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Relationship between the shape of the central and third tarsal bones and the presence of tarsal osteoarthritis

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ABSTRACT

Osteoarthritis (OA) of the low motion joints of the tarsus, commonly termed 'bone spavin', is common in horses. Whilst the aetiology of this condition is multifactorial, it has been suggested that dorsal wedging of the central tarsal bone (CTB) and third tarsal bone (TTB) may predispose to the development of this disease. The aim of this study was to investigate the relationship between tarsal bone conformation and osteoarthritis of the proximal intertarsal (PIT), distal intertarsal (DIT) and tarsometatarsal (TMT) joints. It was hypothesised that wedging of the CTB and TTB would be associated with OA in these joints. Multiplanar reconstructions based on computed tomographic (CT) images were used to measure the height of the central and third tarsal bones at their dorsal and plantar aspects in three parasagittal planes in cadaver specimens. A wedging index was calculated as the ratio between the dorsal and plantar measurements. All tarsal bones were graded for OA on CT images. There was a significant moderate negative correlation between the wedging index of the CTB and OA of the DIT ($\rho = -0.45$, $P < 0.01$), TMT ($\rho = -0.49$, $P < 0.01$) and PIT joints ($\rho = -0.43$, $P < 0.01$). Dorsal wedging of the TTB was seen in mild and moderate grades of OA, but severe cases of OA were associated with plantar wedging. Our study suggests that wedging of the small tarsal bones is associated with OA in the associated joints and hence care should be taken in foals to prevent the development of wedging.

Introduction

Lameness related to the tarsus is common in horses and is often caused by osteoarthritis (OA) of the distal intertarsal (centrodistal) (DIT) joint, tarsometatarsal (TMT) joint or both, with uncommon involvement of the proximal intertarsal (talocalcanealcentroquatral) (PIT) joint (Adams, 1970; Shelley and Dyson, 1984; Wyn-Jones and May, 1986). This condition is commonly referred to as 'bone spavin' and is thought to be associated with repetitive, low grade trauma (Kidd et al., 2001).

Many risk factors are associated with development of OA in the DIT and TMT joints; it has been proposed that conformation related parameters, including sickle hocks, cow hocks and straight hocks, predispose to development of distal tarsal OA (Rooney, 1969). These types of conformation may be associated with increased forces acting on the medial aspect of the tarsus (Baxter, 2011). In Icelandic horses, a breed predisposed to OA in the DIT and TMT joints, a decreased dorsal tarsal angle was associated with an increased incidence of 'bone spavin' (Axelsson et al., 2001). It has been postulated that this decreased tarsal angle increases the compressive forces on the dorsal aspect of the tarsus, which may contribute to the development of OA (Murray et al., 2005). However, many horses with distal tarsal OA exhibit normal tarsal conformation (Baxter, 2011).

Several authors have suggested that tarsal bone collapse, resulting in 'wedging' of the tarsal bones, in foals may contribute to the development of 'bone spavin' (Auer et al., 1982; Dutton et al., 1998; McIlwraith, 2003; Ross and Dyson, 2011). Tarsal bone 'wedging' and collapse are thought to be associated with defective endochondral ossification of the central tarsal bone (CTB) and third tarsal bone (TTB) in the last 2 months of gestation and first month of life (Dutton et al., 1998). Foals can show varying degrees of ossification in the central and third tarsal bones at birth (McLaughlin and Doige, 1982; Ruohoniemi et al., 1995). The degree of ossification is lower in premature and dysmature foals, foals with hypothyroidism and following illness affecting the mare during pregnancy compared with healthy foals (Auer et al., 1982; McLaughlin and Doige, 1982; Adams and Poulos, 1988).

