Lameness in 46 horses associated with deep digital flexor tendonitis in the digit: diagnosis confirmed with magnetic resonance imaging

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Summary

Reasons for performing study: **The differential diagnosis of foot pain has long proved difficult and the use of magnetic resonance imaging (MRI) offers the opportunity to further the clinical understanding of the subject.**

Objectives: **To determine the incidence of deep digital flexor tendon (DDFT) injuries in a series of 75 horses with lameness associated with pain localised to the digit, with no significant detectable radiographic or ultrasonographic abnormalities, using MRI; and to describe a variety of lesion types and relate DDF tendonitis with anamnesis, clinical features, response to local analgesic techniques and nuclear scintigraphic and ultrasonographic findings.**

Methods: **All horses undergoing MRI of the front feet between January 2001 and October 2002 were reviewed and those with DDFT injuries categorised according to lesion type; horses with primary tendonitis (*Group I*) and those with concurrent abnormalities of the navicularbone considered to be an important component of the lameness (*Group II*). The response to perineural analgesia of the palmar digital nerves and palmar (abaxial sesamoid) nerves, intra-articular analgesia of the distal interphalangeal (DIP) joint and analgesia of the navicularbursa were reviewed. The result of ultrasonography of the pastern and foot was recorded. Lateral, dorsal and solar pool and bone phase nuclear scintigraphic images were assessed subjectively and objectively using region of interest (ROI) analysis.**

Results: **Forty-six (61%) of 75 horses examined using MRI had lesions of the DDFT considered to be a major contributor to lameness. Thirty-two horses (43%) had primary DDFT injuries and 14 (19%) a combination of DDF tendonitis and navicular bone pathology. Lesions involved the insertional region of the tendon alone (n = 3), were proximal to the navicular bone (n = 23) or were at a combination of sites (n = 20). Lesion types included core lesions, focal and diffuse dorsal border lesions, sagittal plane splits, insertional injuries and lesions combined with other soft tissue injuries. Many horses had a combination of lesion types.**

Lameness was abolished by palmar digital analgesia in only 11 of 46 horses (24%). Twenty-one of 31 horses (68%) in *Group I* showed >50% improvement in lameness afterintra-articular analgesia of the DIP joint, whereas 11 of 12 horses (92%) in *Group II* had a positive response. Twelve of 18 horses (67%) in *Group I* had a positive response to analgesia of the navicular bursa.

Nineteen horses had lesions of the DDFT extending proximal to the proximal interphalangeal joint seen using MRI, but these were identified ultrasonographically in only 2 horses. Scintigraphic abnormalities suggestive of DDFT injury were seen in 16 of 41 horses (41%), 8 in pool phase images and 8 in bone phase images.

Conclusions and potential relevance: **DDFT injuries are an important cause of lameness associated with pain arising from the digit in horses without detectable radiographic abnormalities. Lameness is not reliably improved by palmar digital analgesia, but may be improved by intra-articular analgesia of the DIP joint in at least 68% of horses. Ultrasonography is not sensitive in detecting lesions of the DDFTin the distal pastern region, but a combination of pool and bone phase scintigraphic images of the digit is helpful in some horses. Further follow-up information is required to determine the prognosis for horses with lesions of the DDFT in the digit and to establish whether this is related to lesion severity and/or location.**

Introduction

Pathophysiology

Primary lesions of the deep digital flexor tendon (DDFT) have only recently been recognised clinically using magnetic resonance imaging (MRI) (Dyson *et al.* 2002, 2003; Schramme *et al.* 2002; Dyson 2003a,b) or computed tomography (CT) (Nowak 2002) and there is limited information concerning pathophysiology. Primary DDF tendonitis may be the result of repetitive over-stress, or be an acute onset traumatic tear. Predisposition to injury may include degenerative ageing changes, common to many other tendons and ligaments, or a progressive increase in proteoglycans seen in the

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Fig 1: Lateral pool phase image of a right front foot. There is focal increased radiopharmaceutical uptake in the region of the DDFT(arrow).

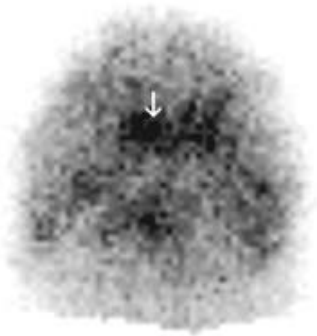

Fig 2: Solar bone phase image of the same horse as Figure 8. There is marked focal increased radiopharmaceutical uptake in a region of the insertion of the DDFT(arrow).

distal aspects of the DDFTand distal sesamoidean impar ligament (DSIL), as an adaptation to stress (Bowker *et al.* 2001).

Lesions of the DDFT within the foot were identified in less than 10% of horses with unknown history in a *post mortem* study of superficial digital flexor tendon (SDFT) and DDFT lesions in the metacarpal region and digit (Webbon 1977). In a *post mortem* study of 38 horses with suspected navicular disease, 13% had core lesions of the DDFT. One horse had a core lesion of the DDFT with no associated pathology of the navicular bone; 4 additional horses had histological evidence of focal regions of necrosis within the tendon concurrent with other pathology of the navicular bone (Wright *et al.* 1998). Surface fibrillation was a common finding in horses with navicular disease, but not in age-matched control horses. No lesions of the DDFT were described in the age-matched controls. Pool *et al.* (1989) considered lesions in the DDFT to be secondary to navicular disease. Inflammation at the intersection of the DDFT and DSIL was recognised in the Quarter Horse in association with other signs compatible with navicular disease (Van Wulfen and Bowker 1997). It was considered that these lesions may be involved with the pathogenesis of navicular disease.

