

IMAGING OF LISFRANC INJURIES IN THE ATHLETE

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The Lisfranc joint complex is a complicated skeletal and capsuloligamentous structure that provides stability to the midfoot and forefoot. The tarsometatarsal joint is named after Jacques Lisfranc de Saint-Martin (1790-1847), a French army field surgeon who described a forefoot amputation through the tarsometatarsal joint during the Napoleonic wars.

Lisfranc injuries can occur due to high impact forces such as motor vehicle accidents and are termed Lisfranc fracture-dislocation. Additionally, low impact midfoot injuries/sprains are commonly seen in sport-related injuries and are termed a Lisfranc injury. Recently, radiographic and orthopaedic literature has emphasised this distinction between low and high impact injuries and their clinical and radiographic differences.

Injury of the tarsometatarsal joint (Lisfranc) is uncommon, accounting for 0.2%

of all fractures. However, these injuries may have devastating consequences in athletes. If the high-energy injuries (usually related to automobile and motorcycle crashes) are easily diagnosed by imaging, the low-energy injuries can be subtle and difficult to recognise by radiography. The diagnosis is overlooked in about 20% of cases, exposing athletes to a functional disability. An understanding of the anatomy, mechanism of injury, classification systems and imaging features are necessary to facilitate the early and accurate diagnosis and treatment of these injuries. In this article, we will only review the low-impact injuries that may cause difficulties for radiologists.

ANATOMY

The Lisfranc joint complex, connecting the cuneocuboid block to the bases of the metatarsals, describes a complex interline configuration. In the transverse plane, it

forms an anterior convex arch from the medial to the lateral side of the foot; its lateral extremity is located 20 mm posterior to its medial extremity. In the frontal plane, the Lisfranc interline describes a curve, in which the apex is situated at the third cuneometatarsal joint (M3-C3).

The Lisfranc interline appears as a broken line formed by the protrusion of the medial and lateral cuneiforms providing a mortise for the second metatarsal (M2). By consequence, C1 is located about 8 mm anteriorly to the base of M2 and C3 is located about 4 mm anteriorly to the base of M2 and 2 mm anteriorly to the base of M4 or the cuboid bone. In this way, the second metatarsal is the key to the stabiliser of the Lisfranc joint and any movement of this joint will affect the mortise of the second metatarsal resulting in either a fracture of the base of M2 or Lisfranc ligament disruption.

