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Tarsometatarsal Joint: Anatomic Details on MR Images[1]

PURPOSE: **To evaluate the diagnostic capabilities of magnetic resonance (MR) imaging in the tarsometatarsal ([TMT] Lisfranc) joint with close anatomic correlation.**

MATERIALS AND METHODS: **Six normal cadaveric feet were imaged by using T1-weighted spin-echo (oblique axial) and three-dimensional spoiled gradient-recalled acquisition in the steady state ([SPGR] coronal, sagittal) sequences. Subsequently, gadolinium-enhanced arthrography was performed in three specimens followed by T1-weighted spin-echo and SPGR MR imaging. Specimens were sectioned in all three planes followed by correlation of the MR imaging results with gross anatomic findings.**

RESULTS: **In all specimens, the oblique axial and, less effectively, the coronal and sagittal planes allowed visualization of the Lisfranc ligament. Intermetatarsal ligaments were seen almost exclusively on the coronal images, and TMT ligaments on the sagittal images. Bone alignment could be assessed on the oblique axial images.**

CONCLUSION: **MR imaging reliably depicts the anatomy of the TMT joint including ligamentous and osseous structures.**

THE tarsometatarsal (TMT) joint, also called the Lisfranc joint, consists of the distal row of tarsal bones and the five metatarsal bases (1) (Fig 1). The keystone for stability of this joint, and therefore for the whole transverse arch of the foot, is the triangular base of the second metatarsal bone, which is recessed proximally and located in a mortise between the medial and lateral cuneiform bones (2). Stability is afforded by the firm ligamentous components of the joint, including the TMT ligaments, located on the plantar and dorsal aspects between the tarsal bones and the metatarsal bases, and especially the intermetatarsal (IMT) ligaments, which connect the bases of the second through fifth metatarsals plantarly and dorsally. No ligament is present between the first and the second metatarsal bases; instead, a ligamentous connection originates from the lateral face of the medial cuneiform bone and extends to the medial face of the second metatarsal base (Lisfranc ligament) (2). It provides stability between the medial cuneiform bone and first metatarsal base and the lateral four metatarsal bases. The purpose of our study was to outline the diagnostic capabilities of magnetic resonance (MR) imaging in the TMT (Lisfranc) joint with close anatomic correlation.

MATERIALS AND METHODS

Six fresh cadaveric feet, thawed after having been deep frozen, were examined with MR imaging by using a 1.5-T superconducting unit (Signa; GE Medical Systems, Milwaukee, Wis). The specimens were prepared and positioned according to the methods described in the literature (3). MR images were obtained with a knee surface coil in an oblique axial plane parallel to the dorsum of the foot by using a T1-weighted spin-echo sequence (repetition time msec/echo time msec = 400/20) with a section thickness of 3 mm and an intersection gap of 1 mm. Subsequently, spoiled gradient-recalled acquisition in the steady state (SPGR) sequences (38/12, 60° flip angle) were obtained in a three-dimensional volume acquisition mode in the coronal and sagittal planes. Section thickness was 1.0–1.2 mm, acquisition matrix was 256 × 128 or 256 × 256 pixels, and the field of view was 14 cm for all images according to a routine MR examination of the foot.

Intraarticular injection of 1.5–3.0 mL of gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) was performed in the TMT joint in three specimens to determine whether this technique improves the depiction of ligamentous connections in this joint. With fluoroscopic guidance, all joint compartments were filled with contrast solution, after which MR images were obtained by using the same techniques and positions as previously outlined.

All specimens were frozen again and sectioned with a band saw (3). One specimen was sectioned in the oblique axial plane, one in the coronal plane, and one in the sagittal MR imaging plane in such a way that sections in each plane could be correlated with MR images (both with and without contrast material). All sections

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Abbreviations: IMT = intermetatarsal, SPGR = spoiled gradient-recalled acquisition in the steady state, TMT = tarsometatarsal.