Ectopic mineralisation within the DDFT has been identified radiographically, at the level of the navicular bone and immediately proximal to it, but its clinical significance has been speculative (Butler *et al.* 2000). Entheseous new bone at the site of insertion of the DDFTon the *facies flexoria* and semilunar crest of the distal phalanx has been described associated with lameness, but unassociated with navicular disease (Ueltschi 1999). Nuclear scintigraphic examination of horses with palmar foot pain has revealed horses with focal regions of increased radiopharmaceutical uptake (IRU) in the region of insertion of the DDFT(Dyson 2002; G. Ueltschi, personal communication), either alone or in association with IRU in the navicular bone. Many of these horses had no detectable radiographic abnormality. DDF tendonitis within the digit was identified in one horse *post mortem* using both MRI and CT and the lesion was verified using gross inspection and histopathology (Whitton *et al.* 1998).

Functional anatomy

Within the hoof capsule, the deep digital flexor tendon (DDFT) is moulded to the palmar (plantar) surface of the distal sesamoid (navicular) bone and separated from it by the podotrochlear (navicular) bursa. The distal recess of the navicular bursa separates the DDFT and the distal sesamoidean impar ligament (DSIL). The DDFT has a terminal fan-like expansion, containing cartilage that occupies the entire space between the medial and lateral palmar processes of the distal phalanx. It inserts on the facies flexoria and semilunar crest of the distal phalanx. The dorsal portion of the DDFT joins with the DSIL immediately before insertion on the *facies flexoria* of the distal phalanx. There are parallel fibres of dense connective tissue, separated by loose connective tissue, within which are many sensory nerves and numerous blood vessels (Bowker *et al.* 1994). A prominent line (tidemark) indicates the transition from nonmineralised tendon and ligament, to mineralised regions of the DDFT and DSIL, before attachment to the distal phalanx (Bowker *et al.* 2001).

Within the digit, the DDFT induces axial compression of the articular surfaces of the proximal (PIP) and distal (DIP) interphalangeal joints (Bowker *et al.* 2001; Denoix 1994). It has an important role in stabilising the DIP joint. The anatomical arrangement of the collateral ligaments of the navicular bone facilitates compression of the articular surfaces of the navicular bone into those of the middle and distal phalanges (Bowker *et al.* 2001). The DDFT has a dorsal fibrocartilaginous pad that supports pressure of the *tuberositas flexoria*, the transverse prominence on the proximopalmar aspect of the middle phalanx (Denoix 1994).

The relationship of the DDFT to the navicular bone varies with the phase of the stride. During the full weightbearing stance of the stride, the DDFT is only in contact with the distal aspect of the bone, whereas in the propulsion phase the DDFT bends over the middle scutum (the fibrocartilaginous insertion of the straight sesamoidean ligament on the middle phalanx) and comes into full contact with the navicular bone. Tension in the DDFTis maximal, and active muscle contraction and the elasticity in the tendon and in its accessory ligament result in extension of the DIP joint (Denoix 1994). At the beginning of the swing phase of the stride the tension in the DDFTcontributes passively to induce flexion of the interphalangeal joints. During extension of the DIP joint, which is maximum at the propulsion phase of the stride, pull on the DDFT creates a shear force between the DDFT and the DSIL (Bowker *et al.* 2001).

TABLE1: Breed and discipline of horses with primary deep digital flexor (DDF) tendonitis (*Group I*) and DDF tendonitis and navicular bone lesions (*Group II*)

	Group I (n = 32)	*Group II* (n = 14)	Total
Breed			
Thoroughbred	9	4	13
Thoroughbred-cross	5	6	11
Warmblood	9	2	11
Crossbred	7	0	7
Pony	2	2	4
Discipline			
Dressage	4	1	5
Show jumping	7	1	8
Eventing	7	5	12
Racing (NH)	0	1	1
Hunting	1	0	1
General purpose	13	6	19

In this study, it was hypothesised that 1) DDF tendonitis is an important cause of forelimb lameness associated with the digit in the absence of significant radiological abnormality; 2) palmar digital analgesia would not reliably eliminate pain associated with DDF tendonitis in the digit; 3) lesions in the pastern region proximal to the PIP joint should be detectable ultrasonographically and 4) DDFT tendonitis may be associated with abnormal nuclear scintigraphic findings.

The purposes of this study were to describe lesions of the DDFT within the digit identified using MRI, and to relate these to anamnesis, lameness characteristics, response to local analgesia, and ultrasonographic and scintigraphic findings.

Materials and methods

Horse selection

All horses (n = 75) undergoing MRI of the front feet, January 2001 to October 2002, were reviewed and categorised according to injury type. Horses were selected for MRI based upon localisation of pain causing lameness to the digit and negative or equivocal radiographic and ultrasonographic examinations (Dyson *et al.* 2002). Horses with primary lesions of the DDFT (*Group I*, n = 32) and those with lesions of both the DDFT and navicular bone (*Group II*, n = 14) considered to be the cause of lameness were selected for further analysis.

Breed (Thoroughbred, Thoroughbred-cross, Warmblood and other) and work discipline (showjumping, eventing, racing [National Hunt], racing [Flat], dressage and general purpose) were compared with all other horses presented to the clinic with lameness or poor performance and examined by the senior author (S.D.) between January and December 2001 (n = 236). Horses competing at unaffiliated level were classified as general purpose horses. Chi-squared tests in a contingency table analysis were used to assess the effect of breed and work discipline, with statistical significance set at $P<0.05$.

Anamnesis, lameness characteristics and response to local analgesia were reviewed. Local analgesic techniques included perineural analgesia of the palmar digital nerves performed immediately proximal to the cartilages of the foot and the palmar nerves performed at the base of the proximal sesamoid bones (1.5–2.0 ml mepivacaine [Intra-Epicaine][1]/site); intra-articular analgesia of the DIP joint (6 ml mepivacaine); intrathecal analgesia of the navicular bursa (3.0–4.0 ml mepivacaine) (Dyson 2003a). Lameness was reassessed 10 mins after perineural analgesia and 5 mins after intrasynovial analgesia. Horses stood still after injection, before re-evaluation of the gait in both straight lines and circles.