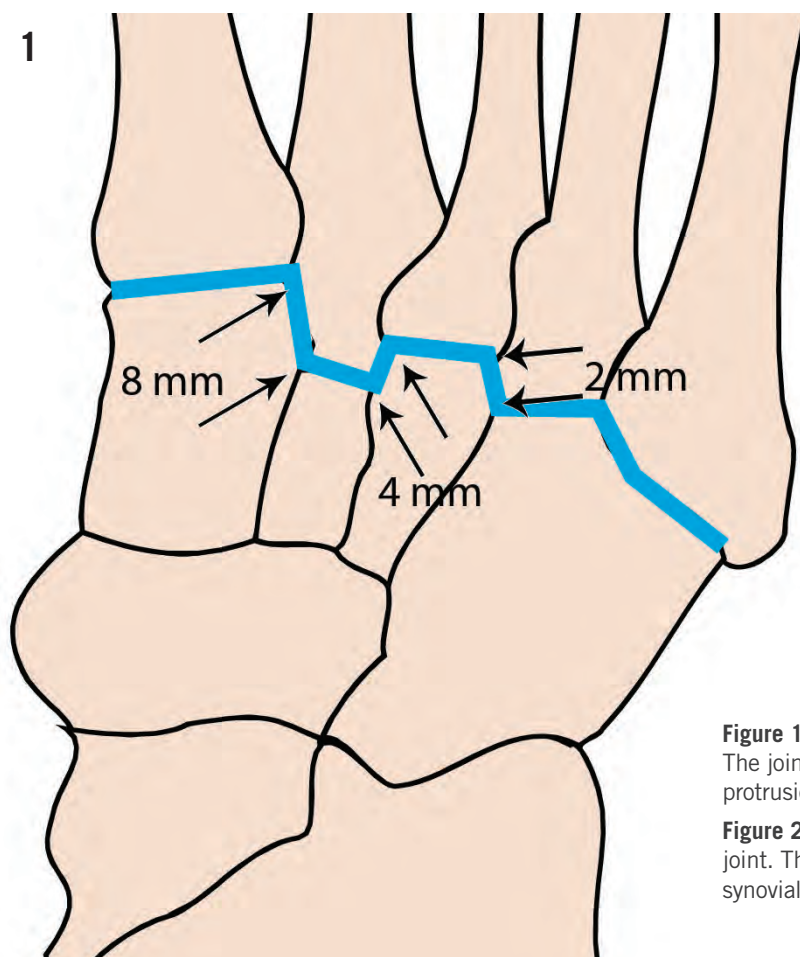
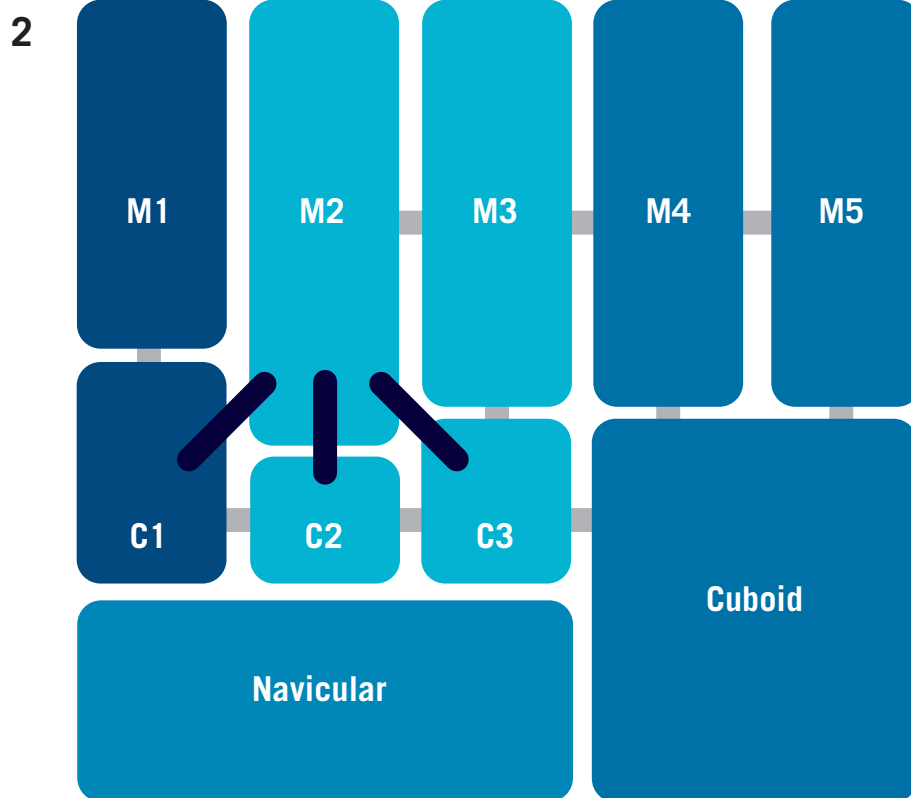


Figure 1: Schematic diagram of the Lisfranc interline. The joint appears as a broken line formed by the protrusion of the medial and lateral cuneiforms.

Figure 2: Schematic diagram detailing the Lisfranc joint. The Lisfranc joint is divided into three distinct synovial articulations: medial, middle and lateral.



The Lisfranc joint is divided into three distinct synovial articulations:

- Medial joint is formed by the articulation of the first metatarsal with the medial cuneiform.
- Middle joint is formed by the articulation of the second and third metatarsals with the middle and lateral cuneiforms.
- Lateral joint is formed by the articulation of the fourth and fifth metatarsals with the cuboid.

Detailed anatomic studies have divided the numerous stabilising Lisfranc ligamentous structures into dorsal, interosseous and plantar components^{1,2}.

There are seven dorsal ligaments uniting the tarsal and metatarsal components. Unlike the other metatarsals, the second metatarsal receives three dorsal ligaments from each cuneiform. The dorsal ligament, uniting the base of the first metatarsal with the medial cuneiform, is the strongest.