Tarsal bone collapse is thought to be due to the inability of the incompletely ossified bones to withstand the forces acting during weight bearing, resulting in dorsal 'wedging' of the CTB and TTB (Morgan, 1967; Sedrish and Moore, 1997; McIlwraith, 2003). Foals with a greater degree of tarsal bone collapse are less likely to be used for their intended purpose at follow-up; OA is not always evident at the time of radiographic assessment, but horses that did show radiographic signs of OA also showed a greater degree of collapse (Dutton et al., 1998). In more than half of affected foals, both

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the CTB and TTB showed some degree of collapse and, in cases where only one tarsal bone was affected, this was most frequently the third tarsal bone (Dutton et al., 1998).

The aim of the present study was to investigate the relationship between the degree of wedging of the CTB and TTB and the occurrence and severity of OA in the associated joints on computed tomographic (CT) images. We hypothesised that there would be a correlation between the degree of wedging of the CTB and TTB and the observed grade of OA in the PIT, DIT and TMT joints.

Materials and methods

Source of material for imaging

Forty-five cadaver tarsi from a random sample of 45 skeletally mature horses were obtained from a local abattoir. The horses had been euthanased for reasons unrelated to this study and the tarsi were frozen immediately after euthanasia. Transverse CT images were acquired from the distal tibia to the proximal metatarsus (1.5 mm slice thickness, 120 kV and 200 mA; Lightspeed, GE Healthcare).

Conformational measurements

Multiplanar reconstructions were used to derive standardised measurements of all tarsi (Mimics 13.1, Materialise). The heights of the CTB and TTB were measured in medial parasagittal, mid-sagittal and lateral parasagittal planes. Since these bones curve at their dorsal and plantar aspects, the measurements were not taken at the most dorsal or plantar aspects of the bones, but at a standardised distance from these aspects. To achieve this, the whole length of the bone was measured and 15% of that length was calculated. The calculated 15% measure was then subtracted from the dorsal and plantar aspects, and the width of the bones was measured at these locations.

As a measure of collapse, the ratio between the dorsal and plantar heights was calculated and termed the 'wedging index'. Wedging indices were calculated for each measurement plane for the CTB and TTB. Dorsal wedging was defined as a wedging index $\leq$0.95, indicating a narrower bone dorsally in comparison with plantarly. Plantar wedging was defined as a wedging index $\geq$1.05, indicating a narrower bone plantarly in comparison with dorsally. The 0.05 margins of these ratios were selected on the basis of the repeatability of the measurements; repeat measurements resulted in a repeatability coefficient of 0.47 (Bland and Altman, 1986).

Occurrence and grade of tarsal osteoarthritis

The PIT, DIT and TMT joints from each horse were graded for signs of OA on the CT studies by an experienced equine radiologist using a grading scheme adapted from Byam-Cook and Singer (2009). The following parameters were used as indicators of joint OA: joint narrowing, subchondral bone sclerosis, subchondral bone lysis and periarticular modelling. The severity of each of these imaging signs was graded by allocating a score of 1–3: 1, mild; 2, moderate; and 3, severe. The scores for each of the four parameters were then added to give an overall score for each joint: grade 1, mild (0–4); grade 2, moderate (5–8); and grade 3, marked (9–12).

The talus, CTB, TTB and proximal third metatarsal bone were assessed separately for subchondral bone sclerosis and lysis. The scores for each individual bone were also added: grade 0, none (0); grade 1, mild (1–2); grade 2, moderate (3–4); and grade 3, marked (5–6). The robustness of the grading system was tested by having a second observer review a subset of the CT studies (12 studies); the resulting scores of both observers were within one grade of each other and the final score used for analysis was reached by consensus.

Data analysis

Data were found to be not normally distributed using the Kolmogorov–Smirnov test. To evaluate the correlation between tarsal bone wedging and the presence of OA in the adjacent joints, Kendall's τ-b test was performed. Correlation between OA grade and wedging index was assessed by calculating the Spearman's rank correlation coefficient (rho, ρ). To compare differences in wedging index between different grades of OA in the PIT, DIT and TMT joints, a Kruskal–Wallis test was performed. SPSS (Version 20, IBM) was used and a *P* value of $P < 0.05$ was considered to be significant.

