Review Article

Nonseptic osteitis of the distal phalanx and its palmar processes

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Keywords: horse; foot; pedal bone; nuclear scintigraphy; magnetic resonance imaging; side bone; bone trauma

Summary

There is a large spectrum of radiological variants of the distal phalanx that can be seen in both sound and lame horses. Osteitis of the distal phalanx implies active inflammation, a diagnosis that can only be made supported by nuclear scintigraphy, magnetic resonance imaging or computed tomography. Osteitis of the distal phalanx as a primary cause of lameness is relatively unusual, but may be the result of acute or chronic bone trauma or be associated with adjacent laminar disruption. Bone trauma may also be seen in association with moderate to extensive uniaxial or biaxial ossification of the cartilages of the foot. Bone lesions also occur in association with osteoarthritis of the distal interphalangeal (DIP) joint or at, or adjacent to, the insertion of one of the collateral ligaments of the DIP joint.

Introduction

Pedal osteitis strictly means inflammation of the distal phalanx and has long been suggested as a cause of forelimb lameness (Rendano 1979; Moyer *et al.* 1999; Stashak 2002). However, it is a poorly defined condition, previously diagnosed radiologically, characterised by focal or general demineralisation around the solar margin of the distal phalanx and widening of the vascular channels, with or without abnormal lucent areas in the palmar processes (Rendano 1979). It is now recognised that considerable variation exists in the radiological appearance of the distal phalanx in normal horses (Rendano and Grant 1978; Linford *et al.* 1993; Butler *et al.* 2008). Radiological changes of the distal phalanx, once established, often persist over the long term and are therefore not synonymous with active inflammation. Radiographs represent a historical record of previous activity or injury. The cause of pedal osteitis has not been defined, although abnormal concussion (Stashak 1987) or a solar variant of laminitis (Pool 1991) have been suggested. The gross and histopathological changes in the distal phalanx and adjacent laminae have also not been well described. This author therefore suggests that the term pedal osteitis is inappropriate and should not be used to describe a cause of lameness (Dyson 2003).

Nonetheless, a variety of radiological changes of the margins of the distal phalanx can be identified, the causes of which are poorly defined (**Figs 1** and **2**). With our current state of knowledge, attribution of lameness to these radiological changes seems inappropriate unless there are localising clinical signs, or concurrent evidence of active osseous or laminar pathology documented using magnetic resonance imaging (MRI), with or without abnormal bone turnover determined scintigraphically.

Anatomical considerations

The distal phalanx (pedal or coffin bone) is a unique bone, lacking a medullary cavity and having a remarkable blood supply. It is suspended within the hoof capsule by the epidermal laminae, integrated with the laminar corium, which attaches via Sharpey's fibres into the dorsal surfaces of the distal phalanx. The palmar processes or angles of the distal phalanx are prism-shaped masses that project backwards on the medial and lateral aspects of the bone. Each is divided into proximal and distal parts by a notch or is perforated by a foramen, that leads to the dorsal groove of the distal phalanx. In a normal horse the solar and abaxial surfaces of the palmar processes are relatively smooth, although there may be mild irregularity on the dorsomedial and dorsolateral aspects midway between the proximal and distal extremities. The cartilages of the foot attach to the proximal border of each palmar process. They originate as hyaline-type cartilage and

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Fig 1: a) Dorsoproximal-palmarodistal oblique radiographic view of a distal phalanx to show normal variation. Note the concavity at the toe, the crena, and the rather irregular solar margin of the bone. The oval-shaped radiolucent areas proximally (arrows), surrounded by a distinct relatively radiopaque rim are the areas of insertion of the collateral ligaments of the distal interphalangeal joint and are more obvious than in b) and c). b) Dorsoproximal-palmarodistal oblique radiographic view of a distal phalanx to show normal variation. Compare with a). There is no crena. There are a smaller number of vascular channels, which are broader, and the solar canal is more obvious. c) Dorsoproximal-palmarodistal oblique radiographic view of a distal phalanx. Medial is to the left. There is a solar margin fracture medial to the crena (arrow). The vascular channels are wider compared with a) and b), especially abaxially.

become fibrocartilage in adults. Their size and shape vary, as does the degree of ossification. The cartilages have axial extensions and provide an internal support structure for the palmar aspect of the foot (Bowker *et al*. 1998). An extensive network of venovenous anastomoses is present within the cartilages. Marked differences in the thickness and tissue composition exist in the front and hind feet. The cartilages of the foot tend to be thicker in forelimbs than in hindlimbs, perhaps reflecting the greater weightbearing capacity of the forelimbs (Bowker *et al*. 1998). The digital cushion has more fibrous or cartilaginous tissue in forelimbs than in matched hind feet, which have more adipose and elastic tissues. There may also be breed differences. An extensive and complex relationship exists between the cartilages of the foot and the digital cushion. Their combined role is thought to be energy dissipation, which is dependent on haemodynamic flow (Bowker *et al*. 1998).

