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Review

Ankle and midfoot ligaments: Ultrasound with anatomical correlation: A review

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ABSTRACT

We present a detailed overview of anatomical and US features of ankle and midfoot ligaments based on our own dissections and cadaver studies as well as US imaging in cadavers and volunteers. The ligament anatomy about the ankle and midfoot is complex. Most ligaments are superficial and hence very well accessible for US. US technique to obtain optimal visualization however is difficult and requires a learning curve. We discuss US technique in detail for each individual ligament. We divided the ligaments in different groups: tibiofibular ligaments, Bassett's ligament, lateral collateral ligament complex (anterior talofibular ligament, calcaneofibular ligament, lateral talocalcaneal ligament, posterior talofibular ligament), medial collateral ligament complex, spring ligament, Chopart joint ligaments (bifurcate ligament, dorsal talonavicular ligament, lateral calcaneocuboid ligament, long and short plantar ligaments), Lisfranc ligaments, sinus tarsi ligaments.

1. Introduction

Ankle and foot ligaments play an important role in providing stability to the joints they cross. Ankle and mid-foot injuries are common [1] and can disrupt these ligaments leading to acute and chronic joint instability, as well as pain.

The anatomy of the ligaments around the ankle and foot is quite complex. In this overview in the form of a pictorial essay, we present a detailed depiction of normal anatomy of these ligaments and their imaging appearance on ultrasound (US), which can be very useful in the correct diagnosis [2] and treatment planning [3] of traumatic and non-traumatic ligamentous abnormalities [4]. Ultrasound can additionally be useful in needle guidance for interventions more accurately and efficiently compared to blind procedures, especially in ankle and foot where the anatomy is complex, different structures need to be identified and precise technique is a requisite [5].

We divide the ligaments in different groups. At the level of the ankle, we address the tibiofibular ligaments, Bassett's ligament, lateral collateral ligament complex (anterior talofibular ligament, calcaneofibular ligament, lateral talocalcaneal ligament, posterior talofibular ligament), and medial collateral ligament complex (also known as 'deltoid' ligament complex).

We discuss the spring ligament together with the tibiospring component of the deltoid ligament. Ligaments at the Chopart joint include the bifurcate ligament, dorsal talonavicular ligament, lateral calcaneocuboid ligament as well as long and short plantar ligaments. The emphasis of our work is less on Lisfranc ligaments: The several tarsometatarsal ligaments can be assessed, in particular along the dorsum of the foot [6] but the interosseous Lisfranc ligament is beyond the reach of US [7]. Also the sinus tarsi ligaments are largely beyond the reach of ultrasound [8].

2. Discussion

After an initial description of general ultrasound features of ligaments, we describe the ligaments systematically on the basis of the joints they stabilize. Special anatomic and US features of the ligaments will be emphasized and illustrated.

Ankle ligaments are essentially bundles of collagen fibers [9,10]. In general, on US images, they appear as echogenic fibrillary structures similar to any other ligaments [10].

The US beam should be as perpendicular as possible to the ligament to avoid anisotropy artifact [9]. If this is not the case, the ligament may artifactually lose its fibrillary structure and misdiagnosis may occur.

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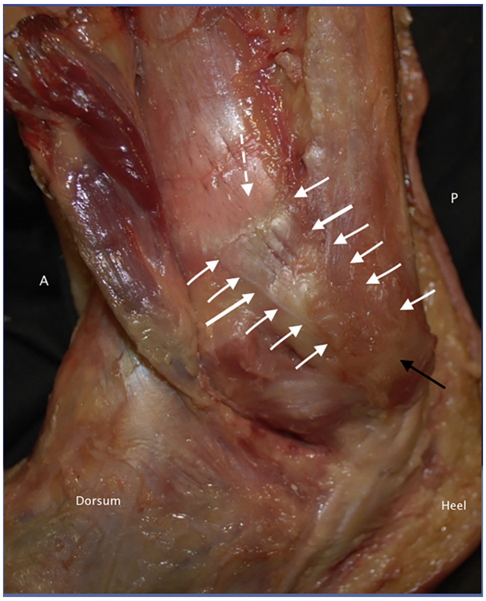

Fig. 1. Anatomical specimen of ankle viewed from lateral side showing anterior tibiofibular ligament (arrows). The ligament extends between the anterior tubercle of the tibia on one side (dashed arrow) and the anterior border of the fibular shaft and lateral malleolus on the other side (black arrow). Note its multifibered appearance. (A = anterior, P = posterior).

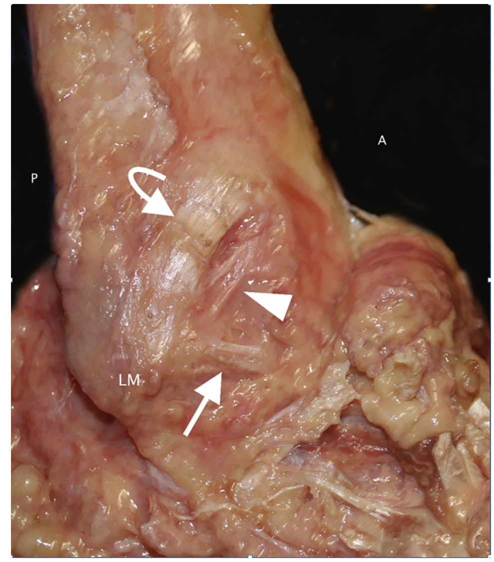

Fig. 3. Anatomy specimen of ankle viewed from anterolateral aspect: The Bassett's ligament (arrowhead) is seen in relation to the anterior tibiofibular ligament (curved arrow) which lies superior to it and the anterior talofibular ligament (straight arrow) which lies inferior to it. Bassett's ligament is the most distal fascicle of the anterior tibiofibular ligament. (A = anterior, P = posterior, LM = lateral malleolus).

On US, ankle ligaments are usually scanned along their long axis. Short-axis US, however can provide important additional information [10] and we recommend always assessing the ligaments in both axes.

Dynamic stress maneuvers may provide additional information about ligament integrity [10,11]. However, these techniques are not standardized and reference values are largely absent in the literature.

3. Tibiofibular (syndesmotic) ligaments

The distal tibiofibular joint (syndesmosis) is reinforced by an anterior tibiofibular ligament and posterior tibiofibular ligament [1,12,13].

The anterior tibiofibular ligament courses obliquely downward and laterally from the anterior tubercle of the tibia and inserts on the anterior border of distal fibular shaft and lateral malleolus (Fig. 1).

To visualize the ligament with US, the ankle should be placed in dorsiflexion. Our approach consists of placing the probe in an oblique transverse plane above the level of the ligament where a clear gap can be seen between the tibia and fibula. When the probe is moved inferiorly both bones join up closely, and just distal to this level the ligament is best depicted (Fig. 2). It should be emphasized that the ligament courses very obliquely and when the probe is not placed along this oblique axis, the ligament will not be well shown.