Radiographic images (a minimum of lateromedial, dorsoproximal-palmarodistal oblique and palmaroproximal-palmarodistal oblique views and often dorsopalmar and flexed oblique views of the interphalangeal joints and palmar processes of the distal phalanx) (Butler *et al.* 2000) were examined (S.D.) to ensure that no horse had any significant radiological abnormality which permitted definitive diagnosis without MRI.

Scintigraphic images (vascular, pool and bone phase images; dorsal, lateral and solar views) were analysed (S.D.) both subjectively and objectively using region of interest (ROI) analysis (Dyson 2002). Radiopharmaceutical uptake in the region of the navicular bone was compared to the mean uptake in 3 peripheral regions of the distal phalanx. IRU in the region of the navicular bone was classified as mild (>110≤120%), moderate (>120≤140%) and marked (>140%), respectively. Focal IRU in

Fig 3: Sagittal 3D SPGR image. There is an extensive core lesion (arrows) in the enlarged DDFT proximal to the navicular bone.

TABLE 2: Response to local analgesic techniques in horses with either primary deep digital flexor (DDF) tendonitis (*Group I*) or DDF tendonitis and abnormalities of the navicular bone (*Group II*). Lameness in all horses was eliminated by palmar (abaxial sesamoid) nerve blocks

	Group I (n = 32)		*Group II* (n = 14)		Total (n = 46)	
Palmar digital nerve blocks						
NC	9	28%	3	21%	12	26%
I >50%	18	56%	5	36%	23	50%
S	5	16%	6	43%	11	24%
Intra-articular analgesia DIP joint						
NP	1	3%	2	14%	3	7%
NC	12	31%	1	7%	13	24%
I >50%	19	59%	10	71%	29	63%
S	2	6%	1	7%	3	7%
Intrathecal analgesia of navicular bursa						
NP	14	44%	3	31%	17	37%
NC	6	19%	0	0%	6	13%
I >50%	9	28%	6	43%	15	33%
S	3	9%	5	36%	8	17%

NP= not performed; NC = no change; I = improved; S = sound.

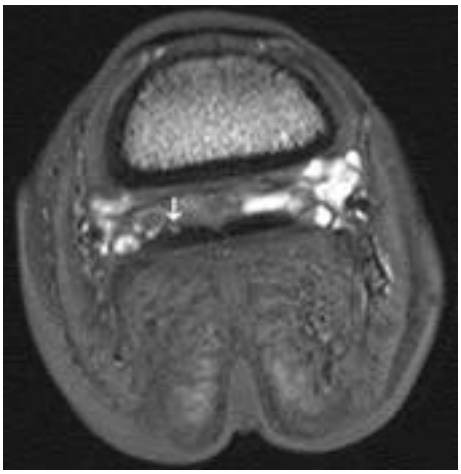

Fig 4a: Transverse 3D T2 GRE image at the level of the middle phalanx and proximal outpouching of the navicular bursa. Lateral is to the left. Dorsal is to the top. There is a focal dorsal border lesion in the lateral lobe of the DDFT (arrow). Note also the proliferative synovium within the navicular bursa.*

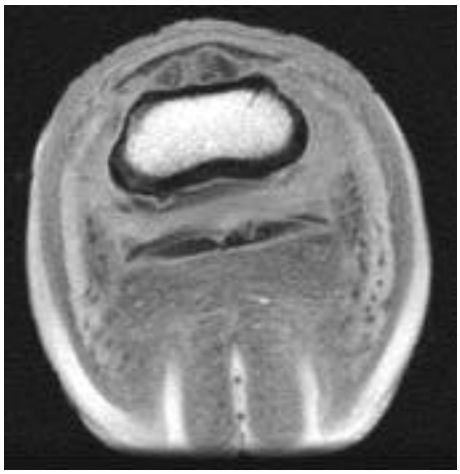

Fig 4c: Transverse 3D SPGR image at the level of the middle phalanx. Medial is to the right. Dorsal is to the top. There is a focal defect in the dorsal border of the medial lobe of the DDFT with a discrete 'punched-out' lesion.

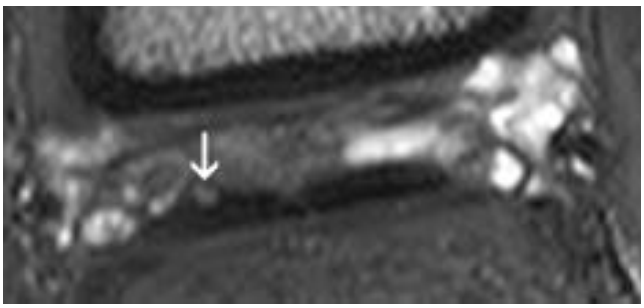

Fig 4b: Close-up of DDFT from Figure 4a.

Fig 4d: Close-up of DDFT from Figure 4c.

lateral pool phase images between the palmar coronary plexus and the distal phalanx (Fig 1) was considered significant. A focal region of IRU in the region of insertion of the DDFT on the distal phalanx in bone phase images was also categorised as a significant finding (Fig 2), but more generalised uptake, often seen bilaterally in solar images, was not, because this pattern of radiopharmaceutical uptake is often seen in horses without foot pain (Dyson 2002). Duration of lameness was compared between horses with and without scintigraphic abnormalities associated with the DDFT using a Mann-Whitney U test.

The results of ultrasonography of the palmar aspect of the pastern (Reef and Genovese 2003), the dorsal aspects of the coronary band region using a linear 10 MHz transducer (Denoix 1999), and images of the foot obtained via the bulbs of the heel (Sage and Turner 2000) and the frog using a small convex array 6.5 MHz transducer (Busoni and Denoix 2001) were reviewed.

