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Magnetic Resonance Imaging of Plantar Plate Rupture

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ABSTRACT

Degenerative plantar plate failure is an under-recognized cause of lesser metatarsalgia. We performed magnetic resonance imaging (MRI) with a small receiver coil in 13 patients in whom plantar plate ruptures of the second or third metatarsophalangeal joint were clinically suspected. In eight patients, MRI showed focal hyperintensity in the plantar plate that was interpreted as a rupture of the plate. Ruptures were confirmed in all five patients who underwent an operative procedure to treat the unstable, painful metatarsophalangeal joint. MRI is a noninvasive technique that can visualize plantar plate abnormalities and aid the clinical evaluation of problematic lesser metatarsalgia.

INTRODUCTION

The thick, rectangular, weightbearing portion of the metatarsophalangeal joint (MTPJ) capsule is called the plantar ligament or plate. This ligamentous plate provides a smooth gliding surface for the metatarsal head and the flexor tendons.⁵ The plantar plate receives attachments from the collateral ligaments, the deep transverse metatarsal ligaments, and the vertical fibers of the plantar aponeurosis.⁸ The plantar plate is an important static stabilizer that resists hyperextension of the MTPJ.^{1,2}

Spontaneous or degenerative plantar plate rupture affects the lesser toes—particularly the second—more commonly than is recognized, and may be associated with an exuberant synovitis and a localized metatarsalgia.^{4,9} Degeneration or derangement of the plantar plate of the lesser toes is also important in the genesis of hammertoe or clawtoe.^{1,2}

MTPJ arthrography can be used to diagnose plantar plate rupture.^{6,10} Magnetic resonance imaging (MRI)

has been effective in assessing the integrity of tendons and ligaments in general. In this article, we present our preliminary experience in the MRI evaluation of the plantar plate of the lesser toes using a small, local MRI receiver coil.

SUBJECTS AND METHODS

MRI of the MTPJ was performed on 13 patients (10 second rays, three third rays) with suspected plantar plate ruptures. Three patients had had previous surgery in the affected area (one Morton's neuroma resection, one metatarsal shortening osteotomy, and one hemiphalangectomy). Five asymptomatic volunteers also underwent MRI of the second MTPJ.

For the MRI, a flexible, 3-cm, receive-only surface coil was placed horizontally over the toe of interest, deep into the web spaces, with the patient supine. MRI was performed at 1.5 T (General Electric, Signa, Milwaukee, WI) with commercially available software. Sagittal and coronal (relative to the body) T1-weighted images were obtained through the MTPJ (field of view: 8 cm, slice thickness: 3 mm, matrix: 192 × 256, signal averages: 2). Sagittal, three-dimensional Fourier transformed (3DFT), gradient-recalled images acquired in the steady-state were obtained using TR 38 msec, TE 12 msec, and flip angle 30° (field of view: 10 cm, slice thickness: 0.7 mm, matrix: 256 × 192 × 32, signal averages: 2). Sagittal multiplanar gradient-recalled images were acquired using TR 400 msec, TE 9 to 15 msec, and flip angle 20–45° (field of view: 10 cm, slice thickness: 3 mm, matrix: 192 × 256, signal averages: 4).

Associations between clinical features and the finding of a plate rupture on MRI examination were analyzed using Fisher's exact test or the Mann-Whitney *U*-test.

RESULTS

Normal MRI Findings

In all asymptomatic volunteers, the plantar plate was seen on T1-weighted images as a smooth, low-

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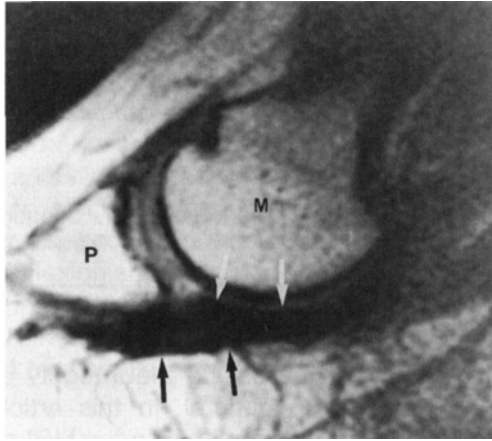


Fig. 1. Normal plantar plate. On sagittal T1-weighted image (500/20), the plantar plate (white arrows) is very low in signal intensity and difficult to distinguish from overlying flexor tendon (black arrows) (M = second metatarsal head, P = proximal phalangeal base).

