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Radiographic, scintigraphic and magnetic resonance imaging findings in the palmar processes of the distal phalanx

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Keywords: horse; palmar process; distal phalanx; scintigraphy; IRU; MRI; lameness

Summary

Reasons for performing study: **Increased radiopharmaceutical uptake (IRU) in the palmar processes of the distal phalanx is recognised but its clinical significance has not been established.**

Objectives: **To investigate the relationship between radiographic, scintigraphic and MRI findings in the palmar processes of the distal phalanx.**

Hypotheses: **Increased radiopharmaceutical uptake in the palmar processes of the distal phalanx is associated with MRI abnormalities; IRU and MRI abnormalities are over-represented in lame limbs.**

Methods: **Clinical data, radiographic, scintigraphic and MRI findings of 258 horses with unilateral or bilateral foot pain were recorded. Scintigraphic images were assessed subjectively and using region of interest and profile analysis, and intensity of IRU graded. Alteration in signal intensity in T1 and T2 weighted and short tau inversion recovery (STIR) MR images was documented, and MRI abnormalities graded. Relationships between scintigraphic, MRI, radiographic and clinical findings were assessed.**

Results: **Focal IRU was over-represented in palmar processes with most MRI abnormalities. There was a significant correlation between IRU and MRI grades and IRU was over-represented in palmar processes with MRI *Grades 2* and *3*. Both IRU and MRI abnormalities occurred most frequently in the medial palmar process. MRI abnormalities were generally over-represented in lame limbs. The most common MRI abnormality was mild diffuse decreased signal intensity in T1 and T2 weighted images, which was associated with mild generalised IRU.**

Conclusions: **There was considerable variation in the radiographic, scintigraphic and MRI appearance of palmar processes of the distal phalanx. Focal IRU in a palmar process was seen in association with MRI abnormalities and lameness or as an incidental finding. Magnetic resonance imaging abnormalities occurred more frequently in lame limbs, either contributing to lameness or as a consequence of lameness.**

Potential relevance: **Further investigation is needed to establish the clinical significance of MRI abnormalities in the palmar processes of the distal phalanx and their relationship with lesions in adjacent structures.**

Introduction

There is a wide variation in the radiographic appearance of the distal phalanx in clinically normal horses (Butler *et al*. 2000). Focal increased radiopharmaceutical uptake (IRU) in one or both palmar processes of the distal phalanx has been documented (Dyson 2002), but its clinical significance has been questioned, because it can be seen in the absence of both radiographic abnormalities and lameness (Dyson 2003). However, IRU can be associated with osteitis of the palmar processes of the distal phalanx, characterised by abnormal modelling identified radiographically (Dyson 2003), which has been related to long-toe, low-heel conformation, flat soles and horizontal orientation of the solar surface of the distal phalanx.

Magnetic resonance imaging (MRI) is a more sensitive imaging modality for detection of bone pathology than radiography and can detect abnormalities of osseous structures in the foot, which cannot be identified radiographically (Dyson *et al*. 2005; Martinelli and Rantanen 2005; Dyson and Murray 2007a). Bone trauma, cortical irregularity and focal mineralisation in the palmar processes of the distal phalanx have been documented using MRI (Dyson and Murray 2007a). However, there is no information about their frequency and no detailed description of MRI findings in the palmar processes. Focal mineralisation in the palmar processes in MR images has been observed in association with IRU (Dyson and Murray 2007a), but the relationship between IRU and other MRI abnormalities or clinical findings has not been assessed. In a recent study of 264 horses with foot pain, IRU in one or both palmar processes was identified in 10.4% of feet (Dyson and Murray 2007b).

The purpose of the current study was to investigate the relationship between IRU and both radiographic and MRI abnormalities of the palmar processes of the distal phalanx. The aims were to describe frequency and intensity of IRU in the palmar processes, document radiographic appearance of the palmar processes and MRI findings, and investigate relationships between radiographic, scintigraphic and MRI findings and their association with lameness. It was hypothesised that IRU in the palmar processes of the distal phalanx would be associated with MRI abnormalities and that IRU and MRI abnormalities would be over-represented in lame limbs.

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Materials and methods

All horses were examined at the Animal Health Trust between January 2001 and December 2004. Horses were selected for inclusion based on the presence of unilateral or bilateral forelimb lameness abolished by perineural analgesia of the palmar (abaxial sesamoid) nerves and having undergone radiographic, scintigraphic and MRI examinations of the fore feet. Horses were excluded if there was poor radiopharmaceutical uptake in the bone phase images in one or both distal limbs (total count <300,000 for dorsal scintigraphic image and <150,000 for lateral scintigraphic image), or if the series of MR images of either forelimb was incomplete. Clinical records were reviewed and age, gender, breed, discipline and lame limb(s) for each horse recorded.