Bassett's ligament is considered to represent the most distal fascicle of the anterior tibiofibular ligament [14,15]. In reality, it is clearly separated from the rest of the ligament by fibro-fatty tissue and lies deeper to the rest of the ligament (Fig. 3). To visualize the ligament with US, the exact same approach as for the anterior tibiofibular ligament can be used. Once the level of the latter ligament is reached, the probe is displaced slightly more inferiorly, still in an oblique plane, and Bassett's ligament becomes evident. At this level, the bony contour of the talus can be visualized, providing another US clue that the probe is actually positioned at Bassett's ligament rather than at the anterior tibiofibular ligament (Fig. 4).

Bassett's ligament has been implicated in anterolateral impingement, although this is not entirely agreed upon. Correlation of abnormal imaging findings with clinical impingement tests is a prerequisite to consider such a diagnosis. Excision of Bassett's ligament (arthroscopically or by open surgery) could relieve the pain without compromising ankle stability [1,16,17].

The posterior tibiofibular ligament (Fig. 5) is stronger than the anterior tibiofibular ligament [10]. It has two components, superficial and deep. The superficial and superior component originates at the

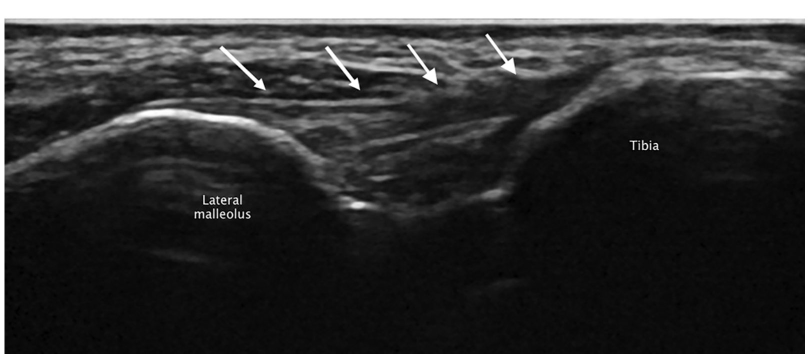

Fig. 2. US image of distal anterior tibiofibular ligament (arrows). An excellent view of the anterior tibiofibular ligament can be obtained by holding the probe obliquely with the foot in dorsiflexion.

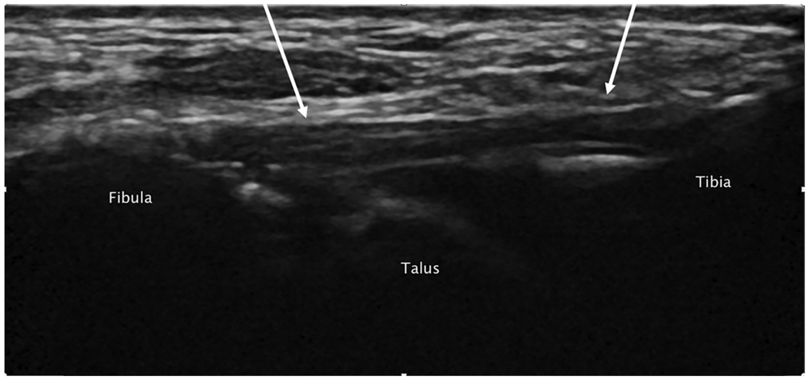

Fig. 4. Transverse US image depicting Bassett's ligament (arrows). It can be visualized just inferior to the anterior tibiofibular ligament. The talus comes in view when the probe is placed at the level of this ligament.

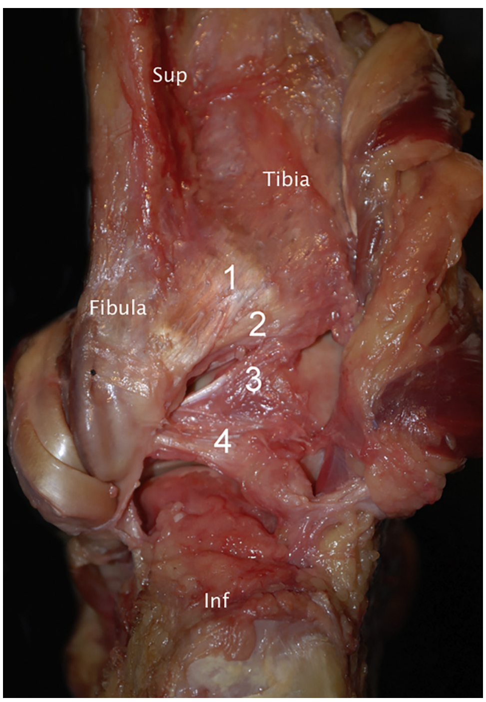

Fig. 5. Anatomy specimen of the ankle joint viewed from posterior aspect showing 1. Posterior tibiofibular ligament 2. Inferior transverse ligament 3. Intermalleolar ligament 4. Posterior talofibular ligament. (Sup = superior, Inf = inferior).

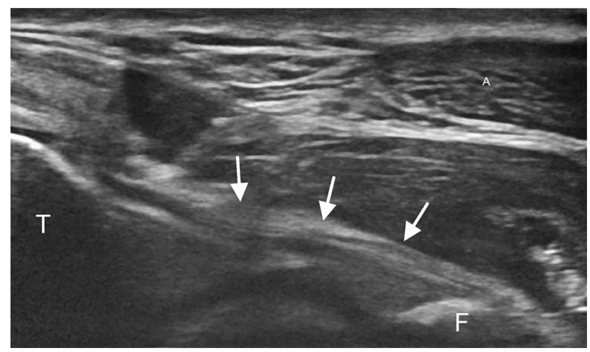

Fig. 7. US image showing the intermalleolar ligament (arrows) spanning the space between the fibula (F) and the tibia (T). This ligament can be seen on a transverse view from the posterior side of the ankle using Achilles tendon (A) as a window.

posterior edge of the lateral malleolus, courses superiorly and medially to insert on the medial tibial tubercle. The term posterior tibiofibular ligament is used to indicate this component [1]. The deep and inferior component is cone shaped and originates from the malleolar fossa to insert on the posterior edge of the tibia. This component is termed the inferior transverse ligament [1,18]. During routine ultrasound exams, the ligament is not typically studied. The ligament, however, can be exquisitely depicted with US. To visualize it, the patient should be placed prone on the examination table, with the foot hanging over the edge of the table. The probe should be placed in an oblique transverse plane similar to that used for the anterior tibiofibular ligament. The probe should be placed lateral to the Achilles tendon exerting a decent

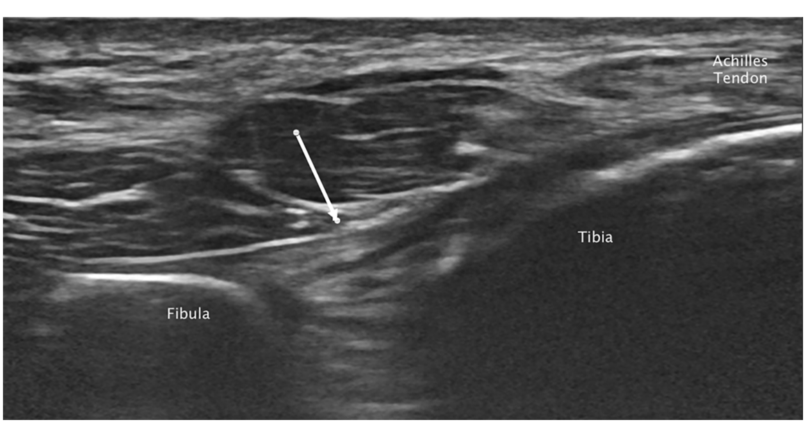

Fig. 6. US image of the posterior tibiofibular ligament (arrow). This ligament is not usually a part of routine ultrasound examination. It can however be well depicted by placing the patient prone on the table with the foot hanging over the edge of the table. The ultrasound transducer is placed lateral to the Achilles tendon in an oblique transverse plane similar to that used for anterior tibiofibular ligament. The probe is moved towards the distal edge of tibia and fibula where the ligament is brought in view.

