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Pictorial Essay

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Metatarsalgia: An ultrasound perspective

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SUMMARY

Research on metatarsophalangeal joint instability and the plantar plate was conducted from May 2002 to May 2006. Along with plantar plate tears, we found a range of pathologies. This is a pictorial review of our experience.

Key words: *cartilage; forefoot; joint instability; metatarsophalangeal joint; neuroma*.

INTRODUCTION

Metatarsalgia is a debilitating and common problem in the community. The anatomy in the region of the metatarsophalangeal joints (MTPJ) is complex and many different structures may cause pain (Fig. 1). The consequences of untreated and undiagnosed forefoot problems include early onset of arthritis, foot deformities, callosities and chronic pain.

Research on MTPJ instability and the plantar plate was conducted from May 2002 to May 2006. Although the research targeted the plantar plate, we gained experience in assessing the forefoot for other pathologies and corroborated our findings with MRI. This is an article that describes our sonographic techniques and is a pictorial review of forefoot pathology.

The aim of this paper is to illustrate the causes of metatarsalgia that can be diagnosed with ultrasound.

MATERIALS AND METHODS

Sonography was carried out using the Antares scanner (Siemens Medical Systems, Erlangen, Germany) with a 5- to 13-MHz linear transducer. The forefoot was scanned in the longitudinal and transverse planes, from both the plantar and dorsal sides. The gel was applied generously between the skin and the probe.

The patient was positioned supine on the examination trolley, leg bent with the foot flat and the forefoot examined from the dorsal aspect.

At the level of the lesser MTPJ, the cortical bone and joint capsule were evaluated for evidence of bone erosion, effusion or synovitis. Extensor tendons were also observed. The intermetatarsal spaces were assessed for solid or cystic foci, compressible or non-compressible. Transducer pressure from the dorsal aspect and the sonographer's non-imaging finger pressing from beneath was the method generally used, thereby splaying the metatarsals.

The plantar aspect was evaluated on a number of levels. First, the fat pad was scanned for the presence of fluid or masses and vascularity observed. Then, more deeply, the tendons and plantar plates were dynamically assessed. Dorsiflexion of the phalanx tenses the plantar fascia and its distal insertion onto the plantar plate, bringing the loosely curved structure into a taut linear state. The distal insertion onto the proximal phalanx is identifiable at rest, but dorsiflexion allows the integrity of the plantar plate to be evaluated. Evaluation of the intermetatarsal spaces from the plantar aspect is the exact reverse of the dorsal technique. The non-imaging finger presses on the dorsal web space, whereas the transducer compresses and images plantarly.[2]

RESULTS

Inflammatory Process

Adventitial bursitis

Adventitial bursae develop in adults as a result of excessive friction between the soft tissue and underlying bone protuberances.[3] They are not true synovial-lined potential spaces, as in congenital bursae, and are not associated with inflammatory

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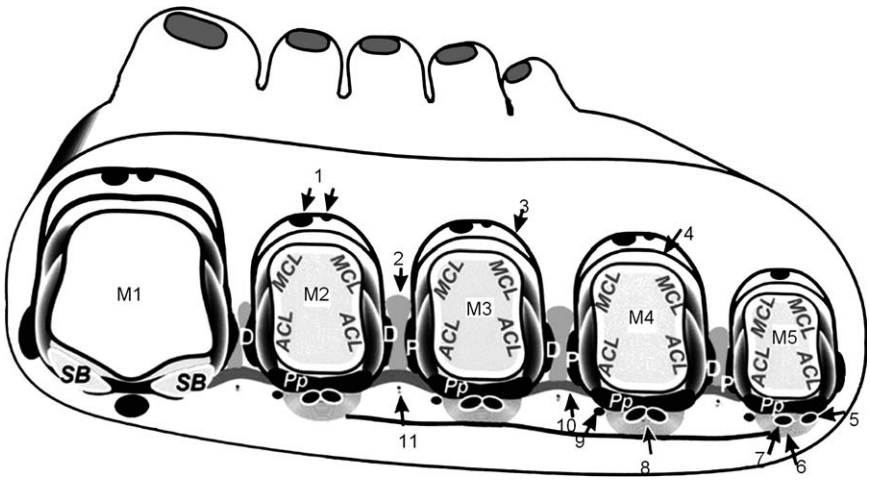