Radiographic image analysis

Lateromedial (LM), dorsopalmar (DPa), dorsolateral-palmaromedial oblique (DL-PaMO), dorsomedial-palmarolateral oblique (DM-PaLO), dorsoproximal-palmarodistal oblique (DPr-PaDiO) and palmaroproximal-palmarodistal oblique (PaPr-PaDiO) radiographic views (Butler *et al*. 2000) were reviewed. Mediolateral orientation of the distal phalanx was determined by measuring the distance between the distal aspect of the distal phalanx and the horizontal ground surface on the DPa radiographic view, drawing 2 lines perpendicular to the ground surface at the most medial and lateral aspects of the distal phalanx (Fig o1; this and other additional figures [o1–o13] can be found at www.evj.co.uk/suppinfo).

Solar thickness was determined on the LM radiographic view: a perpendicular line was drawn from the most palmar aspect of the extensor process of the distal phalanx to the sole. This distance and the distance between the solar surface of the distal phalanx and the sole were measured and the ratio of measurements (solar thickness ratio) calculated to take into account differences in foot size between horses (Fig o2). Feet were included only if the palmar processes of the distal phalanx were superimposed in the LM view. Dorsopalmar orientation of the distal phalanx was assessed by measuring the angle between the solar surface of the distal phalanx and the ground surface (Fig o3) (Smith *et al*. 2004). Repeatability of measurements was assessed 10 times on 10 feet.

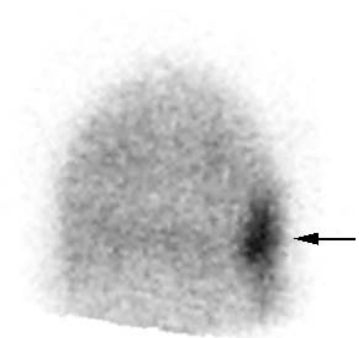

Fig 1: Solar scintigraphic image of the right front foot of an 8-year-old Warmblood gelding. Medial is to the right. There is intense focal increased radiopharmaceutical uptake in the medial palmar process of the distal phalanx.

Presence of marked cortical irregularity, with or without focal radiolucent zones (Figs o4 and o5), marked new bone formation on the ventral aspect of a palmar process (Fig o6), elongation of a palmar process (Fig o7), a separate centre of ossification (SCO) (Fig o8) or a fracture was recorded.

Scintigraphic image analysis

Bone phase scintigraphic examination was performed as previously described (Dyson and Murray 2007b). Presence or absence of focal IRU in a palmar process of the distal phalanx in the solar scintigraphic view was recorded (Fig 1) (S.J.D.; Dyson and Murray 2007b). Dorsal and lateral scintigraphic images were assessed (AN) and location of the IRU determined: 1) restricted to the palmar process of the distal phalanx; 2) present in both the palmar process of the distal phalanx and in the ipsilateral cartilage of the foot; or 3) restricted to the cartilage of the foot.

Region of interest (ROI) analysis was used to determine the intensity of IRU in the solar scintigraphic images of horses in which IRU was restricted to a palmar process of the distal phalanx. A rectangular ROI was drawn within the confines of the area of IRU, to occupy as large an area as possible (ROI 1) (Fig o9). Region of interest 1 was copied and moved to the midline of the toe region, as dorsal as possible (ROI 2). Mean counts per pixel in ROIs 1 and 2 were recorded. Intensity of the IRU was graded based on the difference between ROIs 1 and 2: *Grade 0* (normal) = difference ≤10%, *Grade 1* (mild) = difference >10–20%, *Grade 2* (moderate) = difference >20–40%, and *Grade 3* (intense) = difference >40%. If there was an area of moderate to intense IRU (>20% difference compared to the toe region) adjacent to the palmar process, or an area of intense IRU (>40% difference compared to the toe region) in any other area of the foot, this region was masked out before performing ROI analysis. Repeatability of ROI analysis was tested 10 times in 5 feet.

Profile analysis was used to determine whether there was mediolateral symmetry of radiopharmaceutical uptake (RU) in the palmar processes of the distal phalanx. A profile was drawn on the solar scintigraphic image with its palmar border at the most palmar extremity of RU in the palmar processes and the dorsal border at 1/3 of the distance between the most palmar extremity of RU in the palmar processes and the most dorsal extremity of RU in the toe region (Fig o10). Counts per pixel at the peaks of the curve in the medial and lateral palmar processes were recorded. Palmar processes with focal IRU were excluded from analysis. Repeatability of profile analysis was tested 10 times on 10 feet.