The degree of ossification of the cartilages of the foot is breed dependent, with heavier types (cobs, Finnhorses, Ardennes) and large British Native Pony breeds having greater ossification than other breeds such as Irish Draught, Thoroughbred, Thoroughbred cross and Warmbloods (Ruohoniemi *et al*. 1993; Verschooten *et al*. 1996; Down *et al*. 2007). There is normally a similar ossification grade for medial and lateral cartilages, or the lateral cartilage is one grade higher (on a scale of 0–5) (Down *et al*. 2007).

The distal phalanx, together with the middle phalanx and navicular bone, are integral parts of the distal interphalangeal (DIP) joint supported medially and laterally by strong collateral ligaments (CLs) and dorsally by the common digital extensor tendon. The distal sesamoidean impar ligament (DSIL) and the deep digital flexor tendon (DDFT) insert on the palmar aspect of the

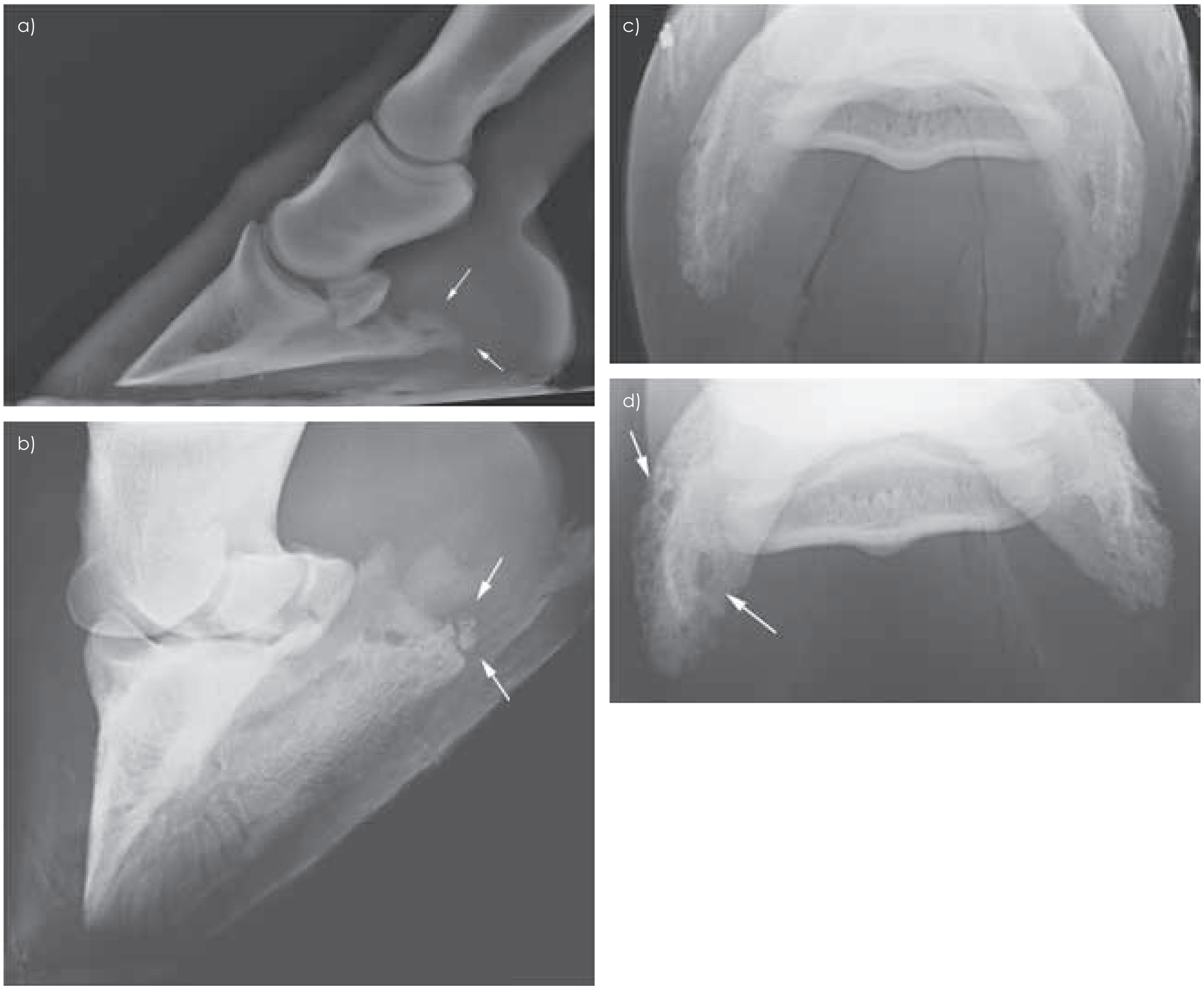

Fig 2: a) Lateromedial radiographic view of a foot with palmar elongation of the palmar processes of the distal phalanx (arrows). This was associated with increased radiopharmaceutical uptake. Note also that the sole is quite thin at the toe. b) Flexed dorsolateral-palmaromedial oblique radiographic view of a foot. There is a separate centre of ossification or an old fracture of the palmar aspect of the lateral palmar process of the distal phalanx (arrows). Note also the mild increased opacity of the most palmar aspect of the main part of the palmar process. These were incidental radiological findings. c) Palmar 45° proximal-palmarodistal oblique radiographic view of a foot to show the normal appearance of the palmar processes of the distal phalanx. d) Palmar 45° proximal-palmarodistal oblique radiographic view of a foot of a horse with low collapsed heel conformation. Medial is the left. Note the large radiolucent areas in the medial palmar process of the distal phalanx (arrows) and the generalised loss of opacity on the abaxial palmar aspect. This was associated with increased radiopharmaceutical uptake.

concave solar surface of the distal phalanx and also function in part to stabilise the DIP joint. The cartilages of the foot are joined to adjacent structures by a variety of ligaments that vary in size and definition. The chondrocompedal ligament attaches the palmaroproximal aspect of each cartilage to the proximal phalanx, with a medial branch to the distal phalanx. The chondrocoronal ligament connects the dorsal part of the cartilage with the middle phalanx and the chondrosesamoidean ligament runs between each cartilage and the ipsilateral aspect of the navicular bone.