signal structure abutting the plantar aspect of the metatarsal head, attaching at the proximal phalangeal base adjacent to the joint surface (Fig. 1). The plantar plate was difficult to distinguish from the thicker, overlying flexor tendons. On gradient-echo scans, the plantar plate was slightly higher in signal intensity than the adjacent flexor tendons and thus more easily distinguished from them. Higher signal hyaline cartilage was normally seen at the phalangeal attachment of the plate (Fig. 2). This finding could be distinguished from a tear of the plate by its immediate, juxtacortical location and focality. The plantar plate was imaged to best advantage on a 3DFT gradient-echo scan, which could be reformatted in the most appropriate, double

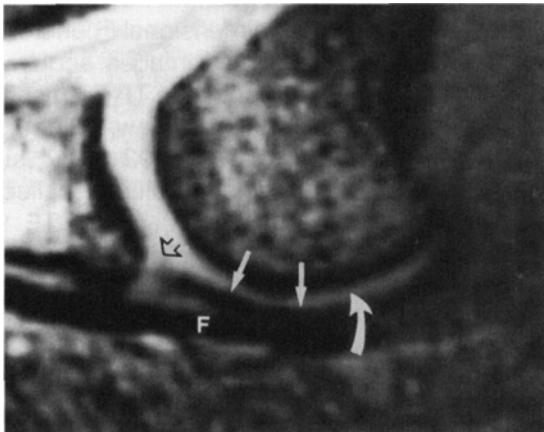


Fig. 2. Normal plantar plate. Sagittal reformation of 3DFT gradient-recalled images acquired in the steady-state (38/12, 30° flip angle) shows the plantar plate as a linear hypointense structure (straight arrows) between high-signal hyaline cartilage of metatarsal head (curved arrow) and lower signal intensity flexor tendon (F). The hyaline cartilage of the phalangeal base (open arrow) undercuts the plantar plate at its distal bony attachment; this finding should not be mistaken for a tear of the plantar plate.

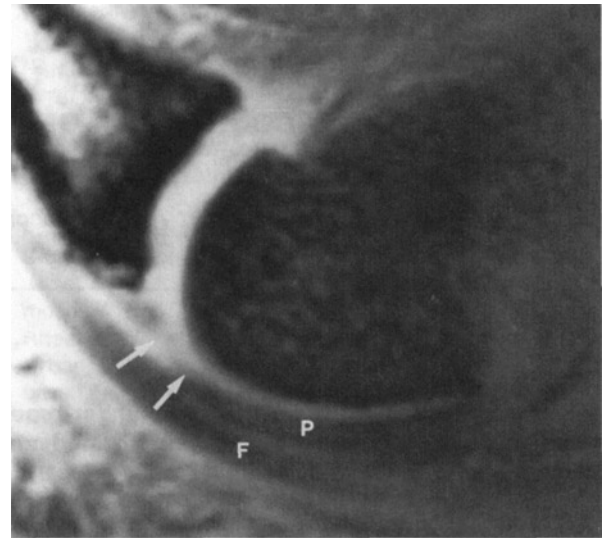


Fig. 3. MRI shows plantar plate rupture in a 41-year-old man who can no longer play tennis because of metatarsalgia. The sagittal multiplanar gradient-recalled image (400/14, 45° flip angle) reveals area of hyperintensity (black arrows) within the distal plantar plate (P) (F = flexor tendon).

oblique imaging plane (Fig. 2). Variable toe alignment and metatarsal rotation necessitate reformations in oblique planes.

Clinical Subjects

Thirteen clinical subjects were thought to have plantar plate ruptures based on clinical evaluation by one of the authors (A.C.). Subjects ranged in age from 30 to 69 years (average age, 55 years); there were four men and nine women. All patients reported symptoms of metatarsalgia centered over the metatarsal head for greater than 5 months. There was antecedent trauma in only one case, where second metatarsal pain began after a martial arts maneuver. Six patients had an ipsilateral hallux valgus, and five had a hammertoe deformity of the affected ray. There were no crossover toe deformities. On physical examination, all patients had pain that reproduced their presenting symptoms when the second toe was stressed in a dorsoplantar direction. Eight patients had local swelling and 10 had clear evidence of MTPJ instability only on the symptomatic foot. None of the cases exhibited findings of arthrosis on x-ray.