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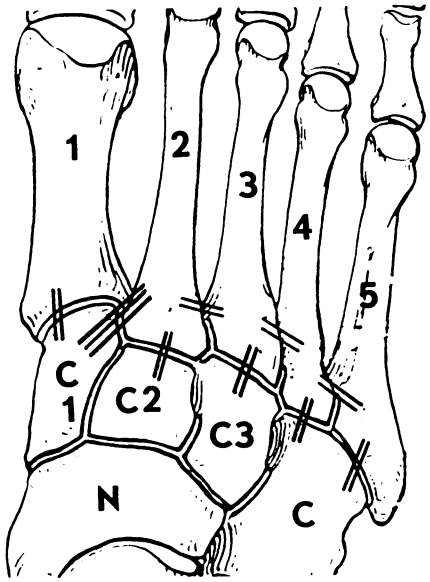
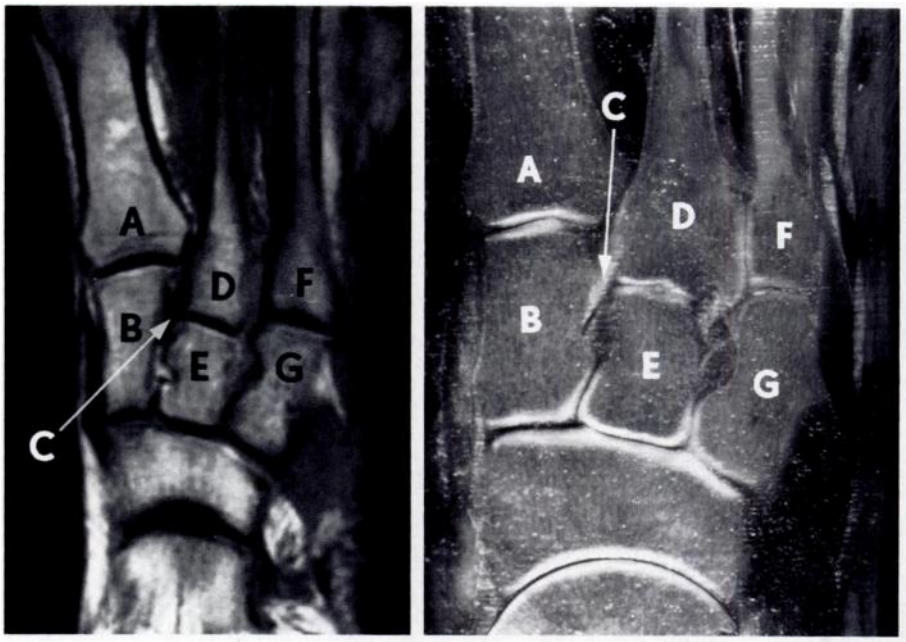
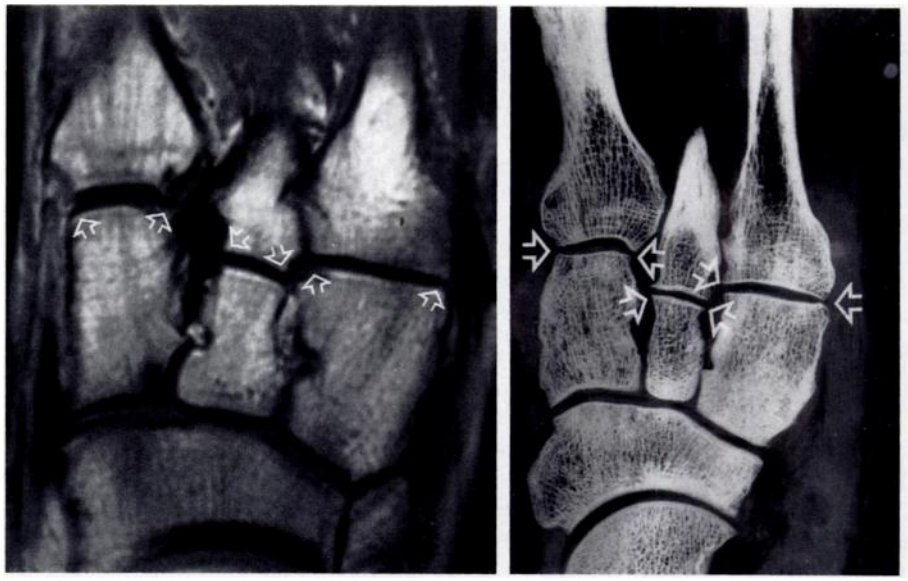