Magnetic resonance imaging

The pastern region and both front feet of all horses were examined using a human radiofrequency extremity coil, with the feet positioned in the isocentre of a short-bore, flared-end 1.5 Tesla GE Signa Echospeed magnet (Dyson *et al.* 2003). Sagittal, dorsal and transverse MR views were obtained using 3-dimensional (3D) T1 weighted spoiled gradient echo (SPGR), 3D T2* gradient echo (GRE) and short inversion recovery (fast STIR) or fat-saturated 3D T2* GRE sequences, with a slice thickness of 1.5 mm (SPGR and T2*GRE images) or 4 mm (fast STIR) (Dyson *et al.* 2003; Whitton *et al.* 2003). Transverse images were orientated perpendicular to the short axis of the navicular bone. In some horses, additional transverse images were obtained perpendicular to the insertion of the DDFT. Images were examined by the second author (R.M.) and clinical significance was ascribed to the lesions by the primary clinician (S.D. or M.S.) following their review of the MR images and clinical findings.

Slight dorsal border irregularity, small isolated focal core lesions and isolated sagittal plane splits of the DDFTin the region of the navicular bone were regarded as incidental findings because these have been identified in the nonlame limb of unilaterally lame horses (S.J. Dyson and R. Murray, unpublished data). Horses with small (<0.5 mm diameter), focal, discrete abnormalities of the DDFT at the level of the navicular bone were excluded from the study. Lesions were classified as genuine only if they were identified in both transverse and sagittal images. A slightly increased signal at the most distal aspect of the DDFT is sometimes seen in fat-suppressed images in nonlame limbs (S.J. Dyson and R. Murray, unpublished data); therefore, this alone was not considered significant. However, increased signal extending further proximally or increased signal in the distal phalanx at the insertion of the DDFT were considered significant.

Lesions of the DDFT were categorised further into core lesions (Fig 3), dorsal border lesions (focal, Fig 4, or diffuse, Fig 5), sagittal plane splits (Fig 6), insertional injuries (Figs 7 and 8) and lesions combined with either DSIL injury (Fig 9) or collateral desmitis of the DIP joint (Fig 10). Many horses had a

Fig 5a: Transverse 3D T2 GRE image at the level of the middle phalanx. Dorsal is to the top. Medial is to the right. The abaxial aspect of the medial lobe of the DDFTis enlarged dorsally and has increased signal (arrow).*

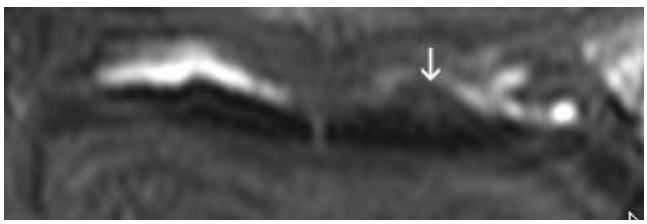

Fig 5b: The same horse as Figures 5a and c. Transverse 3D T2 GRE image distal to Figure 5a. Dorsal is to the top. Medial is to the right. The dorsal border of the medial lobe of the DDFT is irregular with tissue protruding into the navicular bursa (arrow).*

Fig 5c: The same horse as Figures 5a and b. Sagittal 3D T2 GRE image. There is a diffuse dorsal border lesion of the DDFT (arrows); the dorsal border is irregular and has increased signal.*

combination of different types of lesion in the DDFT. Assessment of insertional injuries of the DDFT was made only in the 3D T2* GRE and fat suppressed images because of the increased signal seen in the DDFT distally in T1 weighted images associated with the magic angle effect (Busoni and Snaps 2002).

Many horses with primary DDFT lesions (*Group I*) had increased signal in the palmar third of the navicular bone in fat-suppressed (fast STIR and fat-saturated) MR images. Horses categorised in *Group II* (DDF tendonitis and navicular bone pathology) had abnormalities in the navicular bone identified in T1 or T2 weighted MR images, including one or more distal border fragments, in addition to abnormalities on fat-suppressed images. Horses in *Group II* also had moderate or marked IRU in the navicular bone of the lame limb; equivocal radiographic abnormalities of the navicular bone in some horses (Dyson 2003);

Fig 6: Transverse 3D SPGR image at the level of the middle phalanx. Dorsal is to the top. Lateral is to the left. There is a full thickness sagittal plane split in the lateral lobe of the DDFT (arrows).

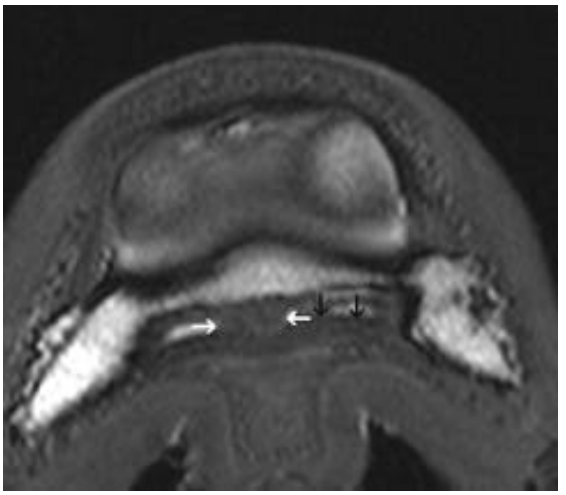

Fig 7: Transverse 3D T2 GRE image at the level of the distal phalanx. Medial is to the right. There is an insertional injury of the DDFT; the tendon is enlarged medially (black arrows) reducing the fluid space between it and the DSIL and there are adhesions between the DSIL and DDFTin the midline (white arrows).*

and significant improvement in lameness after intrathecal analgesia of the navicular bursa (if performed). Horses with primary navicular bone abnormalities with no lesions of the DDFT were not included in the study.