Fig. 1. Coronal illustration of the metatarsophalangeal joint and nearby structures, modified with permission from Radiologic Society of North America.[1] 1, extensor digitorum longus and brevis tendons; 2, intermetatarsal bursa; 3, extensor expansion; 4, fibrous capsule; 5, flexor digiti mini brevis tendon; 6, vertical fibres of the plantar fascia; 7, flexor digitorum longus tendon; 8, flexor digitorum longus and brevis tendons; 9, lumbrical tendon; 10, deep transverse intermetatarsal ligament; 11, neurovascular bundle; ACL, accessory collateral ligament; D, dorsal interosseous tendon; M1–5, first to fifth metatarsal heads; MCL, main collateral ligament; P, plantar interosseous tendon; Pp, plantar plate; SB, sesamoid bone.

arthropathies.[3] Adventitial bursitis under the metatarsal heads may appear as focal or broad areas of ill-defined black zones (fluid collections) (Fig. 2).

Intermetatarsal bursitis

The normal intermetatarsal region is fat filled and echogenic. Intermetatarsal bursitis is recognized on ultrasound as 'black zones', as an anechoic area between the distal heads of the metatarsal bones.[4] They may appear similar to ganglions, but are compressible. Unlike adventitial bursitis, intermetatarsal bursitis is associated with rheumatoid arthritis, infection, trauma and gout. Imaging is carried out from either dorsal or plantar surfaces or both. Compressible fluid is the finding, but it may be hypoechoic or complex (Fig. 3a,b). The walls of the bursa may become thickened and difficult to differentiate from a Morton's neuroma. It is not uncommon for both to be present and separating these pathologies from each other may be difficult.

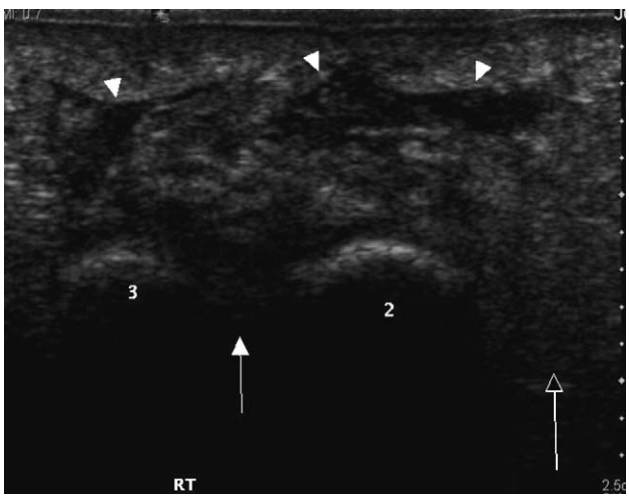

Fig. 2. Transverse sonographic image of the plantar surface at the level of the metatarsal heads. The normally echoic fat pad has focal areas of fluid, 'black zones' (arrowheads), superficial to the second and third metatarsal heads representing adventitial bursitis. The normal intermetatarsal region is echoic (black arrow), whereas the abnormal intermetatarsal region is hypoechoic, representing a Morton's neuroma (white arrow).

Joint effusion

Bone profile and cartilage are the main landmarks in the assessment of joints, whereas the joint capsule can only be indirectly defined according to the profile of the joint cavity. A small amount of anechoic synovial fluid between the cartilage and the synovial membrane may be observed in asymptomatic patients. The bone profile is easily detectable as a sharp hyperechoic line. The normal cartilage appears as a subtle anechoic band with sharp chondrosynovial and osteochondral margins (Fig. 4a).[5] Joint effusions have a hypoechoic content and the distance between the joint capsule and the bone (joint space) becomes larger (Fig. 4b). Joint effusions may contain reverberation echoes from nitrogen bubbles. With complex effusions, there may be variable echogenicity reflecting debris within the fluid.[6]

Synovitis

Ultrasound allows the distinction between joint effusion and synovial proliferation. This distinction is possible because of the difference between the anechoic pattern of fluid collection and the soft echogenicity of synovial proliferation that can appear as a homogeneous thickening of the synovial layer or