Magnetic resonance image analysis

Magnetic resonance imaging was performed as previously described (Dyson *et al*. 2005). Magnetic resonance images of all available sequences (3 dimensional [3D] T1 weighted spoiled gradient echo [SPGR], 3D T2* gradient echo [GRE] and short tau inversion recovery [STIR] or fat saturated 3D T2* GRE sequences) in 3 planes (sagittal, dorsal and transverse) were evaluated subjectively (A.N.). The palmar processes of the distal phalanx were defined as the lateral and medial aspects of the distal phalanx palmar to the insertion site of the collateral ligaments of the distal interphalangeal joint. Alteration in signal intensity at different locations was recorded and the degree of signal alteration was documented as mild or marked. Thickening of the axial cortex and the presence of an osseous cyst-like lesion (OCLL), an axial

entheseophyte (1 or 2 well-defined entheseophyte[s]) at the axial aspect of the palmar process), a fracture, an axial defect in the palmar process, marked diffuse cortical irregularity (Fig o11) and a palmar SCO (Fig o12) were also recorded.

Magnetic resonance imaging grades were assigned to each palmar process: *Grade 0* = no abnormality, *Grade 1* = mild diffuse

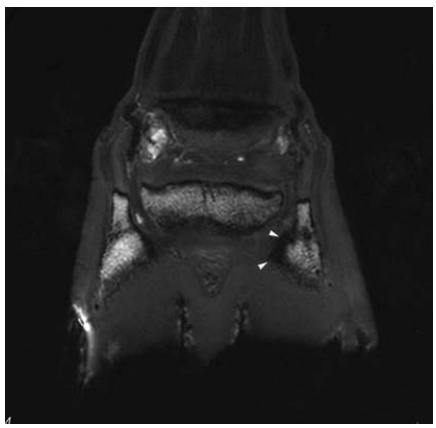

Fig 2: Dorsal 3D T2 GRE image of the right front foot of a 12-year-old showjumper. Medial is to the right. There is mild diffuse decreased signal intensity in the medial palmar process of the distal phalanx with thickening of the axial cortex (arrowheads).*

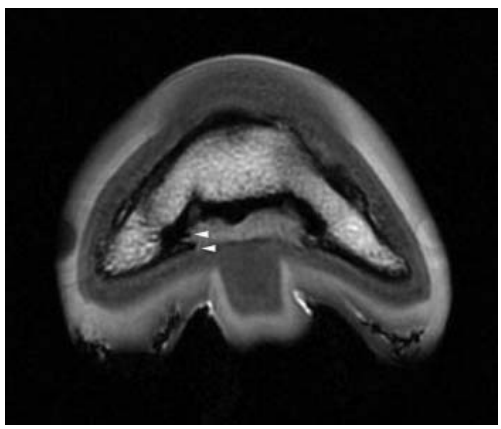

Fig 3: Transverse 3D T1-weighted SPGR image of the left front foot of an 8-year-old dressage horse. Medial is to the left. There are 2 entheseophytes at the axial aspect of the medial palmar process of the distal phalanx (arrowheads).

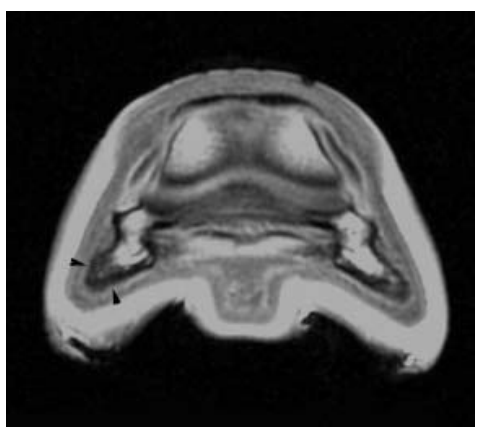

Fig 4: Transverse 3D T1-weighted SPGR image of the left front foot of a 3-year-old Thoroughbred. Medial is to the left. There is focal decreased signal intensity in the medial palmar process of the distal phalanx.