Results

Degree of wedging in the central and third tarsal bones

Table 1 shows the number of tarsi with wedging of the CTB and TTB in three planes. Some degree of wedging was exhibited by the majority of CTBs and TTBs. All possible 'wedging' conformations were observed in both bones, but the most commonly observed conformation of the CTB was plantar wedging medially and in the mid-sagittal plane, and dorsal wedging laterally. In the TTB the opposite was observed with regards to lateral to medial appearance of these bones; most bones exhibited dorsal wedging in the medial and mid-sagittal planes and plantar wedging laterally. The median (interquartile range, IQR) wedging index for the CTB was 1.07 (0.83–1.26) medially, 1.01 (0.81–1.22) mid-sagittally and 0.99 (0.70–1.11) laterally. The median (IQR) wedging index for the TTB was 0.97 (0.64–1.10) medially, 1.00 (0.84–1.20) mid-sagittally and 0.99 (0.70–1.11) laterally. There was a strong, positive, significant correlation between wedging of the CTB and wedging of the TTB ($\rho = 0.65$, $P < 0.01$).

Table 1
Number of tarsi categorised as showing dorsal wedging (wedging index $\leq$ 0.95) and plantar wedging (wedging index $\geq$1.05) of the central tarsal bone (CTB) and third tarsal bone (TTB) in the lateral, mid-sagittal and medial planes of 45 equine tarsi.

Bone	Wedge	Medial sagittal plane	Mid-sagittal plane	Lateral sagittal plane
CTB	Dorsal	4	10	7
	Plantar	29	15	6
TTB	Dorsal	19	21	12
	Plantar	10	4	17

Occurrence and grade of osteoarthritis

OA was most frequently observed in the TMT joint (69%) followed by the DIT joint (58%). The severity was mild in 44% of TMT and 40% of DIT, moderate in 18% of TMT and 13% of DIT, and severe in 7% of TMT and 4% of DIT. OA was less frequently observed in the PIT joint (31%) where 29% were classified as mild (29%), 2% as moderate and none as severe. Subchondral bone changes (SBC) were frequently seen in both the TTB (31%) and CTB (29%). These were seen less commonly in the third metatarsal bone (11%) and were rare in the talus (2%).

There was a positive, moderate, significant correlation between the occurrence and grade of OA in all three joints: PIT and DIT ($\rho = 0.78$, $P < 0.01$); PIT and TMT ($\rho = 0.69$, $P < 0.01$; and DIT and TMT ($\rho = 0.65$, $P < 0.01$).

Tarsal bone conformation and computed tomographic evidence of osteoarthritis

Figs 1 and 2 illustrate the distribution of wedging indices of the CTB and TTB for the different OA groups. The significance of the differences between the different grades of OA for each joint in wedging of the TTB and CTB bones in the lateral, sagittal and medial planes are indicated. There was a significant difference between DIT OA groups in CTB wedging in the medial plane, with the wedging index becoming smaller with increasing OA grade (Fig. 1a). No significant differences in wedging index of the CTB were seen among the TMT OA groups (Fig. 1b). For the TTB, there was a significant difference in wedging index among the TMT OA groups for the medial and sagittal planes. The wedging index of the TTB was smaller in the medial and sagittal plane in OA grades 0–2, but increased for OA grade 3 for both the DIT and TMT. The wedging index in the lateral plane showed the opposite relationship (Fig. 2a and b).

Spearman Rank correlation coefficients and *P* values for the correlation between CTB and TTB wedging and OA grade of the PIT, DIP and TMT joints are provided in Table 2. There were significant, moderate, negative correlations between: (1) wedging of the CTB in the medial plane and the DIT joint; (2) wedging of the CTB in the sagittal plane and the PIT and TMT joints; and (3) wedging of the CTB in the lateral plane and the TMT joint. The only significant correlation between wedging indexes of the TTB was observed for wedging of the TTB in the lateral plane and the PIT joint.