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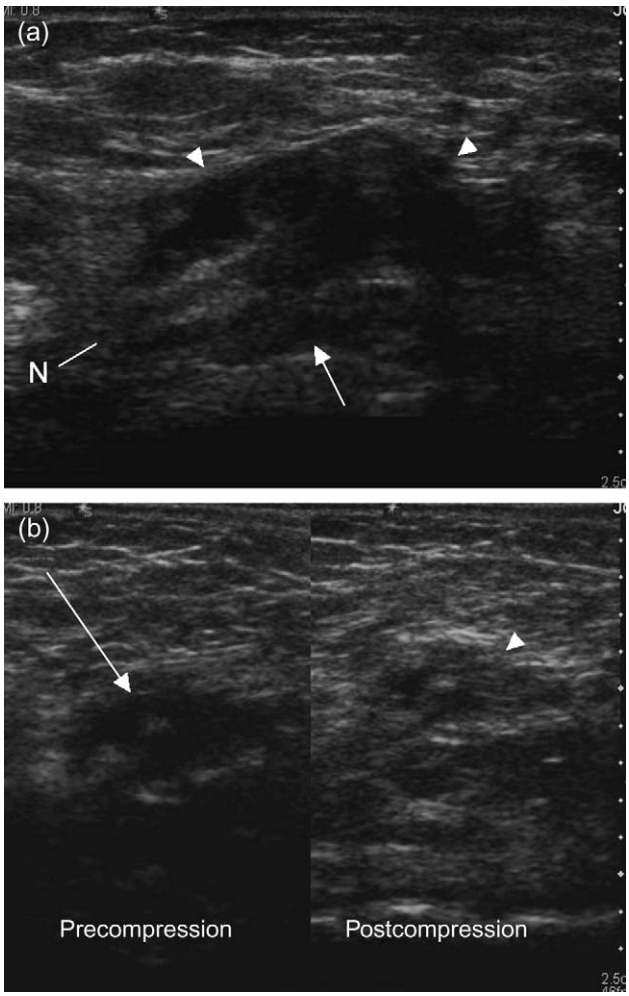

Fig. 3. (a) Sagittal section of a second web space from the dorsal aspect showing a hypoechoic region superficially and also more deeply. The superficial section is an intermetatarsal bursitis (arrowheads). The deeper section is the adjacent neurovascular bundle (N) with some evidence of fibrosis (arrow). (b) Sagittal image in the same web space with a split screen image precompression and postcompression. An ill-defined hypoechoic area (arrow) is seen to decrease in size and appears heterogeneous when compressed (arrowhead). This is a mildly complex bursa.

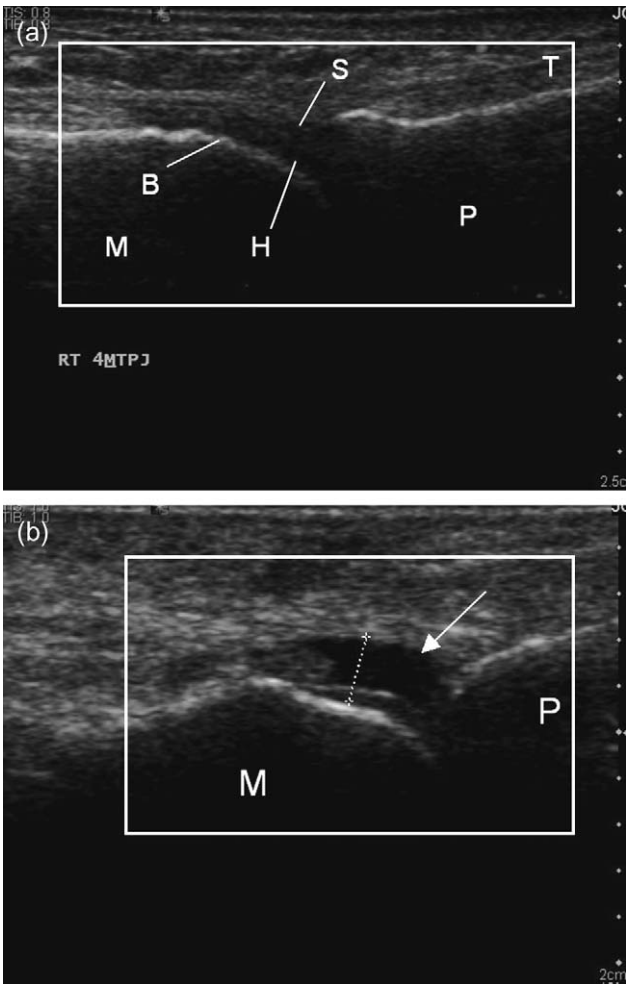

Fig. 4. Dorsal imaging of the metatarsophalangeal joint (MTPJ) capsule. (a) Longitudinal scan of a normal joint capsule at a fourth MTPJ. A thin anechoic hyaline band (H) and the synovial membrane (S) are seen adjacent the bone profile (B). (b) Abnormal MTPJ with hypoechoic content (arrow), representing a joint effusion. M, metatarsal head; P, proximal phalanx; T, extensor tendon.

