additional skyline view is described (Piras and Johnson 2006).

Fractures occur at the origin of the dorsal radiocarpal ligament on the distal radius, and on the distal dorsal margins of the radial carpal bone and ulnar carpal bone with similar distributions between the right and left carpi (Boemo 1993).

Treatment by surgical removal of the bone chip gives a good to excellent prognosis (Ferguson 1986, Piras and Johnson 2006) with a 70% return to satisfactory racing (Boemo 1993). The prognosis with conservative management is poor.

The aetiopathology is considered to be from compressive forces resulting in shear stress on the bone during carpal hyperextension (Boemo 1993).

Sprain of the dorsal radiocarpal ligament
Sprain of this ligament has been reported as causing an intermittent lameness in high activity dogs and was successfully treated by external coaptation (Guilliard 1997). An avulsion fracture of the origin is a common cause of lameness in Greyhounds (Boemo 1993, Piras and Johnson 2006).

Extensor carpi radialis sprain
Injury to this tendon can be found at its insertion on the bases of metacarpal bone two and three. Local swelling may be due to a sprain, rupture of the tendon or an avulsion of its insertion (Blythe and others 1994).

Antebrachiocarpal joint sprain injury
This is defined as pain, swelling and reduced range of motion of the antebrachio-carpal joint, has been classified according to its degree of severity (Farrow 1977, Dunley 1983, Dee L.G. 1987). Haemorrhage may be present in the joint fluid (Needham 1978).

Synovial and osteoarthritic changes have been described following carpal sprain injury (Poulter 1984, Johnson 1987). Carpal injury was likened to human carpal tunnel syndrome (Cooper 1983).

Initial treatments include ice packs and ultrasound followed by the administration of non-steroidal anti-inflammatory drugs, topical application of dimethyl sulfoxide (DMSO) and counter-irritants, intra-articular injections of corticosteroids and polysulfated glycoaminoglycans, local injections of sclerosing agents and pin firing (Needham 1978, Blythe and others 1994).

The prognosis for a successful return to racing is considered poor (Davis 1967, Needham 1978, Dunkley 1983). The high rate of recurrence was attributed to inadequate assessment and treatment of the initial injury (Dee L.G. 1987).

Flexor carpi ulnaris tendon strain

In one survey this injury represented five percent of carpal injuries (Prole 1976) but was much lower in a later survey (Agnew 1992). It can be associated with type IV accessory carpal bone fracture (Johnson 1987) where it is over-represented in the left carpus. Diagnosis is by the palpation of the thickened tendon and radiography (Johnson 1987).

The most successful treatment is reported to be laser pin–firing and three months controlled rest (Davis 1983). Strain-avulsion fractures of the FCU tendon and are best treated by surgical excision of the bone fragment with the tendon ends apposed to the bone with non-absorbable sutures and six weeks of external support with training commencing after 10 to 12 weeks (Dee 1998).

Tear of the palmar superficial fascia

Tear of the palmar superficial fascia over the insertion of the tendon of the flexor carpi ulnaris (FCU) has been described as a cause of mild lameness (Roe 1998, Guilliard and Mayo 2000a). Diagnosis is by the palpation of a horizontal dimple in the fascia over the caudal aspect of the accessory carpal bone. It has been associated with a tear in the FCU in a Labrador retriever (Guilliard and Mayo 2000a).

Surgical suturing together with a flexion splint gives a good prognosis for a return to racing (Roe 1998, Guilliard and Mayo 2000a).

Accessory carpal bone luxation

There is one report of this condition treated by accessory carpal bone removal with pancarpal arthrodesis (Guilliard 2001a).

Subluxation of the second carpal bone.

Two cases are reported successfully treated by reduction and temporary fixation with either a bone screw into the third carpal bone or by arthrodesis pins (Guilliard 2001b).

Enthesiopathy of the origin of the straight part of the radial collateral ligament

A radiographic survey of the carpi of 100 racing Greyhounds showed changes to the outline of the tubercle at the origin of the ligament in 14 carpi. This was not thought to have any clinical significance (Guilliard 1998). There is one case report of sprain of this ligament (Guilliard and Mayo 2000b).

TARSUS

Injuries to the tarsus had an incidence of six percent (Prole 1976) and four percent (Agnew 1992) of total injuries with approximately 65 percent being fractures. In a survey of track injuries in the USA 47 percent occurred in the tarsus (Bloomberg and Dugger (1998). There was no differentiation between fractures and other injuries.

Central tarsal bone fractures

The majority of tarsal fractures involve the central tarsal bone in the right tarsus and there are some early publications on this subject (Bateman 1958, Keene and Yarborough 1966, Prole 1969, Hickman 1975, Kelman 1983). A radiological classification of five fracture types was made (Dee and others 1976).

Type I: non-displaced dorsal slab fracture.
Type: II: displaced dorsal slab fracture.
Type III: diagonal fracture through the body of the bone.
Type IV: dorsal slab fracture and a medial buttress fracture.
Type V: severely comminuted fracture.

Types IV and V are often associated with tarsal collapse (Boudrieau and others 1984a).

Early surgical treatments included the use of a plastic insert (Bateman 1958), a single positional screw (Keen and Yarborough 1966), and a Venables plate (Prole 1969). The technique of interfragmentary compression with one or two lag screws was thought to be superior (Dee and others 1976, Boudrieau and others 1984a, Boudrieau and others 1984b). Fixation using one or two screws with interfragmentary compression was shown to give satisfactory results in all types of central tarsal bone fractures except those that were severely comminuted (Boudrieau and others 1984a). These methods of repair are described in many texts (Dee 1981, Boudrieau and others 1984b, Dee and Dee 1985, Dee and others 1990, Earley 1990, Dee 1998).

In a review of 114 cases of central tarsal bone fractures 64 % had concomitant fractures in other tarsal bones. Sixty two percent were in the fourth tarsal bone, 38% in the calcaneus and 38% of dogs had an avulsion fracture of the lateral base of the fifth metatarsal bone. Other associated fractures were in the second tarsal bone, talus and the medial malleolus of the tibia (Boudrieau and others 1984b). A total of 71% of the dogs returned to competitive racing.

A case report of the use in a type IV central tarsal bone of an implant made of titanium alloy enabled a successful return to racing (Yocham 1988). A histological examination of the tarsus was made at the end of the greyhound's racing career and showed that the implant was encapsulated and had not loosened (Bloebaum and others 1989).

Central tarsal bone fractures can be highly comminuted together with concomitant fractures of the fourth tarsal bone and calcaneus (Vaughan 1987). The high degree of comminution is shown in MRI images of tarsal fractures (Hercock and others 2011). Accurate reduction and rigid fixation is often not possible and treatment is directed at achieving tarsal alignment. Healing results in intertarsal ankylosis (Guilliard 2000).

In an anecdotal report comminuted central tarsal bone fractures were reduced using elastrator rings and then kept in reduction by external coaptation (Jones 2009). Using this technique in about 400 cases approximately 95% returned to racing.

Calcaneal fractures
In the racing Greyhound calcaneal fractures are usually associated with fractures of the CTB (Boudrieau and others 1984, Ost and others 1987). Calcaneal fractures occur following central tarsal bone collapse allowing the talus to displace distally. The strong articulations with the calcaneus pull it distomedially compressing T4 and increasing lateral tensile forces with resultant fracture of either bone (Dee 1998).

Fracture morphology has been catagorised into midshaft, lateral sagittal slab, small dorsal lateral slab and calcaneal base fractures (Dee 1984) and has been further differentiated into dorsomedial slab fractures with combinations of other types (Ost and others 1987). Further classifications are described (Dee 1998).

Fracture of the base of the calcaneus at the origin of the plantar ligament can cause proximal intertarsal subluxation (figure 13). Comminuted fractures through the body result in plantar instability (Ost and others 1987, Dee 1998). Recommended treatment is an intramedullary pin and tension band wire. The prognosis is guarded for a return to racing.

Distal calcaneal slab fractures can be reconstructed with lag screws (Dee 1998).

Success judged as a return to racing following surgical repair was seen in eight out of 22 dogs with concomitant CTB fractures including four with severely comminuted fractures (Ost and others 1987). Of ten dogs surgically treated for proximal intertarsal subluxation none returned to racing (Ost and others 1987).

Talar fractures

In a series of 114 CTB fractures there were seven cases of talar fracture associated with either concomitant fourth tarsal bone or calcaneal fractures (Boudrieau and others 1984a). Three talar fractures occurred in a series of 14 severe CTB fractures (Hercock and others 2011).

Damage to the articular surface of the talar head is a frequent finding associated with the more severe CTB fractures and occasionally a dorsal or medial slab fracture will be seen (Boudrieau and others 1984a).

Fourth tarsal bone fractures

About 40% of types IV and V CTB fractures have concomitant T4 fractures (Dee 1998). Following collapse of the central tarsal bone the weight bearing forces are transmitted solely through the calcaneus and T4, causing compression fractures (Dee 1981). These can be highly comminuted (Hercock and others 2011).

Restoring the integrity of the CTB with a lag screw into T4 decompresses the T4 fracture (Dee 1981).

Third tarsal bone fractures

Fractures of the third tarsal bone are reported but the incidence is low. In the two surveys of racing injuries (Prole 1976, Agnew 1992) only one case was seen. The clinical signs are mild with slight localised swelling and a moderate degree of lameness that rapidly improves and unless radiographs of the tarsus are taken, a misdiagnosis of a sprain may be made (Vaughan 1987).

The radiographic appearance is a displaced dorsal slab fracture (Dee and others 1990). Conservative treatment carries a fair to poor prognosis for a return to successful racing (Dee and others 1990). The recommended treatment is by lag screw fixation and carries a good prognosis. Some cases have a concomitant fracture or luxation of the second tarsal bone (Dee and others 1990, Dee 1998).

In a review of 23 cases of third tarsal bone fractures there were five cases with concomitant second tarsal bone fractures (Guilliard 2010). The prognosis for a return to successful racing was good following lag screw fixation unless there was a degree of dorsal tarsal collapse.

Ankylosing bony lesions on the dorsal aspect of the tarsus have been described as a non-fracture associated hock lesion (Poulter 1981, Vaughan 1987) and have been given the term spavin (Salazar and others 1984). These may not be associated with a dorsal tarsal bone fracture (Prole 1983). These types of lesion are seen in chronic third tarsal bone fractures (Guilliard 2010).

Second tarsal bone fractures

Fracture of the second tarsal bone is rare and is usually associated with third tarsal bone fractures and occasionally CTB fractures. Diagnosis is made on the dorsoplantar radiographic view with increased T3/T2 and CTB/T2 joint spaces (Dee 1998). Treatment is by lag screw fixation into T3 or the fourth tarsal bone.

Tibial fractures

There are reports of a fracture of the bony ridge on the caudal distal tibial margin (CDTM) in two Greyhounds (Butler 1984, Montavan and others 1988) and there is one review of distal articular fractures in the racing Greyhound detailing six cases (Montavon and others 1993). Of these there were two cases with single CDTM fractures and four cases with concomitant malleolar fractures.

Open anatomical reduction with rigid internal fixation gave superior results to conservative management (Montavon and others 1988). The CDTM fractures were treated by lag screw fixation and the malleolar fractures by pins and tension band wire. Conservatively treated fractures rapidly developed signs of osteoarthritis.

Ligamentous tarsal injury

There are few reports of ligamentous tarsal injuries in the racing greyhound although sprained hock is a common diagnosis (Prole 1976, Davis 1983, Agnew 1992) and has been associated with injury to the dorsal ligaments (Davis 1983).

Superficial digital flexor tendon luxation

Luxation of the superficial digital flexor tendon from the point of the calcaneus occurs in racing greyhounds and surgical repair can be successful (Vaughan 1987).

Dorsal proximal intertarsal subluxation

Subluxation of the dorsal proximal intertarsal joint is reported (Dee 1998, Guilliard 2003b) and is thought to occur following a collision resulting in the dog somersaulting and hitting the dorsal aspect of the foot with the ground (Guilliard 2003b).

Dorsal subluxation of the proximal intertarsal joint can have either lateral or medial components and the preferred treatment is arthrodesis. The prognosis for a return to successful racing is described as fair to good (Dee 1998). A single case report describes successful treatment by the placement of screws in the calcaneus and T4 connected by a tension band wire (Guilliard 2003b).

Other dorsal ligament injuries

Screws and a tension band wire were used in the successful treatment of dorsal centrodistal joint and dorsal tarsometatarsal joint instabilities (Guilliard 2003b).

Idiopathic tarsal lameness
Tarsal sprain injuries had a reported incidence of 23% of all tarsal injuries in the two track surveys (Prole 1976, Agnew 1992). The diagnosis was made on the clinical finding of tarsal pain with no specific tarsal injury. Many of these cases were thought to be misdiagnosed third tarsal bone fractures (Vaughan 1987, Guilliard 2010).

METACARPUS

Injuries to the metacarpus had an incidence of 10% (Prole 1976) and 1.6% (Agnew 1992) of total injuries with 90% (Prole 1976) and 75% (Agnew 1992) respectively involving the flexor tendons.

Metacarpal fractures
In a survey of Greyhound fractures the metacarpal bones were involved in 32 of 100 cases. Eighteen were classified as lamellar fractures with radiographic remodelling changes of increased cortical bone density, irregular thickened cortices and increased trabecular thickness (Gannon 1972). In surveys in England there were five cases out of 58 fractures (Prole 1976) and two cases reported out of 32 metacarpal injuries (Agnew 1992).

Three principal categories of metacarpal injury are defined: periostitis, stress fracture and complete fracture, but this demarcation is considered arbitrary as it represents bone changes as a response to cyclical injury (Boemo 1998).

Some young greyhounds develop shin soreness of the metacarpal bones when put into training (Davis 1971, Kidd 1983) and a dorsal periostitis may be seen radiographically (Yore 1983).

Metacarpal fractures are regarded as stress or fatigue fractures (Davis 1971, Gannon 1972) and the most commonly affected bone is the fifth metacarpal bone of the left thoracic limb. This is thought to be due to the increased loading when negotiating the bends in an anticlockwise racing direction (Gannon 1972, Hickman 1975, Bellenger and others 1981). Remodelling of the fifth metacarpal bone with an increase in the thickness of the cortices has been described (Kidd 1983, Lipscombe and others 2001).

Treatment of periostitis and incomplete stress fractures involve various forms of physiotherapy together with a variety of blistering agents, steroidal and non-steroidal anti-inflammatory drugs and rest (Davis 1967, Kidd 1983, Boemo 1998).

Successful treatment of complete metacarpal fractures has involved external coaptation techniques (Kidd 1983), and cerclage sutures (Davis 1967). Reconstruction and fixation with lag screws, cerclage wires and plating is described (Bellenger and others 1981, Boemo 1998).

Superficial digital flexor tendon injury
Injury is characterised by lameness and localised swelling (Prole 1971). It is reported as a common injury (Walpole 1944, Prole 1971, Prole 1976). Flexor tendon injury represented 90% (Prole 1976) and 75% (Agnew 1992) respectively of the total metacarpal injuries. Diagnosis is by the observation of a bowed tendon over the palmar aspect of the metacarpus (Needham 1978).

Occurrence is most common in the left thoracic limb with the most frequently affected tendons being to the fifth digit of the left limb and to the second digit of the right limb (Prole 1976).

Treatment can be conservative with three months rest for strains but severe strains and rupture are best treated by tenectomy (Prole 1971).

METATARSUS

Metatarsal fractures
Fractures of the metatarsus are true stress or fatigue fractures (Gannon 1972, Ness 1993). The metacarpal to metatarsal fracture ratio is reported as 22:1 (Bellenger and others 1981), and 35:5 (Gannon 1972). Metatarsal bone fractures accounted for 5% of all fractures (Gannon 1972).
Fractures occurred in only the second metatarsal bone in two track surveys with no limb over-representation (Prole 1976, Agnew 1992). However the right third metatarsal bone was the most common site of metatarsal bone fracture (Kelman 1983, Boemo 1998). In another survey six single stress fractures of the third metatarsal bone in the right limb were described (Ness 1993).

They can present as periostitis, fractures with no displacement, and complete fractures (Boemo 1998).

Surgical treatments are the same as those detailed for metacarpal fractures. External coaptation and rest failed to resolve lameness in three cases but dorsal plating led to a successful return to racing (Ness 1993).

Digits

Metacarpal/metatarsal phalangeal joint disease
Metacarpal/metatarsal phalangeal joint sprain injuries are found commonly in the fifth digit of the left fore foot and the second digit of the right fore foot (Prole 1976). The injury can be a sprain, subluxation or luxation sometimes associated with small avulsion fractures from the attachments of the collateral ligaments (Eaton-Wells 1998).

Treatments for instabilities involve either conservative management, the injection of irritants (Dee and others 1990), amputation, or reconstructive ligament surgery, the latter being thought to be superior (Dee and others 1990, Eaton -Wells 1998).

Sesamoid injuries
Fracture of the palmar/plantar sesamoid bones is occasionally seen (Bateman 1959, Davis and others 1969, Prole 1976), yet fragmentation of the sesamoids, especially numbers two and seven of the fore feet, is common in greyhounds and is not considered a clinical problem (Bateman 1959, Davis and others 1969). Surgical excision is the recommended treatment.

Sesamoid fragmentation with pain on joint flexion and a reduced range of motion, commonly occurring in the second and fifth metacarpal phalangeal joints, has been classified as sesamoiditis (Needham 1978, Kidd 1983).

Proximal interphalangeal joint sprain
The proximal interphalangeal joint is the most common site for digital instabilities on a grass running surface (Prole 1976). Treatments include the injection of sclerosing agents with blood (Needham 1978, Davis 1983), prosthetic ligament placement with wire, primary ligament repair, the use of suture anchors and arthrodesis (Eaton-Wells 1992). Prosthetic ligament replacement gave a 50% and primary ligament repair between 60% and 75% success for a return to racing (Dee 1992).

The use of an external skeletal fixator to immobilise the joint for three weeks gave good results (Guilliard 2003a).

Distal interphalangeal joint sprain
The P2/P3 joint is the least commonly injured digital joint with only four out of 262 (Prole 1976) and ten out of 326 cases of digital injuries (Agnew 1992). Treatment is reportedly difficult (Davis 1983). The importance of reducing the lever arm of the digit in the treatment of various injuries is described in early publications by either nail shortening or permanent removal (Bateman 1960, Davis 1967). The technique for permanent nail removal (ungual crest ostectomy) is described with the recommendation that the collateral ligament is also repaired (Dee and others 1990, Eaton-Wells 1998).

Prognosis for the successful surgical treatment of P2/P3 luxations is guarded and distal digital amputation may be necessary (Davis 1983, Dee and others 1990).

Occasionally P2/P3 subluxation has a concomitant cut over the abaxial joint margin that rapidly heals with rest but opens into the joint on exercise (Bateman 1960, Eaton-Wells 1998).

Digital fractures
Fractures of the phalangeal bones are uncommon with only four reported by Prole (1976) and five by Agnew (1992). Treatment of diaphyseal fractures is usually by external coaptation, oblique fractures can be screwed but articular and highly comminuted fractures require digit amputation (Dee 1988, Dee 1992). Accurate reconstruction with rigid fixation of articular fractures will get the dog back to racing in a shorter period of time and reduce the degree of subsequent osteoarthritis (Eaton-Wells 1998).

Fractures of the third phalanx are usually treated by amputation (Dee and others 1990).

Flexor tendon injuries

Rupture of the superficial digital flexor tendon results in a dropped toe and rupture of the deep digital flexor tendon a knocked-up toe (Needham 1978). The dropped toe is of no clinical significance while a knocked-up toe can lead to corn formation and lameness (Eaton-Wells 1998, Guilliard and others 2010).

Dermatological causes of lameness

Split webbing

Split webbing is a laceration of the interdigital skin beginning at the leading edge and extending caudally. Small cuts can be sutured but more extensive cuts are best treated by creating a permanent deficit by suturing the dorsal and ventral skin surfaces together (Eaton-Wells 1998). Reconstruction however is recommended (Power 1975), 90% not recurring on return to racing (Davis 1983).

Split foot

A split foot is a full thickness split of the plantar skin between the metatarsal pad and the digital pad overlying the flexor tendons of either digit three or four. This split heals naturally but will open again each time the dog runs. It can be treated by debridement and suturing (Power 1975) but it is not always successful in preventing recurrence (Davis 1973). Recurrence can be prevented by strapping the foot during racing and surgery is not recommended (Davis 1983). A sand rash is an abrasion of the superficial dermis and is a precursor to a split foot (Kidd 1983).

Viral papilloma

Viral papillomas also occur on the skin of the foot and can cause lameness (Davis and others 1983, Eaton-Wells 1998).

Foreign bodies

The pad can be affected by foreign body penetration and corns. Foreign bodies are usually glass or grit and are diagnosed by radiography. There is often a discharging sinus tract (Guilliard and others 2010).

Corns

Corns are found in the digital pads three or four in the thoracic limbs in 85% of cases and can cause severe lameness (Guilliard and others 2010).
The suggested aetiologies are mechanical pressure, foreign body penetration and papilloma virus (Davis 1973, Blythe and others 1994, Eaton-Wells 1998) however no virus has been found (Balara and others 2009). Concomitant foot deformities were present in 40 percent of cases suggesting a mechanical cause (Guilliard 2010). Foreign bodies are rarely found (Swaim and others 2004, Gross and others 2005, Guilliard 2010) but histology is suggestive of a foreign body sinus tract in some cases (Guilliard 2010).

Excision is the recommended treatment (Davis 1973), but a high percentage of corns will return two to three months after surgery (Swaim and others 2004). Excision is generally successful in the short term but after one year over 50 percent of the corns will recur (Guilliard 2010). Laser surgery, physical extrusion, hulling out the hard centre or curretage may be beneficial but recurrence is common (Gross and others 2005).

MATERIALS AND METHODS

The distal limb is distal to and includes the antebrachiocarpal joints in the thoracic limbs, and the talocrural joints in the pelvic limbs. Injuries included those sustained on the race track and those sustained during free exercise during training.

All cases were examined and treated by the author. A retrospective study of selective injuries was undertaken. The selection was based on retrievable radiographs and clinical notes. The prospective study was of all injuries and recorded clinical and radiographic findings, treatments and outcome.

Dogs were treated at either Nantwich Veterinary Hospital or at a provincial Greyhound stadium. The majority of the dogs raced solely at the stadium.

Only dogs with a definite diagnosis of their injury were included. Diagnosis was made by history, clinical examination, examination under general anaesthesia, and radiography.

Radiographic examinations were made at either location. Orthogonal views were taken and when appropriate oblique and stressed views. One case was investigated by computerised tomography.

Specific surgical treatments are described in the appropriate chapters. Conservative management consisted of kennel rest and restricted exercise on the leash. Rehabilitation initially allowed the dog free exercise in a small enclosure progressing to play with other dogs in a larger enclosure followed by straight galloping behind a lure.

External coaptation was generally a support dressing of orthopaedic padding, a conforming bandage and an external layer of Vetrap (3 M). Further support incorporated a Dynacast Prelude (BSN Medical Ltd) splint.

Identification of dogs was by racing name. Follow-up was by contact with the trainer, observation of the dog racing and by access to the dog's full racing history on the website of the Greyhound Board of Great Britain (www.gbgb.co.uk).

Anaesthesia

Two anaesthetic protocols were used for invasive surgical procedures.

Protocol 1: premedication was with a low dose of acepromazine (0.01mg/kg) and morphine (0.3mg/kg) given intramuscularly 30 minutes before induction with propofol (4mg/kg) given intravenously. After intubation anaesthesia was maintained with isoflurane.

Protocol 2: Induction was with medetomidine (25ug/kg), ketamine (5mg/kg) and butorphanol (0.1mg/kg) given intravenously. After intubation anaesthesia was maintained with isoflurane.

For procedures involving the pelvic limbs an epidural injection of 2% lidocaine (0.15ml/kg) was given. For procedures involving the digits a ring block of local anaesthetic was used (lidocaine 2%).

Sedation for radiography was by a combination of medetomidine (25ug/kg) and butorphanol (0.1mg/kg) injected intravenously.

Analgesia

Non-steroidal anti-inflammatory drugs were given 30 minutes before anaesthetic induction and then administered orally for as long as necessary (dosage according to the manufacturer’s data sheet). Morphine was given to effect when necessary.

THE CARPUS

Anatomy

The carpus, lying between the antebrachium and the metacarpus, consists of seven bones. In the proximal row are the radial, ulnar and accessory carpal bones; and in the distal row the first, second, third and fourth carpal bones. In addition there is a small sesamoid bone within the tendon of insertion of the abductor policus longus tendon, situated medial to the distal aspect of the radial carpal bone (Evans 1993a) (figures 1 & 2).

The carpus is a three-level hinge (ginglymus) joint comprising of the antebrachiocarpal joint, the middle carpal joint and the carpometacarpal joint. Approximately 70 percent of carpal motion is from the antebrachiocarpal joint, 25 percent from the middle carpal joint and five percent from the carpometacarpal joint.

The main support of the carpus is from strong collateral and palmar ligaments together with the palmar fibrocartilage, and the flexor mechanism. The latter comprises of the two flexor carpi ulnaris tendons inserting on the non-articular end of the accessory carpal bone (ACB) with the ACB acting as a fulcrum, together with the distal accessoriometacarpal ligaments forming a tension band. The dorsal carpal ligaments are weak in comparison.

The dorsal surface of the distal radius has three grooves containing in the most medial, the tendon of the abductor pollicus longus muscle; in the central the tendon of the extensor carpi radialis muscle; and in the lateral the tendon of the common digital extensor muscle. In addition the dorsal radiocarpal ligament runs from the lateral dorsal rim to the ulnar carpal bone (Evans 1993a).

When weight-bearing there is a slight degree of carpal valgus placing the medial aspect in tension, and a small degree of carpal hyperextension. When racing the carpus can hyperextend up to ninety degrees (Guilliard 2006).

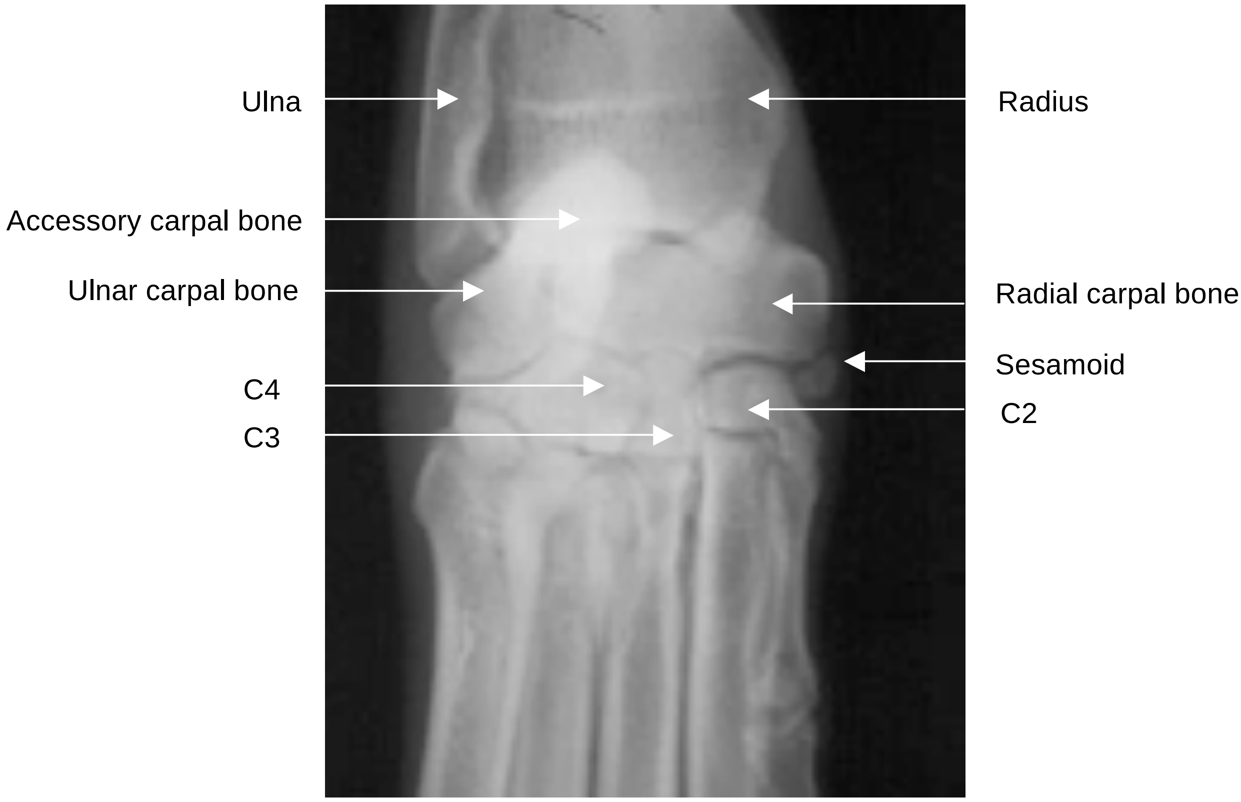


Figure 1: dorsopalmar radiographic view of the carpus

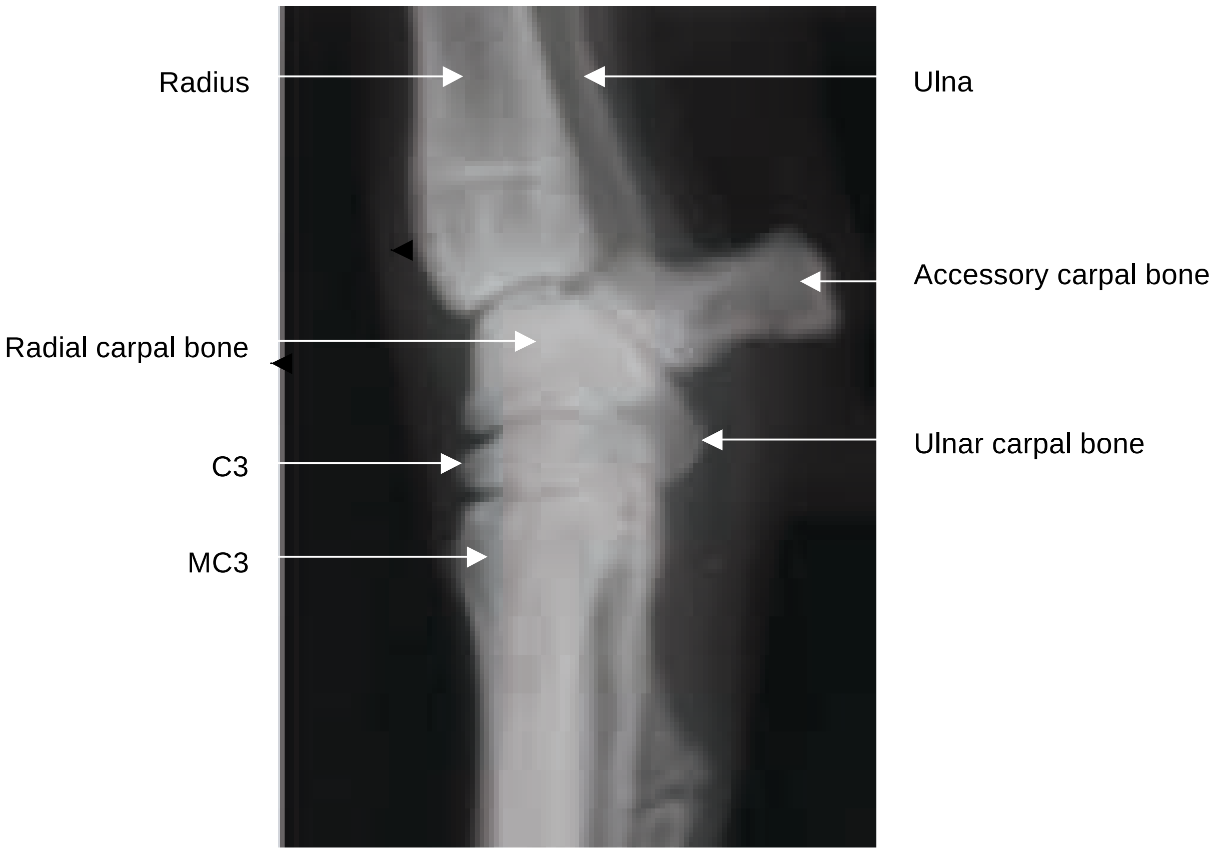


Figure 2: mediolateral radiographic view of the carpus

Accessory carpal bone fractures

Introduction

The accessory carpal bone (ACB) is rod shaped, enlarged at each end and lies on the palmar aspect of the carpus. The main articulation is with the ulnar carpal bone with a smaller articulation to the styloid process of the ulna (Evans 1993a).