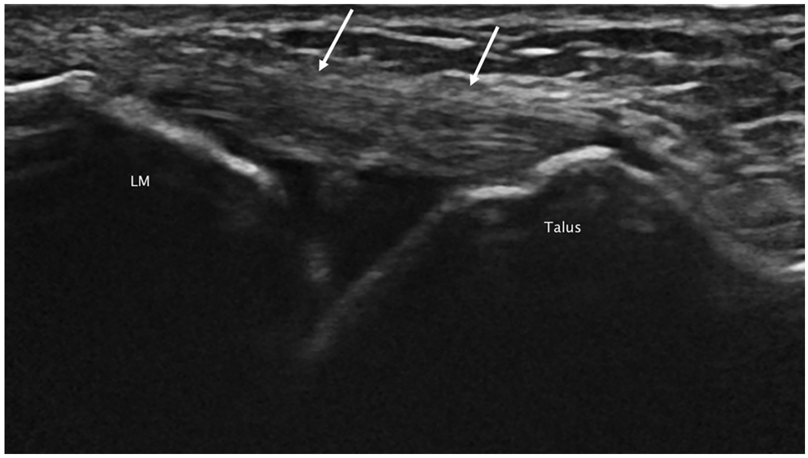

Fig. 8. Transverse US image showing anterior talofibular ligament (arrows). It is part of the lateral collateral ligament complex. It is the most frequently injured ligament of the ankle. (LM = lateral malleolus).

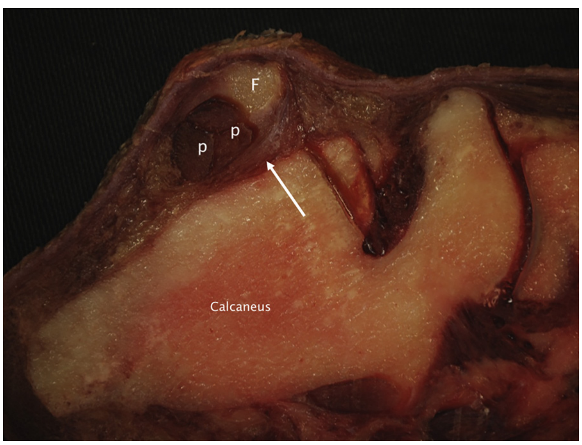

Fig. 9. Anatomy specimen: Transverse section at the hind foot level showing the calcaneofibular ligament. The calcaneofibular ligament is a part of the lateral collateral ligament complex. It runs in a posterior direction from the lateral malleolus, deep to the peroneal tendons (p), forming a sort of hammock for these tendons. (F = fibula).

amount of pressure and the distal edges of tibia and fibula should be brought in view (Fig. 6).

The intermalleolar ligament is located posteriorly between the transverse ligament superiorly and the posterior talofibular ligament inferiorly [18] (Fig. 5). The ligament is usually composed of two or more bands [19]. It spans the space between the fibula and tibia running obliquely upwards from lateral to medial side. Its prevalence in radiological and anatomical studies varies widely from 19% to 100% [1]. The ligament has been implicated in the posterior soft tissue impingement of the ankle [1,20], but this is debatable. It becomes taut in dorsiflexion of the ankle. Hence, forced dorsiflexion injury of the ankle can cause injury or rupture of the ligament or osteochondral avulsion. To visualize the ligament with US, the probe is moved down from the position in which the posterior tibiofibular ligament can be seen. The intermalleolar ligament is then depicted spanning the space between the fibula and the tibia. The Achilles tendon can be used as a window to visualize it or the probe can be placed lateral to the Achilles tendon (Fig. 7).

4. Lateral collateral ligament complex

It is comprised of three distinct ligaments: the anterior talofibular ligament, the calcaneofibular ligament and the posterior talofibular ligament [10,21].

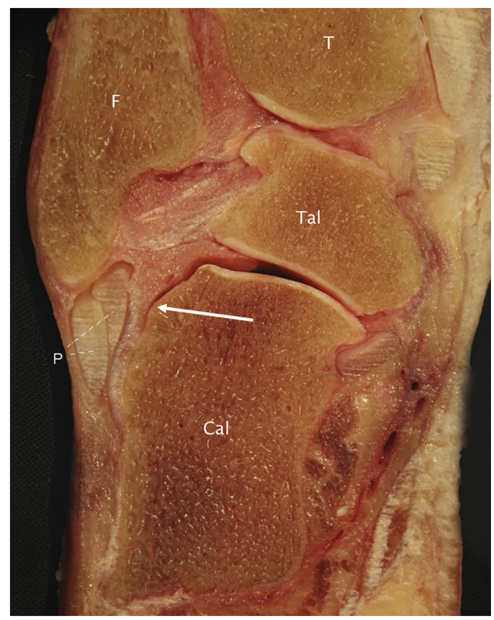

Fig. 10. Anatomy specimen: Coronal section through the hind foot. The calcaneofibular ligament (arrow) lies deep to the peroneal tendons (marked with P and dashed lines). (F = fibula, T = tibia, Tal = talus, Cal = calcaneus).

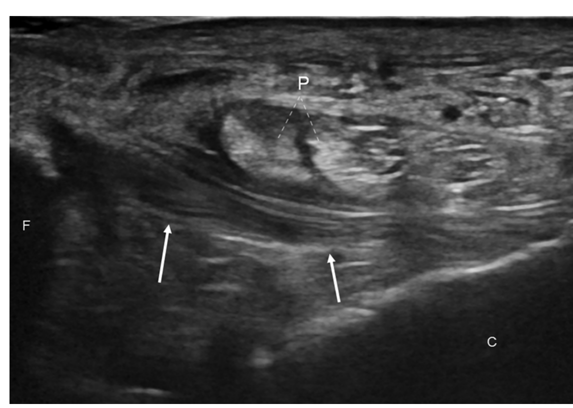

Fig. 11. US image of the calcaneofibular ligament. The US transducer has been held over the tip of the lateral malleolus and directed posteroinferiorly. It can be best seen with the foot in dorsiflexion, which makes the ligament taut with a nearly vertical orientation. The calcaneofibular ligament (arrows) spans the space between the fibula (F) and the calcaneus (C) deep to the peroneal tendons (P).