as irregularly shaped clusters of echoes (bushy and villous appearance) (Fig. 5a,b). Active synovitis is characterized by a marked increase in joint perfusion that can be carefully depicted using the power Doppler technique.[5] Bone erosions may be present with loss of sharpness of the outer margins, loss of clarity of the cartilaginous layer, cartilage thinning and subchondral bone profile irregularities.[7,8]

Tendons/ligaments

Plantar plate degeneration or rupture

The plantar fascia divides near the heads of the metatarsal bones into five processes, one for each toe. The deep portion of the plantar fascia inserts into the proximal plantar plate, whereas the superficial portion inserts into the dermis of the skin.[9] The plantar plate has a central location on each MTPJ with multiple attachments that also include the collateral ligaments, intermetatarsal ligaments, interosseous tendons and the fibrous sheath of the flexor tendons (Fig. 6a–c).[10] The plantar plate is a slightly echoic band with a grainy, but homogeneous appearance in the longitudinal plane (Fig. 7a). It curves over the metatarsal head to insert into the proximal phalanx. In the transverse plane, the plantar plate similarly shows a curved slightly echoic structure overlying the metatarsal head. The short axis view is a more mottled appearance because of the undulating nature of the longitudinal fibrocartilage bundles (Fig. 7b).[11]

Abnormal features of the plantar plate include a loss of the homogeneous appearance. Normal echoic tissue is replaced with focal hypoechoic defects (Fig. 8a–c). Most tears occur at

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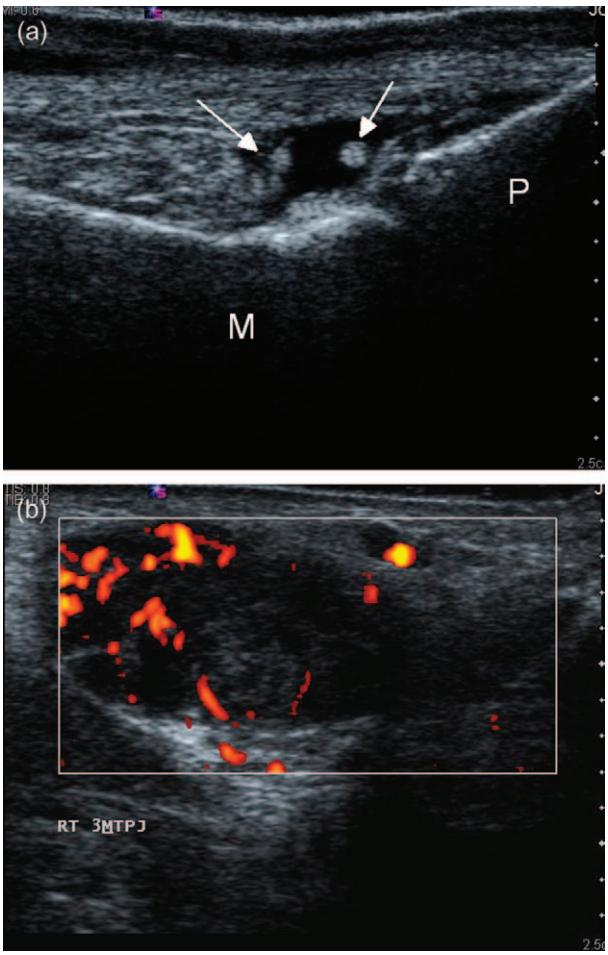

Fig. 5. (a) Metatarsophalangeal joint with hypoechoic content and echoic foci (arrows). (b) Complex capsule with gross swelling, a heterogeneous appearance, and hyperaemia. M, metatarsal head; P, proximal phalanx.