The articular ligaments are multiple and complex. The distal ligaments comprise of the accessorio-ulnar carpal ligament that runs distolaterally from the distolateral aspect of the ACB to the ulnar carpal bone, the accessorio-quartal ligament running distally from the ACB to the fourth carpal bone, and the accessorio-radial carpal ligament running from the medial aspect of the ACB to the radial carpal bone (Mikic and others 1992, Evans 1993a).

The proximal articular ligaments have a proximolateral attachment to the styloid process of the ulna and on the proximomedial aspect, a connection to the palmar ulnar carpal ligament. Further lateral support is given from the tendon of insertion of the extensor carpi ulnaris that has an attachment with the fascia over the lateral ACB.

The caudal end of the ACB has attached on its proximal aspect, the tendons of insertion of the two bellies of the flexor carpi ulnaris muscle, and on its distal aspect the two accessorio-metacarpal ligaments that insert on the bases of metacarpal bones four and five.

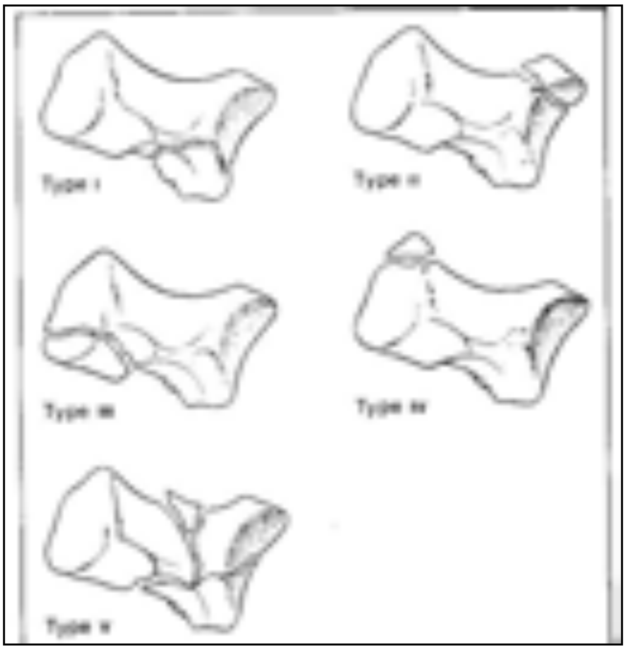
The ACB acts as fulcrum for the carpal flexor apparatus preventing hyperextension of the carpus. The accessorio-carpal articulation lies on the lateral aspect of the carpus with the caudal end in the middle sagittal plane. This places the lateral aspect of the joint under tension during weight bearing (Guilliard 2001a).

Materials and methods

Multiple radiographic views were taken in many cases. The standard views were extended mediolateral and dorsopalmar. Most cases had flexed mediolateral views and a minority had dorso-lateral palmaro-medial oblique views. One case was referred for a computerised tomographic study (CT).

A previous publication (Johnson and others 1988) was used as the classification of the five types of fracture (figure 3). The author further classified type I fractures from an examination of the radiographs. Type I A was considered to be an avulsion fracture from the disto-lateral aspect of the ACB at the attachment of the accessorio-ulnar carpal ligament (figure 4), type I B an avulsion fracture on the disto-medial aspect from the attachment of the accessorio-quartal ligament (figure 5), and a previously unreported avulsion fracture on the medial aspect from the attachment of the accessorio-radial carpal ligament (figures 7, 8 & 9) designated as a type I C.

Palmar (caudal)



Articular or dorsal

Figure 3: classification of accessory carpal bone fractures (Johnson and others 1988).

Type I: An avulsion fracture from the distal articular surface.

Type II: An avulsion fracture from the proximal articular surface.

Type III: An avulsion fracture of the distal apical end at the attachment of the two accessorio-metacarpal ligaments.

Type IV: An avulsion fracture at the tendon of insertion of the flexor carpi ulnaris muscle on the proximal apical end.

Type V: comminuted fracture.

The surgical approach to the ACB was through a lateral incision (Johnson and others 1989). Fragment reduction was with forceps enabling either a 2.0mm or 1.5mm cortical screw to be inserted positionally (figure 6). The carpus was coapted in flexion for three weeks and supported in extension with a splinted dressing for a further three weeks.

Type IV ACB fractures are discussed under the section on flexor carpi ulnaris tendon strain.

Figure 4: oblique dorsolateral-palmaromedial radiographic view showing a type I A fracture (arrow).

Figure 5: a pre-operative mediolateral radiographic view showing a type I B fracture from the distal articular aspect of the ACB (arrow) (case 22).

Figure 6: a post-operative mediolateral radiograph of a type I B fracture repaired with a 2mm positional screw (case 22).

Figure 7: a dorsopalmar radiograph showing a type I C fracture on the distomedial articular border of the accessory carpal bone (arrow) (case 20).

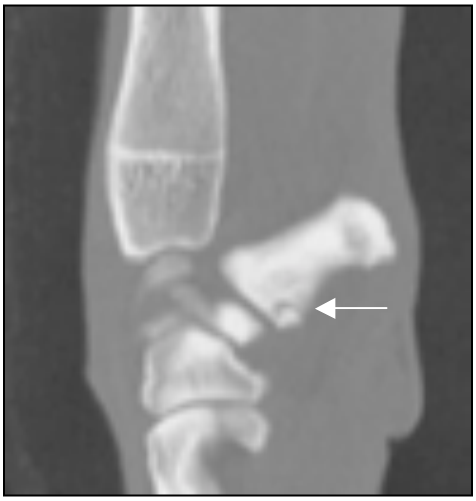


Figure 8: a sagittal CT scan of a type I C fracture (case 20) showing a small fragment on the distal articular border of the ACB (arrow).

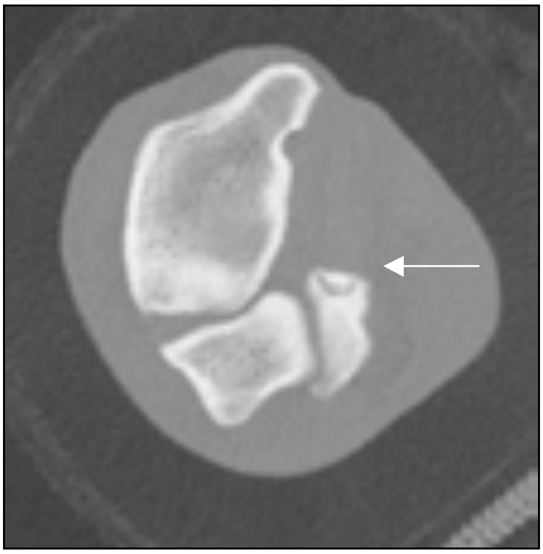


Figure 9: a dorsal CT scan of a type I C fracture (case 20) showing a non-articular bone fragment on the medial aspect of the ACB (arrow).

Results

Thirty-nine ACB fractures were recorded of which five were in the left carpus, 32 in the right carpus and one dog had bilateral type IV fractures.

The clinical signs varied from mild to non-weight bearing lameness with varying degrees of swelling around the ACB and pain on manipulation of the bone. There was a detectable carpal effusion in those cases with articular fractures (types I and II) and if arthrocentesis was performed there was an excess of serosanguinous synovial fluid.

Thirty-one cases were type I fractures, three cases a combination of type I with either type II or III fractures, four cases type IV and one case type V. The type I fractures were subdivided into two type I A, 18 type I B, 12 type I A,B and two type I C

The limb distribution, type, treatment and outcome are shown in table 1.

Case	Limb	Type	Treatment	Outcome
Retrospective				
1	L	IV		retired
2	R	I B		retired
3	R	I B		retired
4	R	I A,B		retired
5	R	I A,B		retired
6	R	I B & III	2 screws	failed
7	R	I A,B		retired
8	R	I B		retired
9	R	I B		retired
10	R	I A,B		retired
11	R	I B		retired
12	R	I B		retired
13	R	I B		retired
14	R	I B		retired
15	L	I C		retired
Prospective				
16	R	I A,B		retired
17	R	IV	rest	failed
18	R	I A		retired
19	R	I A,B	2 screws	failed
20	R	I C	rest	raced
21	R	I B		retired
22	R	I B	1 screw	raced
23	L	I B	rest	raced
24	R	I B	fragment removal	failed
25	R	I A,B	rest	failed
26	R	I A,B		retired
27	R	I B & III		retired
28	L & R	IV	rest	failed
29	R	I B		retired
30	R	I A,B		retired
31	R	I A,B		retired
32	R	I B & III		retired
33	R	I B		retired
34	R	I A,B		retired
35	R	I B		retired
36	L	I A		retired
37	R	V		retired
38	R	I A,B		retired

Table 1: showing the limb distribution, type, treatment and outcome of ACB fractures. Retired = was not returned to racing. Failed = lame on return to racing.

Discussion

The distribution and types of ACB fractures were similar to other published surveys with an over-representation of the right carpus (Gannon 1972, Prole 1976, Johnson 1987, Johnson and others 1988, Agnew 1992). Type I fractures have been subdivided into types I A and I B with the former lying on the lateropalmar aspect and the latter on the mediopalmar aspect (Piras and Johnson 2006).

Unpublished work on an MRI study by the author would indicate that the type I B fracture is an avulsion of the accessorio-quartal ligament and not as suggested the accessorio-ulnar ligament, avulsion of the latter is a type I A fracture.

Types II, III, IV and V ACB fractures are easily diagnosed from mediolateral radiographic views. A diagnosis of a type I fracture can be suspected if there is pain with digital pressure proximo-distally across the articular end of the ACB. Crepitus and mediolateral instability may be detected with type I A fractures. A definitive diagnosis is made with radiography. The flexed and extended (figure 5) mediolateral views will detect almost all types I A and I B fractures and confirmation of a type I A fragment can be made with the oblique dorsolateral-palmaromedial view (figure 4).

The dorsopalmar radiographic view can be difficult to interpret due to the composite shadows of the overlying carpal bones. Good exposure factors and positioning will aid interpretation allowing a further appreciation of types I A and I B fragmentation. Type I C fracture can only be detected from this view. CT is very sensitive in detecting small fractures of the ACB but its use is limited for mainly financial considerations.

Treatment and prognosis of type I fractures are controversial issues with reported cases generally having no differentiation of the subtype of fracture and poor outcome assessment. In the retrospective study of surgical fragment removal in 19 dogs (Chico 1992) there is no differentiation of the subtypes and the success was assessed by the percentage return to racing (70%) and the percentage winning a race (47%). It was not stated whether the dog returned to its previous racing form, had transient carpal lameness after racing or was retired from racing due to a recurrent carpal lameness.

In addition some of these Greyhounds may have been given pre-race pain relief as racing on unlicensed tracks has no testing for prohibited substances.

Treatment by either positional or lag screw fixation through all the major fragments is reported in 12 cases (Johnson and others 1989). Eight cases were type I fractures with no further differentiation of the subtype, two were types I and II, and two were types I and III. In three dogs there were additional secondary chip fractures that were either excised or left in place, being too small for screw fixation. These could possibly have been type I A fractures. Of the ten dogs that returned to racing, two suffered additional unrelated injuries, and five dogs won one or more races. Again no mention is made of the grade of race or if there was transient lameness after racing.

Lag screw fixation of ACB fractures is difficult surgery and not attempted by some orthopaedic Greyhound veterinary surgeons. Surgical exposure and accurate reduction are difficult to achieve, with the fragment often too small to accept a screw or it fractures when drilled.

In a post-mortem study of seven dogs with chronic type I fracture, all fragments were displaced, surrounded by a periosteal proliferation, and attached by fibrous tissue to the ACB and the ulnar carpal bone. In addition the articular cartilage on both joint surfaces was fibrillated (Johnson 1987). As a result of the advanced arthritis seen in the above study it would appear unlikely that conservative management will be successful in returning the dog to racing.

In this study fragment removal was unsuccessful (n=1) and accurate reduction with screw fixation successful (n=1) with the dog completing over 80 races. Two other cases failed due to poor fragment reduction.

The dog with a type I C fracture treated conservatively raced again successfully. These fragments appeared not to involve the articular surface and were probably sprain-avulsion fractures of the accessorio-radial ligament.

The majority of dogs (n = 29) were retired on the advice of the author as a result of the guarded prognosis in the treatment of many fracture types.

Accurate reduction with rigid fixation, when this is possible, appears to offer a good prognosis. The presence of type I A fractures with screw fixation of type I B fractures does not appear to have a detrimental affect on the outcome from a study of three cases (Johnson and others 1989). Further studies using CT are necessary to understand the type I fracture morphology to determine appropriate treatments.

Radial carpal bone fracture

Introduction

The radial carpal bone is located on the medial side of the proximal row of carpal bones. The proximal surface articulates with the radius and the distal surface with all four distal carpal bones (Evans 1993a).

Materials and methods

Diagnosis was from radiography with multiple views. Syniocentesis was through a dorsal approach into the antebrachiocarpal joint. Treatment was by a medial arthrotomy and surgical fixation with a medially placed 2.7mm lag screw. Radiography showed healing of the oblique fracture allowing screw removal after nine weeks.

Results

There was one case of radial carpal bone fracture excluding the dorsal chip fractures.

Clinical signs were severe thoracic limb lameness with pancarpal swelling. The synovial fluid had the appearance of blood.

On the dorsopalmar radiographic view there were oblique fracture lines from the proximo-medial and mid proximal aspects of the radial carpal bone (figure 10 and 11).

The dog returned to racing but was lame after each run and was euthanased. A post-mortem examination of the carpus showed that the mid proximal oblique fracture had healed. There was a large free bone fragment detached from the proximal aspect of the radial carpal bone within the joint.

Figure 10: A dorsopalmar radiograph of the carpus shows an oblique fracture line running from the proximo-medial aspect of the radial carpal bone (arrow).

Figure 11: an oblique fracture line runs from the mid proximal aspect towards C2 (arrow). This was reduced with a 2.7mm lag screw.

Discussion

Radiography did not show the extent of the fractures and other diagnostic modalities such as CT or arthroscopy would be more beneficial in determining the fracture morphology. Dorsal arthrotomy would have detected the articular slab fracture and allowed reduction and fixation.

The fracture morphology is dissimilar to that reported in radial carpal bone fractures in pet dogs where the aetiology is thought to be from non-fusion of the radial carpal bone centres of ossification (Tomlin and others 2001). Lag screw fixation of these fractures in the pet dog results in non-union in contrast to the oblique fracture in this case that healed.

Fourth carpal bone fracture

Introduction

The fourth carpal bone (C4) is on the lateral aspect of the distal row of carpal bones. It articulates proximally with the ulnar carpal bone, medially with the third carpal bone and distally with the fourth and fifth metacarpal bones.

No report of an isolated fracture of this bone was found.

Materials and methods

Orthogonal and oblique radiographic views were taken. Treatment was kennel rest.

Results

One case of an isolated C4 fracture was seen.

The dog had moderate thoracic limb lameness with swelling over the dorsolateral aspect of the carpus.

The fracture could only be seen on a dorsolateral- palmaromedial oblique view (figure 12).

The dog returned to successful racing.

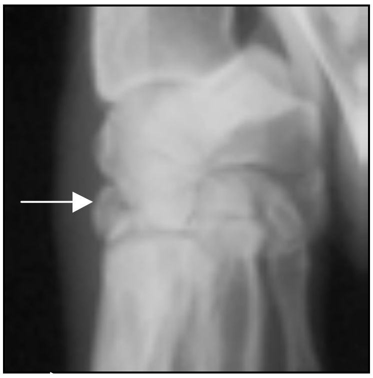


Figure 12: a dorsolateral-palmarmedial oblique radiographic view of the carpus radiograph showing a fracture of the dorsolateral aspect of the fourth carpal bone (arrow).

Discussion

A definitive diagnosis of fracture was only possible on an oblique radiographic view. CT would be the preferred diagnostic modality as concomitant fractures in other carpal bones may have been present.

The fracture morphology suggests compressive forces as the cause. C4 in the left carpus is on the compression aspect of the limb when leaning into the bends.

Multiple carpal bone fractures

Material and methods

Orthogonal and oblique radiographic views were taken. A lateromedial cross pin was inserted (figure 14). The distal limb was kept in external coaptation for six weeks.

Results

One case was recorded in the right carpus.

The dog was non-weight bearing and had pancarpal swelling. Carpal instability was apparent on examination under general anaesthesia.

Various radiographic views showed comminuted fractures of the radial, third and fourth carpal bones (figure 13). Fracture morphology was difficult to interpret from these views.

The fractures healed with a valgal deformity and the dog was retired from racing.

Figure 13: a mediolateral radiograph of the carpus shows fractures of the radial carpal and third carpal bones (arrows).

Figure 14: a dorsopalmar radiograph shows the transcarpal pin used to stabilise the carpus. Fracture of the fourth carpal bone is suspected on this radiograph.

Discussion

The limitations of conventional radiography are highlighted in this case where fracture morphology is impossible to ascertain. CT studies would give an accurate assessment of the fractures leading to appropriate fixation methods.

Dorsal chip fractures

Introduction

Small chip fractures on the dorsal aspect of the carpus have been described (Ferguson 1986, Boemo 1993).

Materials and methods

Diagnosis was made from multiple radiographic views.

The dorsal radiocarpal ligament avulsion fracture (figure 15) and the dorsal radial carpal bone fractures (figure 16) were treated by fragment removal through an arthrotomy directly over the fracture.

Results

The clinical signs included mild lameness, pain on carpal flexion, pain on digital palpation and dorsal carpal swelling over the fracture site.

The avulsion fracture of the origin of the dorsal radiocarpal ligament is seen on the extended mediolateral radiographic view (figure 15). The dorsal chip fractures of the radial carpal bone are seen on the same radiographic view and occur on the distal margin of the bone (figure 16).

Figure 15: a mediolateral radiograph of the carpus showing an avulsion fracture of the origin of the dorsal radiocarpal ligament (arrow).

Figure 16: a mediolateral radiograph of the carpus showing a chip fracture of the distal dorsal rim of the radial carpal bone (arrow).

There were three cases of dorsal chip fractures (table 2). All returned to successful racing.

Case	Bone	Limb	Type
1	Distal radius	R	Origin of dorsal radiocarpal ligament
2	Radial carpal bone	L	dorsal chip
3	Radial carpal bone	L	dorsal chip

Table 2: the bone, limb distribution and type of dorsal chip fractures.

Discussion

The literature implies that dorsal chip fractures of the carpus are common with 38 cases seen over a four year period at two veterinary clinics (Boemo 1993) and the incidence is second only to accessory carpal bone fractures (Piras and Johnson 2006).
This is not the case in this survey and the reasons are unknown.

Small radial carpal bone osteochondral fragments seen on the dorsal aspect but within the joint are discussed under carpal joint sprain injury.

Dorsal radiocarpal ligament sprain

Introduction

The dorsal radiocarpal ligament has its origin on the dorsal rim of the distal radius between the tendons of the common digital extensor muscle and the lateral digital extensor muscle, it inserts on the ulnar carpal bone (Evans 1993a).

Materials and methods

Mediolateral extended and flexed radiographic views were taken.

Treatment was by immobilising the carpus by external coaptation for three weeks with a further four weeks restricted exercise.

Results

Clinical signs were of mild thoracic limb lameness with a discrete linear soft-tissue swelling over the lateral aspect of the dorsal carpus approximately one centimetre in length running distally from the radial rim.

Three cases were diagnosed in the right carpus. One case had a non-displaced fracture of the origin on the distal radius (table 3). A previous study by the author (Guilliard 1997) reported two cases in the racing Greyhound, one in each carpus

All returned to successful racing.

Case	Limb	Fracture	Outcome
1	R		raced
2	L		raced
3	R		raced
4	R	origin	raced
5	R		raced

Table 3: shows the limb distribution, fracture at the ligament origin, and outcome of cases of sprain of the dorsal radiocarpal ligament. Cases 1 and 2 were from a previous study by the author (Guilliard 1997).

Discussion

The three cases of dorsal radiocarpal ligament sprain are similar in presentation, treatment and outcome to previously reported cases (Guilliard 1997). Of the five cases in total four were in the right carpus and one in the left carpus. There are insufficient numbers to say if this is a true over-representation of one limb.

External coaptation appears to give a good prognosis for dorsal radiocarpal ligament sprain and possibly non-displaced avulsion fractures.

Extensor carpi radialis strain

Introduction

The tendon of insertion of the extensor carpi radialis muscle crosses the medial aspect of the dorsal carpus to insert on metacarpal bones two and three (Evans 1993b).

Materials and methods.

A mediolateral radiographic view was taken.

Results

The dog presented with mild thoracic limb lameness. A soft tissue linear swelling was apparent on the dorsal carpus over the distal portion of the extensor carpi radialis tendon (ECR).

One case of strain was seen in the right carpus and treated successfully by external coaptation for three weeks. There was no radiographic evidence of fracture of the insertion.

Discussion

ECR strain is uncommon. Diagnosis is by the observation of swelling over the distal ligament and is one differential diagnosis for discrete dorsal carpal swellings.

Antebrachiocarpal joint sprain injury

Introduction

The antebrachiocarpal joint is between the radius and ulna, and the proximal row of carpal bones and includes the accessorio-carpal joint. There is no communication with the middle carpal joint.

Materials and methods

Synovial fluid was aspirated by a dorsal approach and analysed by visual inspection. Carpal radiography with multiple views to exclude a diagnosis of fracture was undertaken in selected cases.

Treatment was kennel rest for a minimum of eight weeks. One dog had an exploratory dorsal arthrotomy as a bone fragment was apparent on the dorsal aspect of the radial carpal bone.

Results

Twenty-two prospective cases of antebrachiocarpal joint sprain injury were recorded.

A diagnosis of sprain of the antebrachiocarpal joint was made on clinical signs that included reduced carpal flexion compared with the contralateral carpus, pain on forced flexion and carpal swelling.

The limb, chronicity at presentation, joint fluid analysis, radiographic changes and outcome are detailed (table 4). No case of instability was detected.

One dog had an exploratory arthrotomy for the removal of a small osteochondral fragment (case 7) (figure 17). There was considerable damage to the dorsal articular cartilage of the radial carpal bone.

Ten of 21 dogs had recurrent lameness on returning to racing.

Case	Limb	Chronicity	Joint fluid	X-ray	Treatment	Outcome
1	R	acute	sanguinous	C3 chip		raced
2	L	1 month	sanguinous	RCB chip		raced
3	L	4 months	serosanguinous	enthesiopathy		raced
4	L	4 months	clear	NT		raced
5	L	4 months	NT	NT		raced
6	R	acute	serosanguinous	NAD		raced
7	R	acute	serosanguinous	RCB chip		failed
8	R	acute	NT	NAD		no follow up
9	L	1 month	NT	RCB chip		failed
10	L	acute	NT	NAD		raced
11	R	acute	NT	NAD		failed
12	L	acute	NT	NAD		failed
13	L	acute	NT	NAD		raced
14	L	acute	NT	NAD		failed
15	R	acute	serosanguinous	NAD		raced
16	R	acute	clear	NAD		failed
17	L	acute	NT	NAD		failed
18	R	3 months	sanguinous	NAD		failed
19	L	2 weeks	NT	NAD		raced
20	L	acute	NT	RCB chip		failed
21	L	acute	NT	NAD		failed
22	R	acute	NT	RCB chip		raced

Table 4. The limb distribution, chronicity, further investigations and outcome of 22 cases of antebrachio-carpal joint sprain injury.

NT = not tested.

NAD = nothing abnormal diagnosed.

RCB = radial carpal bone.

Enthesiopathy = of medial radiocarpal collateral ligament.

Failed = recurrent lameness.

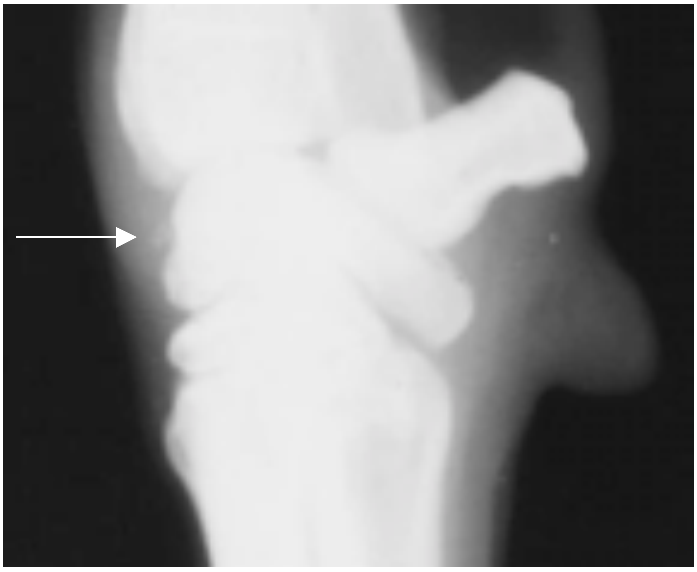


Figure 17: a mediolateral radiograph of the carpus showing an osteochondral fragment (arrow) on the dorsal joint surface of the radial carpal bone of case 7.

Discussion

Representing 5.7% of the total injuries carpal sprain injury has a similar incidence to a previous survey (Prole 1976). No one limb was over-represented in contrast to the previous survey (Prole 1976) that reported a higher incidence in the right carpus.

Diagnosis was made on the clinical signs with the exclusion of other specific injuries. Examination of synovial fluid was considered very sensitive at detecting carpal joint injury especially in cases presenting with mild clinical signs. Increased quantity and discolouration were considered significant.

It was not possible to determine which joint structures were injured. The radiographic detection of radial carpal bone chip fractures found in five cases indicated damage to the dorsal aspect of the radial carpal bone. An osteochondral fragment was found at arthrotomy in one case (case 7). The possible aetiology is from carpal hyperextension with the dorsal radial rim striking the radial carpal bone. The one case that had the osteochondral fragment removed raced four times but then sustained another injury.

The prognosis when treated by rest alone is poor considering that only ten out of 21 cases returned to racing.

Flexor carpi ulnaris tendon strain

Introduction

The flexor carpi ulnaris (FCU) muscle consists of two bellies with the two tendons of insertion attaching to the proximal aspect of the caudal end of the accessory carpal bone (ACB), the weaker ulnar head lying dorsal to the humeral head (Evans 1993b).

Materials and methods

Diagnosis of FCU strains was made by palpation. Mediolateral carpal extension radiographs were taken in selected cases. Twelve weeks rest was recommended.

A flexion cast at about 90 degrees was made using a dorsal slab of 7.5 centimetres Dynacast Prelude (BSN Medical Ltd) replaced after three weeks by a normal support dressing with the carpus held in zero degrees of flexion for a further three weeks.

Results

Clinical signs were a moderate thoracic limb lameness and a palpable thickened FCU tendon over the distal two to three centrimetres.

Ten cases of FCU strain were recorded with one bilateral case. Seven carpi were radiographed and four had avulsion fractures of the ACB. Both carpi in the bilateral case had similar diffuse multiple bone fragments. The other two cases had a small irregular avulsed fragment (figure 18). One dog had a concomitant superficial fascial tear.

The distribution, additional pathology, treatment and outcome are recorded (table 5).

Figure 18: a mediolateral radiographic view of the carpus showing a type IV accessory carpal bone avulsion fracture of the insertion of the flexor carpi ulnaris tendon (arrow).

Case	Limb	X-ray	Pathology	Treatment	Outcome
1	R	no		rest	raced
2	L	yes	chip		retired
3	L	no	fascial tear		retired
4	L	no		rest	failed
5	R	yes	chip	rest	failed
6	L & R	yes	chip	rest	failed
7	R	no		rest	failed
8	L	no			retired
9	R	no		rest	failed
10	R	no		flexion cast	raced

Table 5: shows the distribution, additional pathology, treatment and outcome of 10 cases of flexor carpi ulnaris strain.
Failed indicates recurrent lameness on a return to racing.

Discussion

There was no over-representation of either carpus. A report of six cases of type IV ACB fractures showed over-representation of the left carpus (Johnson and others 1988). One other bilateral case is reported (Johnson and others 1988).

It was not possible to determine the incidence of ACB avulsion fractures associated with FCU tendon strain due to the small numbers that underwent radiographic examination.

Treatments involving laser pin-firing and surgical excision with reconstruction imply that there is a favourable prognosis but no evidence is given (Davis 1983, Dee 1988). In this series treatment by rest alone had a poor prognosis.

The size and fragmentation of the avulsed pieces of bone made reattachment impossible. Flexion casting unloads the tendon and may improve the prognosis.

Palmar superficial fascial tear

Introduction

The antebrachial fascia covers the muscles of the forelimb as a closely applied tube. It is intimately united with the extensors and more loosely covers the flexors. In large dogs, there is a bursa beneath the fascia over the palmar accessory carpal bone (Evans 1993a).

Materials and methods

Surgical treatment was by suturing the defect with 2 metric polydioxone (PDS II, Ethicon) and maintaining the carpus in flexion using a dorsal Dynacast Prelude (BSN Medical Ltd) splint for three weeks, followed by four weeks kennel rest.

Results

Four cases were seen in this survey. The clinical signs were an obvious soft tissue swelling over the non-articular end of the ACB together with a mild lameness. Diagnosis was by palpation of the defect in the fascia.

The distribution, type of injury, treatment and outcome are shown combined with cases from a previous published survey by the author (Guilliard and Mayo 2000a) (table 6).

Case	Limb	Injury	Treatment	Outcome
1	R	FT	sutured	raced
2	L	FT	sutured	raced
3	L	FT	rest	raced
4	L	FT	sutured	raced
5	R	FT	sutured	raced
6	L	FT & FCU		retired
7	L	FT	sutured	failed
8	R	FT	sutured	raced
9	L & R	FT	sutured	raced

Table 6. Distribution, injury, treatment and outcome of palmar fascial tear injury. Cases 1 to 5 were from a previous survey (Guilliard and Mayo 2000a). FT = fascial tear. FCU = flexor carpi ulnaris tendon strain.