MRI studies were interpreted as diagnostic of plantar plate ruptures in eight of the clinical cases. The MRI finding of a tear was an area of increased signal intensity in the plantar plate that extended beyond the immediate area of the plate attachment on the proximal phalangeal base (Figs. 3 and 4, A and B). These findings were most confidently identified on reformatted 3DFT, gradient-recalled images. The area of plate

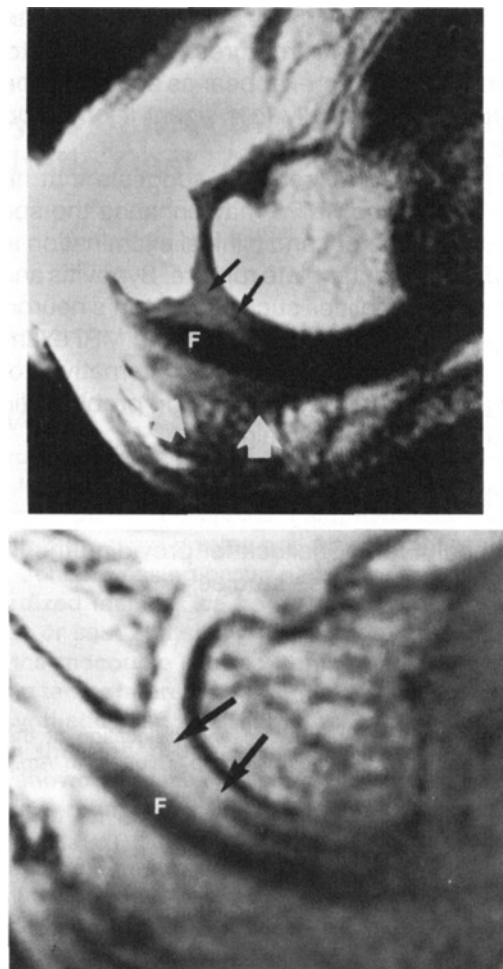


Fig. 4. MRI shows plantar plate rupture in a 59-year-old woman with worsening, chronic metatarsalgia with walking. (A) The sagittal T1-weighted image (500/20) shows a broad area of increased signal (small black arrows) in the distal plantar plate. Note synovitis in the flexor tendon sheath (large white arrows). (B) The oblique sagittal reformation of 3DFT gradient-recalled images acquired in the steady-state (38/12, 30° flip angle) more clearly shows a high signal defect in the plantar plate (short black arrows) (F = flexor tendon).

derangement was isointense with synovium and joint fluid. All plate derangements occurred adjacent to the metatarsal head, near the distal attachment of the plantar plate. Seven of eight positive MRI cases exhibited distension of the MTPJ capsule and the adjacent flexor tendon sheath, consistent with synovitis or effusion (Fig. 5).

MRI evidence of plate rupture was significantly ($P < 0.05$) associated with MTPJ instability on physical examination (8 of 8), and an ipsilateral hallux valgus (6 of 8). Patients with MRI evidence of plate rupture also tended to be female (7 of 8) and older (mean age, 59 vs. 48 years), although these factors did not reach statistical significance in our small group of patients.

Of the five patients with an intact plantar plate by

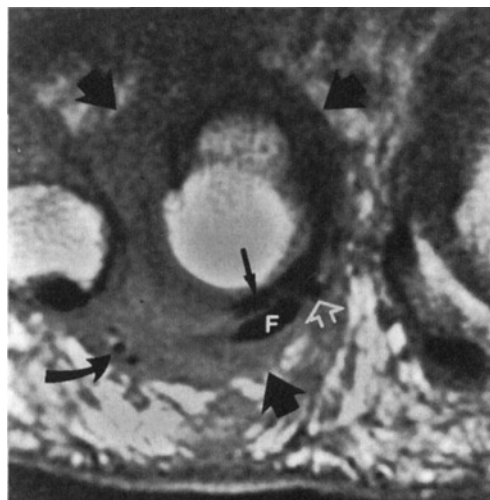


Fig. 5. MRI shows synovitis secondary to plantar plate rupture in a 69-year-old woman with bunion and painful second MTPJ. The coronal T1-weighted image (500/20) through the second MTPJ shows synovitis (large black arrows) that distends the joint capsule and flexor tendon sheath, displacing the plantar digital neurovascular bundle (curved arrow) (small black arrow = plantar plate, open arrow = lumbrical tendon, F = flexor tendons).