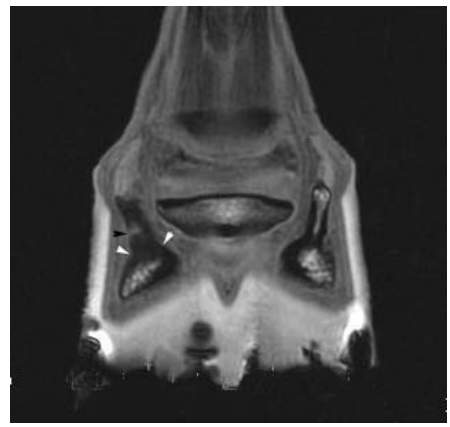

Fig 5: Dorsal 3D T1-weighted SPGR image of the left front foot of a 6-year-old gelding. Medial is to the left. There is marked decreased signal intensity at the base of the medial cartilage of the foot (white arrowheads). Note the defect in the ipsilateral cartilage of the foot (black arrowhead).

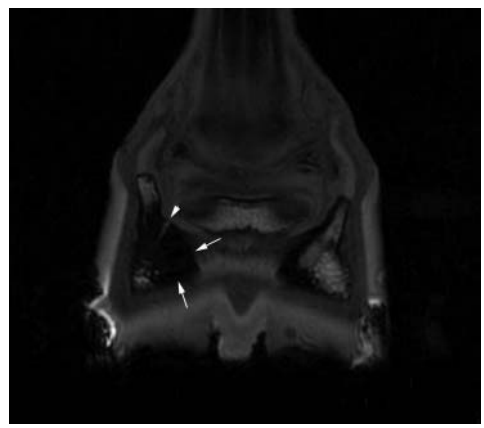

Fig 6: Dorsal 3D T1-weighted SPGR image of the left front foot of an 8-year-old showjumper. Medial is to the left. There is marked diffuse decreased signal intensity in the medial palmar process of the distal phalanx (arrows) with an axial defect (arrowhead).

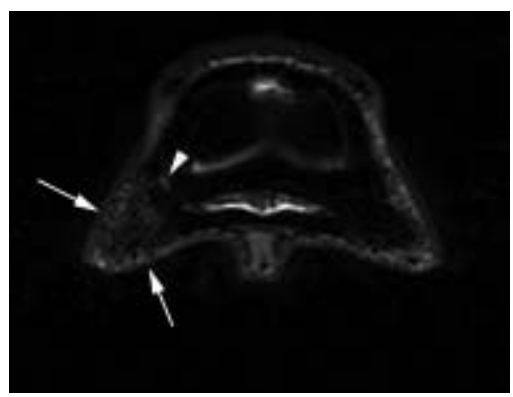

Fig 7: Transverse STIR image of the left front foot shown in Figure 5. Medial is to the left. There is diffuse increased signal intensity in the medial palmar process of the distal phalanx (arrows); the axial defect can be identified as an oblique line of increased signal intensity (arrowhead).

decreased signal intensity in T1 and T2 weighted images involving the whole palmar process (Fig 2), and/or irregular cortex without change in signal intensity, and/or axial entheseophyte (Fig 3), and/or SCO; *Grade 2* = focal palmar moderate to marked decreased signal intensity in T1 and T2 weighted images (subsequently referred to as focal palmar mineralisation) (Fig 4), or thick axial cortex (Fig 2), or marked decreased signal intensity in T1 or T2 weighted images at the base of the cartilage of the foot involving less than half of the palmar process (Fig 5), or increased signal intensity in STIR images without alteration in other sequences, or an OCLL (Fig o13); *Grade 3* = fracture, or axial defect (Fig 6), or crack, or marked decreased signal intensity in T1 and T2 weighted images involving more than half of the palmar process (Fig 6), or a combination of ≥2 abnormalities listed in Grade 2 (Fig 7). Repeatability of subjective image evaluation was tested 10 times in 10 feet.

Statistical analysis

Statistical analysis was performed using statistical software (Analyse-it)[1]. A Chi-square test and/or a Fisher exact test were used to test for differences between the proportions of IRU and MRI abnormalities between different age, gender, breed, discipline and lameness groups respectively. The difference between RU in the medial and lateral palmar processes (profile analysis) was assessed using a paired *t* test. A Spearman rank correlation test was used to test for an association between scintigraphic and MRI grades. A Shapiro-Wilks normality test was used to confirm normal distribution of the radiographic data. Medial and lateral distances in the DPa view were compared using a paired *t* test. Differences between the proportions of radiographic and scintigraphic/MRI findings between lame and sound limbs were assessed using a Chi-square test and/or a Fisher exact test. Statistical significance was set at $P<0.05$.