Discussion

With both fascial tears and strain of the FCU tendon there was no over-representation of one limb. This suggests a common aetiology from carpal hyperextension.

Surgical treatment was successful in all but one case with an unknown reason for failure. Anecdotal evidence shows that cases treated non-surgically can return to racing (Guilliard and Mayo 2000a). Conservative management with a flexion support may be equally successful.

Extensor carpi ulnaris tendon tear

Introduction

The extensor carpi ulnaris (ECU) muscle has a broad tendon of insertion that attaches to the lateral aspect of the accessory carpal bone (ACB). Its function is to extend the carpus and to give lateral support to the ACB (Evans 1993b).

Materials and methods

The integrity of the support ligaments of the ACB was checked by palpation. Radiography was undertaken to rule out avulsion fractures.

The tear was repaired with a skin incision directly over the tear and by placing a mattress suture of 3 metric polydioxanone (PDS II Ethicon) across the tear.

Results

Diagnosis was by the palpation of a defect in the broad tendon of insertion of the ECU muscle over the lateral aspect of the ACB. Case 1 showed mild lameness.

There were two cases of a tear of the ECU tendon of insertion. There was no palpable ACB instability. The limb, chronicity, treatment and outcome are shown (table 7).

Case	Limb	Chronicity	Treatment	Outcome
1	R	acute	stitched	raced
2	R	chronic	none	raced

Table 7: shows the distribution, chronicity, treatment and outcome.

Discussion

No reports of injury to this tendon have been found in the literature.

The ACB has its articular end on the lateral aspect of the carpus and its caudal end in the sagittal plane placing the lateral aspect of its articulation in natural tension during weight-bearing. There is also additional tension on the lateral aspect of the right carpus from leaning into the bends. This accumulative tensile force could be the reason why this injury was found solely in the right carpus.

On the basis of two cases there is no evidence to suggest that surgical treatment is superior to conservative management.

Second carpal bone subluxation

Introduction

The second carpal bone (C2) is in the distal row of carpal bones on the medial aspect of the carpus. It articulates proximally with the radial carpal bone, distally with the second metacarpal bone, laterally with the third carpal bone (C3) and medially with the first carpal bone of the dew claw (Evans 1993a).

Materials and methods

Dorsopalmar, mediolateral and mediopalmar-laterodorsal views of the carpus were taken.

The subluxation was surgically reduced and maintained by a 2mm positional screw into C3 (figure 21). This was removed after three weeks.

Results

There was one case in the left carpus and two cases from a previous study (Guilliard 2001b) all occurring in the left carpus (table 8).

Clinically the dogs had mild thoracic limb lameness with a reducible swelling over the dorsal aspect of the second carpal bone.

The dorsopalmar radiographic view showed an increased joint space between the radial and the third carpal bones, and C2 (figure 19). The oblique view shows a dorsal subluxation of C2 (figure 20). No medial carpal instability was detected.

The dogs returned to successful racing.

Figure 19: dorsopalmar radiographic view showing increased joint space on the proximal and axial aspects of C2 (arrow) (case 2).

Figure 20: mediopalmar-laterodorsal radiographic view showing a displaced C2 (arrow) (case 2).

Figure 21: a dorsopalmar radiograph showing reduction and fixation of C2 subluxation with a 2mm positional screw into the third carpal bone (arrow) (case 3)

Case	Limb	Treatment	Outcome
1	L	pins	raced
2	L	screw	raced
3	L	screw	raced

Table 8: shows the limb distribution, treatment and outcome of C2 subluxation. Cases 1 and 2 are from a previous study (Guilliard 2001b).

Discussion

C2 subluxated dorsolaterally with no damage to the medial collateral ligaments of the carpus. The previous report (Guilliard 2001b) described temporary fixation in one case by pins, and in the other by a positional screw. After implant removal reduction is maintained by periarticular fibrosis.

All three cases were in the left carpus but there were insufficient numbers to determine if this is a true over-representation of one limb. C2 lies on the tensile aspect of the carpus with the bones in the left carpus subjected to additional tensile and torsional forces when running the bends.

THE TARSUS

Anatomy

The tarsus comprises of seven named bones forming three irregular rows. The proximal row, the talus and calcaneus, articulates proximally with the distal tibia and fibula forming the talocrural joint, and distally with the central and fourth tarsal bones. The fourth tarsal bone on the lateral tarsal aspect, articulates distally with metatarsal bones four and five whereas the medially placed central tarsal bone articulates distally with tarsal bones one, two and three forming the centrodistal joint. The distal row of tarsal bones articulates with the metatarsus forming the tarsometatarsal joint (figures 22 & 23) (Evans 1993b).

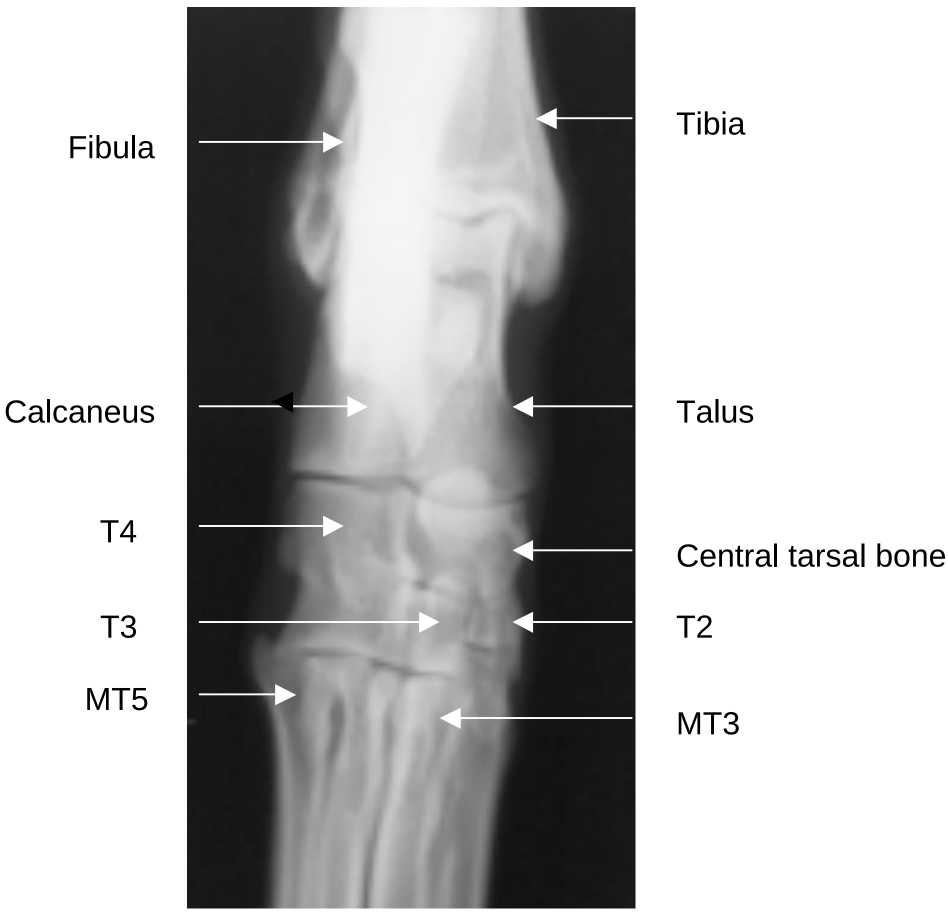


Figure 22: dorsoplantar radiographic view of the tarsus

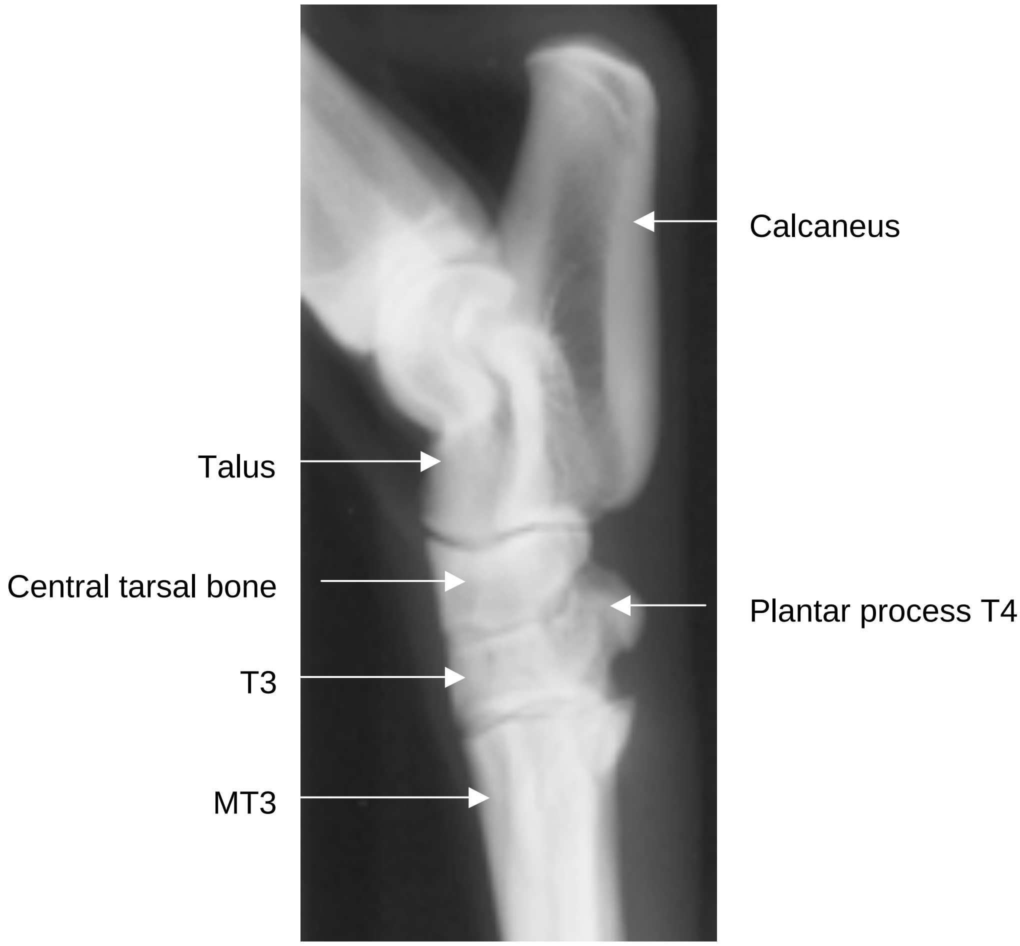


Figure 23: mediolateral radiographic view of the tarsus.

On the plantar aspect is the strong plantar ligament that arises from the sustentaculum tali, plantar body and distal lateral calcaneus to insert on the plantar process of the fourth tarsal bone, the other distal tarsal bones and the metatarsal bones. The dorsal intertarsal ligaments are week in comparison (Evans 1993b).

Central tarsal bone fractures

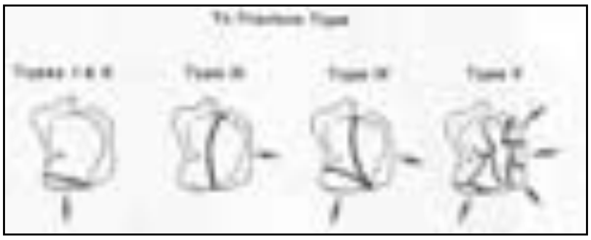
Introduction

The central tarsal bone (CTB) is on the medial aspect of the tarsus and articulates with all the other tarsal bones (Evans 1993c).

A radiographic classification of five fracture types is described (figure 24).

Plantar

Lateral



Medial

Dorsal

Figure 24: radiographic classification of CTB fractures (Boudrieau and others 1984b).

Type I: non-displaced dorsal slab fracture.

Type: II: displaced dorsal slab fracture.

Type III: diagonal fracture through the body of the bone.

Type IV: dorsal slab fracture and a medial buttress fracture.

Type V: severely comminuted fracture (figures 25 & 26).

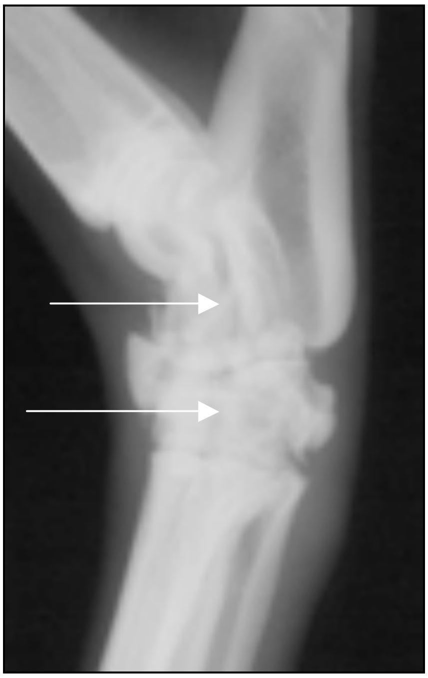


Figure 25: type V central tarsal bone fracture. The mediolateral radiographic view shows dorsal collapse and fractures of the calcaneus and T4 (arrows).

Figure 26: the dorsoplantar radiographic view of the case in figure 25 showing a large medially displaced CTB fragment, comminution of T4 and a fracture of the base of MT5 (arrows).

Materials and methods

Orthogonal radiographic views were taken in all cases.

Conservatively managed cases were treated by external coaptation incorporating either a plantar plastic splint or a Dynacast Prelude (BSN Medical Ltd) lateral splint. Surgical treatment involved the placing of a 2.7mm lag screw through the dorsal fragment in types I, II and III (figure 27). Treatment of types IV and V was reduction of the medial buttress and fixation using a 4mm half threaded cancellous screw or a 2.7mm cortical screw driven through the medial buttress into T4, and in most cases a positional 2.0mm or 2.7mm cortical screw was placed through the dorsal fragment into the body of the CTB (figures 28 & 29).

Some of the lateral sagittal calcaneal fractures were treated by lag screw fixation. Treatment of concomitant fractures of the calcaneus is described in the section on calcaneal fractures. One fracture of the base of MT5 was treated by lag screw fixation.

Cases that were unstable after screw fixation had supplementary support from either a type 2 external fixator or a lateral bone plate.

Implants were not removed. Most dogs had supplementary coaptation with a lateral splint for up to six weeks, no free exercise was give until after three months and galloping was gradually introduced with a return to the track after five or six months.

Results

Forty two retrospective and 39 prospective totalling 81 cases of CTB fracture are recorded. The numbers of each radiographic type are shown (table 9)

Type	Number
I	2
II	9
III	1
IV	23
V	46

Table 9: The distribution of central tarsal bone fracture types in 81 cases.

Concomitant fractures were found in 48 (70%) of 69 types IV and V fractures. The bone and number are shown (table 10).

Bone	Number
T4	30
Calcaneus	19
MT5	11
T2	1
multiple bones	12

Table 10: the numbers of concomitant fractures for each bone in 69 cases of types IV and V central tarsal bone fractures.

Figure 27: a mediolateral radiograph showing repair of a type II CTB fracture with a 2.7mm lag screw.

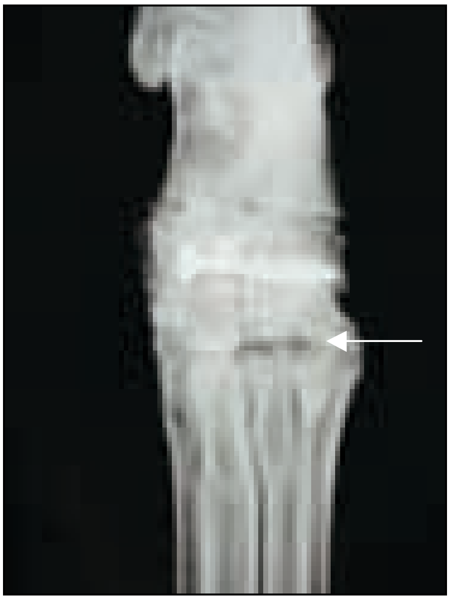


Figure 28: a dorsoplantar radiograph of a type IV central tarsal bone fracture taken five months after the surgery. The medial fragment has been repaired with a 4mm half-threaded cancellous screw and the dorsal fragment with a 2.7mm lagged cortical screw. There is lysis around the T4/metatarsal joint (arrow) from a staphylococcal infection.

Figure 29: a dorsoplantar view of a repair of a comminuted type V CTB fracture using two 2.7mm cortical screws. There is also a sagittal calcaneal fracture (arrow) and comminuted T4 fracture.

Clinical signs varied from mild lameness to non-weight bearing, and in general the severity of the lameness increased with the fracture type. Typically fracture types IV and V would have a palpable displaced large medial fragment of the CTB resulting in tarsal varus and plantar convexity from dorsomedial collapse of the tarsus.

The treatments for each fracture type are shown (table 11)

Type	Treatment				
	rest	1 screw	2 screws	plate	ESF
I	1	1	0		
II	2	7	0		
III	0	1	0		
IV	3	3	17		
V	6	9	31	2	4

Table 11: the numbers of central tarsal bone fractures and treatment techniques for each fracture type.
ESF = external skeletal fixator.

Concomitant fractures having lag screw fixation are shown (table 12). Comminuted unstable fractures of the os calcis are not included as their management is described in the section entitled calcaneus.

Bone	Number
Calcaneus	4
MT5	1

Table 12: the numbers of concomitant fractures treated by lag screw fixation not including comminuted unstable calcaneal fractures.

Pre and post-injury racing records from 11 dogs were down-loaded from the website of the Greyhound Board of Great Britain. The injuries, treatments and results are shown (table 13). Two dogs developed a progressive lameness after returning to training (cases 7 & 11). Radiography of the tarsus showed bone lysis around the proximal intertarsal and tarsometatarsal joints (figure 28) respectively. Surgical debridement cultured staphylococcus intermedius with a wide sensitivity. Six weeks of antibiotic therapy resolved lameness.

Case	Type	Concomitant fracture	Treatment	Grade pre-injury	Grade post-injury
1	I	none	1 screw	OR	OR
2	II	none	rest	A2	A2
3	II	none	1 screw	A2	A2
4	IV	none	1 screw	A1	A4
5	IV	none	2 screws	A4	A4
6	V	T4, MT5	2 screws	OR	OR
7	V	T4, osteomyelitis	2 screws	OR	OR
8	V	Calcaneus	1 screw	A7	A7
9	V	Calcaneus, T4, MT5	1 screw	A1	A2
10	V	T4	1 screw	A3	A3
11	V	T4, osteomyelitis	1 screw	OR	A2

Table 13: showing a radiographic classification, concomitant fractures, and treatments with performance grades before injury and after injury of central tarsal bone fractures.

OR = open race.

A1 to A7 = grade of race over the standard distance.

The A1 grade is the fasted graded race and the A7 the slowest.

Discussion

In a reported series of CTB fractures (Boudrieau and others 1984a), fracture types, limb distribution and concomitant injuries are similar to this series with the exception of the types IV and V that represented 68% and 5% respectively of CTB fractures. In this series the combination of the two types account for 85% of fractures but the distribution is 28% of type IV and 57% type V. More recent publications (Vaughan 1987, Guilliard 2000, Hercock and others 2011) have shown the frequency of severe comminution and with this knowledge the radiographic interpretation has been stricter. Comminution was also suspected in two type II cases and the type III case from the penetration of the drill bit in the far bone.

Many reports on treatment of type IV fractures imply that good reduction is possible with two lag screws securing the two fragments (Dee 1981, Boudrieau and others 1984b, Dee and Dee 1985, Dee and others 1990, Earley 1990, Dee 1998). Examination of post-surgical radiographs showed none to have perfect reduction with many classified as having poor reconstruction. It is often physically impossible to accurately reduce the two main components due to the degree of comminution with small fragments of irreducible bone under the two large fragments.

Reduction of the medial buttress is considered paramount in the prevention of tarsal collapse yet an unrecorded number of cases suffered subsequent tarsal varus and plantar convexity apparent within six weeks of surgery. Reasons for failure include screw placement at the incorrect angle into T4, comminution of T4 with loss of screw purchase, and poor assessment of tarsal instability after screw placement.

Positional screws were generally used to stabilise the dorsal slab fracture as accurate reduction was rarely attainable. Implants were not used on fragments too small to hold a screw or were naturally held in position. Rigid fixation of fragments tended to lead to early use of the limb.

Lag screw fixation of lateral sagittal calcaneal fractures was undertaken in only four cases and it is felt to be only necessary if there is a lateral instability of the calcaneo-quartal joint after CTB repair. Similarly the majority of MT5 fractures did not contribute to tarsal instability and did not require fixation. No surgical treatment was necessary for T4 fractures.

Catastrophic tarsal fracture with instability was treated by screw fixation with lateral plating or with the application of an external fixator. The latter gave high morbidity and poor results. The preference from these results is for a lateral biological healing plate to restore function but with little expectation of a return to racing.

Two dogs developed a septic arthritis and osteomyelitis on the return to training. There were no radiographic signs of lysis around the implants and these were not removed. It is possible that the cause could be from a subsequent haematological spread of infection that has been shown to have a predilection for osteoarthritic joints (Clements and others 2005).

Many of the dogs that underwent surgical repair were retired from racing. Some were trialled but showed transient lameness and were retired. The success for a return to racing was measured in only 11 dogs using GBGB race results. Although this is a small number it appears to show that dogs can return to their previous form following treatment supporting the view that good tarsal alignment is the treatment goal and intertarsal bone fusion, present in varying degrees in most follow-up radiographs, is not detrimental.

Calcaneal fractures

Introduction

The calcaneus lies on the lateral proximal aspect of the tarsus with the tuber calcanei or proximal half, forming a sturdy traction process on which inserts the common calcaneal tendon. Medially it has two articular processes attaching it to the talus and distally articulations with the fourth tarsal bone (T4) and the central tarsal bone (CTB) (Evans 1993c).

Materials and methods

The orthogonal views of radiographs of CTB fractures and tarsal instability cases were reviewed for evidence of calcaneal fracture.

Unstable comminuted fractures (figure 30) were treated by either a lateral reconstruction plate with pin and tension band wires, or by an intramedullary pin and tension band wire.

Proximal intertarsal subluxation (figure 31) was treated by an intramedullary pin and tension band wire. Some distal slab fractures were stabilised with one or two lag screws. The various techniques are described (Ost and others 1987, Dee 1998).

Figure 30: a mediolateral radiograph of a comminuted unstable fracture of the calcaneus with a concomitant central tarsal bone fracture (arrow).

Figure 31: a mediolateral radiograph showing proximal intertarsal luxation with fracture of the origin of the plantar ligament on the calcaneus (arrow).

Results

Twenty-one dogs were diagnosed with calcaneal fractures of which 20 had concomitant CTB fractures. All were in the right tarsus. Injury type and treatments are detailed (tables 14 & 15).

Clinically there was non-weight bearing lameness with soft tissue swelling around the tarsus. The proximal calcaneus was displaced dorsally when comminution of the os calcis occurred.

Lateral distal	Medial distal	Plantar	Comminuted
8	5	1	7

Table 14: distribution of calcaneal fractures showing the main fracture morphology. Secondary non-displaced fractures are not recorded in this table. Comminuted fractures all involved the os calcis with calcaneal collapse.

Injury	Number	Pin & TBW	Plate
Proximal intertarsal subluxation	1	1	
Comminuted fractures	6	4	2

Table 15: injury type, numbers and treatments of calcaneal fractures treated by either a lateral bone plate pin or tension band wire. TBW = tension band wire.

There were 13 cases of distal slab fractures of which four had concomitant undisplaced fractures to the base of the calcaneus at the attachment of the plantar ligament (figure 32). Six cases, including two comminuted fractures, had the lateral sagittal slab fracture reduced with lag screw fixation (figures 33 & 34).

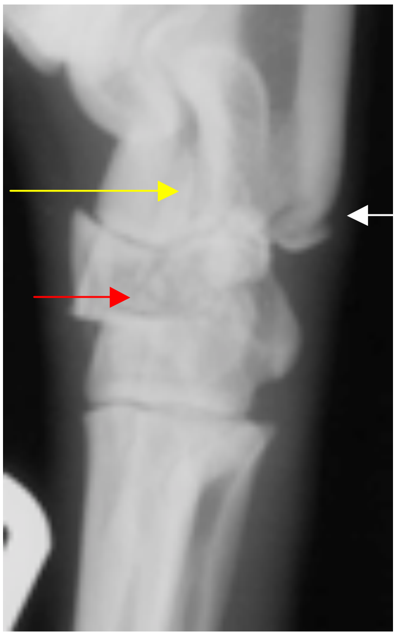


Figure 32: a mediolateral radiograph of the tarsus showing a displaced sagittal fracture of the calcaneus (yellow arrow) with several fracture lines at the attachment of the plantar ligament (white arrow). There is also a type V central tarsal bone fracture with dorsal displacement of two fragments and evidence of comminution within the bone (red arrow).

Figure 33: a mediolateral post-operative radiograph of a comminuted calcaneal fracture and a type IV central tarsal bone fracture. The calcaneus is reconstructed with a 2.5mm intramedullary pin seated in the fourth tarsal bone, and tension band wires. A lateral sagittal calcaneal fracture has been reconstructed with two 2.7mm lag screws. The CTB fracture has been repaired with a medially placed half-threaded 4mm lag screw together with a dorsally placed 2mm lag screw.

Figure 34: a dorsoplantar radiograph of the case seen in figure 33.

No dog detailed in table 15 returned to racing. All were retired and became pets with functional limbs. The tension band wire was removed in three cases due to persistant lameness from the wire.

Two dogs with untreated distal slab fractures returned to successful racing. The six retrospective cases of distal slab fractures treated by lag screw fixation were lost to follow-up.

Discussion

The morphology of calcaneal fractures is difficult to determine from orthogonal radiographs and classification is complicated. Many of the sagittal fractures have an obliquity and the distinction between medial and lateral fractures is arbitrary with many having a degree of comminution (figures 30 & 32).

Provided that there is lateral stability of the calcaneo-quartal joint, treatment by lag screw fixation of the distal sagittal slab fractures may have no advantage over non-treatment as comminuted tarsal fractures generally heal by intertarsal bone fusion (Guilliard 2000).

Pin and wire tension band is the recommended technique for comminuted fractures and proximal intertarsal luxation (Dee 1998). The author’s preferred technique is to seat the intramedullary pin into T4 and cut the proximal end of the pin flush with the calcaneus. This is achieved by pre-sawing through two-thirds of the pin enabling it to be manually broken. The tension band wire is passed through holes drilled through the distal calcaneus and the plantar process of T4 passing under the tendon of the superficial digital flexor muscle.

Three cases remained severely lame until removal of the tension band wire possibly from interference with the superficial digital flexor tendon.

Treatment by fragment reconstruction and fixation with a lateral plate over the calcaneus is more demanding and may be impossible in some cases. The extent of the comminution may only be apparent at surgery.

Talar fractures

Introduction

The talus is the second largest of the tarsal bones. It articulates proximally with the tibia and fibula, distally with the central tarsal bone (CTB), and on the plantar aspect with the calcaneus by three articulations, the two largest are on the body and the smallest articular surface is located on the extreme distolateral part of the bone (Evans 1993c).

Materials and methods

The radiographs of all CTB fractures were examined.

Results

No case of talar fracture was positively diagnosed.

Discussion

Interpretation of radiographs of tarsal fractures has been shown to be poor in identifying fracture morphology with CT being more sensitive (Hercock and others 2011). Figures 35, 36 and 37 give the impression of a split in the talar neck. A distodorsal fragment of the calcaneus has moved dorsally attached to the talus by its distal articulation (figure 35).

Figure 35: a mediolateral radiograph shows the talus has subluxated dorsally (arrow) with a dorsal CTB fragment and a calcaneal fragment.

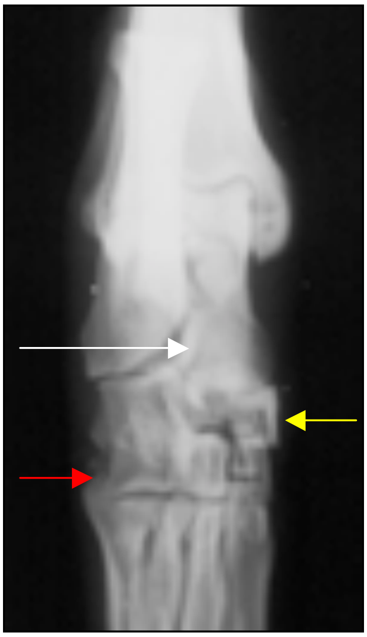


Figure 36: a dorsoplantar radiographic view of the same dog showing a medial fracture of the calcaneus extending through the sustentaculum tali (white arrow), a type IV CTB fracture (yellow arrow) and an avulsion of the base of the fifth metatarsal bone (red arrow).

Figure 37: a mediolateral radiographic post-operative view of the repair of the CTB fractures seen in figures 35 and 36. The talus has been reduced by the CTB fracture fixation. Fracture lines at the base of the calcaneus are visible (arrow).

Fourth tarsal bone fractures

Introduction

The fourth tarsal bone (T4) is on the lateral aspect of the tarsus. Proximally it articulates with the calcaneus, medially with the central tarsal bone (CTB) and third tarsal bone, and distally with metatarsal bones four and five (Evans 1993c).

Materials and methods

Diagnosis of T4 fractures was made by examining orthogonal radiographs of cases with CTB fractures. Fracture was suspected when the proximal and distal joint spaces lost their parallel appearance.

Results

There were 30 cases of T4 fractures and all were concomitant with either types IV or V CTB fractures representing 43% of these fractures. Fracture lines were often difficult to discern (figures 38 & 39).

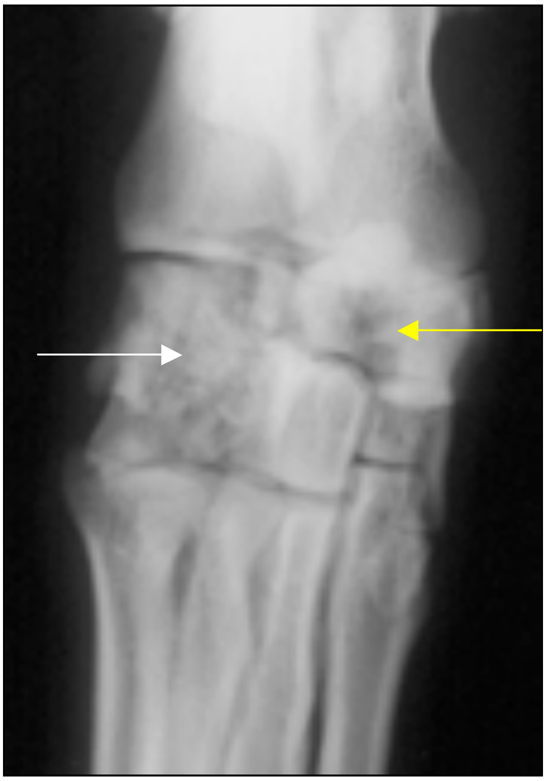


Figure 38: a dorsoplantar radiograph of the tarsus showing a highly comminuted fracture of T4 (white arrow). There is also a minimally displaced fracture of the CTB (yellow arrow).