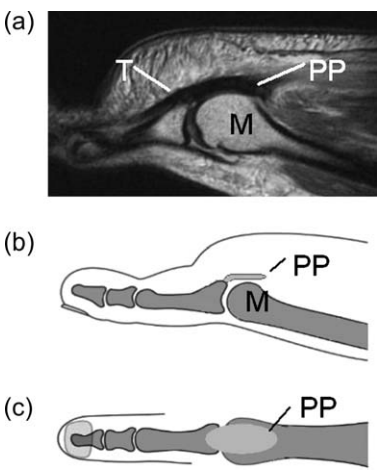

Fig. 6. (a) Sagittal proton density MRI image of the forefoot depicting the flexor tendon (T) abutting the plantar plate (PP) and cradling the metatarsal head (M). (b) Drawing of the metatarsophalangeal joints (MTPJ) in the sagittal plane, with the plantar plate (PP) inserting into the proximal phalanx. (c) Drawing of the MTPJ plantar plate (PP) in the posteroanterior plane.

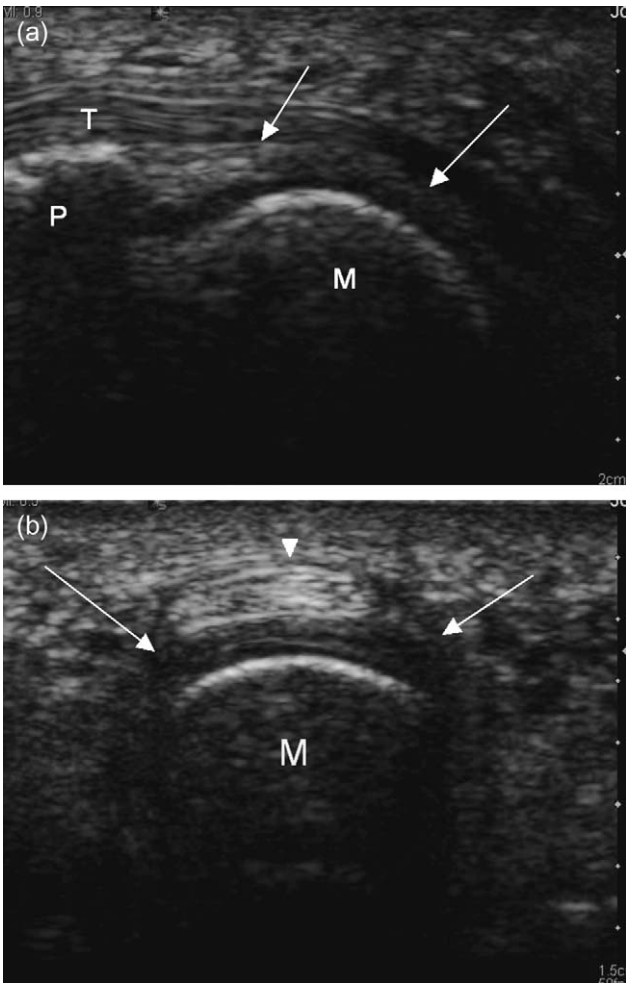

Fig. 7. (a) Longitudinal scan of a normal second metatarsophalangeal joint (MTPJ) plantar plate. A homogeneously echoic structure curves over the metatarsal head (arrows). (b) Transverse scan of a normal second MTPJ plantar plate. The borders are more subtle (arrows), but the plate itself is mildly echoic and mottled in appearance. The ovoid flexor tendon (arrowhead) rests directly on the plantar plate. M, metatarsal head; P, proximal phalanx; T, tendon.

the distal insertion onto the proximal phalanx. Osteophyte formation can sometimes be seen in the region of derangement (Fig. 8c). The normal plantar plate is non-vascular, the presence of vascularity suggesting inflammation (Fig. 8a).[11] Fibrosis of soft tissues superficial to an abnormal plantar plate may also be seen (Fig. 8b).

Tendinosis/tenosynovitis

Tendon sheath widening, loss of the normal fibrillar echotexture and loss of definition of tendon margins are the abnormalities that characterize acute and chronic tendinosis (Fig. 9a).[5]

The synovial sheaths begin over the heads of the metatarsals and extend to the bases of the distal phalanges. Tenosynovitis is characterized by an anechoic zone surrounding the echogenic tendon representing fluid or oedema in the synovial