Table 1
The ankle and midfoot ligaments with their insertions and involvement in trauma and impingement.

Ligament	Insertion	Insertion	Trauma	Impingement
Tibiofibular (syndesmotic)				
Anterior tibiofibular ligament	Anterior tubercle of tibia	Anterior distal fibular shaft and lateral malleolus	yes	Possible - post injury scarring /hypertrophy of ligament - superolateral (syndesmotic) impingement syndrome.
Bassett ligament	Most distal fascicle of anterior tibiofibular ligament separated from it by fibrofatty tissue	—	—	yes (debated)
Posterior tibiofibular ligament	Superficial component: Posterior edge of lateral malleolus	Medial tibial tubercle	yes	Possible - in posterolateral impingement syndrome
	Inferior component (also called inferior transverse ligament): upper part of lateral malleolar fossa in posteroinferior fibula	Posterior edge of tibia		
Intermalleolar ligament	Posterior fibula	Posterior surface of medial malleolus	possible	Possible - in posterolateral impingement syndrome
Lateral collateral ligament complex				
Anterior talofibular ligament	Anterior margin of lateral malleolus	Talar neck	yes	Yes, possible -anterolateral impingement syndrome
Calcaneofibular ligament	Lateral malleolus	Lateral surface of calcaneus	yes	—
Lateral talocalcaneal ligament (inconsistently present)	From talus, anterior to calcaneofibular ligament	Converges with calcaneofibular ligament inferiorly	Yes, possible.	—
Posterior talofibular ligament	Posterior aspect of the lateral malleolus	Lateral tubercle of posterior process of talus.	Not in isolation, Less common than anterior talofibular and calcaneofibular	—
Medial collateral ligament complex			yes	
Deep layer				
Tibiotalar ligament (anterior component - not always present and posterior component)	Medial malleolus	talus	yes	Posteromedial impingement syndrome
Superficial layer	Rather a continuum of ligaments than different separable ligaments			
tibionavicular	Anterior colliculus of tibial malleolus	Navicular tuberosity	yes	Anteromedial impingemen
tibiospring	Medial malleolus	spring ligament	yes	Yes -antero-medial impingement syndrome
tibiocalcaneal	Medial malleolus	Sustentaculum tali of calcaneus	yes	Yes - as above
Spring ligament: 3 components	calcaneus	navicular	Chronic injury. Acute - less common	—
superomedial calcaneonavicular	Medial aspect of sustentaculum tali	Superomedial aspect of navicular bone	See above	—
medioplantar oblique	Just anterior to middle articular facet of calcaneus	Medioplantar portion of navicular bone	See above	—
Inferoplantar longitudinal	Coronoid fossa of calcaneum	Inferior beak of navicular bone	See above	—
Chopart joint ligaments				
Bifurcate ligament:				
Calcaneocuboid part	Rostrum of calcaneus	cuboid	yes	—
Calcaneonavicular part	Calcaneocuboid ligament	Navicular bone	yes	—
Dorsal talonavicular ligament	Neck of the talus	Navicular bone	yes	—
Short and long plantar ligaments	Plantar surface of calcaneus	Plantar surface of cuboid	Yes, possible	—
Sinus tarsi ligaments			yes	Chronic subtalar joint dysfunction - sinus tarsi syndrome
Cervical ligament	inferolateral talar neck	Superior surface of calcaneus	See above	See above
Interosseus ligament	Sulcus tali	Sulcus calcanei	See above	See above
Lisfranc ligaments	Bridging the tarsometatarsal joints		yes	—

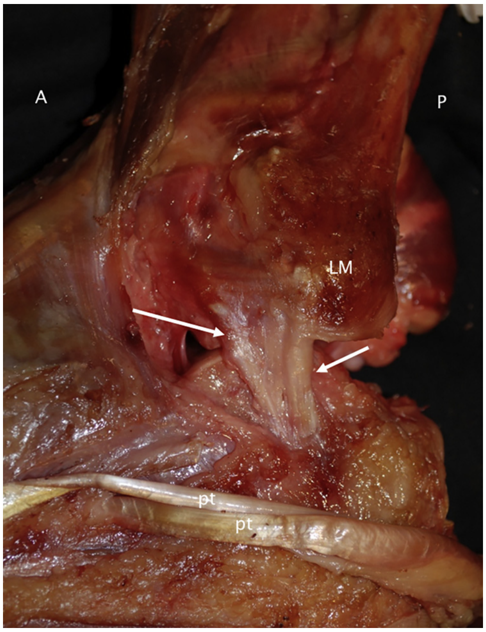

Fig. 12. Anatomy specimen, lateral view of the ankle and hind foot. The peroneal tendons (pt) have been retracted away to reveal the lateral talocalcaneal ligament (long arrow), which is located anterior to the calcaneofibular ligament (short arrow). It is less well known and not consistently present. (A = anterior, P = posterior, LM = lateral malleolus).

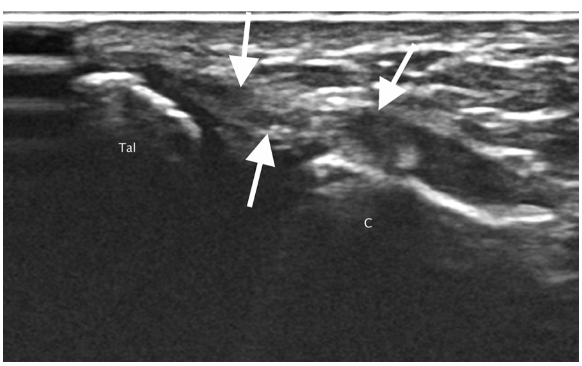

Fig. 13. Long axis US image of the lateral talocalcaneal ligament (arrows) obtained by placing the US probe in a coronal plane just anterior to the fibula. The lateral talocalcaneal ligament is inconsistently present and is situated anterior to the calcaneofibular ligament. (Tal = talus, C = calcaneus).

The anterior talofibular ligament (Fig. 3) originates from the anterior margin of the lateral malleolus and runs anteromedially to its insertion on the talar neck [10,12]. The ligament is oriented horizontally to the ankle in neutral position. It is closely attached to the joint capsule and typically composed of two distinct bands [1,18,22]. Note, that on axial MRI, it should be visible on at least two consecutive MR slices. If it is thinner, one of its two bundles may be torn. It plays an important role in limiting anterior displacement of the talus and is the most frequently injured ligament of the ankle [1,10,12,23] US examination is performed with patient supine on the bed, knee flexed and sole of the foot placed flat on the examination table. Owing to the nearly horizontal orientation of the anterior talofibular ligament, it is best evaluated with the transducer parallel to the examination table (Fig. 8). The foot should be slightly inverted to make the ligament taut.