Results

The results presented for all diagnostic techniques refer to the more lame limb in horses with bilateral lameness unless stated otherwise. Forty-six of 75 horses (61%) examined using MRI were considered to have lesions of the DDFT that were a major contributor to lameness. Horses in *Groups I* and *II* were of similar age range (*Group I* 6–14 years, mean 9 years; *Group II* 6–15 years, mean 9 years). There did not appear to be any breed predilection (Table 1) (P = 0.86). However, when *Groups I* and *II* were compared with the general clinic population, there was a nonsignificant effect of discipline (P = 0.059). There was a nonsignificant trend for horses which jumped (showjumping, eventing, National Hunt racing) to be over-represented in the group with DDFT lesions (P = 0.078).

The duration of lameness was from 1 month up to 3 years, but was generally (n = 34) less than 6 months. Lameness or loss of performance was frequently acute in onset, although some horses in *Group II* were considered retrospectively to have shown previous low-grade lameness. Lameness varied substantially in degree, both between horses and historically within single horses; and was generally accentuated by hard work but improved with rest or light work.

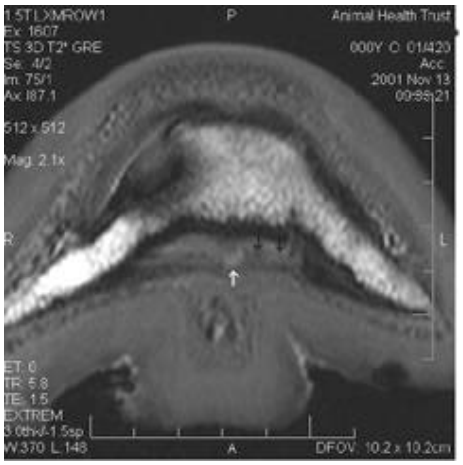

Fig 8a: Transverse 3D T2 GRE image at the level of the distal phalanx. Medial is to the right. There is a insertional injury of the DDFT. The DDFT is enlarged medially (arrows) and has increased signal in the midline (white arrowhead).*

Fig 8b: The same horse as in Figure 8a. Sagittal fast STIR image. The DDFT is swollen distally and has marked increased signal. There is loss of fluid signal between the enlarged DDFT and the DSIL.

No horse had any significant palpable abnormality of the palmar pastern region, nor could pain be elicited by deep palpation between the bulbs of the heel. Horses with moderate to severe lameness at the trot tended to point the lame(r) limb intermittently at rest. Many horses showed accentuation of lameness as they turned to change direction at the walk. Several of the more severely lame horses had a reduced caudal phase of the stride at the walk. The degree of lameness at the trot in straight lines was 0–5 (on a scale of 0–8: 0 = sound; 2 = mild; 4 = moderate; 6 = severe; 8 = nonweightbearing). Most horses were most lame on a circle of 10–15 m diameter on a hard surface, sometimes with the lame(r) limb on the inside of the circle and less commonly with the lame(r) limb on the outside of a circle. A small proportion of horses were most lame with the lame(r) limb on the outside of a circle on a soft surface, but with the lame(r) limb on the inside of a circle on a hard surface.

Group I

Clinical features and response to local analgesia: Twenty-two of the 32 horses (69%) in *Group I* had unilateral lameness and

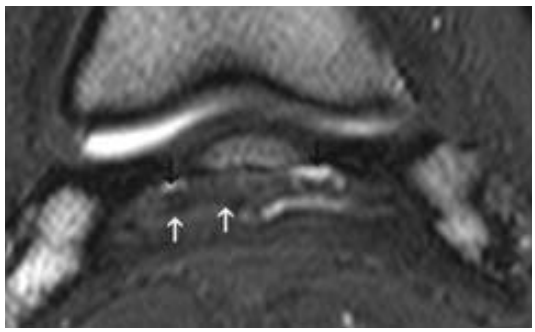

Fig 9: Transverse 3D T2 GRE image at the level of the distal phalanx. Lateral is to the left. There are abnormalities of both the DDFT and the DSIL, with adhesions between the DDFT and DSILlaterally, resulting in loss of the fluid signal in the navicular bursa (white arrows). There are focal areas of bright signal within the DSIL(black arrows).*

10 (31%) bilateral lameness (1 bilaterally symmetrical and 9 asymmetrical in degree), sometimes apparent only after perineural analgesia of the lamer limb. The response to local analgesic techniques is summarised in Table 2. Lameness was completely eliminated by palmar digital analgesia in only 5 horses (16%), but all horses appeared sound after perineural analgesia of the palmar (abaxial sesamoid) nerves. Intra-articular analgesia of the DIPjoint resulted in improvement or resolution of lameness in 21 of the 31 horses (68%) in which it was performed, whereas intrathecal analgesia of the navicular bursa produced substantial improvement in 12 of 18 horses (67%).

Radiography, nuclear scintigraphy and ultrasonography: No significant radiological abnormality was identified in the lame limb of any horse. IRU was identified in lateral pool phase images in the region of the DDFTin 5 of 29 horses (17%). Focal IRU was seen in the distal phalanx in the region of insertion of the DDFT in solar or less commonly lateral or dorsal bone phase images in 8 of 29 horses (28%), 2 of which did not have insertional lesions detected using MRI. Moderate IRU was seen in the navicular bone of the lame or nonlame limb in 3 horses.

Ultrasonography was performed in 29 horses (only the first 12 examined via the frog) and no abnormality other than mild distension of the navicular bursa (n = 25) was detected. A small discrete focal hypoechoic lesion was identified in either the medial or lateral lobe of the DDFT in the mid-pastern region (n = 2) and confirmed using MRI. These focal lesions were considered too small to account for the lameness. One of the collateral ligaments of the DIP joint was enlarged or poorly defined (n = 2) and these abnormalities were also confirmed using MRI.