Figure 1. Anatomy of the Lisfranc joint and ligamentous connections (TMT ligaments) between the bases of the metatarsal bones (*1–5*) and the cuneiform bones (*C1–C3*) and cuboid bone (*C*). IMT ligaments (horizontal lines) are evident between the second through fifth metatarsal bases. Instead of an IMT ligament between the first and second metatarsal bases, a strong ligamentous connection, the Lisfranc ligament (three parallel lines), is provided between the medial cuneiform bone (*C1*) and the second metatarsal base (2). *C2* = intermediate cuneiform bone, *C3* = lateral cuneiform bone, *N* = navicular bone. (Modified and reprinted, with permission, from reference 1.)



a. b.

Figure 2. Correlation of MR imaging with gross anatomic findings in TMT joint. **(a)** Oblique axial T1-weighted MR image (400/20, matrix 256 × 256). **(b)** Corresponding anatomic section. *A* = first metatarsal base, *B* = medial cuneiform bone, *C* = Lisfranc ligament, *D* = second metatarsal base, *E* = intermediate cuneiform bone, *F* = third metatarsal base, *G* = lateral cuneiform bone.



a. b.

Figure 3. Normal bone alignment (arrows in **a** and **b**) between the first metatarsal base and the medial cuneiform bone, the second metatarsal base and the intermediate cuneiform bone, and the third metatarsal base and the lateral cuneiform bone. **(a)** Oblique axial T1-weighted MR image (400/20, matrix 256 × 256). **(b)** Radiograph of a section (oblique axial section).

were recorded photographically (3). In addition, radiographs of the sections were obtained.

The MR images were evaluated simultaneously by two experienced radiologists (K.W.P., J.B.). Assessment included identification of the Lisfranc ligament, the IMT ligaments, and the TMT ligaments; in addition, special attention was paid to bone alignment between the distal tarsal row and the metatarsal bases on the basis of the oblique axial MR images and radiographs of the sections. The MR imaging results were then correlated with the gross anatomic findings.

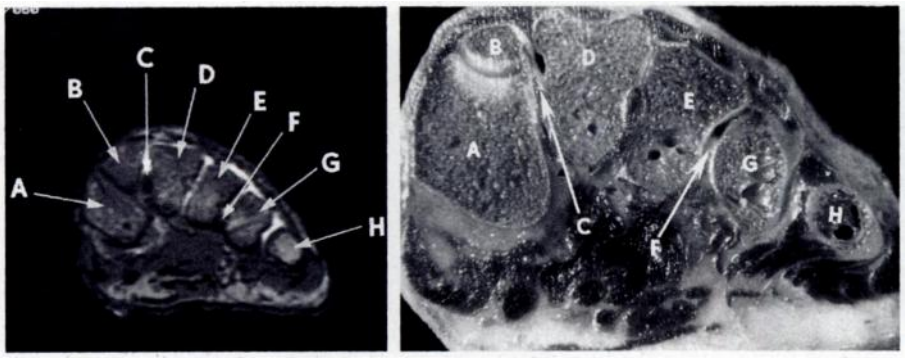
RESULTS

Oblique Axial Plane

In all specimens, all three cuneiform bones, the cuboid bone, and the five metatarsal bases could be identified clearly. The intermediate cuneiform bone was recessed proximally relative to the medial and lateral cuneiform bones, forming a mortise for the second metatarsal base (Fig 2).