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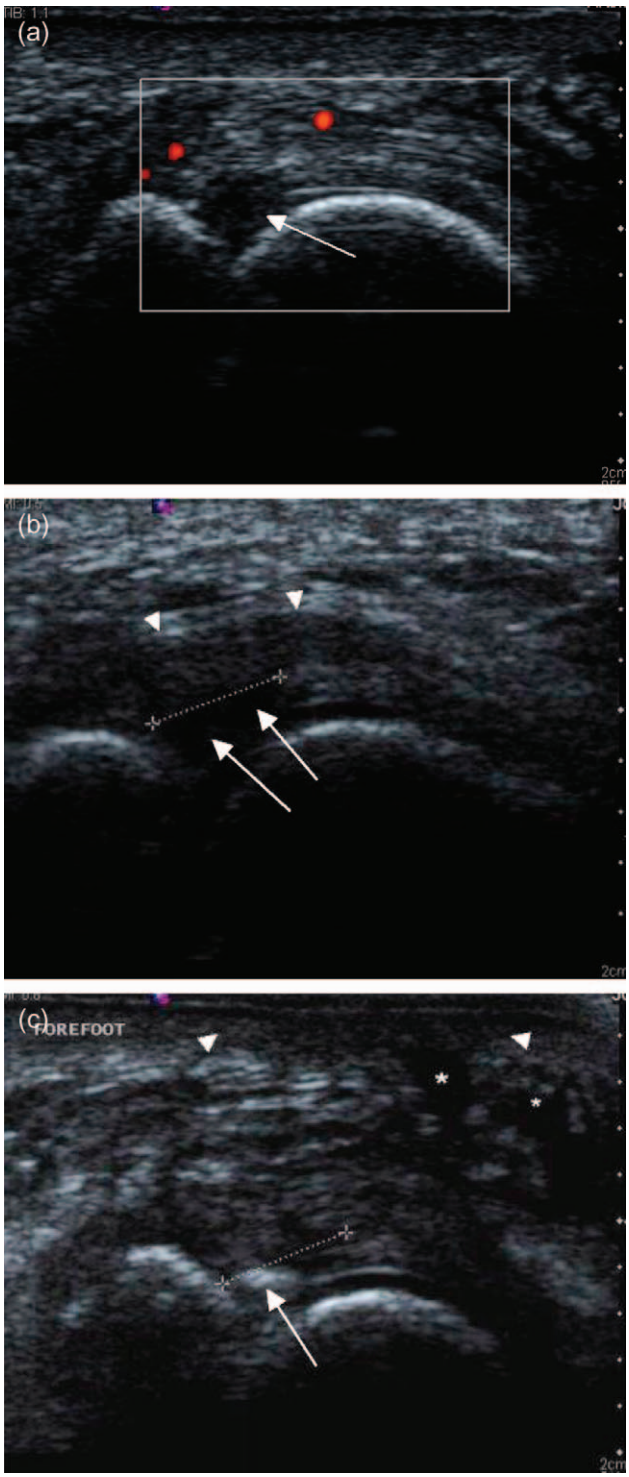

Fig. 8. (a) Longitudinal scan of a large articular surface tear (arrow) with hyperaemia. (b) Longitudinal scan of a long partial tear (arrows) in the plantar plate with fibrosis of superficial soft tissues (arrowheads). (c) Longitudinal scan of a grossly abnormal plantar plate. There is a mainly hypoechoic full thickness defect at the insertion onto the proximal phalanx where there is also osteophyte formation (arrow). The s.c. tissues are swollen and there is a pool of fluid (asterisks) referred to as adventitial bursitis. The skin appears thickened and hypoechoic, suggestive of callus formation (arrowheads).