Magnetic resonance imaging: Lesions of the DDFT were identified as focal or diffuse areas of increased signal in all sequence types, but the sequence type in which the lesions were best identified varied between horses. Many horses had a combination of categories of lesion of the DDFT present at different sites; therefore, subdivision of horses into discrete groups based upon lesion type was not possible. Generally, lesions were present from the middle of the proximal phalanx to the level of the proximal aspect of the navicular bone and distal to the navicular bone in the region of insertion on the distal phalanx. There were lesions confined to the insertion (n = 1), both insertional and more proximal lesions (n = 16) and lesions sited only proximal to the navicular bone (n = 15).

Fig 10a: Sagittal 3D T2 GRE image obtained medial to the midline. The DDFT is enlarged at its insertion (arrow) resulting in reduced space between it and the DSIL.*

Lesions were often confined to either the medial or lateral lobe of the DDFT, but sometimes involved both. The affected lobe was often enlarged. Swelling of the tendon was best seen in transverse images and, in some horses, could be confirmed in sagittal images. Swelling of the tendon near its insertion resulted in loss of space between the DDFT and the DSIL and in some horses the structures appeared to be contiguous, partially or completely obliterating fluid in the navicular bursa (Fig 11). In 4 horses with insertional lesions, some roughening of the palmar cortex of the distal phalanx with irregular endosteal mineralisation was seen in T1 or T2 weighted images. Generally, this was most marked on transverse images but was often also detectable on dorsal or sagittal plane images. The proximodistal extent of lesions was 13–70 mm. Two horse had a concurrent injury of the lateral collateral ligament of the DIP joint and 5 horses had abnormalities of the DSIL. Concurrent distension of the navicular bursa was common. In horses with acute lesions involving the dorsal border of the tendon, there was sometimes tissue protruding from the tendon into the bursa (Fig 12). In these and other horses, there was also proliferative synovial tissue in the navicular bursa. Increased signal in the palmar third of the navicular bone was seen (n = 20) in fat-suppressed images of the lame limb(s).

Group II

Clinical features and response to local analgesia: Six of the 14 horses (43%) had unilateral lameness and 8 (57%) had bilateral lameness. The response to local analgesic techniques is summarised in Table 2. Lameness was eliminated completely by palmar digital analgesia in 6 horses (43%), but all horses were nonlame after perineural analgesia of the palmar (abaxial sesamoid) nerves. Lameness was improved more than 50% after intra-articular analgesia of the DIP joint in 11 of 12 horses (92%), whereas intrathecal analgesia of the navicular bursa produced substantial improvement in all 11 horses in which it was performed.

Fig 10b: Dorsal 3D SPGR image of the same horse as Figure 10a. The medial collateral ligament of the DIP joint is considerably enlarged (arrows).

Radiography, nuclear scintigraphy and ultrasonography: Radiographic abnormalities of the navicular bone were identified in 7 horses and included increased thickness of the flexor cortex, mild localised sclerosis of cancellous bone, large distal border synovial invaginations, modelling of the proximal border of the navicular bone and a distal border fragment. IRU was seen in the region of the DDFT in lateral pool phase images in 3 of 12 horses (25%) in which scintigraphy was performed. Three horses (25%) had moderate IRU in the navicular bone of the lame(r) limb and 3 horses (25%) had marked IRU in the navicular bone of the lame(r) limb. Ultrasonography revealed no abnormality in 13 horses. In one horse abnormalities were identified in the insertion of the straight sesamoidean ligament, but these were not considered to be sufficient to account for the degree of lameness.

Magnetic resonance imaging: The lesions in the DDFT identified using MRI were similar to those in *Group I*, although tended to extend to include the region on the palmar aspect of the navicular bone. One horse had lesions confined to the insertional region of the tendon, 4 had a combination of insertional and more proximally located lesions and 8 had only proximal lesions. However, 3 horses also had evidence of adhesion formation between the DDFT and the palmar aspect of the navicular bone. Abnormalities of the navicular bone included mineralisation within the cancellous bone, areas of fluid within the bone, an irregular outline of the palmar or endosteal aspects of the flexor cortex, endosteal irregularity of the dorsal cortex, thickening of the flexor surface, modelling of the proximal border of the bone, large synovial invaginations along the distal border of the bone, distal border fragments and increased signal in the bone in fat-suppressed images.

Groups I *and* II

Nuclear scintigraphy: Lesion severity, determined subjectively, using MRI was categorised as severe in 7 of the horses with positive scintigraphic findings (44%), moderate in 7 horses (44%) and mild in 2 horses (14%). Overall, there was a similar distribution of lesion severity in *Groups I* and *II*.

Twelve of the 16 horses with positive scintigraphic findings had lameness of less than 3 months and, in 7 of these, less than 2 months duration. No significant difference in lameness duration

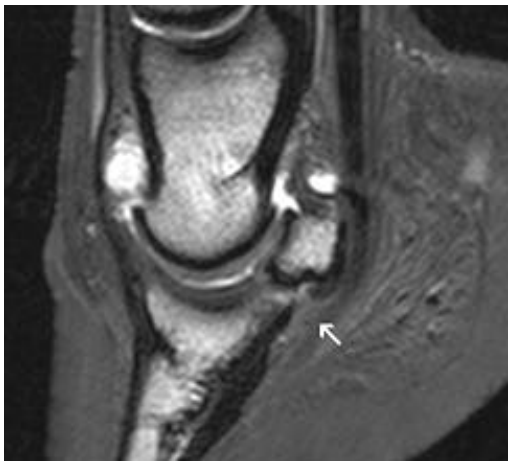

Fig 11a: Sagittal 3D T2 GRE image. The DDFT is enlarged and has increased signal. There is extensive adhesion formation between the DDFT and the DSIL.*