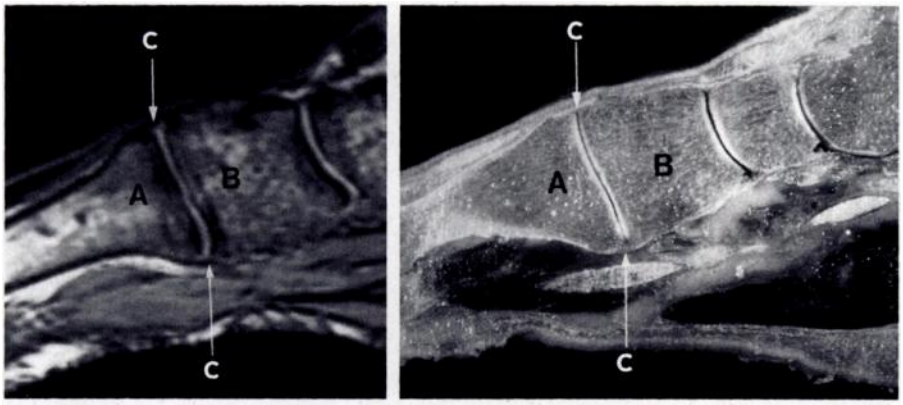
The distal tarsal bones and the metatarsal bases were aligned as follows: In all cases, alignment existed between the medial and lateral edges of the first metatarsal base and the medial cuneiform bone, between the medial and lateral edges of the second metatarsal base and the intermediate cuneiform bone, and between the medial and lateral edges of the third metatarsal base and the lateral cuneiform bone (Fig 3). The medial edge of the fourth metatarsal base was aligned with the medial edge of the cuboid bone, and the lateral edge of the fifth metatarsal base was aligned with the lateral edge of the cuboid bone.

The Lisfranc ligament in full extension could be identified in all specimens in the oblique axial plane as a uniform hypointense bandlike structure running from the lateral face of the medial cuneiform bone to the medial face of the second metatarsal base (Fig 2). In this plane, only parts of the



a. b.

Figure 4. Correlation of MR imaging with gross anatomic findings in TMT joint. **(a)** Coronal SPGR MR image (38/12, 60° flip angle, matrix 256 × 128) after intraarticular injection of gadopentetate dimeglumine. **(b)** Corresponding anatomic section. *A* = first metatarsal base, *B* = medial cuneiform bone, *C* = Lisfranc ligament, *D* = second metatarsal base, *E* = third metatarsal base, *F* = IMT ligament, *G* = fourth metatarsal base, *H* = fifth metatarsal base.



a. b.

Figure 5. Correlation of MR imaging with gross anatomic findings in the TMT joint. **(a)** Sagittal SPGR MR image (38/12, 60° flip angle, matrix 256 × 128). **(b)** Corresponding anatomic section. *A* = first metatarsal base, *B* = medial cuneiform bone, *C* = TMT ligaments.

plantar IMT ligaments could be identified. Depiction of the dorsal IMT and TMT ligaments was not possible.

Coronal Plane

In this plane, all metatarsal bases again were seen to form a dorsal convex arch in the foot (Fig 4). The second metatarsal base had a triangular shape and was located more dorsally than the other metatarsal bases. Proximally, all tarsal bones were visible. In the coronal plane, the position of the metatarsal bases with respect to each other as well as the position of the tarsal bones in relation to each other could be demonstrated, but this plane was not very useful for demonstrating the relationship of the metatarsal bases to the tarsal bones.

Between the lateral surface of the medial cuneiform bone and the medial surface of the second metatarsal base, a round hypointense structure could be observed that represented the Lisfranc ligament. On the plantar and dorsal aspects, between the second through fifth metatarsal bases, hypointense ligamentous structures could be identified that represented the IMT ligaments. The ligaments were thicker on the plantar aspect than on the dorsal aspect.