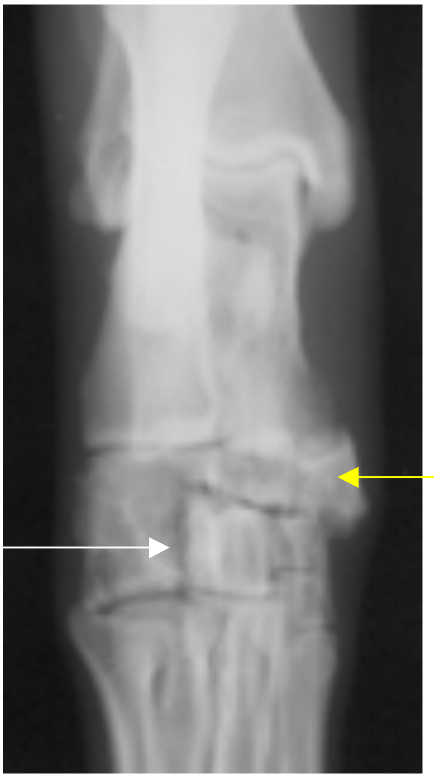


Figure 39: a dorsoplantar radiograph showing collapse of the medial aspect of T4 (white arrow) with converging proximal and distal joint spaces. There is also a displaced medial fragment of a CTB fragment (yellow arrow).

Discussion

The medial collapse of the CTB causes excessive compressive forces on the medial aspect of T4 as the calcaneus is pulled distomedially by the talus. This can result in a medial convergence of the proximal and distal joint spaces of T4 together with an oblique fracture through the proximomedial T4 (figures 38 & 39).

These fractures can be highly comminuted (Hercock and others 2011) (figure 40) making screw placement into the bone for CTB fracture repair difficult (figure 41).

Plantar

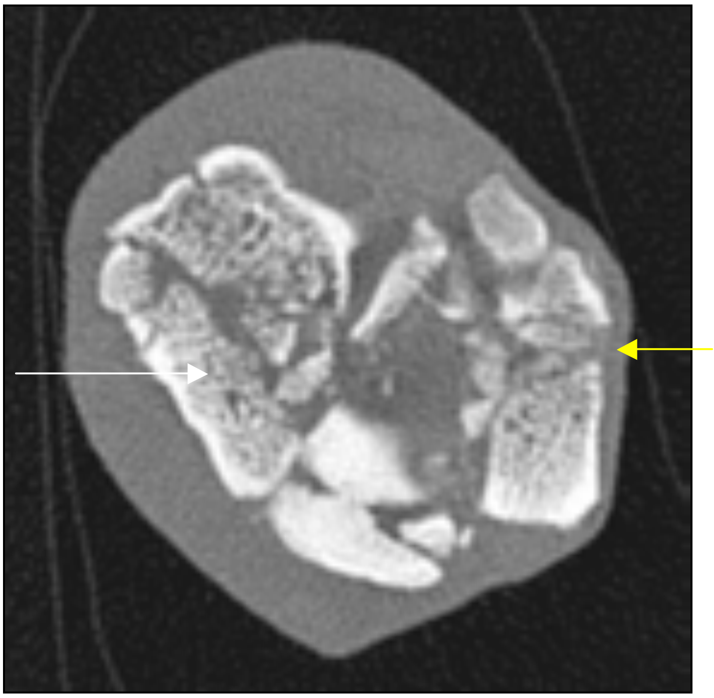


Figure 40: a dorsal slice of a CT image of a highly comminuted T4 (white arrow) and CTB (yellow arrow) fractures (image from Carol Hercock).

Five T4 fracture cases returned to successful racing (table 13) and the presence of this fracture with CTB fractures does not appear to alter the prognosis for a return to racing provided that tarsal alignment is achieved.

Figure 41: a dorsoplantar radiograph shows an oblique proximomedial fracture of T4. A 4mm half-threaded lag screw inserted to repair a type V CTB fracture gains purchase on only the lateral aspect of T4.

Third tarsal bone fractures

Introduction

The third tarsal bone (T3) is part of the distal row of tarsal bones and articulates proximally with the central tarsal bone, laterally with T4, medially with T2 and the base of the second metatarsal bone, and distally with the third metatarsal bone (Evans 1993c).

Materials and methods

Orthogonal, and in some cases oblique, radiographs were taken of the tarsus. The injury was classified as type I with minimal dorsal fragment displacement (figure 42) or type II with obvious dorsal displacement (figure 43) on mediolateral radiographic views. Dorsal tarsal collapse was assessed on mediolateral radiographic views (figure 43). No collapse was recorded when the plantar margins of the calcaneus and the metatarsal bones were aligned.

Figure 42: a mediolateral tarsal radiograph showing a type I T3 fracture with no fragment displacement (arrow) (case 22).

Figure 43: a mediolateral radiograph showing a type II displaced T3 fracture (arrow) with dorsal collapse. The plantar contour of the calcaneus should be almost in line with the metatarsal plantar contour (lines). There is about 25 degrees of tarsal collapse.

T3 injury was assessed primarily on the mediolateral radiographic views.

The injury was classified as acute if presented within four weeks, or chronic if of longer duration (figure 44).

Surgical treatments were lag screw fixation (figure 45), fragment removal or centrodistal joint arthrodesis as described (Guilliard 2010). Conservative management was by rest alone.

Cases from a previous publication by the author (appendix) are included (Guilliard 2010).

Figure 44: a mediolateral radiograph showing a chronic T3 fracture with periosteal new bone on the dorsal aspect of T3 (arrow).

Figure 45: a medioplantar radiograph showing repair of a T3 fracture with a 2.0mm lag screw.

Results

Twenty-eight cases of T3 fracture were recorded of which 11 were retrospective. One case was in the left tarsus and 27 cases in the right tarsus. Fifteen cases were classified as type I, 11 cases as type II and two cases were indeterminate. Twenty cases were acute presentations and eight were chronic. There were five concomitant T2 fractures.

The clinical signs were of mild pelvic limb lameness that resolved in many cases after several days. There was a small degree of soft tissue swelling over the dorsal aspect of the bone. Focal pressure on the dorsal aspect of T3 produced a pain response.

Two dogs were treated by fragment removal and both cases failed to race again. Two cases were treated by centrodistal joint arthrodesis and returned to successful racing. Fourteen dogs were treated by lag screw fixation of which eight returned to racing, three failed to race and three were lost to follow-up. The three failures had dorsal collapse.

Two dogs with type I fracture treated conservatively returned to racing.

Details are shown in table 16.

Case	Type	Age	T2	Collapse	Treatment	Outcome
1	I	acute			screw	lost to follow-up
2	I	acute				retired
3	I	acute			screw	lost to follow-up
4	II	acute		collapse	fragment removal	failed
5	II	acute			screw	lost to follow-up
6	I	acute			screw	raced
7	I	acute			screw	raced
8	I	chronic			screw	raced
9	II	acute	T2		2 screws	raced
10	?	chronic			fragment removal	failed
11	II	chronic		collapse	screw	failed
12	II	acute		collapse	screw	failed
13	II	acute	T2	collapse	2 screws	failed
14	?	chronic				retired
15	II	acute	T2		2 screws	raced
16	I	chronic			CD arthrodesis	raced
17	II	acute	T2			retired
18	I	chronic			CD arthrodesis screw	raced
19	I	acute			screw	raced
20	I	acute				retired
21	I	acute	T2			retired
22	I	acute			rest	raced
23	II	chronic				retired
24	I	acute				retired
25	I	acute			rest	raced
26	II	acute				retired
27	I	acute			screw	raced
28	II	chronic			rest	failed

Table 16: shows fracture morphology, chronicity, concomitant T2 fractures, tarsal collapse, treatment and outcome for 28 cases of T3 fractures.

CD = centrodistal joint.

? = indeterminate.

Discussion

Fractures of T3 have been infrequently reported with a seemingly low incidence. Many of these fractures will have been misdiagnosed as tarsal sprain injury (Vaughan 1987) and without radiographic confirmation an accurate diagnosis is impossible. Tarsal sprain injuries had a reported incidence of 23% of all tarsal injuries in the two track surveys (Prole 1976, Agnew 1992) and this is similar to the incidence of T3 fractures in this study.

The injury is found almost exclusively in the right tarsus. T3 is on the same main weight-bearing axis as the central tarsal bone and the third metatarsal bone and the aetiopathology is probably similar to stress fractures in those bones.

Eight of the cases presented as a recurrent lameness from three to six months after the original injury. The consistent radiographic appearance was of irregular periosteal new bone on the dorsal aspect of T3 (figure 44) with the periosteal reaction occasionally extending to the central tarsal bone and the third metatarsal bone. The fracture line may or may not be apparent. In two cases there was an obvious non-union on surgical exploration.

The morphology of T3 fractures is difficult to interpret with standard radiography. Some have the appearance of a simple dorsal slab fracture with little displacement (Type I). Others have a displaced dorsal fragment that may or may not show signs of comminution (Type II). Dorsal tarsal collapse evident on mediolateral radiographs was seen in four cases (figure 43) and suggests comminution of the T3 fracture.

Conservative treatment is reported to carry a poor prognosis for a return to successful racing (Vaughan 1987, Dee and others 1990) and that is evident from the chronic cases in this series. In some of these cases the recurrent lameness may be due to an inadequate rest period in view of the benign clinical signs and the lack of an initial diagnosis.

Three cases treated by lag screw fixation had dorsal tarsal collapse (cases 11, 12 &13). Correction of the tarsal collapse was not achieved by surgery and this may be from unidentified comminution preventing accurate reconstruction.

A centrodistal joint arthrodesis was performed in two of the chronic cases (cases 16 & 18), in one case this was the sole surgical procedure as the fracture had the radiographic appearance of being partially healed with new bone attempting to bridge the centrodistal joint The other case (18) had in addition the placement of a compression screw. Drilling or burring the centrodistal and T3/T2 joints at several points has been shown to rapidly induce dorsal bony bridging of the centrodistal joint (Guilliard 2000, Guilliard 2005).

The author would recommend accurate reduction and screw fixation in all cases, however if there is a partial dorsal bridging of the centrodistal joint in the chronic case, an additional arthrodesis may be beneficial. Conservative management may be appropriate in some type I cases.

Second tarsal bone fractures

Introduction

The second tarsal bone (T2) is in the distal row of tarsal bones articulating proximally with the central tarsal bone (CTB), laterally with the third tarsal bone (T3), medially with the first tarsal bone and distally with the second metatarsal bone (Evans 1993c).

Materials and methods

Radiographs of central tarsal bone and T3 fractures were examined. Treatment was by positional screw fixation into T3 (figure 47).

Figure 46: a dorsoplantar tarsal radiograph showing medial displacement of T2 (arrow) (case 1).

Results

There were five T2 fractures associated with T3 fractures and one case associated with a type V CTB fracture.

There were no isolated fractures of T2 and clinical signs were those documented for CTB and T3 fractures.

Three of the concomitant T3 fractures were treated by screw fixation with two returning to racing. The one case concomitant to CTB fracture had positional screw fixation (table 17).

Case	Concomitant fracture	Treatment	Outcome
1	T3	2 screws	raced
2	T3 collapse	2 screws	failed
3	T3	2 screws	raced
4	T3		retired
5	T3		retired
6	CTB type V, T4	3 screws	LTF

Table 17: shows concomitant fractures to T2, treatment and outcome. One screw only was placed through T2 and the other screws were for fixation of the concomitant fractures.
LTF = lost to follow-up.

Discussion

The radiographic changes of T2 injury can be subtle comprising of an increased intratarsal joint space (figure 46) with or without medial displacement. Screw fixation may benefit intertarsal stability.

The success of surgical treatment is probably most dependent on the treatment of the concomitant fractures.

Figure 47: a dorsoplantar radiograph showing T3 and T2 fractures treated with 2.0mm lag and positional screws. There is also a dorsal slab fracture of T2.

Distal Crural Fractures

Fracture of the caudal distal tibial articular margin.

Introduction

The talocrural joint is a hinge joint between the tibia and fibula, and the talus and calcaneus. The medial and lateral malleoli have strong ligament attachments to the talus and calcaneus respectively. These ligaments consist of long components that are taut in extension and a short component that is taut in flexion (Aron and Puriton 1985a).

On the caudal aspect of the distal tibia is a ridge of bone with an intra-articular extension separating tendinous sulci (Montavon and others 1993).

Materials and methods

Orthogonal radiographic views were taken of the talocrural joint.

Fractures of the CDTM were reduced and stabilised by either a single 2.0mm or 2.7mm countersunk lag screw. The medial malleolar fracture was reduced with two 1.4mm pins and a tension band wire.

Results

There were seven cases of distal tibial articular fractures.

Usually a mild lameness occurred several hours after racing. Slight swelling was found over the fracture site. Pain was induced by forced hock extension. The CDTM and medial malleolar fracture case was presented six weeks after the original injury.

The limb, fracture morphology, treatment and outcome are recorded (table 18).

CDTM fractures were easily diagnosed on mediolateral radiographic views (figure 48). The length of the fracture varied from five millimetres to two centimetres and the fragment was minimally displaced. Six were treated with a 2.7mm lag screw (figure 49) and one with a 2mm lag screw (figures 51 & 51). The fragment in the six week old case was small and very loose making accurate reduction impossible. A radiograph at six weeks showed bone union.

Five dogs returned to successful racing. One dog remained lame and a subsequent radiograph showed osteoathritic changes due to poor screw placement. The dog with the combined fractures galloped with no lameness but was lame after trialling on the track. The owner declined implant removal.

Case	Limb	Morphology	Treatment	Outcome
1	Left	CDTM	screw	raced
2	Left	CDTM	screw	raced
3	Right	CDTM	screw	raced
4	Left	CDTM	screw	raced
5	Left	CDTM	screw	lame
6	Left	CDTM	screw	raced
7	Left	CDTM + medial malleolus	screw + pin and TBW	retired

Table 18: the limb distribution, fracture morphology, treatment and outcome of fractures of the caudal distal tibial articular margin (CDTM).

Figure 48: a mediolateral radiograph showing a non-displaced caudal tibial articular fracture (arrow).

Figure 49: a post-operative radiograph showing a caudal distal tibial margin fracture repaired with a 2.7mm lag screw.

Figure 50: a pre-operative dorsoplantar radiographic view of the medial malleolar fracture (arrow) (case 7).

Figure 51: a mediolateral radiograph showing repair of the medial malleolar fracture with pins and tension band wire. The CDTM fracture is poorly reduced with a 2.0mm lag screw (case 7).

Discussion

The presenting signs of CDTM fractures are subtle and these injuries should be suspected if there is mild lameness in the left hock region.

The left hock was over-represented in this series and the assumption is that these injuries are stress fractures from limb overload when running the bends.

Treatment of CDTM fractures with a countersunk lag screw gave good results if reduction was accurate. This is an articular fracture in a major joint and without optimal reduction and fixation osteoarthritis is a likely sequel (case 5). No interference was found in the tracking of the flexor hallicus longus and flexor digitalis longus sheathed tendons that run on either side of the bony ridge of the CDTM fragment.

Luxation of the superficial digital flexor tendon

Introduction

The superficial digital flexor tendon (SDFT) courses over the gastrocnemius muscle tendon laterally to run over the calcaneus and then down to the foot. A firm retinaculum attached to the periosteum holds the tendon on the point of the calcaneus under which is a bursa between the tendon and the bone (Evans1993b).

Materials and methods

Treatment was by suturing the long medial tear in the retinaculum with 3 metric polydioxone sutures (PDS II Ethicon) and supporting the repair with a lateral splint (Dynacast Prelude, BNP Ltd) for three weeks.

Results

There was one case of lateral luxation occurring in the right pelvic limb. The limb was non-weight bearing and there was a reducible soft tissue swelling over the lateral aspect of the point of the calcaneus. At surgery the tear was approximately 10 centimetres in length through the medial retinaculum and fascia.

The dog trialled after six months and was lame after the first trial but went on to race successfully.

Discussion

Luxation has been reported to be either medial or lateral but in a case report on 12 pet dogs all the luxations were lateral (Reinke and others 1993) and clinical signs were described as a mild lameness. This case differs in that the clinical signs of lameness were severe and the tear extensive.

Sprain of the lateral ligament complex of the talocrural joint

Introduction

The talocrural joint is the articulation of the tibia and fibula with the talus and it is primarily a hinge joint. Mediolateral stability is provided by the medial and lateral ligament complexes together with the malleoli.

The lateral collateral tarsocrural ligament consists of three parts. A superficial long component has its origin on the base of the lateral malleolus and inserts on the dorsolateral surface of the distal calcaneus. A second short part, the calcaneofibular ligament, has its origin on the lateral malleolus craniodistally to the long component. It passes under this to insert just proximoplantar to the base of the lateral articular facies of the tuber calcanei. A third, shorter part extends from the caudal fibula to attach to a smaller area on the lateral aspect of the proximal trochlea of the talus. This is a thin narrow structure (Aron and Puriton 1985a).

The long ligament of the lateral complex is taut in extension and lax in flexion whereas the calcaneofibular short component is taut in flexion and lax in extension. The tautness of the talofibular short ligament is unaffected by flexion or extension (Aron and Puriton 1985a).

Transection of the long lateral ligament allows in extension moderate subluxation of the joint away from the incision, but in flexion only a slight subluxation. In flexion with all the major components transected subluxation to the medial side is considerable. This also allows a considerable degree of internal rotation (Aron and Puriton 1985a).

The malleoli and joint capsule also contribute to joint stability demonstrated by the inability to luxate the joint after cutting all the ligamentous components on one side (Aron and Puriton 1985a).

Treatments of lateral collateral ligament injury in the dog involve surgical repair of avulsion fractures and the use of prosthetic ligaments with external support from casts or transarticular external fixators (Aron and Puriton 1985b). No reports of conservative management have been found.

Materials and methods

Joint instability was manually assessed under general anaesthesia.

Flexed and extended mediolateral and extended dorsoplantar radiographic views were taken.

Treatment of two dogs was by kennel rest involving confinement to a small pen with leash exercise only for six weeks followed by progressive amounts of exercise in small grass paddocks for a further four weeks, or in one dog, by external coaptation with a laterally applied splint (Dynacast Prelude, BNP Ltd) for four weeks followed by a similar rehabilitation programme.

Dissection of the lateral ligament complex was undertaken in a Greyhound after euthanasia for a severe racing injury unrelated to the distal pelvic limb.

Results

Three dogs were diagnosed with sprain of the lateral collateral ligament complex, all occurring in the left hock.

No lameness was observed immediately after racing but was apparent after post-race kennel rest. Soft tissue swelling was observed over the lateral malleolus and a pain response was evident with manual hock flexion.

One dog was diagnosed with an avulsion fracture from the lateral aspect of the malleolus at the origin of part of the lateral collateral ligament complex and two dogs diagnosed with suspected third degree sprain of the substance of the ligament.

The avulsion fracture was apparent on the dorsoplantar radiographic view (figure 52). The same radiographic view of the second case showed two small avulsed bone fragments and soft tissue swelling. The third case showed soft tissue swelling only (table 19).

Case	Limb	X-ray	Treatment	Outcome
1	L	avulsed fragment	splint	raced
2	L	2 small fragments	rest	raced
3	L	soft tissue swelling	rest	raced

Table 19: shows the limb distribution, radiographic findings, treatment and outcome of cases of sprain of the lateral ligament complex of the talocrural joint.

Hock instability was detected by joint flexion, internal rotation with internal bending forces.

All dogs made a full recovery running consistently at the same grades pre- and post-injury.

Figure 52: a dorsoplantar radiograph of the talocrural joint showing avulsion fracture of the lateral aspect of the lateral malleolus (arrow).

Dissection of the lateral collateral ligament complex in the cadaveric specimen (figure 53) showed a broad, fan-shaped ligament, designated the superficial calcaneofibular ligament, with its origin over the entire lateral aspect of the lateral malleolus and its distal insertion on the calcaneus. Attached to the distocranial aspect of the malleolus under the previously described ligament is the long lateral collateral ligament. This round linear ligament has its insertion on the dorsolateral tubercle of the distal calcaneus.

The calcaneofibular short ligament, designated as the deep calcaneofibular ligament, is attached on the cranial aspect of the malleolus and tracks under the long collateral and superficial calcaneofibular ligaments to insert on the calcaneus. This is a round strong ligament.

The small talofibular short ligament runs from the caudomedial aspect of the lateral malleolus to insert on the lateral aspect of the talar ridge.

With the joint in flexion all ligaments were taut. In full extension both the long collateral and the calcaneofibular ligaments were taut but the superficial calcaneofibular ligament was slack.

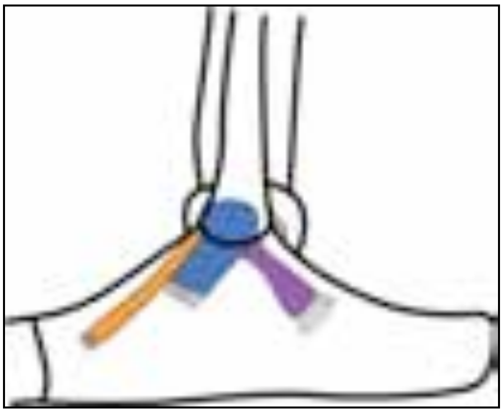


Figure 53: a schematic drawing taken from the cadaveric dissection showing the lateral ligament complex. Orange = long lateral collateral ligament. Blue = superficial calcaneofibular ligament. Purple = deep calcaneofibular ligament. Grey = talofibular ligament.

Discussion

Diagnosis was from a slight soft tissue swelling over the lateral malleolus with a pain response on hock manipulation. Joint instability could be induced by the specific manipulation under general anaesthesia of flexion, inward rotation and bending of the tarsus away from the lateral aspect (Sjostrom and Hakanson 1994). No attempt was made to demonstrate the incongruity by radiography in these cases.

The cadaveric findings differ from a previous anatomic study (Aron and Puriton 1985a) that fails to describe the superficial calcaneofibular ligament running at right-angles to the deep calcaneofibular ligament. Its origin is consistent with the site of the avulsed bone fragment and the two small bone fragments. The strong deep calcaneofibular ligament is reportedly slack in extension but this was not apparent in this study. The medial tibiotalar and lateral (deep) calcaneofibular short ligaments have been shown to maintain stability in both flexion and extension even when all other components have been transected (Aron and Puriton 1985a) and in the author's findings also prevent the malleoli translating cranially during weight bearing.

Instability could only be demonstrated when the hock was subjected to flexion, inward rotation and bending. The forces induced by the manoeuvre would occur naturally in the left talocrural joint as the dog runs around the bend; the hock flexion occurs during the gallop and the thoracic limbs turn the dog into the bend causing the body to rotate outwards against the flexed tarsus during weight bearing. The superficial calcaneofibular ligament, only taut in flexion, must be considered a stabiliser of the flexed joint and therefore prone to overload.

The talocrural joint could only be made to lose stability by applying the diagnostic manoeuvre. Kennel rest prevents the extreme flexion, rotational and bending forces that only occur during the gallop.

The maintenance of joint congruity allows supportive periarticular fibrosis to develop.

Surgical intervention for third degree sprain of the lateral ligament complex in a functionally stable joint in the racing Greyhound appears to be unnecessary as conservative management was successful in these three cases.

Dorsal proximal intertarsal joint instability

Introduction

The proximal intertarsal joint is between the calcaneus and talus, and the fourth (T4) and central tarsal bones. It is supported by strong plantar ligaments. The dorsal ligaments are much weaker and are on the compression aspect of the tarsus (Evans 1993c).

Materials and methods

Stressed orthogonal radiographic views were taken (figures 54 & 55).

Surgical treatment was either by the placement of two 2.7mm screws into the calcaneus, and one screw into T4 with tension band wires (figures 56) or by an external fixator with 2mm pins driven from the dorsal aspect into the talus, calcaneus, CTB and T4 and connected with acrylic paste. In both cases the implants were removed after four weeks.

Figure 54: Mediolateral stressed radiograph of the tarsus showing dorsal subluxation of the proximal intertarsal joint (arrow).

Figure 55: Stressed dorsoplantar radiograph showing lateral subluxation of the proximal intertarsal joint (arrow).

Figure 56: a mediolateral radiograph showing placements of three 2.7mm screws to anchor wire tension bands on the dorsolateral aspect of the tarsus.

Results

There were three cases, including one from a previous study (Guilliard 2003b) affecting the right tarsus and had both dorsal and lateral instability (table 20). The injury was a result of somersaulting causing tarsal hyperextension.

Clinically there is moderate pelvic limb lameness. Palpation of the tarsus detects this subtle instability.

The case stabilised with screws and tension band wires returned to racing with no loss of form. The case treated with an external fixator failed to race again.

Case	Limb	Treatment	Outcome
1	R	screws and TBW	raced
2	R	screws and TBW	raced
3	R	external fixator	failed

Table 20: shows the limb distribution, treatment and outcome of three cases of dorsal proximal intertarsal joint instability.
TBW = tension band wire.

Discussion

The objective of both treatments was to stabilise the joint in normal congruity to allow sufficient periarticular fibrosis to develop. It could not be determined why treatment with the external fixator failed. The dog did not use its limb with the fixator in place.

Treatment by external coaptation may be successful if there is only dorsal instability due to the natural compression of the dorsal aspect of the tarsus during weight-bearing. It is unlikely that concomitant lateral ligament damage would be sufficiently stabilised by this approach.

Treatment by calcaneoquartal arthrodesis with a lag screw is reported but the prognosis for a return to racing is guarded (Dee 1998).

Idiopathic tarsal pain

Materials and methods

Pain on tarsal manipulation without a specific diagnosis was classified as idiopathic tarsal pain. All cases had orthogonal radiographic views taken of the tarsus. Oblique views were also taken in some cases.

Treatment was rest.

Results

Ten cases were classified as having idiopathic tarsal pain. All were in the right tarsus. Lameness varies from mild to non-weight bearing. No instabilities or swellings were detected. One dog failed to return to racing.

No abnormalities were found on radiographs of the tarsus.

Discussion

Tarsal pain could be attributable to non-displaced fractures or soft tissue injury. Computerised tomography is superior to plain radiography and would be more sensitive in detecting tarsal fractures.

Soft tissue injury without joint instability or swelling is difficult to detect. Intertarsal joint sprain may occur. Centrodistal joint lameness diagnosed by a pain response to forced intertarsal torsion, is reported in the dog (Guilliard 2005).

METACARPUS AND METATARSUS

Anatomy

The metacarpus articulates proximally with the carpus and distally with the digits. There are five named metacarpal bones. The first metacarpal bone is small and is part of the dew claw (figure 57).

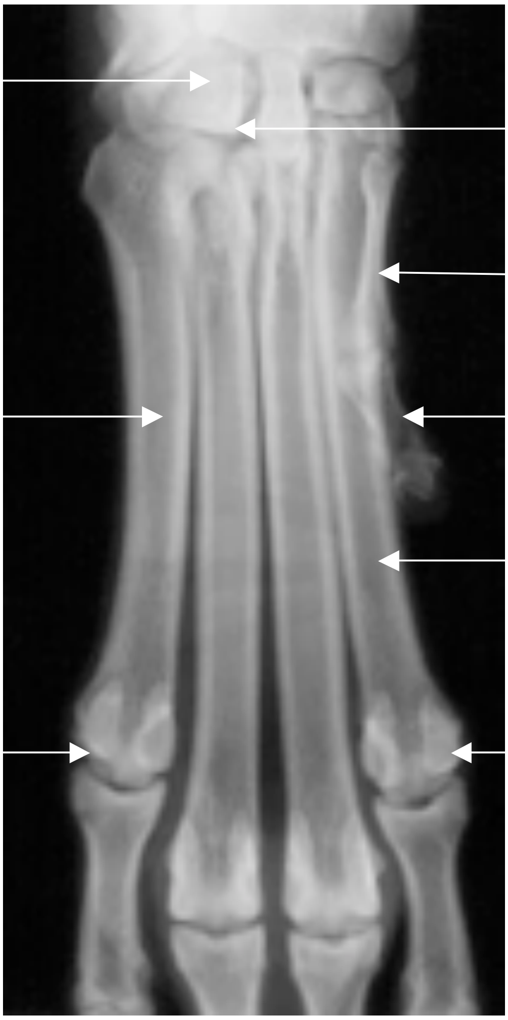


Figure 57: a dorsopalmar radiograph of the metacarpus showing the bones and joints.

Similarly the metatarsus has its proximal articulation with the tarsus and also has five named bones. The first metatarsal bone in the Greyhound is vestigial (figure 58).

Figure 58: a dorsoplantar radiograph of the metatarsus showing the bones and joints.

Metacarpal bone fractures

Materials and methods

Mediolateral and dorsopalmar radiographic views of the metacarpus were taken.

Various treatments were given. Conservative management would involve some form of external support. Surgical treatments were:

- Application of a veterinary cuttable plate acting as a buttress plate removed after six to eight weeks.
- Reconstruction with 2mm lag screws, supplemented with cerclage wire or a uniplanar external fixator (figures 59 & 60).
- Application of a dorsal uniplanar external fixator with 1.6mm pins and an acrylic connecting bar (figure 61).
- Amputation of the digit through the distal metacarpal bone.

Results

Clinical signs were of marked thoracic limb lameness with soft tissue swelling. Crepitus was often detected on palpation.

There were 16 recorded fractures of the metacarpus all involving just one bone. The limb, distribution, fracture morphology and treatment are detailed in table 21.

Case	Limb	Bone	Type	Articular	Treatment	Outcome
	Retrospective					
1	R	MC2	comminuted	proximal	rest	LTF
2	L	MC5	simple		plate	LTF
3	L	MC5	oblique		2 screws + wire	LTF
4	L	MC5	comminuted		plate	LTF
5	L	MC5	comminuted		2 screws	LTF
6	R	MC5	comminuted		plate	LTF
7	R	MC5	comminuted		plate	LTF
8	R	MC2	comminuted		rest	LTF
9	L	MC5	comminuted		plate	LTF
	Prospective					
10	L	MC5	oblique		2 screws	raced
11	L	MC5	simple		rest	lameness recurred
12	L	MC5	oblique		3 screws + fixator	raced
13	L	MC5	oblique		2 screws	raced
14	L	MC5	comminuted		fixator	raced
15	L	MC5	comminuted		rest	raced
16	L	MC2	comminuted	distal	amputate	raced

Table 21: shows the limb distribution, fracture morphology, treatment and outcome of metacarpal bone fractures.
LTF = lost to follow-up.

Figure 59: a dorsopalmar radiograph of the metacarpus shows a mid diaphyseal oblique fracture of the fifth metacarpal bone (case 3).

Figure 60: a dorsopalmar radiograph showing a repair of a comminuted fracture of the fifth metacarpal bone by lag screw fixation with additional support from an external fixator (case 12).

Figure 61. A dorsopalmar radiograph showing a midshaft comminuted fracture of the fifth metacarpal bone repaired with a 3:3 uniplanar external fixator (case 14).

Good follow-up was not available for the retrospective cases. All of the prospective cases returned to racing. One case treated by rest developed a recurrent lameness.

Discussion

The incidence of metacarpal bone fracture is similar to that in the track surveys (Prole 1976, Agnew 1992) and much less than in the Australian fracture survey (Gannon 1972).