MRI, two had physical findings suggesting MTPJ instability and two had MRI findings of MTPJ synovitis. Of the patients with evidence of synovitis, one had MRI findings of Freiberg's infraction and the other had sustained antecedent trauma. None of these cases exhibited effusion or synovitis in the flexor tendon sheath on MRI.

All patients were initially treated conservatively by a reduction or cessation of their walking or jogging exercises, an anterior support to relieve pressure from the involved metatarsal head, and a short course of nonsteroidal anti-inflammatory medication. Five patients elected to have an operative procedure in an attempt to relieve their pain and allow greater function. A flexor digitorum longus tendon transfer was performed to stabilize the MTPJ in these patients using a longitudinal incision across the base of the proximal phalanx from a plantar approach. Although the plantar plate could not be grossly visualized due to the plantar fat pad, it was possible to explore the plate using a blunt nose hemostat. In each case, a rent was found in the plantar plate that allowed the tip of the hemostat to enter the joint. In four of the five patients, the MTPJ was exposed through a dorsal incision at the same time the flexor transfer to the extensor tendon was being completed. In these patients, the tip of the hemostat could be passed from the extensor side of the joint into the superficial plantar soft tissues (Fig. 6). A partial synovectomy was also performed in these patients.

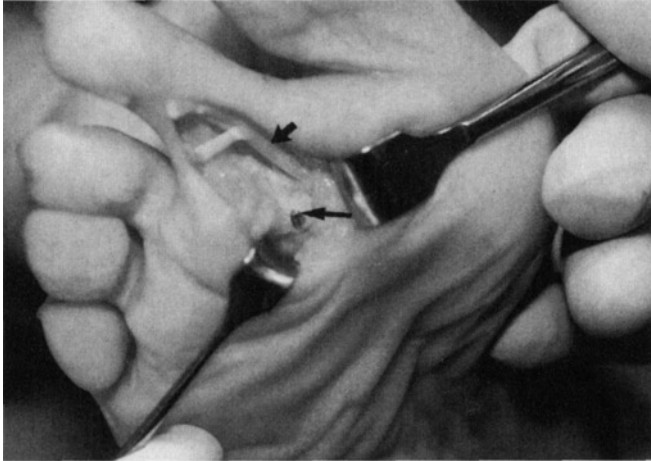


Fig. 6. Intraoperative photograph of a 68-year-old woman with chronic lesser metatarsalgia shows a surgical probe (long arrow) extending through the plantar aponeurosis after being passed through the dorsal aspect of the second MTPJ, confirming a suspected plantar plate rupture. The joint was stabilized by a transfer of the flexor digitorum longus tendon to the proximal phalanx (short arrow = flexor tendon).

DISCUSSION

The differential diagnosis of pain in the area of the lesser metatarsophalangeal joints includes stress fracture, degenerative arthritis, Morton's neuroma, Freiberg's infraction, and inflammatory arthritis.^{4,6} Degenerative plantar plate failure with secondary MTPJ instability is a common and under-recognized cause of lesser metatarsalgia. So-called "monoarticular, nontraumatic synovitis" of the MTPJ⁷ is conceivably a manifestation of plantar plate rupture.

The footwear worn by many women contributes to plantar plate derangement¹ and probably explains the greater prevalence of plate derangements in women. Derangements preferentially involve the second toe, because the second toe is longest.

If clinically suspected, plantar plate rupture can be confirmed using conventional arthrography of the MTPJ. Our early experience suggests that plantar plate rupture can be noninvasively diagnosed with MRI, particularly if a small receiver coil and three-dimensional image acquisition techniques are used. The necessary scan techniques are currently available

on commercial MRI units. On magnetic resonance images, plantar plate ruptures, like ligamentous derangements elsewhere, appear as areas of hyperintensity within the normally low signal ligamentous substance of the plate.

Our preliminary experience suggests that high resolution MRI of the MTPJ may enhance the specificity of a thorough history and clinical examination in cases of suspected plantar plate rupture. Synovitis and extra-articular abnormalities such as Morton's neuroma may also be detected by MRI.³ A tailored MRI examination of the MTPJ is a noninvasive alternative to MTPJ arthrography, and may be useful in problematic cases of focal, lesser metatarsalgia.

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