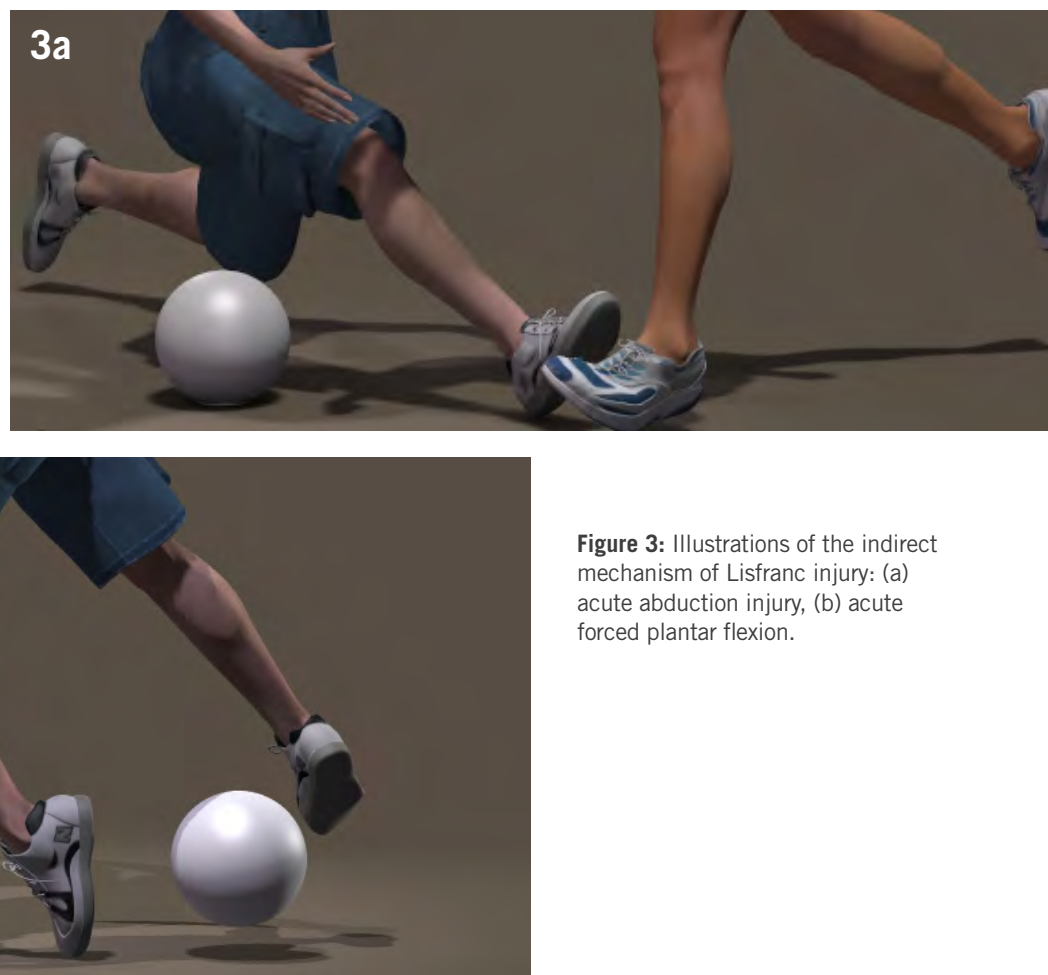


Figure 3: Illustrations of the indirect mechanism of Lisfranc injury: (a) acute abduction injury, (b) acute forced plantar flexion.

The interosseous and plantar components provide the primary ligamentous stability for the Lisfranc joint. The plantar ligaments are variable in number and disposition. The plantar ligament uniting the medial cuneiform with the first and second metatarsal is the key of the tarsometatarsal arch. There is no plantar ligament between the second metatarsal and the middle cuneiform. The plantar ligament between the third metatarsal and the lateral cuneiform is inconstant. The plantar ligaments between the cuboid and the fourth and fifth metatarsals are also often absent.

The interosseous ligaments are divided into three groups corresponding to the first, second and third cuneometatarsal spaces. The Lisfranc ligament connecting the medial cuneiform and the second metatarsal is the strongest ligament and often composed by two bands. There is no interosseous ligament at the fourth interspace.

MECHANISMS OF INJURY

The mechanism of injury to the Lisfranc joint can be divided into direct and indirect trauma^{3,4}. Low impact injuries are usually a result of indirect forces and account for the majority of athlete-related events.

The direct mechanism typically occurs when a high impact force is applied directly to the foot such as when a foot becomes trapped under the wheel of a car or dropping a weight on the foot.