The majority of the fractures were reported in young dogs during schooling (Gannon 1972) when the bones are excessively loaded before adaptive remodelling has strengthened them. The ages of the dogs in this report were not recorded. Most young dogs are schooled in Ireland or at specific schooling tracks and would not be seen by the author.

There were no cases of periostitis or sore shins in this study. This is seen mainly in juveniles (Gannon 1972). This radiographic change has been observed by the author on the dorsal aspect of the bone and is thought to be a healing response to cortical microfracture.

The fracture distribution is similar to reported cases with the majority occurring in MC5 of the left limb (n = 11/16). When the dog leans into the bend the weight will be transferred onto the inside of the left thoracic limb with digit five carrying the most load.

Many of the fractures are highly comminuted making accurate reconstructive surgery impossible. Fracture repair was by buttress plates, lag screws and external fixators.

Reviewing the cases the author is of the opinion that little benefit is gained from internal fixation with the exception of grossly displaced fragments. Good reconstruction (figure 60) will probably lessen recovery time. There is natural support from the other metacarpal bones and rest, with some external coaptation, may give equally good results. There were insufficient cases treated this way to support this view.

Superficial digital flexor tendon injury

Introduction

The superficial digital flexor tendons (SDFT), overlying the deep digital flexor tendons, run proximodistally on the palmar aspect of the metacarpus inserting on the proximal palmar end of the second phalanx (Evans 1993b).

Materials and methods

Treatment was by tenectomy. A linear skin incision was made over the swelling and the affected part of the tendon isolated from its attachments and removed (figure 62). A protective dressing was applied for three days.

After two weeks rest the dogs were put back into light training.

Results

Three cases were diagnosed. The limb and distribution are shown in table 22.

Clinical signs were of mild thoracic limb lameness. A bowed thickened tendon could be palpated on the palmar aspect of the metacarpus. The lesion was a linear fibrous mass about a centimetre in diameter and three centimetres long (figure 62).

Figure 62: an excised ruptured superficial digital flexor tendon with a number 3 scalpel handle for size comparison.

One dog was lame after racing (case 2) and was retired and two dogs returned to successful racing after ten weeks.

Case	Limb	Digit	Outcome
1	LF	5	raced
2	RF	5	lame
3	RF	2	raced

Table 22: the limb distribution and outcome of the superficial digital flexor tendon rupture.

Tenectomy did not result in any change to the digital posture.

Discussion

The incidence of this condition is considerably less than previously reported (Prole 1971, Prole 1976). This may be due to changes in the composition of the racing surface from grass to sand.

Surgical excision is the traditional treatment for severe strain or rupture of the tendon and is considered to be successful (Prole 1971). Case 2 was not examined to determine the cause of recurrent lameness.

Metatarsal bone fractures

Materials and methods

Orthogonal radiographic views were taken

Metatarsal bone fractures were classified as sclerotic with no obvious fracture lines (figure 63), comminuted with no plantar displacement (figure 64), and comminuted with displaced bone (figure 65).

Figure 63: a dorsoplantar radiograph showing sclerotic changes in the proximal third metatarsal bone (arrow) (case 11).

Figure 64: A mediolateral radiograph of a fracture of the third metatarsal bone with no plantar displacement (case 14). The dorsal cortical slab fracture has slight displacement (arrow).

Figure 65: A mediolateral radiograph showing a displaced comminuted fracture of the third metatarsal bone (case 18). There is a plantar displacement of the distal diaphysis (arrow).

Treatments were various. Conservative management was rest with or without a support dressing. Surgical treatments were:

- Dorsal buttress plate (figure 66). The plate was subsequently removed.
- Reconstruction with lag screws with or without an external fixator.
- An external fixator.

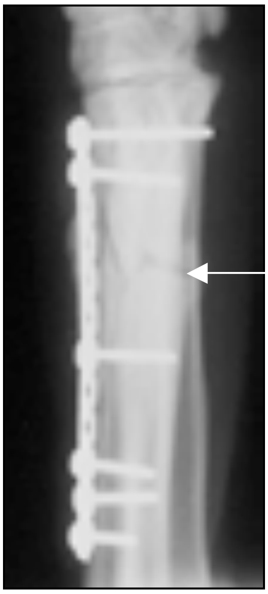


Figure 66: a mediolateral radiograph showing a displaced fracture of the third metatarsal bone repaired with a buttress plate (case 1). The reduced fracture is visible (arrow).

Results

There were 23 metatarsal bone fractures all involving just one bone. MT3 fractures (n = 18) were in the right metatarsus. Fractures to the other metatarsal bones (n = 5) were in the left metatarsus.

Clinical signs varied from mild to severe lameness with metatarsal palpation usually causing pain. Soft tissue swelling was evident in the more severe cases.

Fracture distribution, morphology, treatment and outcome for MT3 fractures are detailed (table 23) and for other metatarsal bone fractures (table 24). All the MT3 fractures occurred in the proximal to mid diaphyses. All dogs that underwent treatment returned to successful racing.

Case	Limb	Type	Treatment	Outcome
Retrospective				
1	R	displaced	plate	raced
2	R	no displacement	plate	raced
Prospective				
3	R	no displacement	plate	raced
4	R	displaced		retired
5	R	no displacement	rest	raced
6	R	displaced		retired
7	R	displaced	2 screws + fixator	raced
8	R	no displacement	rest	raced
9	R	sclerosis	rest	raced
10	R	no displacement	rest	raced
11	R	sclerosis	rest	raced
12	R	no displacement	rest	raced
13	R	sclerosis	rest	raced
14	R	no displacement	rest	raced
15	R	sclerosis	rest	raced
16	R	no displacement	rest	raced
17	R	displaced	3 screws	raced
18	R	displaced	rest	raced

Table 23: showing limb distribution, morphology, treatment and outcome of fractures of the third metatarsal bone.

Case	Limb	Bone	Morphology	Treatment	Outcome
	Retrospective				
1	L	MT2	oblique distal	1 screw	raced
2	L	MT2	simple mid shaft	plate	raced
3	L	MT5	simple distal	plate	raced
	Prospective				
4	L	MT4	simple distal	rest	raced
5	L	MT2	simple distal	fixator	raced

Table 24: showing limb distribution, morphology treatment and outcome of metatarsal bone fractures other than fractures of the third metatarsal bone.

Discussion

Diagnosis of metatarsal fracture was made on orthogonal radiographic views. The dorsoplantar view was sensitive in detecting sclerotic change (figure 63) but insensitive for fracture lines (figure 67). Fracture morphology was more apparent on the mediolateral view.

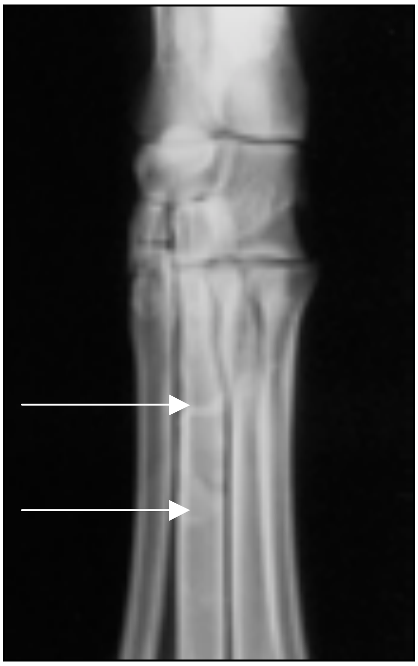


Figure 67: the dorsoplantar radiograph of case 18 (figure 65). On this view sclerotic lines in the third metatarsal bone show fragment overlap but no displacement (arrows).

Fracture distribution was of two types: the MT3 fractures were in the right metatarsus and those in the other metatarsal bones in the left metatarsus.

The probable aetiopathogenesis of fractures in the left metatarsal bones, similar to that of fractures of the left metacarpus, is from increased loading of the inner limb when leaning into the bends.

The predilection for fractures in MT3 in the right metatarsus may occur as a result of excessive compressive forces. The main weight-bearing axis of the tarsus is through the distal tibia, talus, central tarsal bone, the second and third tarsal bones into MT2 and MT3, the latter bearing more of the load (Ness 1993). The dorsal aspect of the metatarsus is also naturally in compression during weight bearing and the lateral aspect of the left distal limb and the medial aspect of the right distal limb will have additional compressive forces from the lean on the bends resulting in accumulated load through the right MT3.

MT3 fractures had a typical morphology with a dorsal cortical slab and further fracture lines extending through the plantar cortex. If displacement occurred the distal fragment moved in a plantar direction.

The sclerotic changes observed in some of the cases were in the proximal part of the bone and are assumed to be healing non-displaced fractures. Lameness would persist in these cases if not given a sufficient rest period.

Initial cases with no displacement were treated with a dorsal plate (n = 2) but subsequent cases were treatment by rest alone. Displaced fractures were treated by reconstructive surgery with lag screws (n = 2) or rest (n = 1). The sclerotic cases were all given further rest (n = 4).

A report on MT3 fractures suggests that external coaptation causes prolonged lameness and dorsal plating is superior (Ness 1993). Possibly the prolonged lameness was from stress protection of the coaptation resulted in fracture disease. In this series one case with displaced comminuted fracture morphology (figure 6) treated by conservative management returned to successful racing after 16 weeks.

Dorsal plating of non-displaced MT3 fractures reportedly allows rapid return to weight-bearing with a return to racing in about 12 weeks (Ness 1993). Natural splinting from the other metatarsals allows biological healing and ultimate recovery. The author’s preference of treatments has evolved from dorsal plating to lag screw reconstruction, to external fixation, to external coaptation, and presently in many cases, to kennel rest only. There may be no benefit from internal fixation.

THE FOOT

Anatomy

The foot consists of five digits. Digit one in the thoracic limb is the dew claw but is not present in the pelvic limb. Digits two to five each consists of three bones with the nail attached to the ungual crest covering the ungual process of the third phalanx (figures 65 and 66).

On the palmar/plantar aspects of the distal metacarpal/tarsal bones are two large sesamoids that form part of the metacarpal/metatarsal phalangeal articulations.

Cushioning the digits from the ground are the digital pads and the large metacarpal/tarsal pad. The digits are connected by skin (webbing).

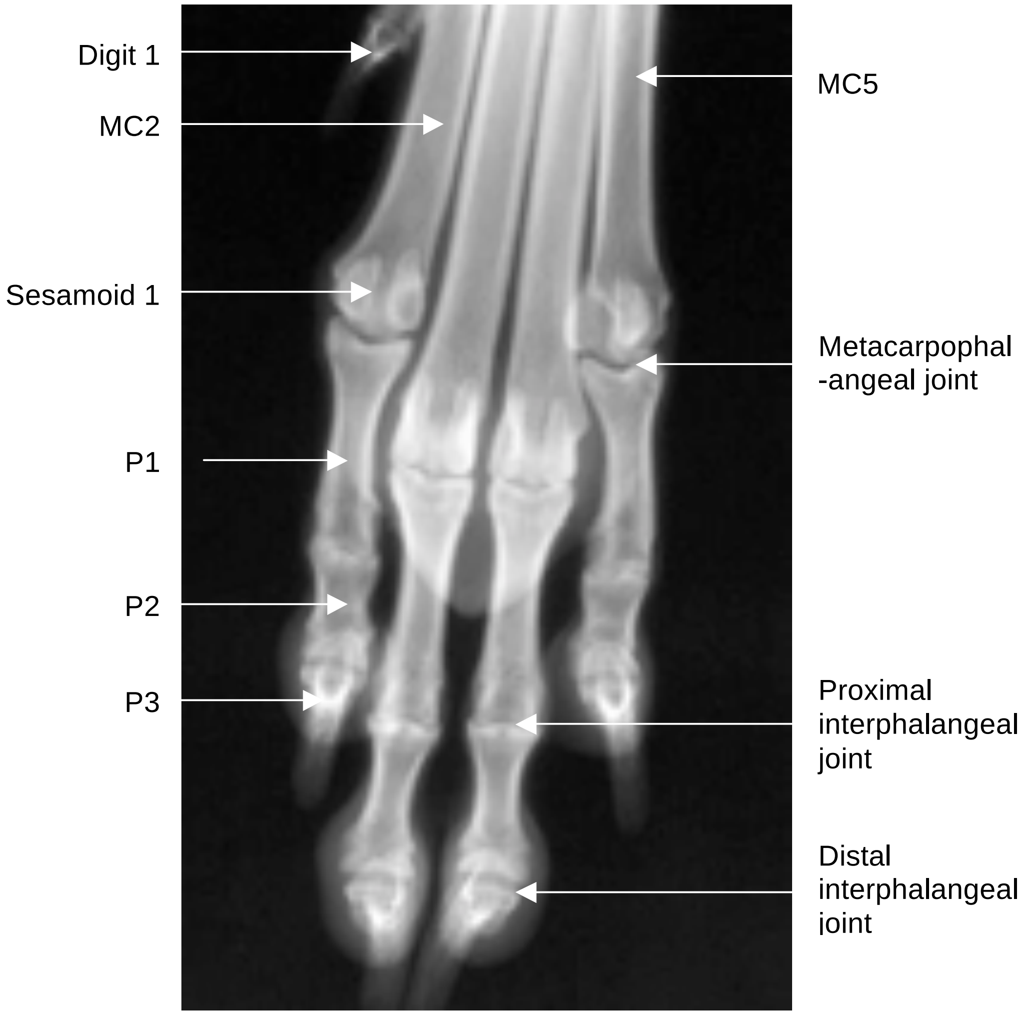


Figure 65: dorsopalmar radiographic view of the manus showing the bones and joints.

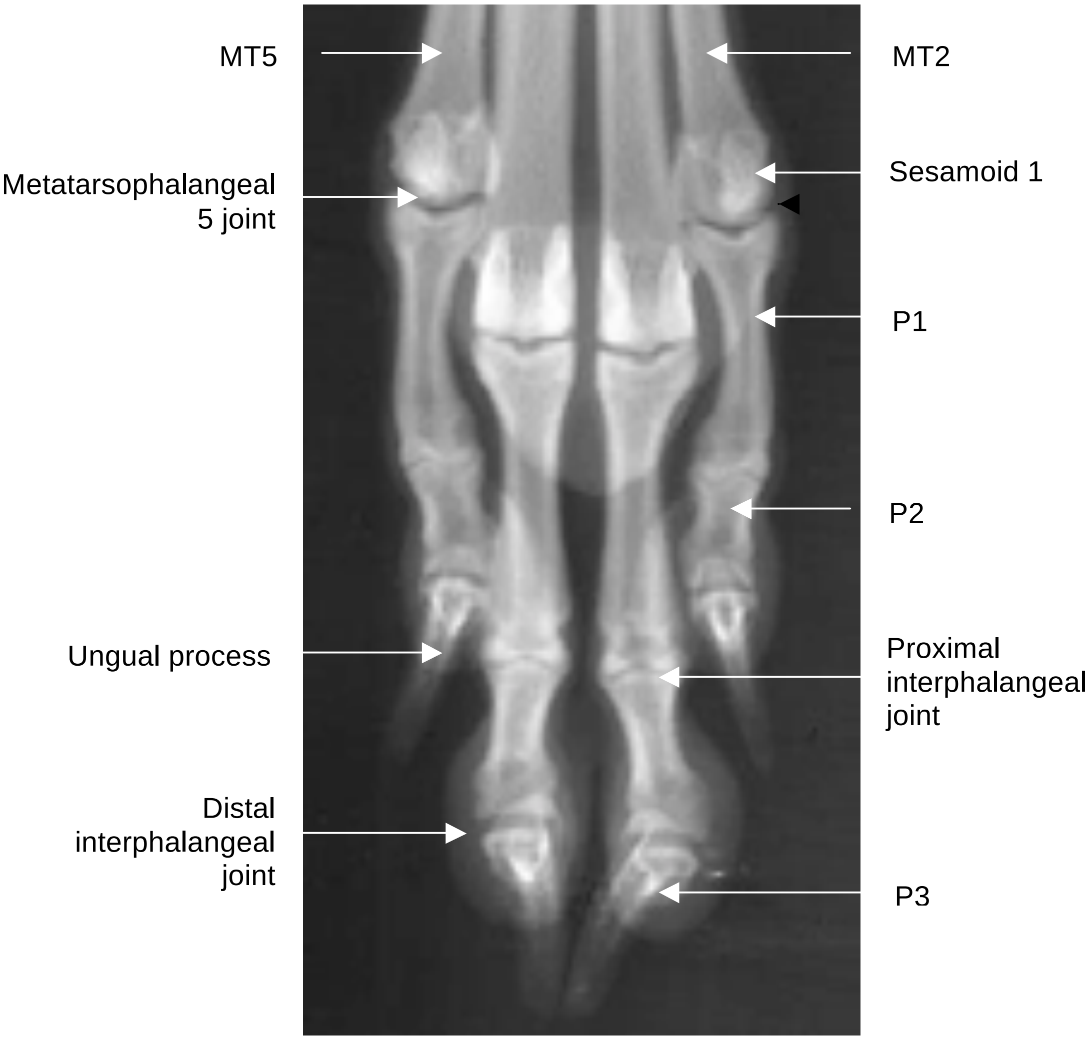


Figure 66: dorsoplantar radiographic view of the pes showing the bones and joints.

Metacarpophalangeal and metatarsophalangeal joint disease

Introduction

The metacarpophalangeal (MCP) joints and the metatarsophalangeal (MTP) joints numbers two to five, are hinge joints. Each joint has two sesamoid bones on the palmar/plantar aspect that connect by a complex series of ligaments to each other, the distal metacarpal or metatarsal bone and the proximal first phalanx (P1). In addition there are collateral ligaments connecting the metacarpal or metatarsal bone to P1. The two sesamoid bones lie on either side of a sharp ridge of bone, the sagittal crest. Overlying the sesamoid bones are the flexor tendons. The deep digital flexor tendon passes through a sheath formed by the superficial digital flexor tendon held against the sesamoids by a transverse annular ligament. A small sesamoid bone is sited within the digital extensor tendon on the dorsal aspect (Evans 1993a).

Materials and methods

The joints were examined for instability under general anaesthesia and radiographed using dorsopalmar/plantar and stressed views. Rotational instabilities were classified by the position of the displaced digit. Axial rotational instability (AxRI) caused the palmar/plantar aspect of the digit to rotate axially (figures 67 and 68) compared with a normal metatarsus (figure 69) and abaxial rotational instability (AbRI) to rotate abaxially (figure 70). A third category of instability was abaxial subluxation (figure 71) subdivided into P1 subluxation, and P1 with sesamoid bone subluxation.

Figure 67. A photograph of the plantar aspect of the pes showing axial rotational subluxation of digit 5 (yellow arrow). The digital pad is rotated axially (white arrow).

Figure 68: a dorsoplantar radiograph of the pes showing axial rotational instability of digit 5 with metatarsal torsion and axial displacements of the sesamoid bones (arrow). Joint incongruity is not apparent on this stressed radiograph.

Figure 69: a dorsoplantar radiograph of normal metatarsophalangeal joints with no obvious metatarsal torsion. MT5 has a distal valgus (arrow).

Figure 70: a dorsoplantar radiograph of the pes showing abaxial rotational instability with lateral displacement of the sesamoid bones (arrow).

Figure 71: a dorsoplantar radiograph of the pes showing lateral rotational luxation of P1 with both sesamoid bones (arrow).

Treatments were either rest, amputation through the distal metacarpal/tarsal bone, or the application of an external skeletal fixator using two 1.4mm arthrodesis pins driven through P1 and either two or three pins through the metacarpal/metatarsal bone. These were bent by 90 degrees approximately one centimetre from the skin and the shafts connected with acrylic paste. The pin placements were on the dorso-abaxial axis.

The fixator was removed after about three weeks and the dog put back into training two months from the original surgery.

Metacarpal/metatarsal bone torsion was determined from a true dorsopalmar/plantar radiograph. Torsion was diagnosed by an axial displacement of the sesamoid bones not attributable to joint instability.

Seventy-seven distal limb radiographs that contained images of the MCP and MTP joints were examined for metacarpal and metatarsal bone torsion to determine its prevalence and association with joint instability.

Two dogs with metatarsal bone torsion had radiographs taken of the contralateral foot.

Results

There were three cases of MCP injury and 26 cases of MTP injury.

Clinical signs were of varying degrees of lameness, joint swelling and occasionally a digital postural deformity.

All cases were presented as injuries occurring within the previous two weeks with the exception of one case of AbRI that was unstable and lame three months after the initial injury, and two cases of AxRI.

The distribution of the lesions is shown in tables 25, 26, 27 & 28.

	Limb	digit 2	digit 5
Axial rotational instability	L		1
Sprain	R	1	
Sprain	L	1	

Table 25: Metacarpophalangeal joint injuries showing types, limb and digit distribution. Sprain is defined as having no palpable instability.

	digit 2	digit 5	total
Left limb	1	6	7
Right limb	2	8	10

Table 26: Metatarsophalangeal joint axial rotational instability showing the limb and digit distribution.

	Left hind digit 5
Abaxial rotational instability	3
P1 luxation with sesamoids	3
P1 subluxation	1

Table 27: Abaxial metatarsophalangeal joint instability showing types, limb and digit distribution.

Right hind	digit 2	digit 5
	1	1

Table 28: Metatarsophalangeal joint sprain injury showing the limb and digit distribution. Sprain in this context is defined as having no palpable instability.

Three cases of metatarsophalangeal injury were in digit 2 and 23 cases in digit 5.

One case of abaxial subluxation had an avulsion fracture of the medial aspect of P1 (figure 72).

Figure 72. a dorsoplantar radiograph of the pes showing fracture/subluxation of MT5/P1 joint. There is an avulsion fracture of the insertion of the medial collateral ligament on P1 (arrow).

Treatment was by either rest, amputation or the application of an external skeletal fixator. The methods are shown in table 29.

Injury	Rest	Amputation	Fixator
Axial rotational instabilities	10	1	7
Lateral instabilities		1	6
Sprain	3		

Table 29: metacarpo/metatarsophalangeal joint injuries showing the numbers of injury types and treatments.

There was pin loosening, often with a localised infection, in all the fixator-treated cases but infections rapidly resolved after frame removal with or without a course of antibiotics.

Two chronic AxRI subluxations were presented with lameness, one had ulceration of the adjacent digit from nail impingement and the other had mild ulcerated interdigital webbing between the digital and metatarsal pads from the abnormal anatomy. The subluxations were not reducible. The nail impingement was treated by ungual crest ostectomy and the ulceration was not treated.

All the dogs returned to successful racing. One case of AxRI treated by external fixation, resubluxated but returned to racing.

Thirty-four radiographs of the metacarpus and 43 radiographs of the metatarsus were examined for evidence of metacarpal and metatarsal bone torsion. The results are shown in table 30.

	MTP torsion	MCP torsion
Total number of radiographs	43	34
number with torsion	13	1
number with axial subluxation	10	0

Table 30: distribution of cases of metatarsal and metacarpal torsion together with those with axial subluxation.

The two dogs with metatarsal bone torsion that had radiographs taken of the contralateral feet, both had bilateral symmetrical MT5 torsion.

Discussion

A previous survey found five cases of MCP injury and eight cases of MTP injury with both the second and fifth joints almost equally affected (Prole 1976). In addition ten of the thirteen cases were in the left fifth and right second digits. These digits are on the aspect of the limbs closest to the inside of the track when running the bends and consequently are more loaded.

In other reports injury types were not described in any detail but had been classified as sprains or luxations, occasionally with avulsion fractures of the attachments of the collateral ligaments (Dee and others 1991, Eaton-Wells 1998).

In this series the majority of injuries were in the MTP joints (n = 26/29). Axial rotational instability was over-represented in the fifth digit (n = 14/17) with similar distribution between the right and left limbs. The non-limb bias found in torsion of the fifth metatarsal bone would suggest that this is a major contributing factor to the aetiology. Abaxial subluxation injuries were found exclusively in the digit five of the left limb, the digit that carries most load when leaning into the bend.

Diagnosis of AxRI was by palpation of the instability together with a characteristic sharp movement of the flexor tendons as they luxated axially. Radiography showed the sesamoid bones subluxated axially with the digit rotated inwards. However after reduction the sesamoids were still radiographically in the same anatomical position leading to the supposition that there is a predisposing metatarsal torsion. Stressed radiographs fail to demonstrate any rotational incongruity (figure 68).

Investigation of specific ligament sprains has not been undertaken but these presumably involve type III sprains of the medial or lateral collateral ligament together with various sesamoidian ligaments.

All the cases of AxRI showed metatarsal bone torsion as did three cases radiographed for other injuries. The distinction between torsion and non-torsion was subjective. Three cases with AxRI were litter mates suggesting that metatarsal bone torsion is a genetic conformational deformity that predisposes to AxRI. The bilaterally symmetrical MT5 torsion cases further supports a conformational abnormality.

AxRI treatments responded to both conservative management and surgery and possibly the only advantage of the latter would be prevention of soft tissue injuries from nail impingement on the adjacent digit or plantar interdigital dermatitis.

None of the cases of lateral instabilities were treated by rest due to marked instability. The fracture/luxation case returned to successful racing but with a severely decreased range of motion (figure 72).

Sesamoid bone disease

Introduction

There are two pairs of sesamoid bones on the palmar and plantar aspects of each of the metacarpo-phalangeal (MCP) and metatarso-phalangeal (MTP) joints apart from digit 1. Each pair is separated by a sharp-edged sagittal crest. The sesamoid bones are intra-articular and the ligamentous support is complex. Proximally they are embedded in the interosseous muscles (Evans 1993a).

The third and fourth MCP and MTP joints have a dorsal orientation with the flexor tendons lying centrally over the sesamoid bones, while the abaxial joints, digits two and five, have a slight axial rotation with the flexor tendons running over sesamoids two and seven (Robins and Read 1993).

Materials and methods

Dorsopalmar and dorsoplantar (figures 73 & 74), and mediolateral radiographs were taken.

One case of fracture was treated surgically by removal of the entire sesamoid bone and the other cases were managed conservatively.

The incidence of fragmented sesamoid bones was made from the same 77 radiographs used in the metacarpal/tarsal bone torsion survey (table 30).

Results

Clinical signs of sesamoid bone fracture were acute onset lameness, joint swelling and pain on joint manipulation. Focal pain was present over the fractured sesamoid. There was a sharp demarcation of the fracture site and distraction of the fragments (figure 73).

Figure 73: a dorsopalmar radiograph showing a fractured seventh sesamoid bone with distraction of the fragments and a sharp demarcation of the fracture (arrow) (case 2).

Fracture of a sesamoid bone was diagnosed in three dogs of which two were acute injuries and one was a coincidental finding. Dogs diagnosed with a fractured bone remained lame for several weeks.

Out of 77 radiographs 13 dogs had fragmented sesamoid bones. Radiographically the sesamoid has the appearance of an irregular, diffuse fracture line with little displacement (figure 74).

Figure 74: a dorsopalmar radiograph showing a bipartite fragmented second sesamoid bone in digit two (arrow).

Distribution of the lesions is documented (Table 31 & 32).

The three cases of fracture all returned to successful racing.

Case	Limb	Sesamoid	Treatment	Outcome
1	RH	1	rest	raced
2	LF	7	excision	raced
3	RF	8	rest	raced

Table 31: shows the limb and sesamoid distribution, treatment and outcome of cases with sesamoid bone fracture.

Sesamoid number	one	two	seven	eight
Left fore			2	
Right fore		4	4	1
Left hind			1	
Right hind	1	3		

Table 32: shows the limb and sesamoid distribution of fragmented sesamoid bones.

Discussion

Diagnosis of sesamoid disease is by radiography and clinical examination. The radiographic appearance of a fractured sesamoid bone has a sharp demarcation of the fracture and displacement of the fragments (figure 73). Clinically the dog remains lame for a longer period than would be expected with a joint sprain.

Radiographic diagnosis of fracture is subjective and in previous reports fragmentation appears to be confused with fracture (Bateman 1959, Davis and others 1969).

Distribution of the 13 cases of fragmented sesamoid bones showed an over-representation in the right thoracic limb (n=8) and this has been previously reported (Bateman 1959). Over-representation of one limb implies that the aetiology of the condition is from the stresses of running the bends. The digital flexor tendons lie eccentrically over sesamoid bones two and seven and it has been suggested that compressive forces from the tendons on the sesamoid bones predisposes to fragmentation (Davis and others 1969).

A definitive diagnosis of fracture was made in two acute cases and was suspected in a retired non-lame greyhound (case 1). Further support for the diagnosis is from the fact that two of the cases were not in sesamoid bones two and seven, the commonest sesamoids in which fragmentation is recorded (Robins and Read 1998).

Surgical treatment is by removal of either the whole sesamoid bone or the fragment and results in a successful return to racing (Bateman 1959, Davis and others 1969). Two cases of fracture in this series managed conservatively also had successful outcomes. Lameness may resolve in most cases without surgical intervention.

Sesamoiditis is a speculative diagnosis as the intra-articular sesamoidian ligaments will probably be involved in cases of joint sprain. Historical diagnosis may have been from the observation of a fragmented sesamoid bone within a sprained joint.

Proximal interphalangeal joint instability

Introduction

The proximal interphalangeal joint (P1/P2) is between the first phalanx (P1) and the second phalanx (P2). It is supported by broad collateral ligaments, the flexor tendons running through an annular ligament, and dorsally by the tendon of the common extensor tendon in which is a small sesamoid bone (Evans 1993a).

Materials and methods

The joint was palpated under general anaesthesia for signs of instability. Dorsopalmar/plantar radiographs were taken in selected cases.

All prospective cases of P1/P2 instability were treated by the application of a 2:2 uniplanar transarticular external skeletal fixator applied dorsolaterally on the abaxial aspect of the digit for approximately three weeks. Arthrodesis pins of 1.4mm diameter were inserted without predrilling the cortices. The pins were bent over at 90 degrees about one centimetre from the skin and connected using an acrylic paste (figure 75). Prophylactic antibiosis was given for ten days.

Ungual crest ostectomy (UCO) was performed on instabilities in digits three and four, and on marked instability in other digits. UCO involved a skin incision about 3mm from and around the nail base. The ungual process and nail were removed with bone cutting forceps enabling the germinal layer of the nail and the ungual crest to be removed using rongeurs.

Results

Clinical signs were of varying degrees of lameness. Joint swelling was always present. In the more severe cases the distal digit would have a postural deformity often with a degree of rotation.

Eighteen dogs were diagnosed and treated for P1/P2 instabilities. Distribution and treatment is shown in table 33. One dog had an avulsion fracture at the insertion of the axial collateral ligament (figure 75) and one dog had instability in both central digits in the left hind foot causing a rotational deformity of those digits.

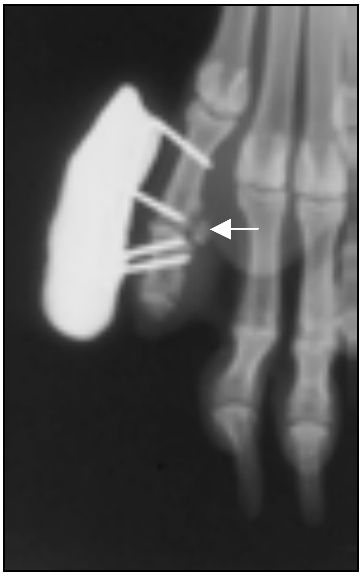


Figure 75: A dorsopalmar radiograph showing P1/P2 instability of digit five treated with a 2:2 fixator and ungual crest ostectomy. There is a large articular avulsion fracture of the distal attachment of the axial collateral ligament (arrow) (case 9).