TABLE 1: Distribution of magnetic resonance imaging (MRI) abnormalities in medial and lateral palmar processes of the distal phalanx (%). The majority of MR abnormalities occurred more frequently in the medial palmar processes

MRI abnormality	Medial palmar process	Lateral palmar process
Mild diffuse decreased signal intensity	23.4	7.1
Marked diffuse decreased signal intensity	1.4	0.8
Focal palmar mineralisation	7.1	2.6
Thick axial cortex	10.9	4.3
Decreased signal intensity at the base of the cartilage of the foot	2.7	1.2
Increased signal intensity in STIR	1.6	1.1
Cortical irregularity	1.3	0.6
Axial entheseophyte	2.5	1.5
Fracture, crack or axial defect	1.0	0.1
OCLL	0.2	0.3
SCO	0.5	0.3

STIR – short tau inversion recovery; OCLL – osseous cyst-like lesion; SCO – separate centre of ossification. Except where stated otherwise, MR abnormalities were identified in both T1 and T2 weighted images.

Results

Two hundred and fifty-eight horses were included in the study. In 4 horses, only one limb underwent MRI, therefore data for 512 feet were available. One hundred and twenty-seven horses were lame unilaterally and 131 were lame bilaterally. Age varied from 3–18 years (mean 9.09 ± 2.66 years). Breeds included Warmbloods (n = 96, 37.2%), Thoroughbred cross horses (n = 58, 22.5%), Thoroughbred (n = 37, 14.4%), other cross breeds (n = 48, 18.6%), Large Native Ponies (n = 9, 3.5%), Cobs (n = 6, 2.3%) and ponies (n = 4, 1.5%). Male horses predominated in the study population (n = 175 geldings [67.8%] and n = 7 stallions [2.7%]), and there were n = 76 mares (29.5%).

Scintigraphic findings

Profile analysis showed that RU was greater in the medial palmar processes of the distal phalanx than in the lateral palmar processes ($P<0.0001$). There was focal IRU in the solar scintigraphic image in 54 palmar processes of the distal phalanx. Comparison with the lateral and dorsal scintigraphic images revealed that, in 12 feet, IRU was located in the ipsilateral cartilage of the foot, and these feet were excluded from further analysis. Focal IRU was present in the medial palmar process of the distal phalanx of 29 feet (n = 5.6%) and in the lateral palmar process of 12 feet (n = 2.4%). In one foot there was IRU in both the medial and lateral palmar processes.

Repeatability of scintigraphic grading was confirmed. In the solar scintigraphic image there was mild (*Grade 1*) IRU in a palmar process of one distal phalanx, moderate (*Grade 2*) IRU in 13 palmar processes, and intense (*Grade 3*) IRU in 29 palmar processes. Mild IRU was not detected in either dorsal nor lateral scintigraphic images. Six of 13 regions of moderate IRU and 18 of 29 regions of intense IRU could also be identified in the dorsal and/or lateral scintigraphic images.

Gender, breed and discipline did not influence the distribution of IRU. Although IRU was relatively over-represented in horses age 3–5, 8–9 and 14–18 years ($P = 0.0089$), there was no pattern of increase nor decrease with age.

TABLE 2: Distribution of magnetic resonance imaging (MRI) grades in palmar processes of different lameness groups (%). A lame/lamer limb was defined as the lame limb in unilaterally lame horses and the lamer limb in bilaterally lame horses, when it was possible to differentiate the degree of lameness. A less lame limb was defined when there was a detectable difference in degree of lameness between the 2 limbs in bilaterally lame horses. When it was not possible to differentiate, both limbs were assigned as the lame/lamer limb. There was a significant difference in the distribution of MRI grades between nonlame, lame/lamer and less lame limbs when data were compared for all palmar processes ($P = 0.0043$), or for medial ($P<0.0001$) or lateral ($P<0.0001$) palmar processes

MRI grade	Medial and lateral palmar processes			Medial palmar process			Lateral palmar process		
	Nonlame	Lame/lamer	Less lame	Nonlame	Lame/lamer	Less lame	Nonlame	Lame/lamer	Less lame
0	59.3	47.3	56.8	56.9	15.6	48	61.8	79.2	65.6
1	19.5	28.4	18	14.6	51.5	16	24.4	5.3	20
2	15.1	15.6	14.8	17.9	20.8	20	12.2	10.2	9.6
3	6.1	8.7	10.4	10.6	12.1	16	1.6	5.3	4.8

Magnetic resonance findings

Repeatability of subjective evaluation of MR images was confirmed. Abnormalities were documented in 47.7% of all (n = 488), 67.0% of medial and 28.3% of lateral palmar processes of the distal phalanx. Of all palmar processes, 23.7% (n = 243) were MRI *Grade 1* (17.0% medial, 6.7% lateral), 15.2% (n = 156) MRI *Grade 2* (10.0% medial, 5.2% lateral), and 8.5% (n = 87) MRI *Grade 3* (6.3% medial, 2.2% lateral).