The indirect mechanism occurs commonly with acute abduction or forced plantar flexion of the forefoot. Acute abduction mechanism occurs when the forefoot is violently abducted with the hindfoot in a fixed position leading to lateral displacement of the metatarsals. The forced plantar flexion mechanism occurs commonly in the athlete when an axial force applied to the heel with the ankle in plantar flexion causing tension of the dorsum

of the tarsometatarsal joint, tearing of a weak dorsal capsulo-ligamentous structure and leading to a fracture of the base of the second metatarsal, subsequent to the dorsal displacement of the metatarsals⁵.

IMAGING

Despite the lack of consensus for the work up of suspected midfoot sprains, the initial study performed is plain radiography. In the setting of trauma, this consists of unilateral non-weight bearing anteroposterior (AP), lateral and 30 degree medial oblique views. If this first evaluation is normal, bilateral anteroposterior and lateral weight bearing views can be beneficial. Stress radiographs are often painful in the acute phase and the patient may require anaesthesia.

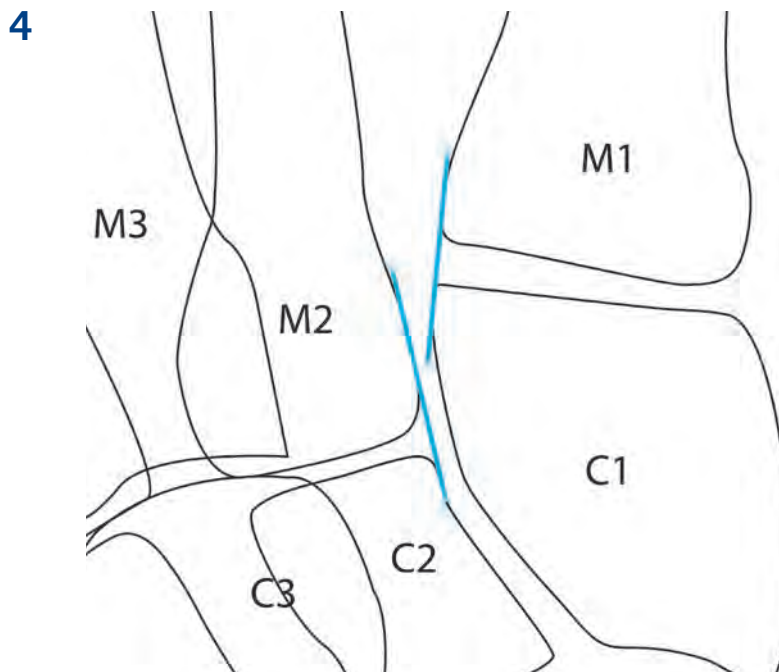
In the AP standing view:

- The lateral border of the first metatarsal is aligned with the medial cuneiform. Lateral displacement of the first

Figure 4: Schematic diagram of normal AP radiograph evaluation. The lateral border of the first metatarsal is aligned with the medial cuneiform and the medial border of the second metatarsal should align with the middle cuneiform.

Figure 5: AP radiograph demonstrates misalignment of M1 with the medial cuneiform indicated injury to the Lisfranc joint.

Figure 6: AP radiograph demonstrates misalignment of M2 with the middle cuneiform indicated injury to the Lisfranc joint. AP=anteroposterior.



metatarsal base relative to the lateral border of the medial cuneiform is a reliable radiologic sign of Lisfranc injury.

- The medial border of the second metatarsal should align with the middle cuneiform. Slight lateral displacement of the base of the second metatarsal relative to the medial border of the second cuneiform is the most common and reliable radiologic sign of a Lisfranc sprain.
- The distance between the first and second metatarsals should be less than 2 mm, however, it depends on the obliquity of the X-ray beam and is not a reliable radiologic sign.

In the 30 degree medial oblique view:

- The lateral border of M3 should align with the lateral border of the lateral cuneiform.
- The cuneocuboid interline should be parallel and uniform in width.

In the lateral view:

- The dorsal proximal border of the second metatarsal should align with the dorsal border of the middle cuneiform.

In the bilateral lateral weight bearing view:

- The plantar border of the medial cuneiform should lie above the plantar border of the fifth metatarsal base. Decrease in this distance or inversion of these two lines in comparison to the non-injured foot corresponds to flattening of the medial arch and suggests a significant Lisfranc injury with a poor outcome.

When weight bearing or stress radiographs are equivocal, computed tomography (CT) or magnetic resonance imaging (MRI) may be performed in the appropriate clinical scenario.