One dog had a complete luxation of P1/2 (figure 76).

Figure 76: a dorsoplantar radiograph of digit 5 showing a luxation of P1/P2 successfully treated with a 2:2 fixator and UCO (case 18).

Pin loosening with infection and occasionally osteomyelitis was common but infections rapidly resolved after frame removal with some cases requiring a course of antibiotic therapy.

All the dogs returned to successful racing with stable joints and no recurrence.

Case	Limb	Digit	Treatment	Comments	Outcome
1	RH	4	ESF + UCO		raced
2	RH	5	ESF		raced
3	RF	3	ESF + UCO		raced
4	RF	4	ESF		raced
5	LF	2	ESF		raced
6	LF	5	ESF		raced
7	LF	3	ESF + UCO		raced
8	RF	5	ESF		raced
9	RF	5	ESF + UCO	avulsion fracture	raced
10	RF	2	ESF + UCO		raced
11	RF	2	ESF + UCO		raced
12	LH	3&4	ESF + UCO		raced
13	LF	5	ESF + UCO		raced
14	LF	5	ESF		raced
15	LF	2	ESF		raced
16	LH	3	ESF + UCO		raced
17	RH	5	ESF + UCO		raced
18	LH	5	ESF + UCO	luxation	raced

Table 33: the distribution and treatment of P1/P2 instabilities showing the limb and digit distribution, treatment and outcome.
ESF = external skeletal fixator. UCO = ungual crest ostectomy.
LF = left fore limb, RF = right fore limb, LH = left hind limb, RH = right hind limb.

Discussion

P1/P2 joint instability is a common injury. No one digit in either the thoracic or pelvic limbs was over-represented.

Historical treatments relied on periarticular fibrosis to stabilise the joint with reduction of the nail lever arm. In the author’s experience the injection of sclerosing agents, prosthetic ligament replacement and primary ligament repair all gave unpredictable outcomes primarily because of the difficulty in holding the joint in normal congruity for the required period.

The collateral ligaments are broad and the isometric points shift with flexion and extension. Prosthetic ligaments tend to be linear and defining the anchor points is difficult. They inevitably stretch or fail (Guilliard 2003a).

Primary ligament repair is not possible to achieve with accuracy as the ligaments are frayed or avulsed. At best the sutures act as a prosthesis.

Use of an external fixator to maintain congruity allows the formation of periarticular fibrosis providing joint stability. Pin loosening or infection can act as an advantage as it increases the amount of temporary inflammation around the joint increasing the stability.

The decision to routinely remove the ungual crest from the central digits was taken because of their greater length and longer lever arm. UCO was performed on the abaxial digits when the joint had marked instability.

The case of fracture subluxation (figure 11) was also successfully treated by external fixation even though the fracture was articular and not accurately reduced or firmly fixated.

Distal interphalangeal joint subluxation

Introduction

The distal interphalangeal joint (P2/P3) lies between the second phalanx (P2) and the third phalanx (P3). A sesamoid cartilage is located on the palmar/plantar aspect of the joint capsule within the deep digital flexor tendon that has its insertion on P3. There are two collateral ligaments. Dorsally the dorsal elastic ligament and the common digital extensor tendon insert on P3 (Evans 1993a).

Materials and methods

P2/P3 joint sprains are classified by the author as type 1: joint swelling but stable, type 2: an instability that can be manually subluxated but returns to normal congruity, and type 3: a grossly unstable joint that luxates easily (figure 77). Diagnosis of instability was made by palpation under general anaesthesia.

Treatments for type 1 injury was by conservative management with nail shortening, for type 2 injury ungual crest ostectomy (UCO) and for type 3 injury, UCO together with a soft tissue mattress suture of polyglactin 910 (Vicryl, Ethicon) through the damaged collateral tissues. Accurate reconstruction of the collateral ligament was not attempted.

The technique for performing UCO is described in under the heading of proximal interphalangeal joint instability.

No external coaptation was used in any of the cases.

Figure 77: a dorsopalmar radiograph showing a type 3 luxation of the P2/P3 joint of digit of digit 3.

Results

Clinical signs were of mild lameness with swelling of the distal digit.

Nine cases of P2/P3 subluxation were recorded and the distribution and treatments are shown (table 34).

All cases returned to successful racing with no recurrence of injury and training was resumed after six to eight weeks.

Case	Limb	Digit	Type	Chronicity	Treatment	Outcome
1	LH	3	2	acute	UCO	raced
2	LF	5	2	acute	UCO	raced
3	LH	2	2	acute	UCO	raced
4	RF	5	2	acute	UCO	raced
5	LF	5	1	acute	shorten nail	raced
6	RF	2	3	acute	UCO + suture	raced
7	LH	5	3	acute	UCO + suture	raced
8	RH	5	3	6 weeks	UCO + suture	raced
9	LF	5	3	6 months	UCO + suture	raced

Table 34: showing the limb and digit distribution, type of injury, chronicity, treatment and outcome of cases of distal interphalangeal instability.
UCO = ungual crest ostectomy.

Discussion

P2/P3 instability is more common than in previous injury surveys (Prole 1976, Agnew 1992). No one foot is over-represented and digits two and five are most commonly affected.

Stability was achieved in all cases by maintaining the joint in normal congruity allowing the development of periarticular fibrosis. Nail shortening or removal reduced the lever arm during this process.

There were no long term complications following UCO although nail regowth and infection can occur (author’s observations).

The inclusion of two chronic cases suggests that conservative management alone is not sufficient for type 3 injuries.

Osteomyelitis of the third phalanx

Introduction

Osteomyelitis of the third phalanx (P3) is not reported as a specific problem in the racing Greyhound.

Materials and methods

Dorsopalmar/plantar radiographs were taken and the distal interphalangeal joint palpated for instability under general anaesthesia.

Bacteriology was not performed.

Amputation was through the distal condyles of the second phalangeal bone preserving the pad. Ungual crest ostectomy (UCO) is described in the section on proximal interphalangeal joint instabilities. The choice of surgical technique evolved from amputation to UCO.

The antibiotic given orally for two weeks contained amoxicillin and clavulanic acid (Noroclav 250mg, Norbrook Labs Ltd) at 12.5mg/kg twice daily), the choice of antibiotic treatment was empirical.

Results

There were four cases. The distribution, treatment and outcome are recorded (table 35). The nail was broken in two cases and exudative at the nail/skin junction. When performing an UCO the bone in the ungual crest was found to be soft.

No bone changes were seen on radiography.

Case	Limb	Digit	Treatment	Outcome
1	LH	5	amputation	raced
2	LF	3	amputation	raced
3	RF	2	UCO + antibiotics	raced
4	RF	2	UCO + antibiotics	raced

Table 35: shows the limb and digit distribution, treatment and outcome of cases of osteomyelitis of the third phalanx.

UCO = ungual crest ostectomy.

Discussion

Osteomyelitis is suspected when the distal digit is very swollen and painful. The differential diagnoses are P2 and P3 fractures and P2/P3 instability. In older dogs tumours including squamous cell carcinoma and malignant melanoma have similar presenting signs (Henry and others 2005).

In the author's experience antibiotic therapy alone is non-curative as the infected nail bed acts as a nidus of infection. Complete removal of the soft bone of the ungual crest and process with remnants of nail together with antibiosis, was curative in two cases.

The advantage of UCO is that it preserves natural weight-bearing on the digital pad.

Fractures of the digits

Materials and methods

Dorsopalmar/plantar radiograph view was taken and in selected cases, the mediolateral view.

Management of the fracture was dependent on its location, degree of instability, and joint involvement. Internal fixation was used in the retrospective study but in the prospective study the application of an external fixator was often the preferred method.

Conservative management involved rest with a support dressing for usually no more than three weeks.

Internal fixation was by the placement of 1.5mm cortical screws, lagged to provide compression (figure 78).

The application of an external skeletal fixator (ESF) was made by inserting 1.4mm pins with an acrylic connecting bar. In all cases the ESF was transarticular crossing either one or two joints (figure 79). Generally the frame was removed after three to four weeks.

Ungual crest ostectomy (UCO) was the treatment method for P3 fractures and is described under the section on proximal interphalangeal joint instability.

Digital amputation was either distal through the condyles of the second phalanx (P2) preserving the pad, or proximal in digits two and five through the condyles of the metacarpal or metatarsal bone, and in digits three and four through the metacapo/metatarsophalangeal joint. Proximal amputation was used for some P1 fractures and distal amputation for some P2 and P3 fractures.

Figure 78: a comminuted proximal articular fracture of P1 treated by reconstruction using 1.5mm lag screws.

Figure 79: a spiral fracture of P2 treated by a transarticular fixator.

Results
Twenty-two fractures of the digits are recorded.

There were nine fractures of P1. Distribution, type, articular involvement, treatment and outcome are presented (table 36)

Case	Limb	Digit	Type	Articular	Treatment	Outcome
1	LH	5	comminuted	no	rest	raced
2	RF	3	comminuted	proximal		euthanasia
3	RH	4	comminuted	proximal	screws	raced
4	LH	2	simple	proximal	rest	raced
5	RF	5	comminuted	no	rest	LTF
6	LH	5	comminuted	proximal	amputate	raced
7	RH	4	comminuted	proximal	amputate	raced
8	LF	5	spiral	no	fixator	raced
9	LH	5	comminuted	no	rest	LTF

Table 36: shows the limb and digit distribution, type, articular involvement, treatment and outcome of fractures of the first phalanx.

LTF = lost to follow up.

There were 11 fractures of P2. Distribution, type, articular involvement, treatment and outcome are presented (table 37)

Case	Limb	Digit	Type	Articular	Treatment	Outcome
1	LF	5	condylar + comminuted	distal	amputation	raced
2	RF	4	spiral	no		retired
3	LH	2	condylar	distal	screw	raced
4	RH	4	comminuted	no	fixator	raced
5	RF	4	condylar	distal	screw	raced
6	LF	4	spiral	no	fixator	raced
7	LH	3	spiral	no	conservative	raced
8	RH	5	comminuted	proximal		retired
9	RH	2	comminuted	proximal & distal	fixator	raced
10	RF	2	comminuted	proximal & distal	fixator	raced
11	RF	5	spiral	no	fixator	raced

Table 37: shows the limb and digit distribution, fracture morphology, articular involvement, treatment and outcome of fractures of the second phalanx.

There were two fractures of P3. Radiography failed to show the fracture. Diagnosis was on abnormal movement of the nail. Limb and digit distribution, treatment and outcome are presented (table 38)

Case	Limb	Digit	Treatment	Outcome
1	RF	5	UCO	raced
2	RF	4	UCO	raced

Table 38: shows the limb and digit distribution, treatment and outcome of fractures of the third phalanx.

UCO = ungual crest ostectomy.

Clinical signs were severe lameness and a swollen digit. Crepitus was normally apparent on palpation under general anaesthesia.

Both fractures of P3 treated by UCO were through the body of P3 at the base of the ungual crest. The fracture site did not involve the ungual crest.

Discussion

Fractures of the phalanges were mainly in P1 and P2. Distribution was spread over all the limbs and digits with no over-representation.

Diagnosis of P1 and P2 fractures from radiographs is straightforward. Diagnosis of P3 fractures requires palpation under general anaesthesia to differentiate between a loose nail, an ungual process fracture within the nail, and a fracture within the body of P3. The main differential diagnosis of P3 fracture is osteomyelitis and the two may be concomitant following ungual crest fracture.

A standard UCO procedure for P3 fractures was performed to remove the lever arm and prevent the ingress of infection through the nail/skin junction.

Internal fixation with screws was undertaken in some of the earlier cases of P1 and P2 fractures. The surgery was often difficult and reduction less than ideal. The application of an external fixator is a much simpler technique allowing good alignment. However as the construct crosses either one or two joints pin loosening with subsequent infection was universal necessitating early removal of the frame at three to four weeks. This had no effect on outcome as sufficient periosteal fibrosis and callus had formed to stabilise the fracture.

Conservative management of P2 fractures can lead to a malunion with elevation of the nail and abnormal pad wear with lameness (author’s observation).

Articular fractures in general require accurate reduction and rigid fixation to prevent the onset of osteoarthritis. The cases treated by external fixation (n=2) with no articular fracture reduction returned to successful racing in spite of joint ankylosis or a reduced range of movement. Long term outcome is unknown.

The prognosis for all phalangeal fractures was generally good and not dependent on treatment method.

Webbing injuries

Split web

Introduction

The webbing is the interdigital skin. A split web refers to a cut in the cranial edge of the webbing that can extend any distance up to the metacarpal or metatarsal pad (figure 80).

Figure 80: a split in the interdigital webbing between digits three and four.

Materials and methods

All dogs presented with a cut in the cranial edge of the webbing had the web surgically cut back to the metacarpal or metatarsal pad (incisional separation podoplasty). The dorsal and palmar/plantar skin was sutured together to form a permanent open "V" (figure 82). The suture material used was polyglactin 910 (Vicryl, Ethicon). The sutures were not removed but were left to be absorbed.

Results

There were six cases. The distribution is shown in table 39.

The clinical signs are a split in the cranial border of the interdigital webbing that may extend from only several millimetres to the metacarpal/tarsal pad. Lameness is transitory.

Case	Limb	Web	Outcome
1	LH	4 & 5	raced
2	LF	2 & 3	raced
3	LH	4 & 5	raced
4	RF	3 & 4	raced
5	RF	3 & 4	raced
6	LH	3 & 4	raced

Table 39: shows the limb and web distribution, and outcome after incisional separation podoplasty for a split web.

All cases returned to successful racing. No subsequent injuries to the adjacent digits were recorded.

Discussion

Webbing reconstruction was not undertaken as an incisional separation podoplasty is a quick and simple procedure that in this series has given excellent results.

Split foot

Introduction

A split foot is a full thickness split of the plantar skin between the metatarsal pad and the digital pad overlying the flexor tendons of either digit three or four.

Materials and methods

All dogs presented with a split foot (figure 81) underwent surgery. The adjacent abaxial web was incised back to the metatarsal pad and sutured in a “V” using the method described for split web surgery (figure 82). The original split was apposed using one or two simple sutures. If the split recurred the webbing between digits three and four was incised in a similar fashion. The foot was temporarily dressed for two days. The sutures were not removed.

Figure 81: shows a full thickness skin split in the plantar webbing over the flexor tendons of the third digit.

Figure 82: shows an abaxial incisional separation podoplasty of the webbing between digits two and three for the treatment of a split foot.

Results

There were 15 cases of split foot. The distribution is shown in table 40.

Clinical signs are a longitudinal full thickness split in the plantar skin over the underlying flexor tendon. The dog shows lameness when racing.

Case	Limb	Resected web	Further web surgery
1	LH	4 & 5	
2	LH	4 & 5	
3	RH	2 & 3	
4	RH	4 & 5	
5	LH	2 & 3	
6	RH	2 & 3	
7	RH	2 & 3	
8	RH	2 & 3	
9	RH	2 & 3	
10	RH	2 & 3	3 & 4
11	RH	2 & 3	
12	RH	2 & 3	3 & 4
13	RH	4 & 5	
14	RH	2 & 3	
15	LH	4 & 5	

Table 40: Shows the limb and web distribution of cases of split foot, and the cases requiring further web resection surgery.

The split recurred in two dogs on return to racing and these underwent resection of the webbing between digits three and four. All dogs subsequently had no recurrence of the split and no reported injuries to the adjacent digits.

Discussion

Splitting of the plantar interdigital skin occurred only in the hind feet and only overlying the flexor tendons of digits three and four. The cause of the split is possibly due to the action of coarse sand on the tensed skin overlying the flexor tendons. Superficial abrasions of the skin at these sites are a common finding after racing. In the author’s experience a split foot will heal naturally but will always split again at every race.

Cutting back the abaxial web relieves the tension on the plantar skin when the digits are in full extension. In the two recurrent cases additional resection of the central web was successful and would further relieve skin tension over the split.

Strapping the foot during racing is a recommended preventative measure for split foot (Davis 1983). This is against the rules of racing in the United Kingdom.

Viral papilloma

Introduction

Viral papilloma can occur on the palmar/plantar skin of the webbing causing lameness (Davis and others 1983, Eaton-Wells 1998).

Materials and methods

The papilloma was surgically excised and the abaxial web incised with the method described for a split foot.

Results

Clinical signs were a mild to moderate lameness with a friable cauliflower-like growth on the plantar skin. There was oedema of the skin around the lesion.

There was one case of a papilloma causing lameness. It was on the plantar interdigital skin overlying the flexor tendons to digit 4 in the left hind foot. The surgery was successful with no recurrence.

Discussion

Although viral papilloma will resolve naturally in time, surgical excision leads to a rapid recovery from lameness. The abaxial web was resected as a prophylactic measure on the assumption that the surgical wound would break down under racing conditions due to its position.

Corns

Introduction

A corn is a circular area of hyperkeratisation usually found on the digital pad and occurs almost exclusively in sight hounds (figure 83). It is a cause of both chronic and after racing, sudden onset lameness (Guilliard 2010).

Figure 83: shows a large central corn in the centre of third digital pad in the right thoracic limb (case 10).

Materials and methods

The majority of the cases in this study have been reported by the author (Guilliard 2010).

All of the cases were treated by surgical excision apart from the two cases of P2/P3 ankylosis and one case of P3 amputation, treated by distal digital ostectomy.

Surgical excision was by elliptical incisions around the corn through the dermis allowing the corn to be dissected away from the underlying connective tissues. The pad was stitched using simple interrupted sutures placed away from the margins of the incisions. Suture material used was 3 metric polyglactin 910 (Vicryl, Ethicon). The foot was covered by a protective dressing for three weeks.

Distal digital ostectomy involved the removal of the distal condyles of the second phalanx together with any remaining bone and nail of the third phalanx. The pad was sutured on its dorsal aspect over the stump of the second phalanx. In order to prevent the pad from rotating dorsally a full thickness oval skin excision was made just caudal to the palmar/plantar aspect of the pad and closed.

The minimum follow-up time was six months.

Results

Clinical signs were of mild to non-weight bearing lameness often worse when walking on hard surfaces. Dorsopalmar/plantar digital pressure usually produces a pain response. Mediolateral palpation often detected a focal thickening of the pad. Visual inspection of the pad shows a circular keratinised lesion.

Corns were diagnosed in 11 dogs. The distribution, concomitant injury and recurrence are detailed (table 41).

Case	Limb	Digit	Concomitant injury	Outcome
1	RH	5	none	
2	LF	3 & 4	DDFT	recurred
3	RF	3	none	
4	RH	4	P2/P3 ankylosis	
5	LF	4	none	
6	LF	3	none	
7	RF	4	none	recurred
8	RF	4	none	recurred
9	LF	4	P3 amputation	
10	RF	3	none	
11	RF	4	none	

Table 41: shows the limb and digit distribution, concomitant injury and outcome of digital pad corns following excision.
DDFT = deep digital flexor tendon rupture.

One case presented as acute onset lameness after racing and at excision there was contusion of the subdermal tissues. The other cases had chronic, low grade lameness that was aggravated by walking on hard surfaces. The two cases that were treated by distal digital ostectomy did not have the corns removed and these disappeared naturally.

At excision some corns had a thickened pad with hyperkeratosis and others had the appearance of a sinus tract in the subcutis together with hyperkeratosis (figure 84).

Figure 84: showing an excised corn with a sinus tract (arrow) and hyperkeratosis.

Discussion

The distribution of the corns is similar to that reported previously by the author (Guilliard 2010) (appendix). There is no further evidence to contradict the findings in that study.

Concomitant digital deformity altering the area of pad contact with the ground, reported to occur in 40 percent of cases (Guilliard 2010), was seen in 27% of cases (n=3). This, together with corn resolution following distal digital ostectomy supports a mechanical aetiology.

Subsequent to this study histiopathological examinations of corns have found inclusion cysts within the subdermal tissues in four cases, further supporting the mechanical aetiology theory.

SUMMARY OF THE RESULTS

There were a total of 387 documented cases of injuries in Greyhounds of which 229 were fractures (59%). The distribution was 160 injuries in the thoracic limb (41%) and 227 in the pelvic limb (59%) (table 1). The most common site of injury was the foot (56%) followed by the tarsus (35%) of which 88% were fractures. Carpal injuries accounted for 22% of injuries of which 53% were fractures.

Thoracic limb			
		Injuries	**Fractures**
	Carpus	85	45
	Metacarpus	19	16
	Foot	56	14
Pelvic limb			
	Tarsus	134	118
	Metatarsus	23	23
	Foot	70	13
	Totals	**387**	**229**

Table 1: shows the distribution of cases between the thoracic and pelvic limbs with the distribution of total injuries and fractures within each anatomical region.

In the retrospective study there were 87 fracture cases (table 2),

Bone	Number
Accessory carpal bone	15
Central tarsal bone	42
Calcaneus	5
Third tarsal bone	11
Metacarpus	9
Metatarsus	5

Table 2: shows the bone distribution and numbers of retrospective fracture cases.

There were no adverse anaesthetic reactions.

DISCUSSION

The aims of the study were to further determine the nature, incidence and response to treatment of injuries to the distal limbs in the racing Greyhound. The study includes all distal limb injuries but, due to low case numbers and varying treatment regimes for some conditions, meaningful results are not found with all injuries.

The nature of injury

Diagnosis

Investigation of lameness was by thorough clinical examination, often with palpation under general anaesthesia, in most cases radiography, and occasionally syniocentesis. The broad anatomical location was found by a pain response from joint or bone manipulation, the application of focal pressure or a decreased range of joint movement. Pain on carpal flexion and reduced range of motion are sensitive methods of detecting sprain of the antebrachiocarpal joint, while focal pain may be the only clinical abnormality in type I fractures of the central and third tarsal bones.

Digital palpation detects subtle swellings as seen with joint effusion, ligament sprain and tendon strain injuries. Discrete swellings on the dorsal aspect of the carpus are found from the medial to the lateral aspects, as sprain of the medial collateral carpal ligament (Guilliard and Mayo 2000b), strain of the abductor pollicus longus tendon (Grundmann and Montavon (2001), strain of the extensor carpi radialis tendon (Blythe and others 1994), and sprain of the dorsal radiocarpal ligament (Guilliard 1997). In addition dorsal palpation will detect dorsal chips fractures (Boemo 1993), avulsion fracture of the extensor carpi radialis insertion (Blythe and others 1994) and subluxation of the second carpal bone (Guilliard 2001b). A good anatomical understanding is necessary for diagnosis.

On the palmar aspect palpation is essential for the diagnosis of flexor carpi ulnaris tendon strain, tears in the palmar superficial fascia (Guilliard and Mayo (2000a) and tear of the extensor carpi ulnaris tendon of insertion. More distally it will detect strain of the superficial digital flexor tendon (Prole 1971), and injuries to the digital joints.

In the pelvic limb digital palpation is useful in the diagnosis of superficial digital flexor tendon subluxation over the point of the calcaneus, and in the detection of subtle swelling such as those associated with sprain of the lateral ligament complex of the talocrural joint and minor tarsal fractures.

Radiography is essential for the accurate diagnosis of many injuries. True orthogonal views should be taken and additional views may be necessary for some injuries such as type I A accessory carpal bone fractures and subluxation of the second carpal bone (Guilliard 2001b). Stressed views are useful in cases of joint instability such as dorsal proximal intertarsal joint instability (Guilliard 2003b) and metatarsophalangeal joint subluxation.

Radiography has its limitations when determining fracture morphology particularly with carpal and tarsal bone fractures. Computerised tomography (CT) is more sensitive but is expensive and not locally available.

Syniocentesis is easily performed on all the high motion joints of the distal limbs and visual examination of the synovial fluid is particularly useful in detecting low grade sprain of the antebrachiocarpal joint. It is also essential in the elimination of joint infection as the cause of arthritis, a common differential diagnosis in cases of distal digit swelling especially in the pet dog (author's observation).

Carpal Injuries

While many injuries to the carpus have been well documented in the literature others are poorly described. There are two common major injuries with poor clinical outcomes, antebrachiocarpal joint sprain and fracture of the accessory carpal bone (ACB). Literature on the former is sparse and the exact pathology is unknown. This study suggests that joint damage is primarily to the dorsal aspect of the radial carpal bone, possibly from hyperextension with the distal radial rim striking the radial carpal bone. Arthroscopy is likely to further the understanding of this condition.

Fractures of the ACB are common and there is extensive literature on the condition (Gannon 1972, Hickman 1975, Dee and Dee 1985, Vaughan 1995, Kealy 1987, Johnson 1987, Johnson and others 1989). Type I fractures have the highest incidence and have been subdivided into types I A and I B (Piras and Johnson 2006). This study hypothesises that the subdivisions are not from sprain avulsion fractures of the ligaments suggested, but using a previous MRI study by the author and observing the anatomical position of the avulsed fragments, are from the accessorio-ulnar carpal ligament (type I A) and the accessorio-quartal ligament (type I B). In addition a further fracture type has been designated type I C from radiographic and CT studies.

Publications by the author on previously unreported carpal injuries are tear of the palmar superficial fascia (Guilliard and Mayo 2000a), dorsal radiocarpal ligament sprain (Guilliard 1997) and subluxation of the second carpal bone (Guilliard 2001b). Further cases have been added in this study and these do not contradict the initial findings.

Tear of the insertion of the flexor carpi ulnaris tendon on the lateral aspect of the ACB is previously unreported, but although uncommon, is important in that it is a differential diagnosis for palmar carpal swelling.

Fractures of the radial and fourth carpal bones together with the case of multiple carpal bone fracture show the inadequacies of radiography in determining fracture morphology making the optimal repair method impossible to select.

Tarsal injuries

Injuries to the tarsus were common and the majority were fractures (88%). Isolated tarsal bone fractures were mainly seen in the central (CTB) and third tarsal bones with fractures to the other tarsal bones usually concomitant to CTB fracture.

The distribution of types and concomitant fractures are similar to a previous report on 114 CTB fractures (Boudrieau and others 1984a) with the exception of the ratio of type IV to type V CTB fractures, the latter being more common in this study. One reason for this anomaly is a better understanding of fracture morphology (Vaughan 1987, Guilliard 2000) especially from MRI studies (Hercock and others 2011). The other reason is from the original contrary definitions of the fracture types that state that type V is highly comminuted with more than two fragments, and is also a non-reconstructable type IV fracture (Boudrieau and others 1984a, Boudrieau and others 1984b). Many highly comminuted fractures can be surgically repaired but that does not grade them as type IV fractures using the radiographic definition.

The publication by the author on 23 third tarsal bone fracture cases (Guilliard 2010) together with further cases in this study highlights the benign presentation of this injury and the variations in fracture morphology. Again radiography was often inadequate in determining the latter.

The report on distal crural fractures in the literature contains only six cases (Montavon and others 1993) and this study has added another seven cases. The difference in the findings is that the incidence of isolated caudal distal tibial margin fractures is much higher (n = 6) in this study. The left hock is also over-represented.

Soft tissue injuries represented 12% of tarsal injury. Sprain of the lateral ligament complex of the talocrural joint is unreported in the literature. The position of the avulsed bone fragment (figure 52) and the small fragments (case 2) were incompatible with ligament insertions reported in the literature. A cadaveric dissection identified a further lateral collateral ligament inserting at the site of the avulsion that was only in tension in hock flexion (figure 53).

One case of luxation of the superficial digital flexor tendon from the point of the calcaneus was seen. It differed from previously reported cases in pet dogs (Reinke and others 1993) in its severity with more extensive tearing of the retinaculum and crural superficial fascia.

The author has previously reported one case of dorsal proximal intertarsal joint instability (Guilliard 2003b) and this study adds a further two cases confirming the clinical findings.

Metacarpal and Metatarsal injuries

The morphology of metacarpal and metatarsal bone fractures is described in the literature (Bellenger and others 1981, Ness 1993, Boemo 1998) together with strain of the metacarpal superficial digital flexor tendon (Prole 1971), and this study adds no new information.

Injuries to the foot

This study further classifies metacarpophalangeal (MCP) and metatarsophalangeal (MTP) joint instabilities into axial and abaxial rotational instabilities, and lateral instability or subluxation with or without luxated plantar sesamoid bones. From examining a series of metacarpal and metatarsal radiographs the conclusion is that there is a predisposition towards axial rotational instability due to an anatomical torsion of mainly the fifth metatarsal bone. There are no reports of this anomaly found in the literature.

Using the same series of 77 radiographs 17% showed fragmented or bipartite (the second or the seventh) sesamoid bones and the conclusion is that it has no clinical relevance.

Proximal interphalangeal joint instability has been reported by the author (Guilliard 2003a) and this study supports the previous findings.

A classification of types of distal interphalangeal joint injury based on the degree of instability has been made allowing the selection of the optimum treatment.

Osteomyelitis of the third phalanx has not been previously reported in the racing Greyhound. It is a differential diagnosis of distal phalangeal swelling together with distal phalangeal joint instability and fractures of the second and third phalanx.

Fractures of the digits are common and this study describes fracture morphology and joint involvement.

Cuts to the palmar/plantar interdigital skin (webbing) are common and are described. Viral papilloma on this aspect of the webbing has been identified as a cause of lameness.

Corns are a common cause of severe lameness in both pet and racing sight hounds and are often difficult to permanently cure (Guilliard and others 2010). A previous report by the author found that 85% of corns occur in either digit three or digit four in the thoracic limbs. The evidence suggests that the cause is mechanical in the majority of cases. This study supports the findings of the previous study.

Aetiopathology of injury

This study supports the fact that many injuries are limb specific. This is due to asymmetric cyclical forces on the limbs leading to adaptive remodelling of both bone and soft tissues. The asymmetry is from the body lean that counteracts the centrifugal forces when running the bends, placing compressive forces on the aspects of the limbs closest to the inside of the bend and tensile forces on the opposite sides of the limbs (Emmerson and others 2000, Johnson and others 2001, Lipscombe and others 2001, Hercock and others 2008a).

In addition there are natural compressive and tensile aspects on the distal limbs that will act synergistically with the asymmetric cyclical forces. An example is subluxation of the second carpal bone found only in the left carpus. The second carpal bone is on the medial, tensile aspect of the carpus with the bone in the left carpus subjected to additional tensile forces when the dog leans into the bends.

Adaptive remodelling occurs after each run and while the bone is supposedly becoming stronger there is an initial weaker phase that can account for catastrophic fracture. Greyhounds generally run two or three times every two weeks with only straight training gallops in between races. It has been shown that race horses that are trained by galloping around bends daily are less prone to stress fractures (Carrier and others 1998).

An additional factor in the aetiology of stress fractures is the sudden increase in forces across the limb from interference with other dogs. The incidence of mishaps and falls per race, dependent on the track, varies from 25% to 80% (Bloomberg and Dugger 1998). These may be an under-representation as interferences probably occur in every race at some point. A common cause of mishap occurs by placing the dogs in starting boxes unsuitable for their style of racing, such as putting a wide runner in an inside box. As the dog moves across the track to gain its natural running position collisions on the run up and at the first bend are more likely to occur. A minor interference would be when a dog has to check its pace or change direction to avoid running into the dog in front.