Age, gender, breed and discipline did not influence the distribution of MRI abnormalities. Mild diffuse decreased signal intensity in T1 and T2 weighted images was identified in 30.5% (n = 312) of palmar processes; marked diffuse decreased signal intensity in T1 and T2 weighted images was documented in 2.2% (n = 23). There was focal palmar mineralisation in 9.7% (n = 99) palmar processes and the axial cortex was thickened in 15.2% (n = 156). There was decreased signal intensity in T1 and T2 weighted images at the base of the cartilage of the foot in 3.9% (n = 40) of palmar processes. Increased signal intensity in STIR images was identified in 2.7% (n = 28) of palmar processes. Cortical irregularity was seen in 1.9% (n = 19) palmar processes and axial entheseophyte(s) were present in 4.0% (n = 41). There was a defect (fracture, crack or axial defect) in 1.1% (n = 11) of palmar processes. An OCLL was identified in 0.5% (n = 5) of palmar processes and there was a SCO in 0.8% (n = 8). Differences between MRI abnormalities in medial and lateral palmar processes of the distal phalanx are summarised in Table 1.

There was a significant difference in the distribution of MRI grades between nonlame, lame/lamer and less lame limbs when data was compared for all palmar processes and individually for medial and lateral palmar processes (Table 2). The greatest difference in distribution was noted for MRI *Grade 1*, which was greatly over-represented in the medial palmar process and under-represented in the lateral palmar process of the lame/lamer limbs (P<0.0001). Magnetic resonance imaging *Grade 3* was over-represented in all lame (lame/lamer and less lame) limbs for all palmar processes of the distal phalanx (P = 0.0043) and also for medial (P<0.0001) and lateral (P<0.0001) palmar processes, respectively.

Mild diffuse decreased signal intensity in T1 and T2 weighted images was significantly over-represented in the medial palmar process of the lame or, in bilaterally lame horses, in the lamer limbs (72.7%) (nonlame limbs 17.9%; less lame limbs in bilaterally lame horses 20.8%) (P<0.0001). Mild diffuse decreased signal intensity in T1 and T2 weighted images was significantly under-represented in the lateral palmar process of the lame or, in bilaterally lame horses, the lamer limbs (4.2%) (nonlame limbs 27.6%; less lame limbs in bilaterally lame horses 21.6%) (P<0.0001).

Radiographic findings

Radiographic examination of 355/512 feet (69.3%) was performed and a complete series was available for 201 feet (39.3%). The mean angle between the solar surface of the distal phalanx and the horizontal ground surface was 7.6° ± 5.3. The solar thickness ratio was 0.18 ± 0.04. Marked cortical irregularity was recorded in 21.1% of palmar processes. There was new bone formation on the ventral aspect of the palmar processes in 10.9% of feet in the LM views. A SCO was identified in 2.3% of palmar processes and 4.6% were elongated. In the DPa view the mean distance between the distal medial aspect of the distal phalanx and the ground surface was significantly smaller than the distance between the lateral distal aspect of the distal phalanx and the ground surface (P<0.0001). The distal medial aspect of the distal phalanx was lower in 62.9% of feet.

Association between radiographic, scintigraphic and MRI findings

Correlation between greater generalised RU in one of the palmar processes, radiographic and MRI findings: There was a significant negative association (r = 0.13, P = 0.0118) between MR signal intensity and RU in the palmar processes. Therefore mild diffuse decreased signal intensity in the palmar processes was associated with generalised greater RU. In 62.3% of medial palmar processes with mild diffuse decreased signal intensity, RU was greater than in the lateral palmar process (P<0.0001). 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 palmar process (P<0.0001).