Orientation of the distal phalanx

The orientation of the solar margin of the distal phalanx varies considerably. An often quoted figure is a 5–10° angle to the horizontal ground surface, sloping proximally toward its palmar aspect (**Fig 2a**). In a study of 34 clinically normal horses the mean angle between the solar surface and the horizontal ground surface was 6.1° ± 2.84° (Smith *et al*. 2004). In a recent study of 258 horses with foot-related pain the mean angle between the solar surface and the horizontal ground surface was 7.6° ± 5.3° (Nagy *et al*. 2008). There is currently no firm evidence to support the concept that an abnormally small angle of the distal phalanx or a thin sole alter the risk of injury of the distal phalanx, although a thin sole may predispose to solar bruising. So-called 'inversion' of the distal phalanx in hindlimbs, with the plantar processes lower than the toe, has been seen in association with more proximal sites of pain causing hindlimb lameness, such as proximal suspensory desmitis, but this author has not recognised this as a primary cause of hind foot pain.

Theoretically, the solar surface should be horizontally aligned from medially to laterally. However, a recent study in 258 horses with foot related pain showed that in the majority of horses (62.9%) the medial aspect of the distal phalanx was significantly closer to the ground surface than laterally (P<0.0001) (Nagy *et al*. 2008).

Conformation of the foot, shape and orientation of the distal phalanx

Until recently, there have been no good studies which have correlated gross foot conformation and orientation and radiological appearance of the distal phalanx. Angles measured from digital photographs of the lateral aspect of the feet of 300 horses with foot-related lameness and 50 horses free from lameness were compared with angles of the distal phalanx measured from radiographs (Dyson *et al*. 2010b). There were modest correlations between the dorsal hoof wall angle and angle of the solar margin of the distal phalanx (RS value 0.46, P<0.0001) or the concave solar surface of the distal phalanx (RS value 0.53, P<0.001). There were weak correlations between the heel angle and angle of the solar margin of the distal phalanx (RS value 0.42, P<0.0001) or the angle of the concave solar surface of the distal phalanx (RS value 0.40, P<0.0001). Thus, foot shape was not a particularly accurate predictor of the orientation of the distal phalanx, which was hugely variable between horses.