Only small numbers of injuries are not from overload of remodelling structures but occur from falls. Collisions resulting in high speed somersaulting are relatively common but rarely result in injury provided that there is no impact with objects on the sides of the track.

There is a large variation in the incidence and anatomical site of specific injuries between the different surveys. Many factors affect the injury rate including track design, the running surface and track maintenance. Tracks in Australia and the USA tend to have a larger radius having the affect of decreasing the amount of lean and compression on the inner track aspects of the limbs.

The centrifugal force that the dog has to combat is equal to the mass of the dog multiplied by the square of its speed, and divided by the radius of the bend. The weight of the dog has been shown to have no influence on injury rate (Sicard and others 1999) presumably because the size and strength of the tissues is proportional to body size. The fast dogs have been reported to be more prone to injury (Bloomberg and Dugger 1998) (Sicard and others 1999). This equation shows that a larger radius will decrease the centrifugal force.

The bends are banked to decrease the amount of lean and so distribute the loading more equally between the inside and outside limbs. However this will increase the speed of the dog in the bends and this has been shown to possibly be a factor in an increase in injury rate (Sicard and others 1999).

Hydration of the sand racing surface is a great variable and affects the overall race times. The ideal composition is hard wet sand. During the summer the sand tends to dry rapidly needing frequent watering whilst during heavy rain the sand can be too wet. Drainage on banked straights and bends can result in uneven hydration across the track as the water flows to the inside of the track. There is a decrease in the injury rate during winter (Prole 1976) probably due to natural overwatering with heavy, slow going. Faster speeds predispose to injury (Bloomberg and Dugger 1998) (Sicard and others 1999).

Another factor that may affect injury rate is genetics with an inherited predisposition towards specific injuries. Anecdotal reports state that some breeding lines are predisposed to certain injuries.

Incidence of injury

Racing injuries are common in the Greyhound. In one survey there was approximately one injury in every 1000 runs, however 12.5% of dogs were being rested for lameness at any one time (Prole 1976). The injury book at a licensed UK track attended by the author shows an incidence of 24 injuries per 1000 runs although many were minor abrasions that would not be included in this or the Prole study.

There are two comprehensive surveys of injuries sustained on UK tracks (Prole 1976, Agnew 1992). The accuracy of these surveys depends on a number of criteria that include the ability of the veterinary surgeon to give an accurate diagnosis, the reporting of injury to the veterinarian, and whether x-ray facilities are available to confirm suspected diagnoses.

Detection of injury is often not possible immediately after racing as lameness may only be apparent on the following day. Dogs with injuries such as fractures to the accessory carpal bone, third tarsal bone, metacarpus or metatarsus sometimes complete the race with little or no loss of pace. It is then at the trainer’s discretion to report the injury or to withdraw the dog from racing. With no veterinary examination these are excluded from the injury data base.

The distal limb accounts for 70% of all injuries (Prole 1976) with 77% found in the thoracic and 23% in the pelvic limbs. In this study the ratio was 41% thoracic to 59% pelvic, the difference probably due to different track and running conditions. However the distribution of injuries is skewed due to the inclusion of 87 retrospective cases that only recorded specific fractures and not soft tissue injuries.

There are a few discrepancies in the incidence of certain injuries that are not related to an inadequate diagnosis. The incidence of metacarpal superficial digital flexor tendon strain was 68 cases compared to five metacarpal bone fracture cases (Prole 1976) and the ratio in a later survey was 18 cases to two of fracture (Agnew 1992). In this study there were only three cases of tendon strain with seven prospective cases of metacarpal bone fracture.

Bellenger and others (1981) report a ratio of 22 metacarpal bone fractures to one metatarsal bone fracture while this study found a ratio of 16 metacarpal to 23 metatarsal bone fractures. This difference may be due to different track conditions such as the running surface and the radius of the bends.

Prole (1976) had an incidence of 262 proximal interphalangeal joint instabilities out of a total of 342 foot injuries and Agnew (1992) had 48 out of a total of 322 foot injuries. This study had a ratio of 18 to 126 foot injuries in keeping with Agnew. The difference in the incidences between Prole and Agnew is almost certainly due to the running surfaces changing from grass to sand.

Response to treatment

Treatment outcome measures

Almost all previous studies looking at response to treatment have been retrospective with the inherent difficulties of obtaining accurate data. Good reported outcomes have been judged on the ability to return to racing and to win one race. None takes into account a decrease in grade or the long term affects of the injury on racing performance.

An example is the study into fragment removal for the treatment of type I accessory carpal bone fractures (Chico 1993). This type of fracture has been shown to result in osteoarthritis of the antebrachiocarpal joint (Johnson 1998) that is progressive with shortening of the dog's racing career. The specific race tracks were not recorded with the possibility of many of the cases racing on independent tracks where the administration of pain killers was permissible. Recordings of the grade of race, post-race transient lameness or long term outcome, were not made.

Outcome measurement in this study was mainly by accessing racing histories through the website of the Greyhound Board of Great Britain. This enabled the post-injury race grades and long-term outcome to be recorded but not transient lameness.

Recording outcome through the website is highly sensitive in that a return to previous racing form is an accurate assessment of success.

The specificity is low for a number of reasons:

- Many dogs do not return to racing for reasons other than treatment failure. Dependant on age, racing ability and the owner, many are treated to ensure a good quality of life and are retired.
- Certain injuries such as tarsal bone fractures often show a transient lameness when first returning to the track and are subsequently prematurely retired.
- Changing from a licensed track to an independent track means that the races are no longer put on the data base.
- Further injury during rehabilitation may force the dog into retirement.
- Subsequent injury on return to racing will shorten the racing career.

Principles of treatment

Conservative management is defined in this context as any treatment not requiring surgical intervention. Its mainstay is controlled rest for a defined time. Racing Greyhounds live in small kennelling areas with a raised bed and a walking area usually only about three by two metres in area. Concrete paddocks that are only several metres square are used for toileting. Daily exercise is free running in large grass paddocks with other dogs several times a day. Therefore controlled rest is simple to administer in most racing kennels.

In addition to rest many trainers possess and use therapeutic treatment aids such as magnetic therapy, ultrasound and laser, often supplemented by the application of liniments. These treatments were not recorded.

Support dressings are used in fractures to reduce movement at the fracture site and to relieve pain. They are also used to prevent over-use of soft tissue injuries, examples of which are a dorsal splint for dorsal radiocarpal ligament and extensor carpi radialis injuries, and a carpal flexion bandage for strain of the flexor carpi radialis tendon.

Complications arising from the use of support dressings are very common mainly due to the inability of the trainer to monitor the condition of the dressing especially its dryness. Male dogs frequently urinate on their own thoracic feet.

Surgical intervention is often used for fracture repair. Accurate reduction with rigid fixation using lag screws or bone plates leads to an early use of the limb but the surgery is often difficult and the repair suboptimal. In addition bone plates need removing as they create stress concentrations at their extremities and stress protection of underlying bone, factors that can result in pain, screw loosening or further fracture on a return to racing.

External fixation using pins and a connecting bar provide bone alignment and a degree of rigidity. The fracture site is undisturbed allowing biological healing. It is a useful, relatively cheap and simple technique for the treatment of metacarpal and metatarsal bone fractures, and digital fractures.

Surgical intervention in soft tissue injuries is used in the treatment of a variety of conditions. External fixation gives rigid support to allow biological healing of joint instabilities in the metacarpo/metatarsophalangeal and proximal interphalangeal joints, and the dorsal proximal intertarsal joint. Permanent nail remove (ungual crest ostectomy) reduces the lever arm. Surgery is also used to appose torn soft tissues in selected cases but is supplemented by an external support dressing. Examples are subluxation of the superficial digital flexor tendon off the calcaneus and tear of the extensor carpi ulnaris tendon. Surgical excision was used for the treatment of metacarpal superficial digital flexor tendon strain, corns and papilloma. Web resection reduces the tension in the interdigital skin allowing healing of cut webs and splits of the plantar skin (split foot).

Carpal injuries

This study adds little to the literature on the success of treatments of fractures of the accessory carpal bone (ACB) due to the fact that most dogs went untreated and were retired from racing. Type I fractures are the most common and fragment removal would seem to give a reasonable prognosis for a return to successful racing (Yore 1983, Dee and Dee 1985, Chico 1992). The author is of the opinion that this treatment is unlikely to give good long term success due to the development of osteoarthritis (Johnson 1987). He is also of the opinion that long term successful treatment of type I B fractures can only be achieved by screw fixation. The new classification of type I fractures proposed in this study will aid future treatment selection particularly in the management of types I A and I C fractures.

There were few cases of dorsal chip fractures (n = 3) but the results of fragment removal support a previous publication in which 70% returned to racing (Boemo 1993).

Treatment of antebrachiocarpal joint sprain injury by conservative management had unpredictable results with 50% of cases returning to racing. This agrees with the poor prognosis given in previous reports (Davis 1967, Needham 1978, Dunkley 1983). A better understanding of the nature of the injury may assist future treatment management.

Flexor carpi ulnaris tendon strain also carries a poor prognosis with conservative management, only two out of five dogs returning to racing. The author is of the opinion that small type IV ACB avulsion fractures have no influence on outcome and surgical removal is unnecessary. Flexion bandaging may offer a better prognosis.

The results of surgical treatment for isolated tears in the superficial palmar fascia would appear to give a good prognosis with success in six out of seven cases. The author has however anecdotal evidence that surgery has a poorer success rate possibly because there is a variation in the anatomical location and extent of the tears.

The success of treatment of dorsal radiocarpal ligament sprain and extensor carpi radialis strain injuries supports the use of a splinted support dressing to prevent carpal flexion, thereby unloading the structures to allow healing.

Tarsal injuries

Suboptimal repair of central tarsal bone (CTB) fractures where accurate reduction and fixation are not possible, does not result in a poor prognosis with eight out of 11 dogs returning to their pre-injury racing grade. Concomitant fractures, with the exception of comminuted unstable calcaneal fractures, had no effect on outcome with five out of six cases returning to their pre-injury grade. Late-onset osteomyelitis following fracture repair also had no effect on outcome (n = 2).

Comminuted unstable calcaneal fractures and proximal intertarsal luxation require surgical repair and carried a guarded prognosis for a return to racing.

Third tarsal bone (T3) fractures had an excellent prognosis following lag screw fixation (n = 10) provided that there was no dorsal tarsal collapse (n = 3).

Fracture of the caudal tibial rim margin treated by a lag screw gave excellent results (n = 5), the one failure was due to poor screw placement.

Temporary fixation of calcaneoquartal joint in normal congruity was successful in the treatment of dorsal proximal intertarsal instability (n = 2) as apposed to arthrodesis that carries a guarded prognosis (Dee 1998).

Kennel rest with or without external coaptation, successfully resolved the lameness in cases of sprain of the lateral ligament complex of the talocrural joint (n = 3).

Metacarpal and Metatarsal injuries

There were 30 metacarpal and metatarsal bone fractures with follow-up, 29 returned to racing. Treatments ranged from internal reconstruction, external fixation, external coaptation to conservative management with no support. The author now usually advocates conservative management with the exception of over-ridden simple fractures that require reduction and fixation by an external fixator.

The three cases of superficial flexor tendon strain treated by tenectomy were an insufficient number to evaluate surgical treatment. The author is of the opinion from cases seen outside this study that tenectomy is the treatment of choice agreeing with a previous report (Prole 1971).

Digital injuries

Proximal interphalangeal joint instability, treated by temporary support of the joint in normal congruity with the application of an external fixator had a 100% success rate (n = 18). The use of external fixation for this injury was discovered by the author having achieved inconsistent results by conventional treatments that fail primarily because none hold the joint surfaces congruent to enable healing by periarticular fibrosis.

Metacarpo/tarsophalangeal joint instabilities treated in the same way produced similar results (n = 13).

Distal interphalangeal joint instabilities were treated by shortening the lever arm by ungual crest ostectomy, and in type 3 instabilities with the addition of a suture to give temporary joint congruity. This was 100% successful (n = 9). Fractures of the first and second phalanxes treated by a variety of methods including internal reconstruction, external fixation and conservative management all returned to racing (n = 12). Articular involvement was not detrimental to the outcome with the proximal interphalangeal joint either ankylosing or having a reduced range of motion.

Fractures of the third phalanx healed following ungual crest ostectomy to reduce the lever arm.

Dermatological injuries

Web resection surgery (n = 21) had no complications and did not result in instabilities in the joints of the adjacent digits. It was 100% successful in all cases of split webs and split feet although two cases of split feet required additional surgery to prevent recurrence.

Corns were diagnosed in 11 dogs. The distribution, concomitant injury and recurrence were similar to a previous study by the author (Guilliard and others 2010). Corns are difficult lesions to permanently cure but surgical excision can be successful.

Conclusion

The treatment of fractures has evolved during the course of this study through internal reconstruction and fixation, external fixation, external coaptation to kennel rest with no support in the cases of some central tarsal bone, metacarpal/tarsal bone and digital fractures. Internal fixation can be technically challenging with possible complications and equally there are unacceptable complications associated with external coaptation.

The success rate in the use of external fixation for joint instabilities is far higher than with other techniques. Complications are high but resolve on frame removal. The principle of temporarily holding an unstable joint in normal congruity to allow the formation of periarticular fibrosis is valid for many joints, the exceptions being hyperextension instabilities of the carpus and tarsus.

Limitations of the study

Some of the dogs in the retrospective part of the study were recorded under pet names and an accurate outcome was not obtainable. Follow-up was from speaking to the trainers with anecdotal results. Accurate name recording is essential for the website histories and in the prospective part of the study a few dogs had running names misspelt making follow-up impossible.

The retrospective part of the study has been used to gather more case numbers for certain injuries mainly to determine fracture morphology, and not all have been included in the outcome measurements.

Investigations and treatments have been curtailed by financial restrictions. The value of the majority of the Greyhounds is very low and many are treated as commodities and have little sentimental value. This has prevented the use of further investigative modalities and has limited the use of radiography. However as a result of this, some cases were treated conservatively and not by the preferred option of surgery allowing comparison between the two treatment methods.

Further studies

To gain better understanding of many of the injuries more advanced imaging is necessary. Computerised tomography has already been applied to some tarsal fractures but its use for accessory carpal and third tarsal bone fractures would undoubtedly be beneficial in understanding the fracture morphology and treatment planning. Financial constraints will limit these studies.

Acknowledgements

The author would like to thank Dr Angus Anderson for his help and advice in the preparation of this thesis, and Ms Beverley Stevens for help with the presentation of the thesis.

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APPENDICES

Two articles follow:

Appendix 1 - Corns in dogs; signalment, possible aetiology and response to treatment

Appendix 2 - Third tarsal bone fractures in the racing Greyhound

Corns in dogs; signalment, possible aetiology and response to surgical treatment

Objectives: To describe the signalment and response to surgical treatment, and to propose aetiopathogenetic mechanisms for the development of paw pad corns in dogs.

Methods: A combined retrospective and prospective study was conducted on 30 dogs that presented with paw pad corns. The age, breed and gender of the dogs, together with anatomical positions of the corns were recorded. Surgical treatments involved either excision (n=27) or distal digital ostectomy (n=3). The minimum follow-up period was one year.

Results: The age at presentation was from two to 15 years. All the breeds in this study were either greyhounds or sighthounds. Males were over-represented. Ninety percent of the corns were found in the digital pads of digits three and four, and 90% were found in the thoracic limbs. The evidence suggests a mechanical aetiology or foreign body penetration. Long-term response to surgical excision resulted in a recurrence rate of more than 50% (n=27). Distal digital ostectomy gave good results in selective cases (n=3).

Clinical Significance: Corns can cause severe chronic lameness in greyhounds and related breeds. Long-term response to surgical treatments is disappointing but it is recommended as an initial treatment as it can be curative.

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Journal of Small Animal Practice (2010) **51**, 162–168
DOI: 10.1111/j.1748-5827.2009.00892.x

Accepted: 3 November 2009

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INTRODUCTION

In man, hyperkeratotic lesions are described as calluses, corns or porokeratosis plantaris discreta. A callus is defined as a thick and hard area of skin formed as a response to repeated contact or pressure trauma (Freeman 2002). Corns are more discrete calluses with a central conical core of keratin found on the dorsal, lateral or interdigital aspect of the toes (Gibbs 1980, Booth & McInnes 1997, Freeman 2002). They result from chronic pressure or friction where there is insufficient soft tissue between the skin and underlying bone (Haneke 1982, Freeman 2002, Kurvin & Volkering 2007).

The causes of corns in man are inappropriate or poorly fitting shoes, anatomic deformity resulting in abnormal foot mechanisms, high heels or high levels of activity (Omura & Rye 1994, Singh and others 1996, Freeman 2002, Menz & Morris 2005). The lesions regress once the abnormal stress has been removed or corrected (Thomas and others 1985, Singh and others 1996, Booth & McInnes 1997, Freeman 2002).

Porokeratosis plantaris discreta in man is similar to a corn and is a painful hyperkeratotic lesion found on the weight-bearing plantar surface of the foot. It is thought to be due to hypertrophy of the eccrine sweat glands (Mandojana and others 1984). It has been suggested that corns in greyhounds resemble this condition but no similarity was found on histological examination (Balara and others 2009).

In dogs, the corn is described as a circumscribed hyperkeratosis on the paw pad, which is sensitive to pressure (Fig 1). A synonym for corns is paw pad keratomas. They are mostly seen in middle-aged to older racing or retired greyhounds, but the incidence is not known. The majority occurs on the centre of the digital pads that carry the most weight but can also be found on the metacarpal and metatarsal pads (Gross and others 2005).

Foreign body penetration and papilloma virus infection are some of the causes as mentioned by breeders, trainers and clinicians. The introduction of small particles of epithelium into the subcutis, either by foreign body penetration or by the exploration of cuts resulting in scar tissue formation, has also been suggested as a cause (Davies 1973, Blythe and others 1994, Eaton-Wells 1998). Foreign bodies are however rarely found (Swaim and others 2004, Gross and others 2005).

Digital papillomatosis is described in a beagle, the lesions occurring on the junction of footpad and skin (DeBey and others 2001). A study of 24 dogs with

FIG 1. An example of a paw pad corn showing a circular area of hyperkeratosis in the middle of the pad

wart-like lesions on the paw pads found no evidence of a viral aetiology in the 18 greyhound cases (Balara and others 2009). In the experience of one author (DHS) the digits are a common site for viral paillomas; however, these tend to occur in young and elderly dogs, have characteristic histopathological features and are usually on the digital haired skin rather than the middle of the pad.

It has been postulated that canine paw pad corns have a similar aetiology to human corns, and result from mechanical abnormalities associated with chronic low-grade pressure (Swaim and others 2004) and the physical stresses of racing (Gross and others 2005).

Excision is the recommended treatment (Davis 1973, Faulkner Besancon and others 2004), but a high percentage of corns will return two to three months after surgery (Swaim and others 2004). Laser surgery, physical extrusion, hulling out the hard centre or curretage may be beneficial but recurrence is common (Gross and others 2005). The foot can be padded by the use of special boots (www.therapaws.net). Subdermal silicone block gel particle implantation has also been attempted (Swaim and others 2004). Ten greyhounds treated by a variety of methods all gave unsatisfactory results (Balara and others 2009).

The objective of this study was to describe the signalment and propose possible aetiologies and pathogenesis of paw pad corns, as well as document the response to surgical treatment.

MATERIALS AND METHODS

A four-year retrospective and a two-year prospective survey of all cases of corns seen by one author (MJG) were undertaken. Breed, age, gender, affected pads and concomitant foot abnormalities were recorded. The majority of corns were treated surgically either by excision or by distal digit ostectomy with pad repositioning.

The dogs were heavily sedated with butorphanol at 0.1mg/kg (Torbugesic, Fort Dodge Animal Health) and medetomidine at 25mcg/kg (Domitor, Pfizer Animal Health) and the digit ringblocked with local anaesthetic (procaine hydrochloride, Willcaine, Arnolds). The dog was placed in either dorsal or lateral recumbency. Haemostasis was achieved using digital pressure across the caudal pad by an assistant. Surgical excision was by elliptical incisions around the corn through the dermis allowing the corn to be dissected away from the underlying connective tissues. The pad was stitched using simple interrupted sutures placed away from the margins of the incisions (Fig 2). Suture materials used were 3 metric polyglactin 910 (Vicryl, Ethicon), 3 metric monofilament nylon (Monosof, Syneture) and 3 metric polypropylene (Surgipro, Syneture). No one type of suture proved to be preferable. The foot was placed in a protective dressing, changed at weekly intervals for three weeks, when the sutures were removed.

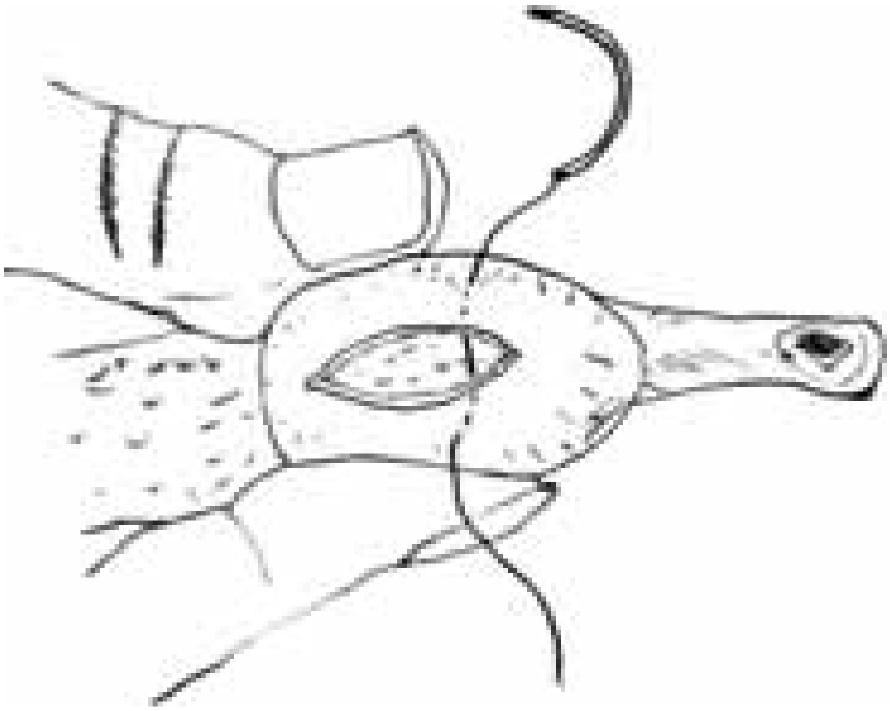

FIG 2. Excision surgery. The corn has been removed by full thickness pad incisions. Sutures are placed away from the margins of the incisions. An assistant provides haemostasis with digital pressure across the caudal pad

Distal digital ostectomy involved the removal of the distal condyles of the second phalanx together with any remaining bone and nail of the third phalanx. The pad was sutured on its dorsal aspect over the stump of the second phalanx (Brinker and others 1990). In order to prevent the pad from rotating dorsally a full thickness oval skin excision was made just caudal to the palmar/plantar aspect of the pad and closed. Corn excision was undertaken only if the corn would still be on the weight-bearing part of the pad after the reconstruction.

Follow-up was between one and five years and was either by telephone or by re-examination. The recurrence of lameness or subsequent surgery was recorded.

Twelve excised corns from eight cases within the study and three cases seen subsequent to the study, were sent for histopathological examination. Three normal distal digits from the third phalanx of the thoracic limb from greyhounds, and two from German shepherd dogs, were submitted for comparative histology. The dogs had been euthanased for unrelated problems.

The samples for histopathology were fixed in 10% neutral buffered formalin. The specimens were sectioned longitudinally in a craniocaudal direction through the paw pad corns. The tissue was then put through a standard histological processing, embedded in paraffin wax and 3 to 4 µm sections stained with haematoxylin and eosin using an automatic staining system.

Five pads with corns were radiographed for signs of foreign bodies.

RESULTS

There were 13 retrospective and 17 prospective cases. The minimum follow-up period was one year and the maximum five years. Of the 30 cases seven (23%) had multiple corns (Table 1) making a total of 40 corns. Thirty-six corns were in the digital pads of the thoracic limbs and four were in the digital pads of the pelvic limbs. Anatomical distribution of the corns was tabulated (Table 1). Age distribution was spread from 2 to 15 years (Table 1). The breeds involved were racing and pet greyhounds, racing and pet Whippets and greyhound crosses (Lurchers) (Table 1). The sex ratio was 25 males to five females and nine of the males and all five of the females were neutered (Table 1).

A concomitant lesion in the same limb as the corn was seen in two dogs and this was carpal hyperextension, and concomitant lesions in the same digit as the corn were seen in 10 dogs and these were deep digital flexor tendon rupture (n=6), superficial flexor tendon rupture (n=1), phalanx (P) 2/3 ankylosis (n=1), P2/3 subluxation (n=1) and P3 amputation (n=1). The deep digital flexor ruptures were classified as complete (n=3) or incomplete (n=3).

Fifteen corns were submitted for histopathological examination. A variety of changes were seen; however, two distinct histological patterns were found. These patterns were as follows:

1. Acanthosis with marked orthokeratotic and parakeratotic hyperkeratosis, fissuring of the stratum corneum and loss of the normal rete ridges forming plaque-like areas of pad epidermis (Fig 3). These changes were similar to those described in the literature as paw pad keratoma or paw pad corn (Gross and others 2005).
2. Sinus tracks lined by keratinising epidermis running from the surface into the dermis and subcutis associated with variable amounts of dermal and subcutaneous necrosis, granulation tissue formation and fibrosis (Figs 4 and 5).

In the first described pattern (case 19) a plant foreign body was found embedded in the stratum corneum overlying the acanthosis (Fig 6).

Five digital pads were radiographed (Table 1) and one (case 8) had a radiopaque foreign body (grit) within the pad. This was surgically removed and a subsequent corn excised three weeks later. No other foreign bodies were found at surgery.

At the primary treatment 34 corns were surgically excised, three had distal digital ostectomies and three had no treatment (cases 13 and 18). In the 27 dogs that had surgical excisions, one dog remained lame after the initial surgery, two dogs were less lame and there was recurrence of lameness in 11 dogs.

Three dogs (four corns) (cases 3, 9 and 12) had the surgical excision procedure repeated for recurrence, one dog four times and three dogs twice. The mean period between successive surgeries was 20 months.

The three dogs that underwent distal digital ostectomies had no recurrence of lameness.

Of the normal digits submitted from three greyhounds and two German shepherd dogs no difference was found in the gross anatomy between the two breeds.

CLINICAL SIGNS

The corns presented as a circular hard areas of hyperkeratosis usually around the centre of the digital pads (Fig 1). Some protruded above the pad surface and often had a softer centre mimicking the appearance of a foreign body penetration wound. Pain could be elicited by dorsopalmar digital pressure across the pad. The degree of lameness varied from non-weight bearing to being pain-free on certain affected digits (cases 13 and 18). Lameness usually had a gradual onset and was progressive although an acute onset of severe lameness was seen (cases 14 and 24). Typically the lameness was more severe when walking on hard surfaces. The nails were often less worn on the affected foot due to a tendency to bear weight on the metacarpal or metatarsal pad.

DISCUSSION

The definition of a paw pad corn in the dog is similar to that of the hard corn in man; it is a circumscribed hyperkeratotic lesion with a central conical core of keratin that causes pain and inflammation (Freeman 2002).

It is reported that corns occur almost exclusively in racing or retired greyhounds (Gross and others 2005) but this study shows that corns are a common cause of lameness in both greyhounds and related breeds. The lower incidence of Lurchers and Whippets in this study probably reflects the case load of the hospital. The incidence within the breeds could not be determined.

Diagnosis was made by the clinical appearance of a hard circular area of

Table 1 Breed, age and anatomical distribution of corns together with treatments and outcome

Case number	Breed	Age	Gender	Left fore digits	Right fore digits	Left hind digits	Right hind digits	X-ray	Histology	Recurrence	Comcomitant injuries
1	Racinggreyhound	3	M				5				None
2	Racinggreyhound	3	M	3	4			Yes		1 year	DDFT complete
3	Whippet	7	MN		4					3 years	None
4	Greyhound	4	MN		4					2 years	None
5	Lurcher	11	MN	3							None
6	Greyhound	5	FN	3							None
7	Greyhound	7	MN	3							None
8	Greyhound	6	MN		3			Yes – grit			None
9	Whippet	8	MN	3	3				Yes × 2	1 year	Carpalhyperextension
10	Greyhound	9	FN	4	4					6 months	None
11	Greyhound	10	MN	4						1 year	None
12	Greyhound	8	M			4	4		Yes × 2	1 year	DDFT × 2 incomplete
13	Whippet	4	M	3 & 4	4					1 year	Bilateral carpal hyperextension
14	Racinggreyhound	2	M		3						None
15	Racinggreyhound	2	M				4				P2/3 ankylosis
16	Racing whippet	3	M		2						None
17	Racing whippet	3	M	4						2 months	DDFT complete
18	Greyhound	6	M	3 & 4	3 & 4			Yes	Yes × 2	2 months	None
19	Lurcher	5	FN	3 & 4					Yes × 2		None
20	Racinggreyhound	2	M	4							None
21	Racing whippet	5	MN		4			Yes			DDFT complete
22	Greyhound	6	M	2						6 months	SDFT
23	Racinggreyhound	3	FN	3					Yes		None
24	Racinggreyhound	3	M		4			Yes	Yes	Less lame	None
25	Racinggreyhound	6	M		4				Yes	Less lame	None
26	Lurcher	6	MN	4					Yes		DDFT incomplete
27	Greyhound	7	M		3						None
28	Whippet	9	M		4					lame	DDFT incomplete
29	Greyhound	15	FN	4							P2/3 luxation
30	Racinggreyhound	2	M	4							P3 amputation

M, male, F, female, MN, male neuter, FN, female nueter, DDFT, deep digital flexor tendon, SDFT, superficial digital flexor tendon, P, phalanx.

hyperkeratosis on the pad with digital pressure across the lesion eliciting a pain reaction. Three of the corns present in the dogs with multiple corns were considered asymptomatic and were not treated. Diagnosis was by visual appearance alone. Many of the excised corns had a hard cylindrical root with a soft core (Fig 7). Typically the corn was in the central weight-bearing area of the digital pad. Histological confirmation was made in 12 cases within the study and three cases seen subsequent to the closure of the study.

The most common differential diagnosis is a foreign body within the pad. Acute cases of foreign bodies have an entry wound and often exude serous fluid. Secondary changes to the pad with a superficial appearance similar to a corn may be apparent in chronic cases, especially if removal has been attempted. Radiography will detect grit, metal or glass foreign bodies but not plant material.

Other pad lesions include pad papilloma (Balara and others 2009) and epidermal cysts but they present with different physical appearances (personal observation by MJG). Canine papillomas and epidermal cysts have characteristic histopathological features neither of which were seen in the pad lesions of the dogs in this study.