Relationships between IRU, radiographic and MRI findings: Association between IRU in a palmar process with MRI abnormalities is summarised in Table 3. Increased RU was significantly over-represented in palmar processes that had marked diffuse decrease in signal intensity in T1 and T2 weighted images, a thick axial cortex and decreased signal intensity in T1 and T2 weighted images at the base of the cartilage of the foot. Increased RU was significantly over-represented in palmar

TABLE 3: Summary of the significant relationships between increased radiopharmaceutical uptake (IRU) in a palmar process of the distal phalanx (%), and MRI abnormalities. Except where stated otherwise, MRI abnormalities were identified in both T1 and T2 weighted images

	IRU in palmar processes		
MRI abnormalities	All	Medial	Lateral
Mild diffuse decreased signal intensity		2.9^ (P = 0.0115)	
Marked diffuse decreased signal intensity	43.5* (P<0.0001)	40.0* (P = 0.0002)	50.0* (P<0.0001)
Thick axial cortex	10.3* (P = 0.0005)	10.7* (P = 0.0324)	9.1* (P = 0.0383)
Decreased signal intensity at the base of the cartilage of the foot	27.5* (P<0.0001)	25.0* (P = 0.0012)	
Focal palmar mineralisation	13.1* (P = 0.0002)	14.1* (P = 0.0024)	
Cortical irregularity	38.0* (P = 0.0001)	31.5* (P = 0.0009)	
Increased signal intensity in STIR images	17.9* (P = 0.0099)	25.0* (P = 0.0214)	
Axial defect, crack or fracture	40.0* (P<0.0001)	45.5* (P = 0.0032)	

^ significantly under-represented; * significantly over-represented.

processes with focal palmar mineralisation, cortical irregularity, increased signal intensity in STIR images or with an axial defect, crack or fracture when assessing all and medial palmar processes, but not when assessing lateral palmar processes. Increased RU was significantly under-represented in medial palmar processes with mild diffuse decrease in signal intensity in T1 or T2 weighted images.

Increased RU was significantly over-represented in palmar processes assigned MRI *Grades 2* (4.5%) and *3* (25.3%) compared with palmar processes assigned MRI *Grades 0* (1.9%) and 1 (1.7%) ($P<0.0001$). There was significant correlation between scintigraphic and MRI grades (r statistic = 0.20, $P<0.0001$). However, IRU was also present in 9 palmar processes with no MRI abnormalities.

There was no significant difference between proportions of IRU, MRI abnormalities or lameness between feet with or without significant difference in distances between the medial or lateral palmar process and the ground surface. There was no relationship between solar angle of the distal phalanx and the presence of IRU, MRI abnormalities or lameness. Increased RU was significantly over-represented in feet with diffuse cortical irregularity of the palmar process of the distal phalanx identified radiographically (20/146, 8.2%, $P = 0.0199$). There was no relationship between solar thickness ratio and either IRU, MRI abnormalities or lameness. No significant difference between proportions of scintigraphic and MRI findings was found between palmar processes with other radiographic abnormalities.

Discussion

This study revealed a variety of radiographic, scintigraphic and MRI findings in the palmar processes of the distal phalanx. Increased RU was over-represented in palmar processes with MRI abnormalities, supporting the hypothesis tested. Increased RU was over-represented in palmar processes with MRI *Grades 2* and *3*, suggesting that certain MRI abnormalities (in isolation or combination) are more likely to be associated with IRU. Contrary to the hypothesis, IRU was not significantly over-represented in lame limbs, but the relatively low number of palmar processes with IRU has to be taken into account when interpreting this result. However, mild diffuse decreased signal intensity in T1 and T2 images was significantly over-represented in the medial palmar process of lame limbs, and MRI *Grade 3* abnormalities were significantly over-represented in both palmar processes of lame limbs.

In this study no correlation was found between IRU and lameness and, although IRU was over-represented in palmar processes with most MRI abnormalities, it was also observed in palmar processes in which no MRI abnormalities were identified. It is possible that increased osteoblastic activity precedes alteration in signal intensity in MR images, but as no correlation was found with lameness, IRU without MRI abnormalities is unlikely to be of clinical significance. The absence of IRU in some palmar processes with MRI abnormalities may reflect old, end-stage bone injury (e.g. advanced sclerosis) or primary necrosis.

Mediolateral asymmetry between the palmar processes was observed in this study for radiographic, scintigraphic and MRI findings. Generalised greater RU and IRU and the majority of MRI abnormalities were over-represented in the medial palmar processes of the distal phalanx. Previous studies have shown a higher incidence of fracture of the medial palmar process of the distal phalanx (Robson *et al*. 2004), fracture of the medial ossified cartilage of the foot (Dakin *et al*. 2006) and injury of the medial collateral ligament of the distal phalanx (Dyson *et al*. 2004; Dyson and Murray 2004). These data suggest that there is a higher risk of injury of the medial aspect of the distal phalanx and adjacent structures, which may be related to the biomechanics of the foot. Horses land on the lateral side of the hoof and then rock on to the medial aspect (Chateau *et al*. 2006). At midstance the centre of maximum vertical ground reaction force (GRF) on the foot is medial to midline (Keegan and Dyson 2003). Conformation may also predispose to injury; the lengthened side of the foot lands first and the GRF shifts toward the elevated wall (Wilson *et al*. 1998). However, we found no correlation between mediolateral imbalance of the distal phalanx established on a DPa radiographic view and either lameness or MRI abnormalities. Gross foot conformation was not assessed in the current study.