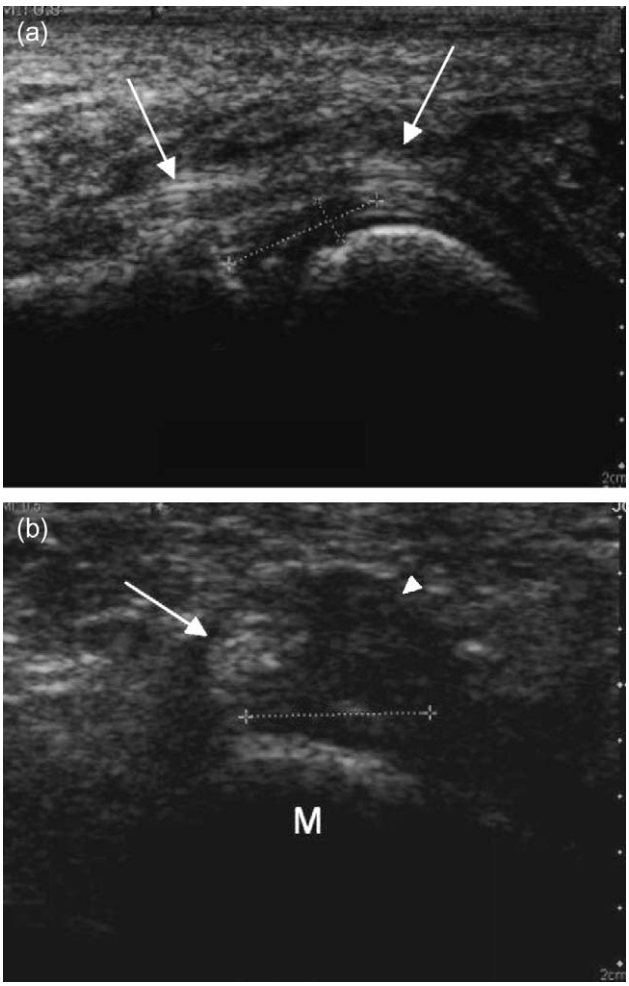

Fig. 9. (a) Sagittal scan of a second metatarsophalangeal joint plantar plate tear. Associated with this, the flexor tendon has reduced definition of the fibrillary pattern and tendon margin (arrows). (b) Transverse scan of a large tear of the plantar plate with medial subluxation of the flexor tendon (arrow) and fibrosis of superficial tissues (arrowhead). The tendon sheath appears hypoechoic and the tendon, heterogeneous, suggestive of tenosynovitis. M, metatarsal head; PP, plantar plate.

sheath (Fig. 9b).[12] Synovial fluid is characteristically anechoic in acute inflammatory processes. Tendon sheath widening may be homogeneous or complex, depending on the severity of inflammation. Chronic inflammatory tenosynovitis may be difficult to differentiate from acute tenosynovitis, but is generally thicker and more complex.

In the presence of a full thickness tear of the plantar plate, the flexor tendon may sublux, usually medially, but this may vary with the location of the tear (Fig. 9b).

Mass effect

Ganglion cyst

Ganglion cysts have been reported to be well defined and oval shaped with thin or thick walls. Ganglia may appear from completely anechoic to hypoechoic, with internal septation.[13] In the forefoot, ganglia are commonly found to be associated with the

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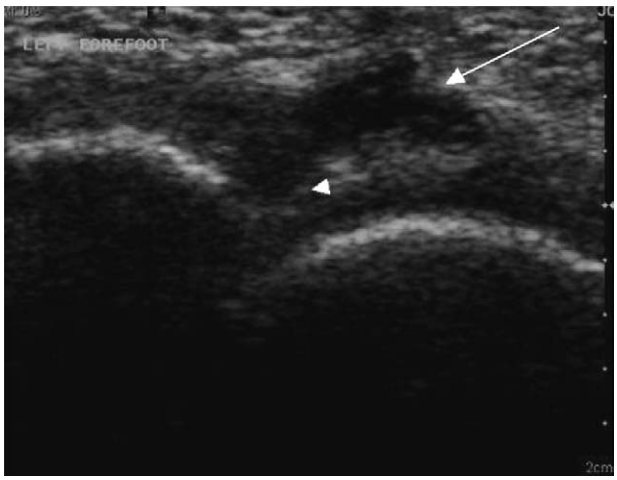

Fig. 10. Longitudinal scan of a second metatarsophalangeal joint plantar plate. A hypoechoic lobulated mass (arrow) superficial to a heterogeneous plantar plate insertion (arrowhead) communicating with the joint is representative of a ganglion cyst.

flexor tendon sheath, superficial to the plantar plate. Others extend from the joint and sit within a plantar plate defect or more superficially (Fig. 10). A tadpole sign may be seen, representing the tapering of the cyst near the site of origin.[14]

Intermetatarsal fibrosis/Morton's neuroma

A Morton's neuroma is perineural fibrosis that commonly occurs proximal to the metatarsal heads.[4] The mass is usually oriented parallel to the long axis of the metatarsals, deep to the interosseous muscles and distal to the intermetatarsal ligament.[15,16] Morton's neuromas have a variable appearance. We found many neuromas to be rounded hypoechoic lesions that were noncompressible. Others were elongated along the line of the nerve, some with lobulations (Fig. 11a–e). The digital nerve may be identified extending to the lesion.[17] The most common location is the third web space, followed by the second web space. In a study conducted by Read *et al.*,[2] any abnormal web space tissue measuring equal to or greater than 3 mm in dorsoplantar thickness (which replaced, displaced or obscured the neurovascular bundle) was diagnostic of a Morton's neuroma.