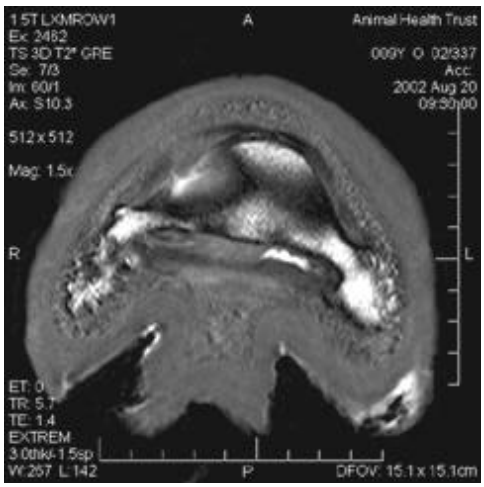

Fig 11b: Transverse 3D T2 GRE image at the level of the distal phalanx of the same horse as Figure 11a. Lateral is to the left. There is extensive adhesion formation between the lateral two-thirds of the DDFT and the DSIL. Note also the irregular contour of the cortex of the lateral palmar process.*

was detected between groups. The mean duration of lameness for *Groups I* and *II* was 5.8 months (range 0.75–36 months) and 7.6 months (range 1–36 months), respectively. When horses with and without scintigraphic abnormalities were compared for both groups, those with positive scintigraphic findings had a significantly ($P = 0.03$) shorter duration of lameness (mean ± s.d. 3.4 ± 2.6 months) than horses with negative scintigraphic findings (mean ± s.d. 6.6 ± 7.1).

Discussion

In this series of 75 horses examined using MRI, 46 horses (61%) had lesions of the DDFT considered to be a major contributor to lameness, substantiating the hypothesis that DDF tendonitis is a significant cause of forelimb lameness associated with the digit in the absence of radiographic abnormalities. Thirty-two horses (43%) had primary DDFT injuries and 14 (19%) had a combination of DDF tendonitis and navicular bone pathology. Horses that jumped (48%) were over-represented compared to the general clinic population (36%). Palmar digital analgesia eliminated lameness in only 11 of 46 horses (24%), supporting the hypothesis that pain associated with DDF tendonitis in the digit is not reliably eliminated by apparent desensitisation of the palmar aspect of the foot. However, the hypothesis that ultrasonography should detect DDFT lesions proximal to the PIP joint was not substantiated. Nineteen horses had lesions of the DDFT proximal to the PIP joint detected using MRI, but lesions were detected ultrasonographically in only 2 (11%). The usefulness of nuclear scintigraphy for predicting the presence of DDF tendonitis was also not proven, with positive results in only 16 of 41 horses (40%), 8 (20%) with positive pool phase images and a further 8 (20%) with positive bone phase images.

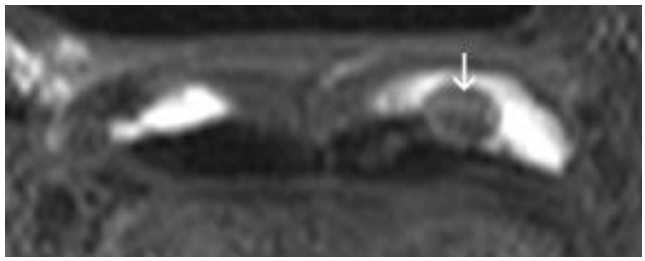

Fig 12: Transverse 3D T2 GRE image at the level of the middle phalanx. The same horse as Figure 2. The medial lobe of the DDFTis enlarged and has a central core lesion. There is tissue protruding into the navicular bursa (arrow).*

Deep digital flexor tendon lesions

A variety of lesion types were identified using MRI, often occurring in combination at different levels in the tendon and usually seen in either the medial or lateral lobe and generally not in the midline. In many horses, the most severe lesions were restricted to one lobe, although the other lobe often had more minor lesions. Injuries to the medial and lateral lobes occurred with similar frequency. Minor focal lesions were seen often in the nonlame limb of unilaterally lame horses. Invariably, lesions were worst in the lamer limb in horses with bilateral lameness. However, one horse in *Group I* with bilateral lameness that was consistently worse in the left forelimb had a history of more severe episodes of right forelimb lameness. Lesions were more extensive in the currently lamer limb, but adhesions between the DDFT and the DSIL were identified in the contralateral limb. Generally, those horses with adhesion formation or other concurrent soft tissue injuries showed the most severe lameness. Mineralisation was not seen in any tendon.

Enlargement of the DDFT was generally best appreciated in transverse images by evaluating symmetry of the medial and lateral lobes and their cross-sectional area but, in some horses, swelling of the tendon could be seen in sagittal images. The sequence type in which lesions were best identified varied between horses and, in many, maximum information about the lesions was determined using a combination of T1 weighted SPGR, 3D T2* GRE and fat-suppressed images. The high signal of fluid in the navicular bursa in T2 weighted images helped to highlight dorsal border lesions. An increased amount of fluid in the navicular bursa was common in the lame limbs. This sometimes resulted in artefactual linear bright signals in the adjacent DDFT in sagittal and transverse 3D T2* GRE weighted images, a Gibbs or truncation artefact (Whitton *et al.* 2003). Reduced fluid signal between the DSIL and the DDFT helped to highlight enlargement of the DDFT close to its insertion.

Small focal central core lesions in the pastern region, focal dorsal border lesions and partial or full thickness sagittal plane splits were often seen only in transverse images, but all other lesion types were seen in both sagittal and transverse views and some long core lesions were identified in dorsal images.

Lesions of the DDFTfrom the navicular bone proximally have been well documented using both MRI (Dyson *et al.* 2002, 2003; Dyson 2003a) and CT (Nowak 2002), but lesions at the insertion have not (Dyson 2003b). If no space could be identified between the DSILand the DDFT, this was presumed to represent adhesion formation or the presence of synovial proliferation. Although abnormal signal in the DDFT was relatively easy to discern, the heterogeneous structure of and therefore signal from the DSIL sometimes made it difficult to interpret subtle signal alterations and to confirm concurrent structural abnormality.