The calcaneofibular ligament (Figs. 9 and 10) [1,9,10,12] is the longest of the three components with a length of about 2 cm [1]. It is a strong cordlike structure with a vertical oblique course extending from the lateral malleolus to the lateral surface of the calcaneus. It is the only ligament bridging both talocrural and subtalar joints [1]. In cross

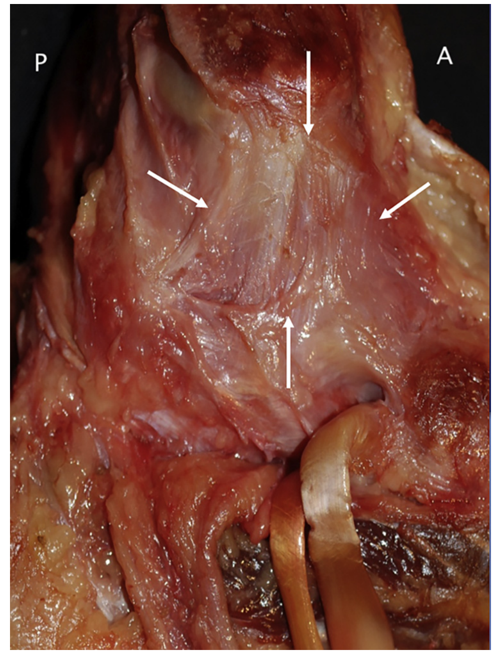

Fig. 14. Anatomy specimen of the ankle viewed from medial aspect. The 'deltoid' ligament (arrows) is a complex structure spanning the entire medial aspect of the ankle joint and is made up of different components: tibiotalar, tibiocalcaneal, tibiospring and tibionavicular ligaments. Its anatomy is very variable with different components being larger than the others in different subjects. It is also rather more of a continuum of fibers than all clearly 'separate' ligaments. The tendons on the medial side of the ankle have been cut and retracted inferiorly. A = anterior, P = posterior.

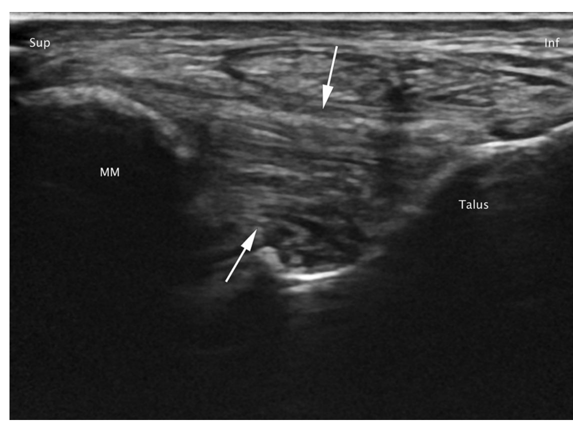

Fig. 15. Coronal US image on medial side of ankle joint showing the tibiotalar component of 'deltoid' ligament complex. It is made up of different fiber bundles and appears striated. This striated appearance should not be mistaken for an evidence of injury. MM = medial malleolus, Sup = superior, Inf = inferior).

section, it is rounded with a diameter of 6–8 mm. It lies just deep to the peroneal tendons and is configured as a hammock on which the tendons lie. For US assessment, the ankle should be placed in dorsiflexion. The calcaneofibular ligament can then be seen by placing the probe obliquely on the lateral malleolus and pointing it posteroinferiorly (Fig. 11). Often it is quite difficult to obtain a good US image with the patient supine and is typically seen much better with the patient prone from a posterior approach (Table 1).

The lateral talocalcaneal ligament (Fig. 12) is a less well-known ligament and is not consistently present in all individuals. In 23% of persons, a lateral talocalcaneal ligament exists anteriorly and independent of the calcaneofibular ligament [1]. It courses from the talus inferiorly where it converges with the calcaneofibular ligament. With

Fig. 16. Coronal PD weighted MR image shows clearly the tibiotalar ligament (between the arrows) made up of different fiber bundles with a striated appearance. It is a part of the deltoid ligament complex. T = tibia, Tal = talus, C = calcaneus.

US (Fig. 13), the ligament can be identified by placing the probe in the coronal plane just anterior to the fibula.

The posterior talofibular ligament is the strongest and deepest portion of the lateral collateral ligament complex. It is intracapsular but extrasynovial and traverses deeply between the posterior aspect of the lateral malleolus and the lateral tubercle of the posterior process of the talus. It has a horizontal course [9,10]. Although it is not typically examined during routine ankle US, it is well depicted from a posterior approach with the patient in prone position. The probe should be placed lateral to the Achilles tendon and the ligament is inferior to the posterior tibiofibular and intermalleolar ligaments. It is also much thicker than these two other ligaments.

5. Medial collateral ligament complex

The medial collateral ligament, also termed the deltoid ligament is a complex of different ligaments [1,10,12,21,24]. Rather than being different separate ligaments they are all attached to each other (Fig. 14). Anatomical variation is very considerable and in some patients, some parts may be more developed and thicker, while in other patients the opposite occurs. US of medial collateral ligaments is best performed with the patient supine. The ankle should be placed in dorsiflexion and eversion to make the ligaments taut. More details for the specific visualization of each ligament are discussed below.

The tibiotalar ligament is the deep layer of deltoid ligament and courses from the medial malleolus to the talus. It consists of an anterior tibiotalar ligament, which is not always present [10,24] and very delicate and a posterior tibiotalar ligament, which is always visible and quite thick [24]. It is made up of layered fiber bundles. It requires some expertise to obtain an adequate image of the posterior tibiotalar ligament with US (Fig. 15) (Fig. 16). With the ankle placed in dorsiflexion and eversion, the probe is placed nearly in a transverse plane at the very posterior margin of the tibia, where the ligament courses between the tibia and talus. Only when the ligament obtains the typical fibrillary US structure of ligaments, an adequate visualization is obtained. In contrast, the anterior tibiotalar ligament can better be assessed with the ankle in plantar flexion. However, in our experience this ligament is rarely present and at best, a few delicate fibers can be visualized.

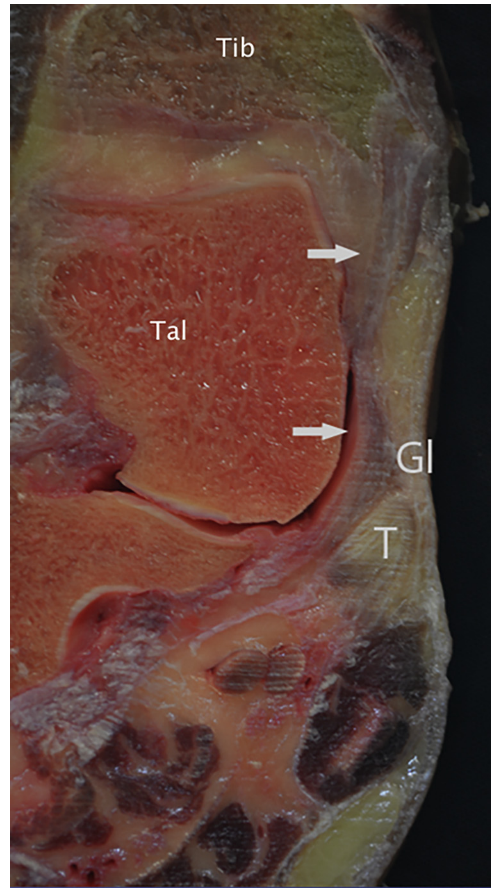

Fig. 17. Anatomy specimen of the ankle in coronal section showing the tibiospring ligament (superior arrow) in continuity with the spring ligament (inferior arrow) on medial side of the ankle. The tibiospring ligament originates from the anterior colliculus of the medial malleolus and inserts on the superomedial component of the spring ligament. There is a fibrocartilaginous nodule called the gliding zone (Gl) between the spring ligament and the posterior tibial tendon (T). (Tib = tibia and Tal = talus).