CT appears reliable to visualise and understand Lisfranc injuries⁶. Multiplanar

CT is ideal for depicting subtle osseous fractures and allows detection of minor lateral displacement of the second metatarsal. Such minor subluxations may be difficult to identify on plain films, even with the weight bearing view. CT also allows detection of a small bony fragment related to Lisfranc ligament avulsion (Fleck sign) that may not be visible on routine radiographs. Occasionally, CT can be helpful in ligamentous evaluation, however MRI is far superior in the evaluation of the soft tissue anatomy.

MRI is sensitive enough to evaluate soft tissues injuries and bone marrow oedema when the radiographs and CT scan are normal⁷⁻¹⁰.

MRI allows identification of the three components of the Lisfranc ligament: dorsal, interosseous and plantar ligaments in the normal foot. However, sometimes it is difficult to separate the three bands in the

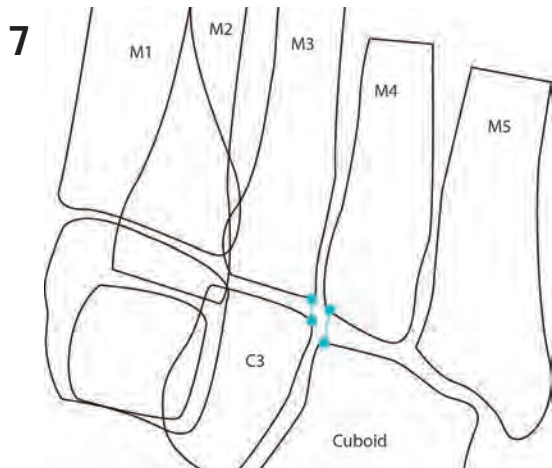


Figure 7: Schematic diagram of normal medial oblique radiograph evaluation. The lateral border of M3 should align with the lateral border of the lateral cuneiform and the cuneocuboid interline should be parallel and uniform in width.

Figure 8: Medial oblique radiograph demonstrates misalignment of M3 with the lateral cuneiform indicated injury to the Lisfranc joint.

Figure 9: Lateral view radiograph demonstrates proximal M2 dorsal subluxation.

Figure 10: Schematic diagram of normal (a) and pathologic (b) lateral weight bearing evaluation. The plantar border of the medial cuneiform should lie above the plantar border of the fifth metatarsal base (a). Decrease in this distance or inversion of these two lines in comparison to the non-injured foot corresponds to flattening of the medial arch and suggests a significant Lisfranc injury with a poor outcome (b).

injured foot or to distinguish a complete tear from a partial tear due to the small size of the Lisfranc complex. The Lisfranc ligament is best identified on the coronal and axial images. It courses from the medial cuneiform to the second metatarsal base and has low signal intensity with a homogenous or striated appearance^{11,12}. Sprains are classified according to the integrity of the Lisfranc ligament¹³: Grade I (stable injury): stretch, Grade II (stable injury): partial tear and Grade III (unstable injury): complete rupture.

Another classification, by Nunley and Vertullo, was proposed for athletic Lisfranc injuries based on clinical findings, comparative weight bearing radiographs and bone scans¹⁴:

- Stage I: sprain of the Lisfranc ligament with no diastasis between the medial cuneiform and the second metatarsal or loss of arch height on a weight-bearing radiograph. Bone scintigram will show increased uptake (stable).
- Stage II: tear of the dorsal and interosseous Lisfranc ligament with diastasis of 1 to 5 mm without arch height loss (unstable).
- Stage III: tear of the Lisfranc ligament with diastasis greater than 5 mm and arch height loss (unstable).

SUMMARY

Low energy Lisfranc injuries in athletes may be extremely subtle radiographically and need careful evaluation of the tarsometatarsal relationships. Comparison with weight bearing radiographs are useful, however may require a CT scan to detect minor displacement and possible bony avulsion. MRI is useful to evaluate ligament injuries especially the Lisfranc ligament complex and distinguish partial tear (stable injury) from complete tear (unstable injury).