Increased signal in the palmar third of the navicular bone in fat-suppressed images was common. This increased signal represents increased fluid in the tissue and, in man, is associated with bone oedema, necrosis or trabecular damage (Rangger *et al.* 1998; Zanetti *et al.* 2000), which agrees with our preliminary findings on histological examination of equine navicular bones (A. Blunden, unpublished data). Four horses in *Group I* have been re-examined using MRI after an interval of at least 6 months and, in 3, the lesions of the DDFT had markedly improved, although abnormalities of signal were still detectable. Signal in the navicular bone was more normal in all horses (S.J. Dyson and R. Murray, unpublished data). Increased signal in fat-suppressed images of the navicular bone tended to be more widespread and more intense in the horses in *Group II* compared with *Group I*. A further 6 of the 75 horses examined using MRI during the period of this study but not included in these results had primary lesions of the navicular bone with only minor changes on the dorsal border of the DDFT restricted to the level of the navicular bone (S.J. Dyson, unpublished data).

Response to local analgesia

Given the high proportion of horses with DDFT lesions that extended proximal to the PIP joint (41%), it is not surprising that palmar digital analgesia resulted in alleviation of lameness in only 11 of 46 of horses (24%), with improvement of more than 80% in a further 5 horses (11%). Proximal diffusion of local anaesthetic solution may result in improvement in lameness associated with a site of pain proximal to the site of injection (Bassage and Ross 2003). However, sensory nerves within the DDFT, that enter further proximally (R. Bowker, personal communication), are not influenced by deposition of local anaesthetic solution at the proximal extent of the cartilages of the foot. Improvement in lameness in horses with similar lesions of the DDFT has been described after intrathecal analgesia of the digital flexor tendon sheath (Schneider 2002), presumably associated with blockade of proximal deep branches of the medial and lateral palmar digital nerves that enter the sheath.

Lameness was removed by palmar digital analgesia in 43% of horses in *Group II* but only 16% in *Group I*, suggesting that navicular bone pain may have been more important than DDFT pain in some of the horses in *Group II*. Ten of the 16 horses with more than 80% improvement in lameness after palmar digital analgesia had insertional lesions of the DDFT and one additional horse had adhesion formation between the DDFT and navicular bone. However, 7 of these 10 horses had additional lesions that extended proximal to the navicular bone.

The relative responses to intra-articular analgesia of the DIP joint (*Group I* 68%; *Group II* 92%) and analgesia of the navicular bursa (*Group I* 67%; *Group II* 100%) further support the hypothesis that navicular bone pain may have been more important than DDFT pain in the horses in *Group II*. Pain associated with the DDFT might potentially be influenced by intra-articular analgesia because of local diffusion of local anaesthetic solution. However, only 10 of 21 horses (50%) in *Group I* and 5 of 12 horses (42%) in *Group II* that responded positively to intra-articular analgesia of the DIP joint had insertional lesions of the DDFT.

Ultrasonographic examination

The high rate of false negative ultrasonographic examinations in the palmar aspect of the pastern was unexpected. All examinations were performed by experienced clinicians (S.J. Dyson and M. Schramme) using a 10 MHz transducer after fine clipping and routine limb preparation. The potential superiority of MRI for detection of healing tendon lesions has been described (Crass *et al.* 1992; Kasashima *et al.* 2002). Chronic fibrosis in the superficial digital flexor tendon (SDFT) was characterised by increased signal using MRI, but was difficult to differentiate from normal tendon tissue using ultrasonography (Kasashima *et al.* 2002), substantiating the results of a previous cadaver study (Crass *et al.* 1992). The stage of damage in the horses in this study is not known, although the duration of lameness was generally less than 6 months and in some horses considerably less, so it would have been expected that at least some of the lesions were relatively acute. A substantial subacute core lesion in the SDFT in the distal third of the metacarpal region and extending into the pastern was diagnosed recently using MRI, although the only structural change that had been identified by 3 experienced, independent clinicians using ultrasonography was enlargement in cross-sectional area (S.J. Dyson and R. Murray, unpublished data). Therefore, ultrasonography may have diagnostic limitations not previously recognised. No lesions were identified imaging prospectively via the bulbs of the heel using a convex array transducer. Ultrasonographic evaluation of the DDFT using a transcuneal approach was considered of limited value once it was recognised that the majority of the lesions occurred off the midline.

Nuclear scintigraphy

Nuclear scintigraphy appeared to have low sensitivity for DDF tendonitis as scintigraphic abnormalities were identified in only 40% of horses with DDFT lesions, in either lateral pool phase images or in solar bone phase images, but rarely both. However, as none of the 29 other horses examined using MRI during the study period (that did not have DDFT injuries) had IRU in the region of the DDFT in lateral pool phase images (S.J. Dyson, unpublished data), these scintigraphic findings had a high specificity for DDFT lesions. Two horses with marked focal IRU in the distal phalanx did not have insertional lesions of the DDFT, but had substantial lesions more proximally. The distribution of lesion severity was similar in horses with and without scintigraphic abnormalities. However, horses with positive scintigraphic findings had been lame for a shorter period than the overall mean duration of lameness for horses in *Groups I* and *II*, which may suggest that scintigraphic findings are an indicator of acute or ongoing injury.

In conclusion, MRI is a valuable tool for the detection of DDF tendonitis in the digit. DDF tendonitis in the digit is an important cause of lameness associated with pain in the digit in horses with no detectable radiographic abnormalities. DDFT injuries may also occur in conjunction with other soft tissue injuries within the hoof capsule. Currently, we have limited follow-up information on the response to treatment. A study of longer duration is required to determine prognosis in relation to lesion type and location, the degree of healing and other factors which may influence the chances of return to full athletic function.

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Manufacturer's address

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