The delta shaped superficial layer of deltoid ligament typically has three components, extending from the medial malleolus to the navicular (tibionavicular ligament), to the spring ligament (tibiospring ligament) and to the calcaneus (tibiocalcaneal ligament) [10]. Even a fourth component has been described [25] but as indicated before, the anatomic separation of individual components is rather difficult because the ligament is rather a continuum than distinct separate bands.

The tibionavicular ligament is the most anterior portion of the superficial layer of deltoid ligament. It is a thin ligament with an oblique course. It originates from the anterior border of the anterior colliculus of medial malleolus and inserts onto the dorsomedial aspect of the navicular [10,24].

For US, the probe should be placed on the anterior colliculus of the medial malleolus oriented obliquely towards the navicular bone.

The tibiospring ligament is the intermediate component and usually the thickest part of the deltoid ligament complex. It originates from the anterior colliculus of the medial malleolus and inserts on the superomedial component of the spring ligament [10,24] (Fig. 17). With US, a long axis view of the ligament can be obtained by placing the probe in the coronal plane from the anterior colliculus of the medial malleolus towards the spring ligament. Between the deeply located spring ligament and the more superficially located posterior tibial tendon, a fibrocartilaginous nodule designated as ‘gliding layer or gliding zone’ can be present. It is tightly connected to the spring ligament and can mimic a thickened ligament [26] (Fig. 18).

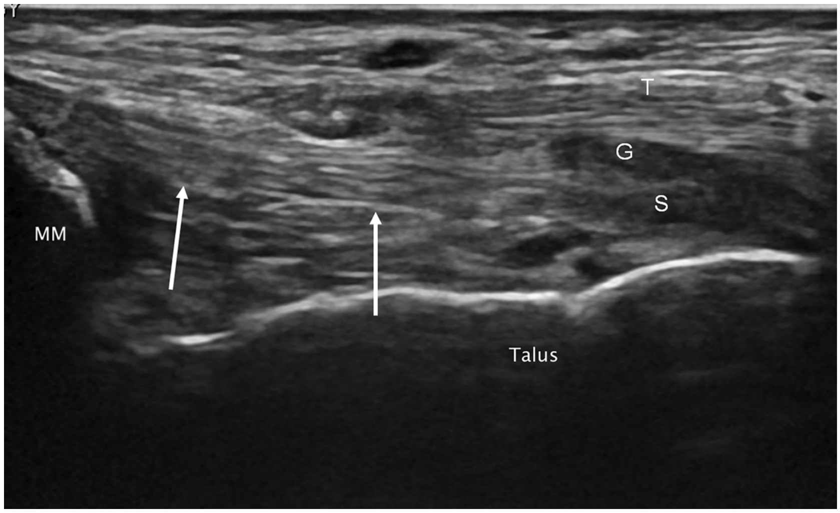

Fig. 18. US image along the long axis of the tibiospring ligament (arrows), a component of the 'deltoid' ligament complex. Note that the ligament terminates in the spring ligament (S). Also note the gliding zone (G) interposed between the spring ligament and the posterior tibial tendon (T). MM = medial malleolus.

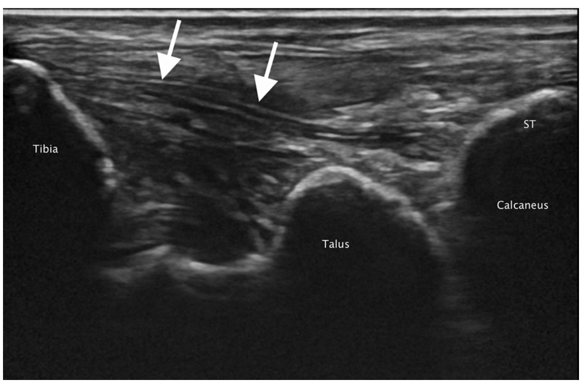

Fig. 19. US image of the tibiocalcaneal ligament (arrows). It is the thinnest component of the superficial layer of deltoid ligament. With US, the probe position is similar to that for the tibiospring ligament but the inferior aspect of the probe should be directed more posteriorly to obtain a view of the sustentaculum tali (ST).

Fig. 20. Anatomy specimen of medial aspect of the mid foot, demonstrating the different components of the spring ligament: 1. Superomedial calcaneonavicular ligament 2. Medioplantar oblique calcaneonavicular ligament 3. Inferoplantar calcaneonavicular ligament. The tendons (t) on the medial side of the ankle have been cut and retracted posteriorly. A = anterior and P = posterior.

The tibiocalcaneal ligament is generally the thinnest component of the superficial layer. It originates from the anterior colliculus of the medial malleolus, descends vertically, and inserts on the medial border of the sustentaculum tali [10,24]. With US, the probe position is similar to that for the tibiospring ligament but the inferior aspect of the probe should be directed more posteriorly to obtain a view of the sustentaculum tali (Fig. 19).

6. Spring ligament

The spring ligament complex includes three ligaments extending between the calcaneus and the navicular bones - superomedial calcaneonavicular ligament, medioplantar oblique calcaneonavicular ligament inferoplantar longitudinal calcaneonavicular ligament [10,26] (Fig. 20).

The superomedial calcaneonavicular ligament is the broadest and clinically most important part of the spring ligament complex. It originates from the medial aspect of the sustentaculum tali and attaches broadly on the superomedial aspect of the navicular bone close to the talonavicular joint [26].

With US, we prefer to obtain a short axis view of the ligament first by localizing its connection to the tibiospring ligament. From this position, the probe is turned 90° to obtain the long axis view. One end of the US probe is then placed inferior to the medial malleolus, over the sustentaculum tali and the other end is tilted slightly superiorly towards the navicular bone [10] (Fig. 21).

The medioplantar oblique calcaneonavicular ligament originates just anterior to the middle articular facet of the calcaneus from the coronoid fossa, has a medial oblique course and attaches at the medioplantar portion of the navicular bone [26]. The inferoplantar longitudinal calcaneonavicular ligament

originates from the coronoid fossa of the calcaneum and attaches at the inferior beak of the navicular bone [26].