Sagittal Plane

All metatarsal bases and tarsal bones were visualized in this plane. Because of the dorsally convex transverse arch of the foot, the second metatarsal base and the intermediate cuneiform bone were positioned most dorsally. The sagittal view also allowed exact definition of the position of metatarsal bases and corresponding tarsal bones especially with respect to the plantar and dorsal bone surfaces. In all specimens, plantar and dorsal alignment was evident between the first metatarsal base and the medial cuneiform bone (Fig 5), the second metatarsal base and the intermediate cuneiform bone, the third metatarsal base and the lateral cuneiform bone, and the fourth and fifth metatarsal bases and the cuboid bone.

Small bandlike hypointense structures could be identified between the tarsal bones and the metatarsal bases on the plantar and dorsal side that represented the TMT ligaments and between the medial cuneiform bone and the base of the second metatarsal bone that represented the Lisfranc ligament.

Gadolinium-enhanced Arthrography

Three joint compartments were observed in each of the three specimens: The first compartment included the first TMT joint, the second consisted of the second and third TMT joints, and the third included the fourth and fifth TMT joints. On the images in the oblique axial plane, the Lisfranc ligament was surrounded by the contrast solution and could be clearly delineated in all three cadaveric feet. The IMT ligaments on both sides again were identified only in the coronal plane and the TMT ligaments only in the sagittal plane. The use of intraarticular injection of gadopentetate dimeglumine did not result in improved depiction of ligamentous structures.

In one specimen, the gadolinium solution diffused into the intercuneiform joints.

DISCUSSION

MR images obtained in at least three planes provide exquisite depiction of anatomic details of the TMT joint. In particular, the excellent delineation of the diagnostically important ligaments makes MR imaging superior to other techniques. The IMT ligaments are best delineated on thin sections in the coronal plane. Such thin sections are necessary to depict the dorsal IMT ligaments, which, in contradistinction to the thick plantar ligaments, are very delicate. These ligamentous structures connect the second through fifth metatarsal bases and prevent the metatarsal bases from undergoing plantar and especially dorsal and lateral dislocation in cases of injury (4,5). The inability to demonstrate the IMT ligaments in the oblique axial plane may be due to the relatively large field of view used in our study. This field of view was chosen according to a standard MR examination of the foot.

The visualization of the Lisfranc ligament is the most important diagnostic consideration. Because there is

no IMT ligament between the first and second metatarsal bases, the Lisfranc ligamentous connection is responsible for the stability of the lateral four metatarsal bones. A tear of the Lisfranc ligament causes joint instability even if such disruption is an isolated finding. Because of its large size, the Lisfranc ligament can be depicted in the oblique axial, coronal, and sagittal planes, although the oblique axial plane is the most optimal.

MR imaging also provides accurate assessment of joint alignment. In the oblique axial and sagittal planes, the positions of the metatarsal bases and the distal tarsal bones are clearly delineated. Contrary to previous reports (6,7), in which the medial and lateral edges of the third and fourth metatarsal bases and the lateral cuneiform bone could not be identified in some cases on conventional radiographs, MR images reliably showed the medial and lateral borders of all metatarsal bases and all tarsal bones, thereby allowing accurate judgment of bone alignment. In every cadaver, exact alignment of the metatarsal bases with the corresponding tarsal bones was observed. We found no offset at the medial edge of the second and fourth metatarsal bases, which has been considered a normal variant in previous articles (6,7).

In conclusion, MR imaging allows exquisite depiction of anatomic relationships at the TMT joint. It is the best imaging method for visualization of the Lisfranc ligament, the disruption of which can be an isolated finding after Lisfranc injury. When oblique axial and sagittal planes are used, MR imaging allows accurate assessment of joint alignment. However, the capability of MR imaging in the assessment of pathologic changes in this joint was not the subject of this study and remains unproved. ■

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