Mild diffuse decreased signal intensity in T1 and T2 weighted images in the medial palmar processes of lame limbs and its association with generalised greater RU suggest that generally there is greater mineralisation in the medial palmar processes in lame limbs. This could be related to the altered biomechanics of a lame limb or that limbs with greater mineralisation and osteoblastic activity of the medial palmar process of the foot (probably resulting from rocking on to the medial aspect of the foot) are predisposed to injury and lameness.

Long-toe low-heel conformation and decreased angle between the ground and the solar surface of the distal phalanx could result in greater concussion in the palmar processes and has been related to osteitis of the palmar processes of the distal phalanx (Dyson 2003). However, in the current study no relationship was found between small distal phalanx angle and IRU, MRI abnormalities or lameness. Distal phalanx angles may be altered by the interval between successive trimmings (Kummer *et al*. 2006), which may have influenced the results of the current study. However, the majority of horses were trimmed at 4 or 5 week intervals, in contrast to the study of Kummer *et al*. (2006) in which the trimming interval was 8–10 weeks.

A thickened axial cortex may reflect continuous greater loading of the affected palmar process, and was usually observed in combination with other abnormalities, most often with focal palmar mineralisation and marked decreased signal intensity at the base of the cartilage of the foot. Decreased signal intensity in T1 and T2 weighted images at the base of the cartilage of the foot was observed with or without alteration in signal intensity in the ipsilateral cartilage of the foot. An axial entheseophyte may be associated with an insertional lesion of the deep digital flexor tendon or the distal sesamoidean impar ligament, but this was not assessed in the current study.

Marked diffuse decrease in signal intensity in T1 and T2 weighted images without alteration in signal intensity in STIR images reflects abnormal mineralisation. Increased signal intensity in STIR images reflects bone oedema, necrosis, fibrosis or trabecular modelling (Zanetti *et al*. 2000). When associated with decreased signal intensity in T1-weighted images and IRU, it is likely to reflect acute bone trauma.

In the current study, MRI was useful to detect fractures, cracks and axial defects, which could not be identified radiographically. These were more frequently observed in the medial palmar process. The presence of IRU and increased signal intensity in STIR images was suggestive of active lesions likely to be associated with lameness.

Bone trauma, cortical irregularity and focal mineralisation in the palmar processes of the distal phalanx have previously been documented using MRI (Dyson *et al*. 2005; Dyson and Murray 2007a), but were generally seen in conjunction with other injuries thought to be the primary cause of lameness.

There are a number of limitations of this study. Radiographs were generally available only for the lame limbs in unilaterally lame horses. Oblique views of the palmar processes were only available for 65% of radiographed feet, therefore the results may under-represent the frequency of occurrence of SCOs or elongated palmar processes. The low number of palmar processes with IRU, relative to all palmar processes, must be considered when interpreting the results. However, the frequency of occurrence of IRU may not be representative of all horses with foot pain because this study included only horses that underwent radiographic, scintigraphic and MRI examinations. There are no data available on IRU and MRI abnormalities in palmar processes of the distal phalanx in horses free of foot pain. The nonlame limbs in this study cannot be used as a completely normal reference, because there are likely to be biomechanical changes associated with contralateral forelimb lameness. Further investigation is needed to assess normal variation in MRI appearance of the palmar processes of the distal phalanx and to assess correlation between MR appearance and histological findings. Association between MRI abnormalities of the palmar processes and other structures of the foot should also be investigated.

In conclusion this study showed a variety of radiographic, scintigraphic and MRI appearances of the palmar processes of the distal phalanx. Focal IRU in the palmar process was observed in association with MRI abnormalities and lameness, or as an incidental finding. Magnetic resonance imaging abnormalities occurred more frequently in lame limbs, either contributing to lameness or as a consequence of lameness. The clinical significance of these lesions alone is yet to be established, but palmar processes should be evaluated carefully when performing scintigraphic and MR examinations.

Manufacturer's address

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