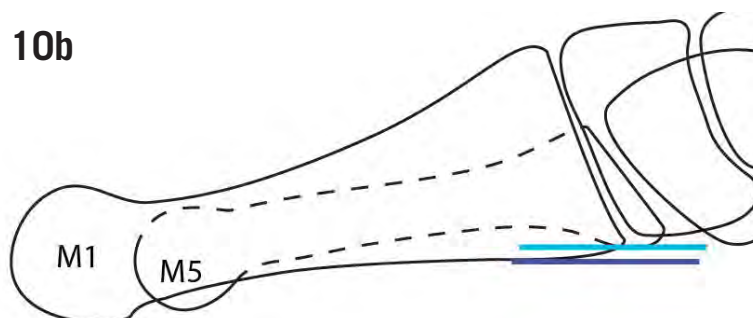
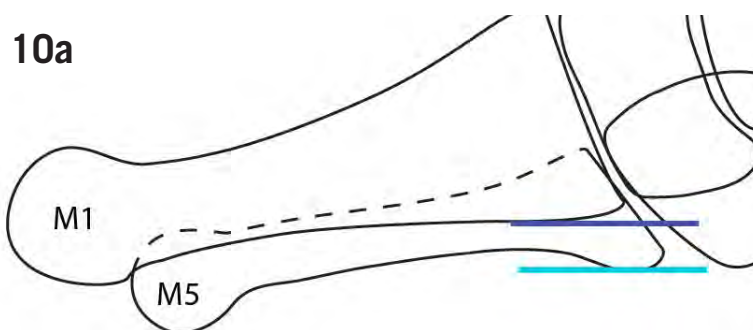
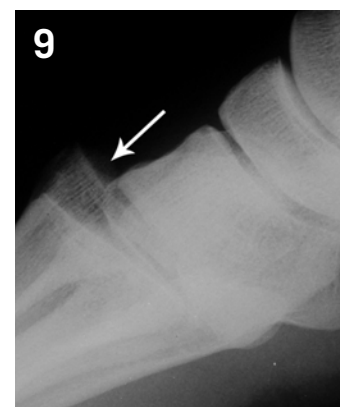
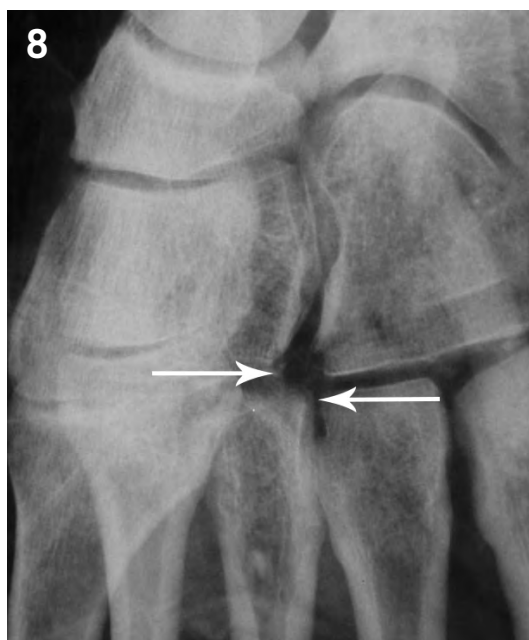
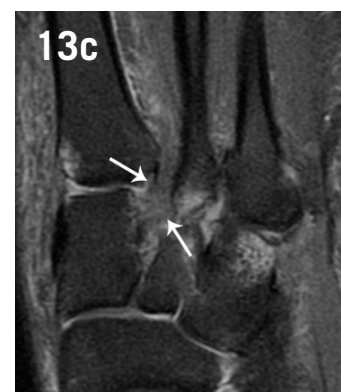
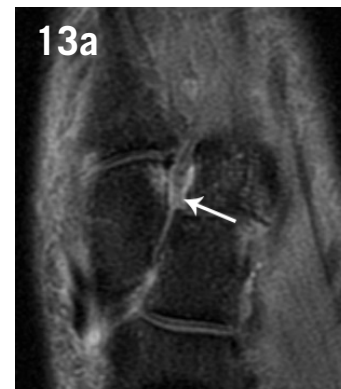




Figure 11: Multiplanar reformation axial CT image shows a subtle misalignment of M2 with the middle cuneiform indicated injury to the Lisfranc joint.

Figure 12: Multiplanar reformation axial CT image demonstrates the 'Fleck sign', a fracture fragment in the interspace between the first and second metatarsal base indicated avulsion of the Lisfranc ligament.

Figure 13: Sprain of the three portions of the Lisfranc ligament. Axial proton density-weighted MRI images demonstrate abnormal signal and disruption of the three portions of the Lisfranc ligament: (a) dorsal, (b) interosseous and (c) plantar. Note the bone marrow oedema of the Lisfranc joint.



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