Radiological interpretation

The radiological architecture of the distal phalanx can be assessed in lateromedial, dorsopalmar and dorsoproximal-palmarodistal oblique views, with additional information about the palmar processes obtained from palmaroproximal-palmarodistal oblique and dorsomedial-palmarolateral and dorsolateral-palmaromedial oblique views. Chronic laminitis may be associated with modelling of the toe of the distal phalanx and bone resorption, with or without new bone on the dorsal aspect at the toe. Abnormal mineralisation has also been identified on the dorsal aspects of the distal phalanx, midway between the coronary band and the solar margin; mineralisation is seen best on lateromedial or oblique views (**Fig 3**). This may represent mineralisation in the dermal laminae or formation of new bone on the dorsal cortex of the distal phalanx. Extensive mineralisation has been associated with lameness, but some roughening of the dorsal cortex in the region of the parietal sulci may be an incidental finding. Some horses with a club foot conformation develop focal loss of bone around the solar margin at the toe of the distal phalanx and new bone on the dorsal aspect of the bone, associated with chronic lameness on hard ground. This author suggests that in these conditions the radiological changes should be described and attributed to the primary cause, rather than labelled as pedal osteitis. Many horses with poor foot conformation suffer chronic lameness, probably associated with abnormal stresses applied to both the soft tissue and bony elements of the foot. Identification of the primary cause of the problem may not be possible without MRI. Recognition that the precise source or sources of pain cannot be defined is preferable to the use of the term pedal osteitis, which implies a definitive diagnosis.

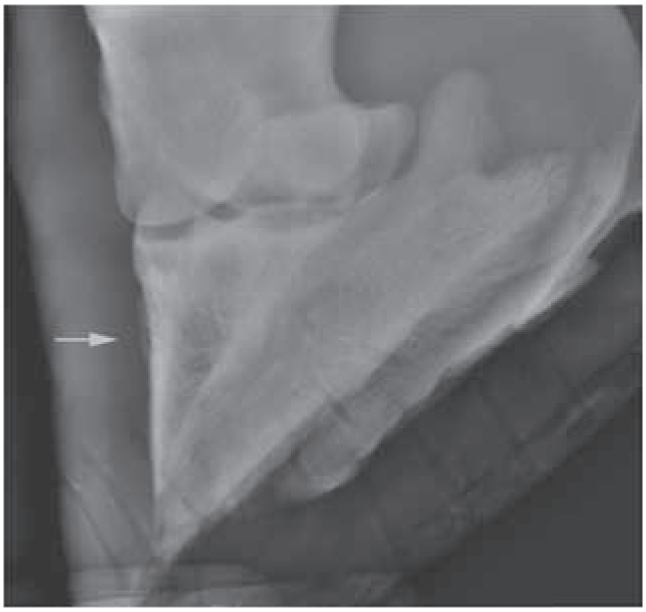

Fig 3: Dorsolateral-palmaromedial oblique view of a foot. Note the irregular new bone on the middle one-third of the dorsomedial aspect of the distal phalanx (arrow). This can be an incidental finding, although in some horses there has been localised laminar disruption identified using MRI.

In a comparative study of radiography, scintigraphy and MRI in 258 horses there was no relationship between the solar angle of the distal phalanx or solar thickness and the presence of increased radiopharmaceutical uptake (IRU) in one or both palmar processes of the distal phalanx (Nagy *et al*. 2008). Increased RU was significantly overrepresented in horses with diffuse cortical irregularity of the palmar processes of the distal phalanx (8.2%, P = 0.0199). However, there was no association between other radiological abnormalities (focal radiolucent zones, new bone formation on the ventral aspect of the distal phalanx or elongation of the palmar processes) and IRU.

In a separate correlative radiographic and scintigraphic study of the ossified cartilages of the foot, there was greater RU at the base of the ossified cartilages compared with proximally, especially in extensively ossified cartilages suggesting that this may be a significant stress point (Nagy *et al*. 2007). Increased RU was generally only seen in horses with moderate to severe ossification of the cartilages of the foot, usually at the base of the ossified cartilage or in the adjacent distal phalanx and correlated with the presence of detectable radiographic abnormalities in 25 of 38 (65.8%) feet in either the ipsilateral aspect of the distal phalanx or in the ossified cartilage. A comparative radiographic and scintigraphic study of the distal phalanx in 62 lame horses showed best correlation between IRU and either a fracture of the distal phalanx or abnormal ossification of one or both cartilages of the foot (Azrib and Ueltschi 1999).

Nuclear scintigraphy

In a comparative radiographic, scintigraphic and MRI study in 258 lame horses, focal IRU was more commonly seen in the medial palmar process of the distal phalanx than in the lateral palmar process (Nagy *et al*. 2008). Focal IRU was over represented in palmar processes with alterations in signal intensity in MR images and was more prevalent in lame than nonlame limbs. The mediolateral distribution may be a reflection of biomechanical loading (Chateau *et al*. 2006). However, it was comparatively unusual to ascribe the primary cause of lameness to abnormalities of the palmar processes of the distal phalanx (Nagy *et al*. 2008).