In our experience, it is not possible to obtain a diagnostic view of the medioplantar and inferoplantar ligaments with US because of their deep location [10].

7. Chopart joint ligaments

Several ligaments are present about the Chopart joint including the bifurcate ligament, dorsal talonavicular ligament, lateral calcaneocuboid ligament, and short and long plantar ligament. Many radiologists do not assess these ligaments during routine ankle ultrasound. This is unfortunate because quite commonly one is not dealing with a typical ankle sprain with injuries of the lateral ligaments, but with a Chopart sprain [27]. Although the treatment is not necessarily very different,

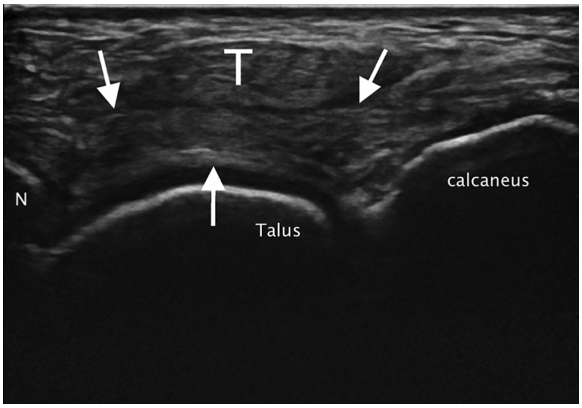

Fig. 21. US image of the spring ligament in long axis (arrows). Spring ligament has three components: superomedial calcaneonavicular, medioplantar oblique calcaneonavicular and inferomedial calcaneonavicular component. Only the superomedial component can be optimally visualized with US. The ligament is first localized in short axis at the inferior end of the tibiospring ligament and then the probe is turned 90 degrees to obtain the long axis of the ligament extending from sustentaculum tali posteriorly, crossing the talonavicular joint and inserting on the navicular bone (N) just distal to the joint. The ligament misses the typical fibrillar appearance of ligaments and tendons. Note the posterior tibial tendon (T) adjacent to it.

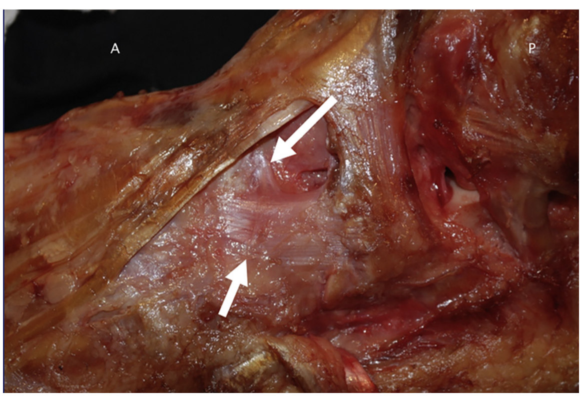

Fig. 22. Anatomy specimen of ankle and midfoot viewed from lateral aspect demonstrating the bifurcate ligament. The calcaneocuboid component (short arrow) and the calcaneonavicular component (long arrow) of bifurcate ligament are visible. The calcaneonavicular component is smaller and difficult to visualize on MRI and US. It actually does not originate from the calcaneus but from the midportion of calcaneocuboid ligament. A = anterior and P = posterior.

patients with Chopart sprains experience pain and discomfort many months longer than patients with simple ankle sprain. It is a typical patient population seen in an ultrasound consultation as there is a clinical concern why their 'ankle sprain' does not recover in a timely fashion.

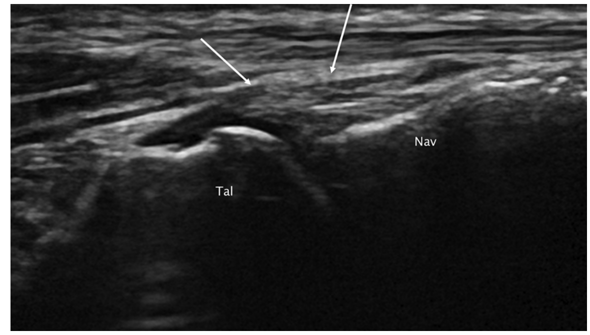

Fig. 24. US image showing dorsal talonavicular ligament (arrows). It extends from the dorsal surface of neck of talus to the navicular bone and can be easily visualized on US with the transducer held in a sagittal plane over the ligament, moving distally from the anterior tibiotalar joint recess. Tal = talus, Nav = navicular.

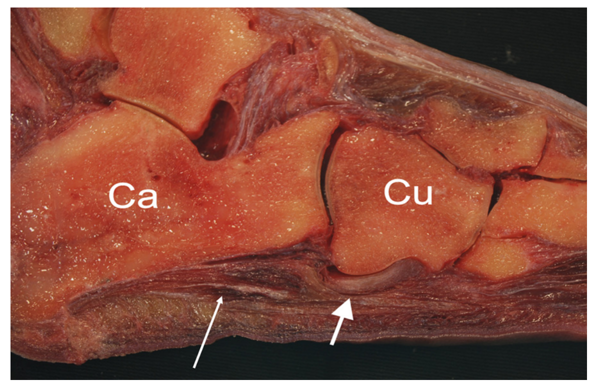

Fig. 25. Anatomy specimen of the lateral aspect of hind foot showing the long and short plantar ligaments (long arrow). The peroneus longus tendon (short arrow) in the cuboid tunnel is an excellent landmark for identification of these ligaments. Ca (calcaneus), Cu (cuboid).

The bifurcate ligament [10] is a Y shaped ligament with two components, the calcaneocuboid and calcaneonavicular ligaments (Fig. 22). The calcaneocuboid ligament originates from the rostrum of the calcaneus and is directed towards the cuboid. It is about 2 cm long. In our anatomic observations, we noted that the calcaneonavicular ligament rather originated from the calcaneocuboid ligament instead of the calcaneus. It was much thinner and shorter than the other component. With US, the calcaneocuboid component can be very well depicted. While the patient's foot rests on the table, we place the probe in the transverse plane at the level of the calcaneocuboid joint line. We then move the probe superiorly and at the superior margin of the calcaneus, the thick long ligament comes in view (Fig. 23).

The dorsal talonavicular ligament extends from the dorsal surface of the neck of the talus to the navicular bone [10,28] (Fig. 24). On US, it can be visualized along its long axis with the transducer in a sagittal

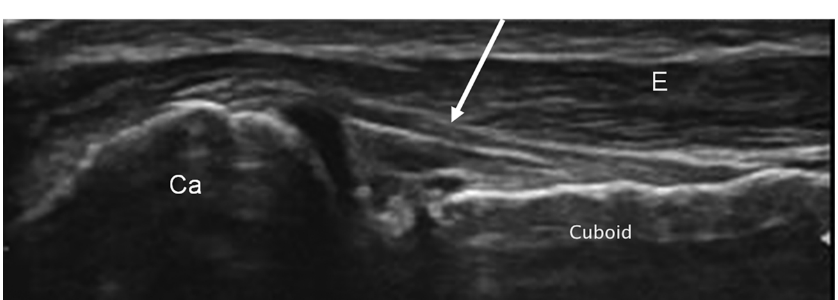

Fig. 23. Long axis US image of calcaneocuboid ligament (arrow) - a component of bifurcate ligament. It originates from calcaneal rostrum and inserts on the cuboid. It can be manoeuvred into view on US by first placing the probe in transverse plane at the calcaneocuboid joint line and then moving the probe superiorly towards superior margin of calcaneus. Ca (calcaneus), E (extensor digitorum brevis).