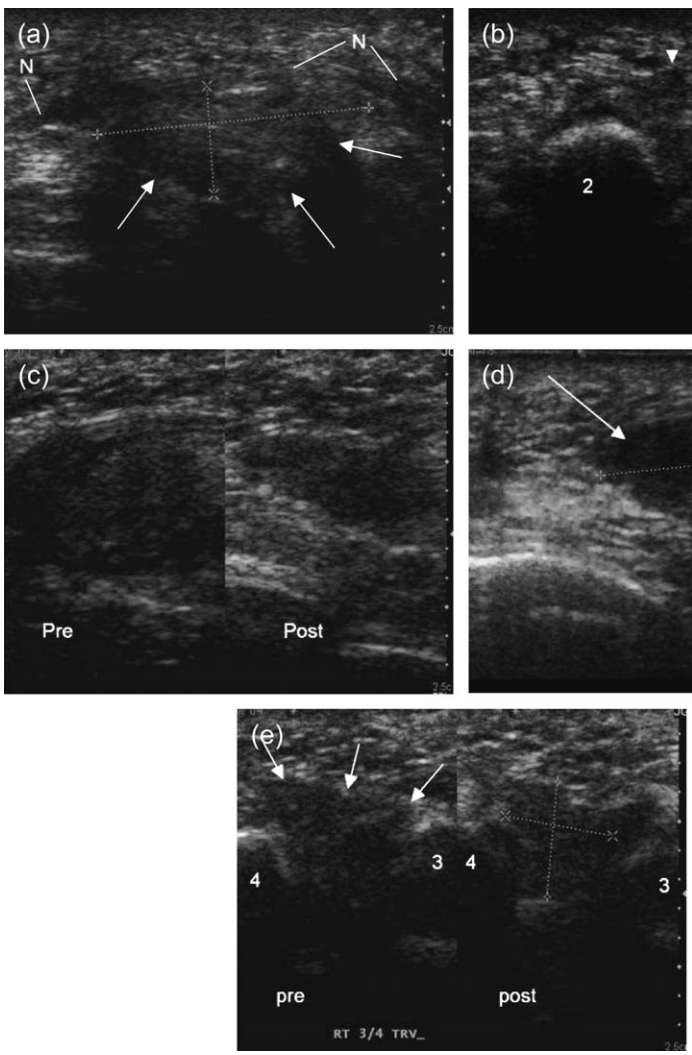

Fig. 11. (a) Longitudinal scan of the second web space from the plantar aspect. A large elongated noncompressible heterogeneous mass (arrows) adjacent to the digital nerve (N) corresponding to a moderate Morton's neuroma. (b) The transverse scan of the same region shows more subtle changes, with a noncompressible region only mildly hypoechoic to normal structures between the metatarsal heads (arrow). A second region of fibrosis lies superficial to this (arrowhead). (c) Longitudinal scan of a third web space, plantar aspect. A rounded heterogeneous mass is seen precompression and postcompression. The volume of the mass is reduced by compression. This is because of an intermetatarsal bursitis that is also present dorsal to the fibrosis. (d) Full-screen longitudinal image of the same web space. Superficial fibrosis (arrow) with pockets of fluid (bursitis) (arrowheads) more deeply. (e) Transverse scan of the same third web space with precompression and postcompression shows an irregularly shaped heterogeneous mass (arrows) protruding from between the metatarsal heads.

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DISCUSSION

Our experience with evaluating feet with MTPJ instability and suspected plantar plate tears has shown that plantar plate tears are common and that multiple pathologies may be present.[11,18] Ultrasound findings suggest that a patient with forefoot pain and MTPJ instability symptoms may also have a joint effusion or tendonosis. The presence of adventitial bursitis was not specific to MTPJ instability and was detected in asymptomatic patients.

Ultrasound of the forefoot can at times be difficult, but with practice, showing pathologies become easier. Providing the clinician with the full picture can only enhance the appropriateness of treatment. The advantage of ultrasound is that it is a fast, inexpensive and accurate test for showing a wide range of forefoot pathologies.

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