Increased RU may be seen at and immediately palmar to the site of insertion of an injured CL of the DIP joint (Dyson and Murray 2007a,b; Dyson *et al*. 2008; Dakin *et al*. 2009) and may extend throughout the ipsilateral palmar process of the distal phalanx. This suggests that in association with CL injury there may be trauma of the ipsilateral aspect of the distal phalanx palmar to the insertion of the CL. This observation is supported by a comparative MRI and *post mortem* study in horses with CL injury and control horses (Dyson *et al*. 2008). In several horses with chronic CL injury there was an irregular spiculated appearance of the cortex of the solar aspect of the distal phalanx in the same frontal plane as the insertion of the CL. This was due to bone loss and infilling by fibrovascular tissue, probably the result of repetitive abnormal concussion.

In lame horses IRU may be localised to the solar margin of the distal phalanx, especially around the toe region (**Fig 4**). This has been seen in association with a gait typical of laminitis but in the majority of horses digital pulse amplitudes have been normal and there has been no response to application of hoof testers. In many horses there are no detectable radiological abnormalities; however, in a small number there is increased thickness of the dorsal hoof wall, suggestive of chronic laminitis. This author has called the condition atypical laminitis and horses have generally responded well to treatment with phenylbutazone, corrective trimming and shoeing

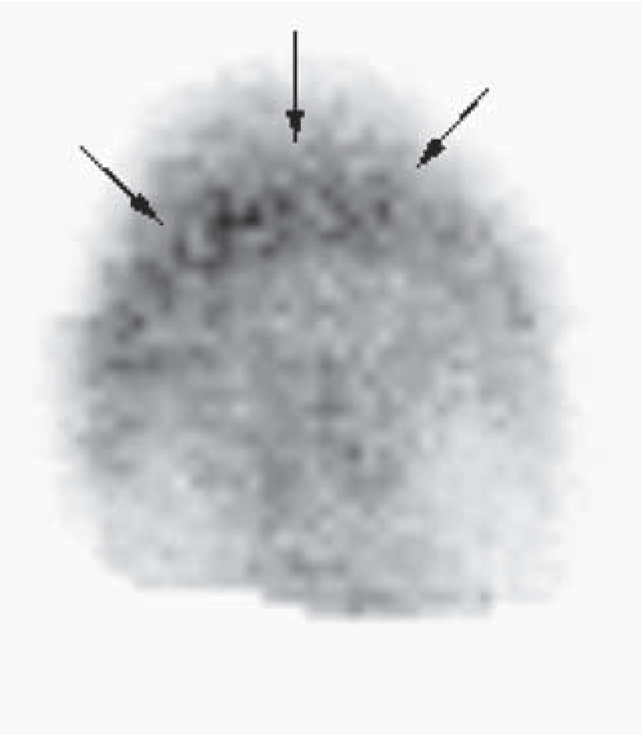

***Fig 4:** Solar scintigraphic image of a foot. There is curvilinear moderate increased radiopharmaceutical uptake around the solar margin of the distal phalanx (arrows) consistent with atypical laminitis.*

performed on an individual basis and appropriate dietary management. MRI performed in a small number of horses has revealed focal areas of laminar disruption and linear regions of increased signal intensity in fat suppressed images in the dorsal aspects of the distal phalanx (Dyson *et al*. 2005; Dyson and Murray 2007d).

Magnetic resonance imaging

It is common to see mild to moderate reduced signal intensity in both T1 and T2 weighted MR images usually in the medial palmar process of the distal phalanx consistent with increased mineralisation ('sclerosis' or bone densification) as either an incidental finding in a nonlame limb, or coexistent with one or more other lesions which are more likely to be the primary cause of lameness (**Figs 5a**,**b**) (Nagy *et al*. 2008). In 64.7% of feet in which the distal medial aspect of the distal phalanx was lower than the lateral, RU was greater in the medial than the lateral palmar process ($P<0.0001$). Mild diffuse decrease in signal intensity in a palmar process was associated with generalised greater RU. Increased RU was also overrepresented in palmar processes with marked diffuse decrease in signal intensity in T1 and T2 weighted images consistent with mineralisation, cortical irregularity, a thick axial cortex, an axial crack or reduced signal intensity in T1 and T2 weighted images at the base of the cartilage of the foot (Nagy *et al*. 2008).