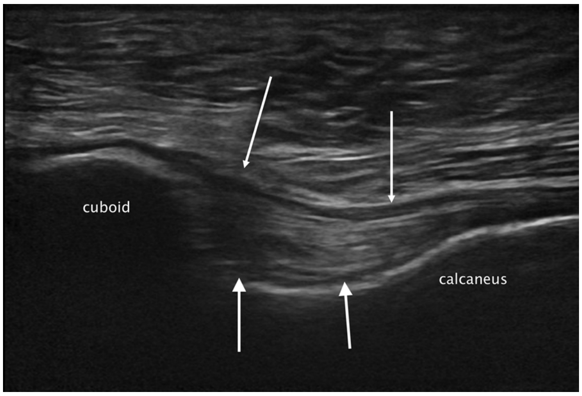

Fig. 26. US image demonstrating the long and short plantar ligaments (arrows). These ligaments run on the plantar side of hindfoot between the calcaneus and the cuboid bones. On US, the short and long plantar ligaments cannot be differentiated from each other. They can be visualized by placing the probe in a sagittal plane posteriorly along the calcaneocuboid joint line.

plane moving distally from the anterior tibiotalar joint recess.

The short plantar ligament originates from the anterior calcaneal tubercle and attaches to the adjacent part of the plantar surface of the cuboid bone. It is short but strong and sustains the lateral plantar arch.The long plantar ligament originates from the plantar surface of calcaneus, anterior to the calcaneal tuberosity and attaches to the plantar surface and tuberosity of the cuboid bone. It lies on the lateral side of the short plantar ligament and is separated from it by a layer of loose areolar tissue. Some of its superficial fibers may attach to the bases of second to fifth metatarsals [29] (Figs. 25 and 26). With US, the short and long plantar ligaments cannot be differentiated from each other. They can be well seen when the probe is placed in the sagittal plane posteriorly along the calcaneocuboid joint line. The cuboid tunnel containing the peroneus longus tendon is an excellent landmark.

The lateral calcaneocuboid ligament is a short thin ligament along the lateral aspect of the calcaneocuboid joint located inferior with respect to the bifurcate ligament. Often it merely represents a delicate capsular thickening. With ultrasound, it can be seen with the probe placed in the transverse plane, in particular with small joint effusions.

8. Sinus tarsi ligaments

For completeness, we discuss sinus tarsi and canalis tarsi ligaments. Sinus and canalis tarsi represents a space located between the subtalar joint and the talocalcaneonavicular joint. It contains fat, blood vessels, nerve endings and ligaments. The primary intrinsic ligaments of the sinus tarsi include cervical and interosseous ligaments. These ligaments limit inversion and maintain talocalcaneal alignment. Acute injury to these ligaments leads to subtalar sprain. Chronic injury causes sinus tarsi syndrome, which causes lateral foot pain, tenderness and subtalar joint instability [29,30].

The cervical ligament is located at the lateral border of the sinus tarsi. It originates from the superior surface of calcaneus and attaches at the inferolateral aspect of the talar neck. The interosseous ligament is located medially in the canalis tarsi and extends from the sulcus tali to the sulcus calcanei (Fig. 27). The ligament of the canalis tarsi follows the course of the latter canalis. In our experience, with ultrasound the individual ligaments in the sinus tarsi cannot be detected. However, the sinus tarsi can be imaged with the probe placed in the transverse plane anterior to the level of the anterior tibiotalar ligament. The sinus tarsi thus appears as a rectangular space. Because its main constituent represents fibrofatty tissue, it has a markedly hyperechoic aspect. In case of an acute or chronic ligament injury, this fibrofatty tissue is replaced by either hypoechoic fluid or scar tissue, representing an indirect sign of ligament damage.

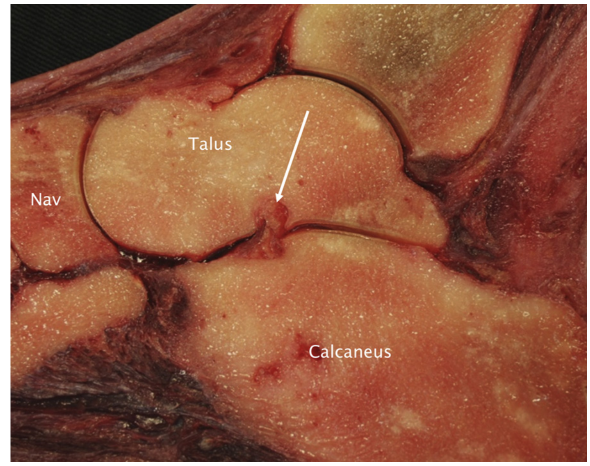

Fig. 27. Anatomy specimen, sagittal section through canalis tarsi (arrow) containing a rudimentary ligament, the ligament of the canalis tarsi and vessels. The ligaments in sinus tarsi and canalis tarsi are not directly accessible with ultrasound. Nav = navicular bone.

9. Lisfranc joint ligaments

Numerous ligaments are present about the Lisfranc joint. Some connect the tarsal bones with the metatarsals both at the dorsal and plantar aspect. Others connect tarsal bones and metatarsal bases [6]. The so-called Lisfranc ligament is an oblique ligament coursing between the medial cuneiform and the base of the second metatarsal. It is a complex ligament made up of three parts: a dorsal part, main central part and a plantar part. The plantar component may also extend to the base of the third metatarsal [7]. As this ligament complex has a deep interosseous location, it cannot be seen with ultrasound. With US, the short ligaments between the tarsal bones and the metatarsals can be detected especially along the dorsum of the foot. With injury they appear hypoechoic and thickened or bone avulsions may be detected. The main component of the Lisfranc ligament is located deep between bony structures and is not accessible with US. The plantar component can be detected with US, but it requires some expertise. Our technique consists first of obtaining a long axis view of the peroneus longus tendon at its insertion on the first metatarsal. From this position, we turn the probe 90° to obtain a view of the plantar Lisfranc ligament.

In conclusion, the anatomy of ankle and midfoot ligaments is quite complex. Understanding anatomical detail is a prerequisite for performing and interpreting US of these ligaments correctly. As most ligaments are superficial, they can be very well detected with US. We recommend not only assessing the anterolateral and medial ankle ligaments, but also the posteriorly located ligaments and Chopart ligaments. In our experience, injuries in these areas are as common as in the typically checked regions and otherwise overlooked.

Conflict of interest

The authors have no conflict of interest.

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