The degree of lameness is variable and is typically worse when ambulating on hard surfaces when the core of the corn is pushed into the subdermal tissues. Two cases presented as an acute onset non-weight bearing lameness subsequent to racing. Surgical excision showed a mature

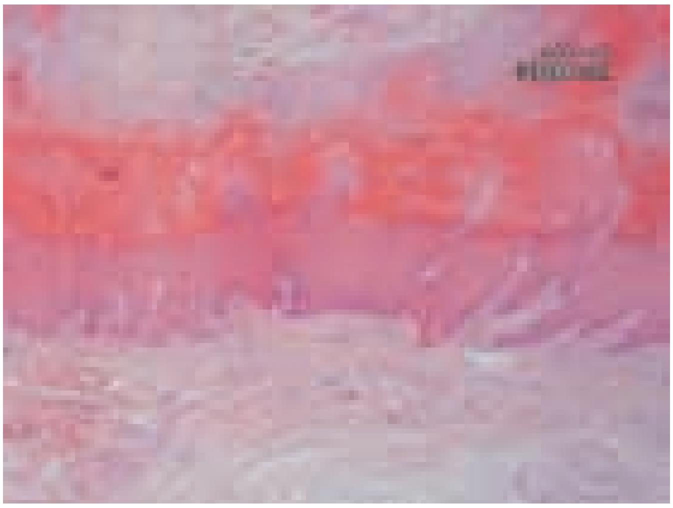

FIG 3. Case 12: plaque-like lesion showing marked orthokeratosis and parakeratotic hyperkeratosis

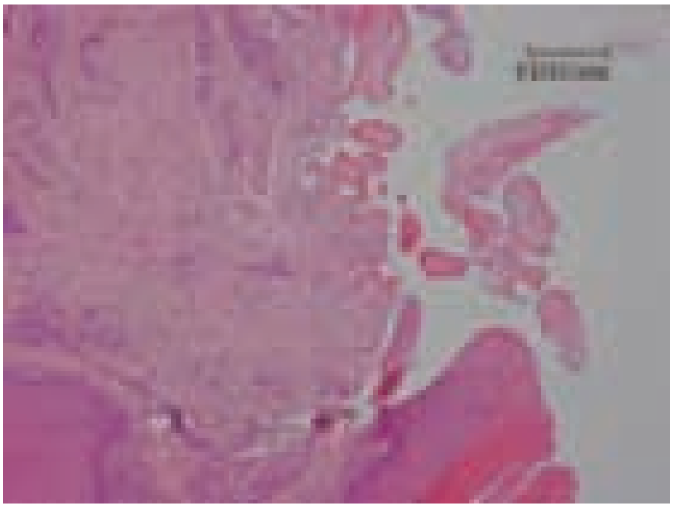

FIG 4. Case 26: a tract lined with granulation tissue and fibrosis which appears to be continuous with the base of a keratin-filled corn core

corn with contusion of the subdermal tissues.

Excessive nail growth on the affected foot results from decreased wear as the dog attempts to weight bear on the metacarpal or metatarsal pad rather than the digital pads.

Thirty-six (90%) of the corns were found in the digital pads of the thoracic limbs and 36 (90%) corns were located in the pads of digits three and four. Vertical forces exerted by dogs during walking on the thoracic limb foot pads is about 1.1 times the body weight and for pelvic limb foot pads the vertical force is 0.8 times the body weight (Hutton and others 1969). It has been shown that digital pads three and four are the main weight-bearing pads (Faulkner Besancon and other 2004). The predilection for digital pads three and four in the thoracic limbs may be in part, due to higher ground reaction forces.

The age range reported is middle age or older (Gross and others 2005) but this study had an age spread from two years to 15 years with all 10 of the dogs under four years of age being either racing greyhounds or racing Whippets. Four of these dogs had concomitant lesions. No corns were recorded in dogs younger then two years of age and this could suggest that repetitive mechanical trauma over a period of time, associated with racing, is necessary for the development of the lesions in younger dogs.

The gender ratio is five males to one female but the ratio of males to females in racing greyhounds found in a study of 6687 dogs is 64:36 (Richard Payne, personal communication). The probability is that the gender ratio of the pet greyhounds will be similar to that of the racing greyhounds as the majority will be rehomed racing animals. Taking this into account there is still a gender bias towards the male (P=0.0522).

From a study of the track data of 2499 racing greyhounds it was found that the average weight of male racing greyhounds is 32.7 kg and that of the females is 27.6 kg (Richard Payne, personal communication) and this sex-related weight difference is reflected in all breeds. However, the heavier larger males will probably have proportionally increased pad areas and would therefore have similar ground reaction forces to the females.

Toe deformities are a common cause of corns in man (Freeman 2002). Concomitant anatomical deformities of the foot were found in 12 cases (40%) in this study. The most common deformity (n=6) was damage to the deep digital flexor tendon causing an elevated nail and more caudal weight bearing on the digital pad. The digits with a complete rupture (cases 2, 17 and 21) had a marked dorsal elevation of the nail. A diagnosis of incomplete rupture of the deep digital flexor tendon (cases 12, 26 and 28) was made by manually extending the limb and observing increased nail elevation in the affected digit. The pathogenesis of this condition is unclear as it could be due to a primary damage to the tendon or secondary to the development of the corn. Partial carpal hyperextension seen in two Whippets caused a compensatory hyperflexion of the digits. Three dogs had anatomical dysfunction of the distal digits through previous surgery (P3 amputation, P2/3 ankylosis), or from trauma (P2/3 subluxation).

Suggested reasons for the exclusivity of corns to the greyhound types include anatomical differences in the foot and in the cushioning action of the pads. greyhounds have long narrow feet with little distance separating the digital pads from

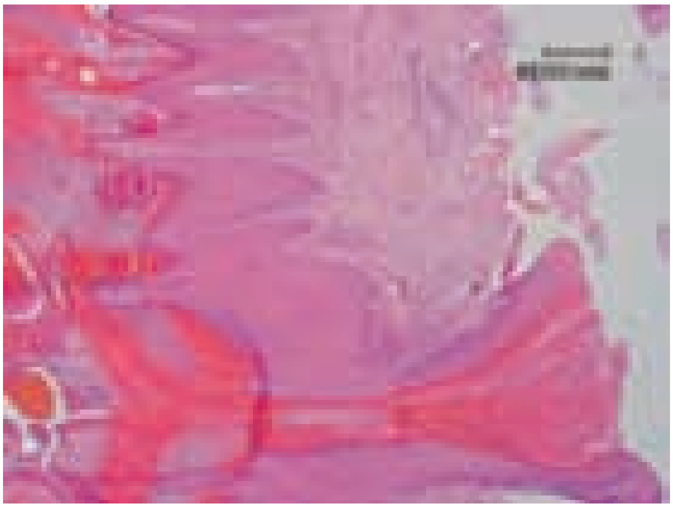

FIG 5. Case 25: corn filled with keratin leading into a deep dermal sinus tract lined by inflammatory granulation tissue

FIG 6. Case19: embedded foreign body in the stratum corneum overlying the acanthosis

each other in contrast to Labrador retrievers with wide-based feet, thereby increasing the ground reaction forces (Faulkner Besancon and others 2004). greyhounds have a scarcity of adipose body tissue compared to other breeds and therefore less subdermal connective tissue would decrease the cushioning of the pads against the flexor process of P3 (Borghese 2003). The histological comparison of the normal digital pads of greyhounds with German shepherd dogs showed no obvious differences.

The average velocity of a medium-grade racing greyhound is 36 miles per hour (extrapolated from track data) and during the gallop photographic evidence shows that the dog becomes airborne and lands initially on one extended foot of the thoracic limb on a firm sand surface. The ground reaction forces will therefore be very high and could account for the incidence of corns in the younger dogs. It is not apparent why corns develop in the more mature dog without concomitant toe deformity although the central thoracic limb paw pads would still be exposed to high ground reaction forces on fast exercise. There may be a genetic predisposition in sight hounds.

The majority of the corns (n=34) in 27 dogs were treated by surgical excision and this was successful in the short term (up to one year) in 20 cases (74%), but in the longer term (up to five years) 14 dogs had a recurrence of lameness due to corn regrowth (52%). The true recurrence figure is probably higher as the minimum follow-up was one year and a recurrence was only noted if the dog became lame.

Treatment by distal digital ostectomy was successful in all three cases. In two of the cases the corn was not removed but resolved naturally when the weight-bearing area of the pad was altered.

The aetiology of canine paw pad corns is reported as being mechanical, as a sequel to foreign body penetration, or from a papilloma virus infection (Davies 1973, Blythe and others 1994, Swaim and others 2004, Gross and others 2005). In man corns are a consequence of the mechanical influences of poorly fitting shoes, foot deformities and high activity levels (Singh and others 1996, Freeman 2002, Menz & Morris 2005). The results of this study tend to support a mechanical aetiopathogenesis in some of the cases because of the following:

1. The selectivity of the digital pads three and four in the thoracic limbs with naturally occurring higher ground reaction forces, especially during galloping.
2. The high incidence of concomitant foot deformity causing abnormal weight bearing on the pad.
3. The fact that two corns resolved naturally after surgery to the distal digit.
4. The exclusivity of corns to racing activity in the younger dogs.

There is also some evidence to implicate foreign body penetration as the cause of corns. The histological finding of a small piece of plant material embedded in the epidermis (Fig 6) in one case could easily have been a secondary penetration through the softer core. The grit foreign body seen on the radiograph was found deep in the subdermal tissues preceding the development of a corn. In two cases (27 and 28) within the study and two cases subsequent to the study the histology was very suggestive of a foreign body or foreign body penetration with the finding of sinus tracts lined with keratinising epidermis. It is possible that as a result of a

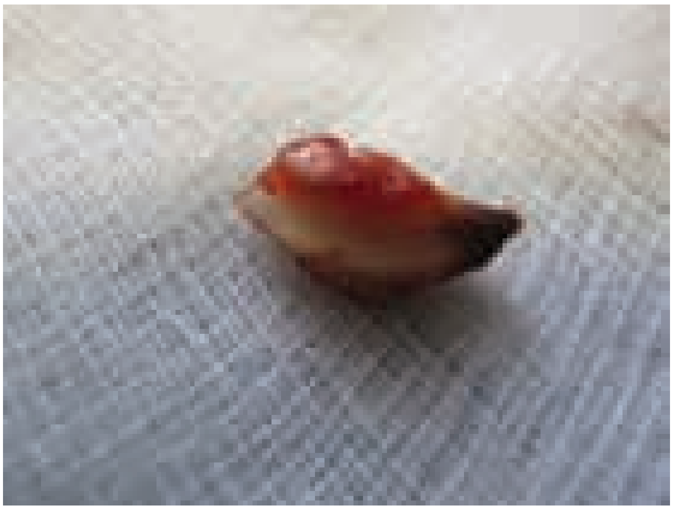

FIG 7. An excised corn showing superficial hyperkeratinisation and the cylindrical sinus track extending into the subdermis

penetrating injury, the sinus tracts become epithelialised and therefore do not heal. However no foreign bodies were found during surgery and only one of the dogs had a previous history of a penetrating wound.

Foreign body penetration would be selective to the central digits of the thoracic limb due to the higher ground reaction forces in these digits that would increase the risk of penetration but a sharp foreign body could enter any pad. Foreign body penetration was not recorded over a two-year period at a licenced greyhound stadium running up to 500 greyhounds a week (personal data MJG).

Papilloma virus infection results in skin warts and is seen occasionally by one author (MJG) in the feet of greyhounds but the pad papilloma with its different clinical appearance, was not observed in the breed. Electron microscopic examination of corns that had been removed did not find papilloma virus (Swaim and others 2004), and immunohistochemical staining and polymerase chain reaction (PCR) assay failed to find evidence of a viral aetiology in the paw pad lesions of 18 greyhounds (Balara and others 2009).

It therefore appears that paw pad corns in greyhounds and sighthounds may occur as the result of mechanical trauma or foreign body penetration.

Surgical excision gives reasonable short-term results (74%) but less good long-term results (less than 50%), although some dogs will have no recurrence throughout their lives. The reasons for failure could be due to poor surgical technique but more likely are due to the fact that the underlying mechanical factors are not corrected. The incidence of recurrence for dogs with concomitant deformities (7 of 9 cases) was twice that of dogs with no foot deformity (7 of 18 cases). In selective cases distal digital ostectomy would seem to give good results.

Repeated surgical excisions proved to be an effective way of management in three recurrent cases.

None of the other reported treatment regimes offers a reasonable prognosis and many are at best palliative (Swaim and others 2004, Gross and others 2005, Balara and others 2009). In the authors' opinion, in spite of the disappointing results, surgical excision should be considered as the initial treatment in the majority of cases as it can be curative.

Acknowledgements

The authors would like to thank Richard Payne MA, Vet MB, Hon F Inst RVAP, MRCVS, for allowing the use of his unpublished research material, and the British Veterinary Orthopaedic Association for a grant towards the study.

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PAPER

Third tarsal bone fractures in the greyhound

OBJECTIVE: To describe the signalment, morphology, response to treatment and prognosis of third tarsal bone fractures in the racing greyhound.

METHODS: All third tarsal bone fractures seen by the author over a ten year period were included in the study. Diagnosis was by radiography. Treatments were reconstruction with a lag screw, fragment removal, centrodistal joint arthrodesis or conservative management.

RESULTS: Twenty-three cases were included in the study of which 16 cases were recent and seven cases chronic fractures. The chronic cases had been rested from between three and six months before an examination for recurrent lameness. There were five concomitant second tarsal bone fractures. Partial dorsal collapse was present in four cases. Thirteen dogs had lag screw fixation; three were lost to follow-up, seven returned to racing and three, all with partial tarsal collapse, failed to return to racing. Two dogs that had a centrodistal joint arthrodesis and one dog treated by rest alone raced again. Two dogs that had fragment removal failed to return to racing.

CLINICAL SIGNIFICANCE: Veterinary examination of greyhounds with third tarsal bone fractures is often not sought at the time of the initial injury due to the benign presenting signs. Recurrence of lameness after rest is common. The prognosis for a successful return to racing would appear to be good following fragment fixation in both acute and chronic cases without dorsal tarsal collapse. Centrodistal joint arthrodesis may encourage bone union. The prognosis for conservatively treated cases is guarded. Fragment removal is not recommended as a treatment.

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Journal of Small Animal Practice (2010) **51**, 635–641

DOI: 10.1111/j.1748-5827.2010.01004.x

Accepted: 30 August 2010

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INTRODUCTION

In the racing greyhound, injuries to the tarsus are common. These represent in two separate surveys approximately 6% of all injuries. Sixty per cent of these injuries were considered to be fractures and 23% sprains (Prole 1976, Agnew 1992).

Fracture of the central tarsal bone is the most common injury and is often associated with concomitant fractures of the calcaneus, fourth tarsal (T4), second tarsal (T2) and the base of fifth metatarsal bone (Boudrieau and others 1984).

The third tarsal bone (T3) is part of the distal row of tarsal bones and articulates proximally with the central tarsal bone, laterally with the T4, medially with T2 and the base of the second metatarsal bone and distally with the third metatarsal bone (Evans and Christensen 1979).

Fractures of T3 are reported but the incidence is low. In the two surveys of racing injuries (Prole 1976, Agnew 1992) only one case was seen. The clinical signs are mild with localised slight swelling and a moderate degree of lameness that rapidly improves and unless radiographs of the tarsus are taken, a misdiagnosis of a sprain may be made (Vaughan 1987).

Due to the benign clinical signs many of these fractures are treated conservatively and carry a fair to poor prognosis for a return to successful racing (Dee and others 1990). The recommended treatment is by lag screw fixation and carries a good prognosis. Some cases have a concomitant fracture or luxation of the second tarsal bone (Dee and others 1990, Dee 1998).

T3 fractures, however, are relatively common injuries, and this paper describes their signalment, morphology, response to treatment and prognosis.

MATERIALS AND METHODS

A seven-year retrospective and a three-year prospective study was undertaken on all racing greyhounds diagnosed with tarsal injuries by the author. All the dogs in the retrospective study were examined at Nantwich Veterinary Hospital and the dogs in the prospective study were examined either at the above hospital or at a licensed greyhound stadium.

The diagnosis of T3 fracture was confirmed by radiography. Orthogonal mediolateral and dorsoplantar radiographs and in some cases oblique medioplantar laterodorsal views were taken.

The affected tarsus, fracture morphology, chronicity of the injury, the presence of partial tarsal collapse, treatment and outcome were recorded.

Of the dogs treated surgically three procedures were used: fragment removal, reduction and fixation of the fracture with a lag screw and centrodistal joint arthrodesis.

The surgical approach was the same for all procedures. With the dog in dorsal recumbency and the pelvic limb fully extended, the distal limb was exsanguinated with a sterile bandage (Co-Plus; BSN medical) that was tightened over the distal tibia to form a tourniquet. A proximodistal skin incision was made just medial to the mid dorsal line over T3. Subcutaneous connective tissues are reflected off the underlying bone. The palpable bases of metatarsal bones 2 and 5 help to identify the distal limit of T3. Other surgical landmarks were the joints between T3 and the surrounding bones detected by stab incisions into the joint spaces with a scalpel blade. T2 was then identified medial to T3 and its integrity determined.

Fragment removal was straightforward. Fragment reduction was achieved with either single- or double-pointed bone reduction forceps across T3. A hole was drilled through the centre of the fragment into the body and plantar process of T3 using a 1·5-mm drill bit. The hole in the fragment was overdrilled with a 2-mm drill bit, countersunk and the depth of the hole measured. It was then tapped and a 2-mm cortical bone screw inserted (Fig 1). A similar method was used to fixate T2 with the hole drilled in a lateroplantar direction across the distal tarsus (Fig 2). Closure was with skin sutures only.

Perioperative analgesia was with a premedicant of 0·25 mg/kg morphine (Morphine sulphate; Martindale Pharmaceuticals), 0·4 mg/kg ketamine (Ketaset; Fort Dodge Animal Health), 0·006 mg/kg acepromazine (ACP injection; Novartis) and 0·004 mg/kg medetomidine (Domitor; Pfizer Ltd) together with an epidural injection of 3·5 mg/kg 2% lidocaine hydrochloride (Lidocaine injection; Braun). A preoperative injection of a non-steroidal anti-inflammatory drug was given and was followed by oral administration for a further 5 days.

The distal limb was kept bandaged for several days to reduce postoperative swelling. The cases that had tarsal collapse or T2 injury were supported in a dressing incorporating a lateral splint for up to 6 weeks.

Centrodistal joint arthrodesis was achieved by drilling the centrodistal and T3/T2 joint spaces with a 1·1-mm drill bit. There was no surgical interference with the tarsometatarsal joint.

The trainers were instructed to confine the dog to a kennel and small run for 8 weeks with exercise on the leash only.

FIG 1. Case 3: placement of a 2-mm lagged cortical screw through the fragment into the body of T3

FIG 2. Case 13: screw fixation of both T3 and T2 fractures. There is a dorsal slab fracture of T2 that was not fixated

After 12 weeks the dog was put into full training.

Dogs that were not treated surgically were either retired from racing or were rested.

Successful treatment was viewed as a return to previous racing form. In the retrospective study, this was by speaking to the trainer between 6 months and 1 year after the surgery. Follow-up on the dogs in the prospective study was by either observing the dogs racing or accessing the race results from the website of the Greyhound Board of Great Britain (www.thedogs.co.uk).

RESULTS

In the survey of 113 tarsal fractures seen by the author, fractures of the central tarsal bone occurred in 79% of cases with concomitant fractures of other tarsal bones seen in 61% of these cases. Apart from the central tarsal bone and one T4 fracture the only isolated fractures were in T3.

There were 12 retrospective and 11 prospective T3 fractures. Twenty-two fractures were in the right T3 and one was in the left T3.

The clinical signs in most cases were of a mild lameness of a few days duration with little soft tissue swelling over the dorsal aspect of the tarsus. Pain could be elicited by applying digital pressure across the fractured bone. Rarely would the dog slow down in the race in which the injury occurred, but lameness would be apparent after a short rest.

The fractures were classified into two radiographic types. Type I fractures had a non- or minimally displaced dorsal slab fracture (Fig 3). Type II fractures had a dorsally displaced slab fracture (Fig 4). The difference in the degree of dorsal displacement between the two types cannot be precisely defined but acts as a guide to the fracture morphology.

FIG 3. Case 1: a type I fracture with minimal dorsal displacement

FIG 4. Case 12: a type II fracture with dorsal displacement, comminution and partial dorsal collapse. The lines drawn parallel to the calcaneus and metatarsus show the degree of collapse

There were 12 type I fractures, 9 type II fractures and 2 old fracture cases in which the type could not be determined due to callus formation. Concomitant T2 injury was diagnosed in five cases.

Sixteen cases were presented as recent acute injuries and seven cases were classified as chronic with the fracture occurring from 3 to 6 months before lameness examination.

Eleven of the type I fractures were diagnosed on mediolateral radiographs and one case could only be identified on the oblique view (Fig 5). T2 fractures were diagnosed on dorsoplantar radiographs only (Figs 6 and 7).

Four cases showed a degree of dorsal tarsal collapse with hyperflexion of the tarsometatarsal joints 2 and 3. The plantar aspects of the calcaneus and the metatarsus on the mediolateral radiograph in the normal distal limb are parallel, whereas the partially collapsed tarsus hyperflexes about 10° (Fig 4).

The success of the various treatments together with fracture morphology is presented in Table 1.

DISCUSSION

Fractures of T3 have been infrequently reported with a seemingly low incidence. Many of these fractures will have been misdiagnosed as tarsal sprain injury (Vaughan 1987) and without radiographic confirmation an accurate diagnosis is impossible. Tarsal sprain injuries had a reported incidence of 23% of all tarsal injuries in the two track surveys (Prole 1976, Agnew 1992) and this is very similar to the 20% incidence of T3 fractures in this publication. The assumption therefore is that many of the tarsal sprain injuries were in fact T3 fractures.

Not all cases of tarsal sprain injury will be misdiagnosed T3 fractures. The author has seen nine cases of idiopathic tarsal pain in addition to the 113 diagnosed tarsal bone fractures.

The clinical signs of T3 fractures are well documented with the majority showing transient lameness with little swelling (Vaughan 1987, Dee and others 1990, Dee 1998). A high degree of suspicion can be made if focal pain is found on digital pressure to the dorsal aspect of T3. A similar presentation can be seen with type I and II central tarsal bone fractures (author's observation).

FIG 5. Case 6: a medioplantar laterodorsal oblique view showing a type I fracture

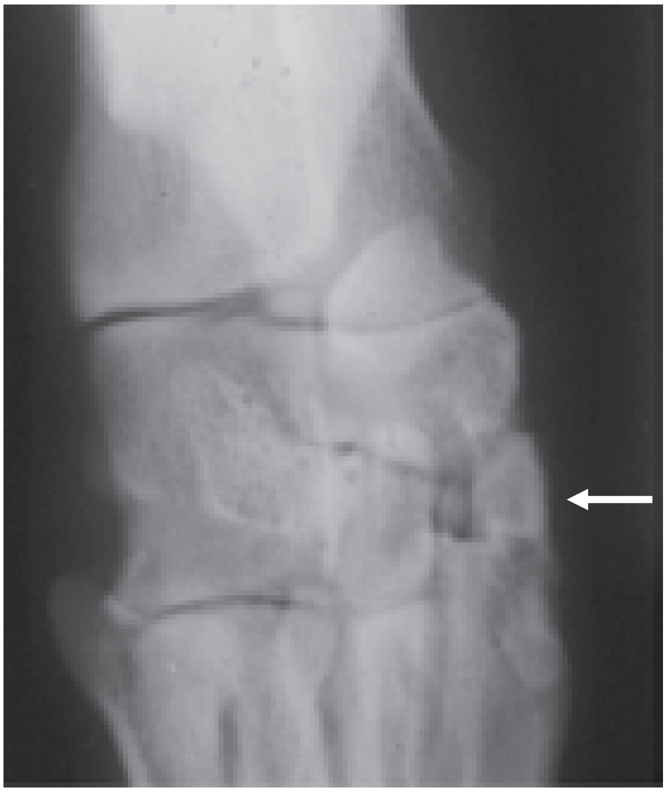

FIG 6. Case 13: a medial T2 fracture

FIG 7. Case 21: a T2 fracture with slight lateral displacement

Table 1. Fracture morphology, chronicity, treatment and outcome

Case no.	Type	Age	T2	Collapse	Treatment	Outcome
1	I	Acute			Screw	Lost to follow-up
2	I	Acute			None	Retired
3	I	Acute			Screw	Lost to follow-up
4	II	Acute		Collapse	Fragment removal	Failed
5	II	Acute			Screw	Lost to follow-up
6	I	Acute			Screw	Raced
7	I	Acute			Screw	Raced
8	I	Chronic			Screw	Raced
9	II	Acute	T2		Two screws	Raced
10	?	Chronic			Fragment removal	Failed
11	II	Chronic		Collapse	Screw	Failed
12	II	Acute		Collapse	Screw	Failed
13	II	Acute	T2	Collapse	Two screws	Failed
14	?	Chronic			None	Retired
15	II	Acute	T2		Two screws	Raced
16	I	Chronic			CD arthrodesis	Raced
17	II	Acute	T2		None	Retired
18	I	Chronic			CD arthrodesis screw	Raced
19	I	Acute			Screw	Raced
20	I	Acute			None	Retired
21	I	Acute	T2		None	Retired
22	I	Acute			None	Raced
23	II	Chronic			None	Retired

CD Centrodistal
? Not defined

Orthogonal radiographs of the tarsus are mandatory with the mediolateral view usually showing pathological changes. The medioplantar laterodorsal view may detect a fracture in cases where no fracture is apparent on the standard views (Fig 5).

Seven cases were presented as a recurrent lameness from 3 to 6 months after the original injury. The consistent radiographic appearance was of irregular periosteal new bone on the dorsal aspect of T3 with the periosteal reaction occasionally extending to the central tarsal bone and the third metatarsal bone (Fig 8). The fracture line may or may not be apparent. In two cases there was an obvious non-union on surgical exploration.

The morphology of T3 fractures is difficult to interpret with standard radiography. Some have the appearance of a simple dorsal slab fracture with little displacement (type I), whereas others have a larger dorsal fragment that may or may not show signs of comminution (type II). Dorsal tarsal collapse evident on mediolateral radiographs was seen in four cases and suggests comminution of the T3 fracture.

The involvement of T2 was confirmed or suspected in five cases. Dorsoplantar radiographs may indicate displacement or fracture of this bone but a definitive diagnosis can only be made on surgical exploration at the time of fracture repair.

Computerised tomography would be superior in imaging the fracture lines and would allow a definite diagnosis, but due to financial constraints was not performed. None of the dogs in this series was euthanased as a result of their injuries and so further examinations were not possible.

Fractures of the tarsus in the racing greyhound are found almost exclusively in the right pelvic limb and this occurs with T3 fractures. It is thought to be from compressive forces when running the bends. The dorsal aspect of the tarsus is naturally in compression. The weight bearing axis of the distal pelvic limb is from the tibia, through the talus, central tarsal bone, T3 and T2 and into the metatarsus. In the UK, greyhounds always run in an anticlockwise direction. The centripetal force generated when running around the bends causes the dog to lean into the bend resulting in the aspect of the limbs closest to the inside of the bend to be in compression. This will therefore give additional compressive forces to the medial or weight bearing axis of the right tarsus.

The majority of tarsal fractures in the racing greyhound are classified as stress fractures. Adaptive remodelling of the bone occurs when bones are subjected

FIG 8. Case 11: a 4-month old fracture showing a diffuse demineralisation and osteophytosis on the central tarsal bone and the third metatarsal bone

to cyclic asymmetrical loading (Johnson and others 2000). This involves bone resorption followed by new bone formation indicated by increases in bone mineral density. Bone mineral density has been shown to be higher in the central tarsal bone, T3 and T2 of the right tarsus in normal racing greyhounds (Carol A. Hercock, personal communication). During remodelling bone is mechanically weaker and more susceptible to damage if subjected to further loading (Muir and others 1999).

Adaptive remodelling is found particularly on the dorsal and medial aspects of the central tarsal bone (Muir and others 1999) and the assumption is that the same remodelling will occur in T3 and T2. Linear microcracks are frequently seen in remodelled bone and are thought to be associated with an increased likelihood of fracture (Muir and others 1999). Microcrack density with branching is increased in fractured central tarsal bones in racing greyhounds (Johnson and others 2000, Tomlin and others 2000).

Conservative treatment is reported to carry a poor prognosis for a return to successful racing (Vaughan 1987, Dee and others 1990) and that appears to be evident from the chronic cases in this series. In some of these cases the recurrent lameness may be due to an inadequate rest period in view of the benign clinical signs and the lack of an initial diagnosis. The one case treated conservatively that returned to racing had a minimally displaced fragment. However, the prognosis for a return to full function as a pet is very good even with a degree of tarsal collapse.

Surgical treatments involved fragment removal in 2 cases and screw fixation in 13 cases. One case of screw fixation also had a centrodistal arthrodesis and there was one case treated solely by centrodistal arthrodesis. Fragment removal was undertaken in the early part of the case series to determine whether it provided a valid treatment method. Apart from these two cases screw fixation was offered as the recommended treatment in all but the one case that was treated by centrodistal arthrodesis alone.

Both dogs that underwent fragment removal failed to return to racing through lameness. A mediolateral radiograph of one case taken 4 months after the surgery showed the gap to be overfilled with diffuse new bone with irregular margins.

Internal fixation with a lagged 2·7-mm cortical screw is the recommended method of treatment (Dee and others 1990, Dee 1998), but the author's preference is a lagged 2·0-mm cortical screw due to the small size of T3. Of the 13 dogs that had screw fixation three cases were lost to follow-up and seven returned to successful racing. Of the three failures all had a dorsal tarsal collapse diagnosed on the initial radiographs. Correction of the tarsal collapse was not achieved by surgery and this may be from unidentified comminution preventing accurate reconstruction. Screw tightening appeared adequate. If partial dorsal collapse is present on the preoperative radiographs, determined attempts should be made to achieve good fragment reduction.

A centrodistal joint arthrodesis was performed in two of the chronic cases, in one case this was the sole surgical procedure as the fracture had the radiographic appearance of being partially healed with new bone attempting to bridge the centrodistal joint (Fig 9). The other case also had the placement of a compression screw. Drilling or burring the centrodistal and T3/T2 joints at several points has been shown to rapidly induce dorsal bony bridging of the centrodistal joint (Guilliard 2000, 2005). This ankylosis occurs naturally during the healing of comminuted central tarsal bone fractures in racing greyhounds and does not seem to be detrimental to racing performance.

The author would recommend accurate reduction and screw fixation in all cases; however, if there is a partial dorsal bridging of the centrodistal joint in the chronic case, an additional arthrodesis may be beneficial. Conservative management

FIG 9. Case 16: a type I chronic fracture treated by centrodistal joint arthrodesis alone

may be appropriate in some cases and this paper does not explore this possibility as the majority of the dogs retired as a result of the injury were quickly rehomed. In view of the long time period from injury to presentation in the chronic cases, internal fixation would appear to offer a shorter and more predictable recovery period.

Other limitations of the paper include poor veterinary and radiographic follow-ups of the failed cases mainly due to unavailability with owners retiring and rehoming the dogs.

In conclusion, the prognosis for a successful return to racing would appear to be good following fragment fixation for both acute and chronic cases without dorsal tarsal collapse. Centrodistal joint arthrodesis may encourage bone union. The prognosis for conservatively treated cases is guarded. Fragment removal is not recommended as a treatment.

Conflict of interest

The author of this article has no financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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