Anatomy of the Spring Ligament

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Background: The spring ligament has been reported to be composed of the inferior calcaneonavicular and superomedial calcaneonavicular ligaments. We investigated the lower layer of the spring ligament fibrocartilage complex under the fibrocartilaginous surface, identified three distinct structures, and examined the morphology and running patterns of their fiber bundles.

Methods: Forty-eight cadaveric feet were examined. After ablation of the ankle joint and extirpation of the talus, the surface cartilage of the spring ligament fibrocartilage complex was carefully removed with forceps, and the length, width, and thickness of the three components of the complex were measured with calipers.

Results: The three components of the spring ligament complex are the superomedial calcaneonavicular ligament, the inferior calcaneonavicular ligament, and a structure that we termed *the third ligament,* which comprises fibers running from the notch between the calcaneal facets to the navicular tuberosity.

Conclusions: We demonstrated a third component of the spring ligament; this component runs from the notch between the anterior and middle calcaneal facets to the tubercle of the navicular in the lower layer of the spring ligament complex, lying beneath the cartilaginous surface of the complex.

Clinical Relevance: More accurate knowledge of the anatomy of the spring ligament complex will enhance our understanding of its role in the support of the head of the talus and, potentially, its critical interactions with the posterior tibial tendon in this regard.

The talocalcaneonavicular joint is a spheroid articulation comprising the head of the talus and the corresponding acetabulum pedis located at the distal end of the loading axis of the lower limb[1]. The acetabulum pedis is a complex joint consisting of the anterior and middle articular facets of the calcaneus, the talar articular surface of the navicular, and the spring ligament. The lateral and medial parts of the spring ligament are composed of the inferior calcaneonavicular ligament and the superomedial calcaneonavicular ligament, respectively[2,3]. The articular surface of the spring ligament is covered with fibrocartilage, creating an articular surface with the head of talus, termed *the spring ligament fibrocartilage complex*. There are no osseous supportive tissues in the calcaneonavicular region, so the talar head is supported by the spring ligament fibrocartilage complex and the posterior tibial tendon located beneath it.

When the spring ligament fibrocartilage complex ruptures, dysfunction of the posterior tibial tendon can occur. The support of the head of the talus collapses, resulting in a flat foot[4,5]. Conti[6] reported that the loss of function of the posterior tibial tendon causes stretching of the calcaneonavicular ligament, resulting in collapse of the medial longitudinal arch and less effective push-off. However, even though the spring ligament fibrocartilage complex plays an important clinical role, there are only a limited number of detailed anatomical studies of it. Furthermore, the precise anatomical characteristics of the spring ligament fibrocartilage complex have not been consistently described. Some investigators have reported that the inferior calcaneonavicular and superomedial calcaneonavicular ligaments cannot be dissociated[1,7], whereas others have suggested that the two ligaments are separated by a triangle-shaped area of fatty tissue[2].

We investigated the layer under the fibrocartilaginous surface of the spring ligament in a group of normal cadaveric feet and found three distinct groups of fibers: the superomedial calcaneonavicular ligament, the inferior calcaneonavicular ligament, and what we have termed *the third ligament*. We examined the morphology and running patterns of the fibers of all three components.

Materials and Methods

Forty-eight embalmed human legs (twenty-three right and twenty-five left) from thirty-one cadavers donated for anatomical training were examined. The cadavers were perfused

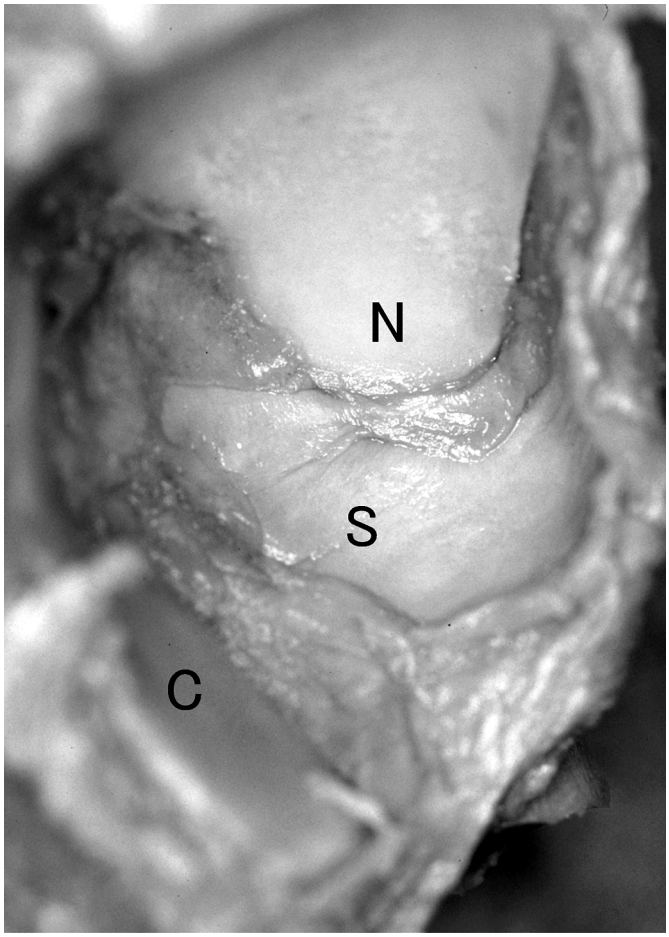

Fig. 1-A

The acetabulum pedis is exposed. The spring ligament fibrocartilage complex (S) provides an articular surface for the talar head. C = anterior and middle facets of the calcaneus, and N = navicular.

and fixed with a mixture of ethanol, glycerol, formalin, and phenol. No specimen had any apparent deformity on either gross or radiographic examination. After ablation of the ankle joint, the talocalcaneal and talonavicular articular capsules were dissected. Subsequently, the interosseous talocalcaneal ligament was cut and the talus was removed so that the acetabulum pedis, consisting of the talar articular surface of the navicular, the anterior and middle articular facets of the calcaneus, and the spring ligament fibrocartilage complex, could be exposed (Fig. 1-A).

The cartilage covering the spring ligament fibrocartilage complex was then carefully removed with forceps to expose the fibers of the third ligament, running from the notch between the anterior and middle calcaneal articular facets to the navicular tuberosity (Fig. 1-B). The fibers of the third ligament were distinct from the superomedial calcaneonavicular ligament but were loosely attached to its lateral edge. Fatty tissue was consistently found lateral to the fibers of the third ligament. On removal of the fatty tissue, the inferior calcaneonavicular ligament could be observed (Fig. 2).

The superomedial calcaneonavicular ligament was then detached from its insertion on the navicular and expanded until it was flat. Its length from the origin at the anterior border of the middle of the talocalcaneal articular surface to the insertion was measured with vernier calipers (Fig. 3). Next, the width was measured at the origin and at the two trisection points between the origin and the insertion. The thicknesses at the central region of the articular surface and at the medial margin bordering on the third ligament were determined as well. Subsequently, the length of the inferior calcaneonavicular ligament and the width and thickness at the central region of that ligament were determined. Finally, the minimum and maximum lengths, the width at the origin, the maximum width, and the thickness of the third ligament were measured. The measurement in each region was repeated three times at intervals of one week by the first author, and the average of the three measurements was calculated.

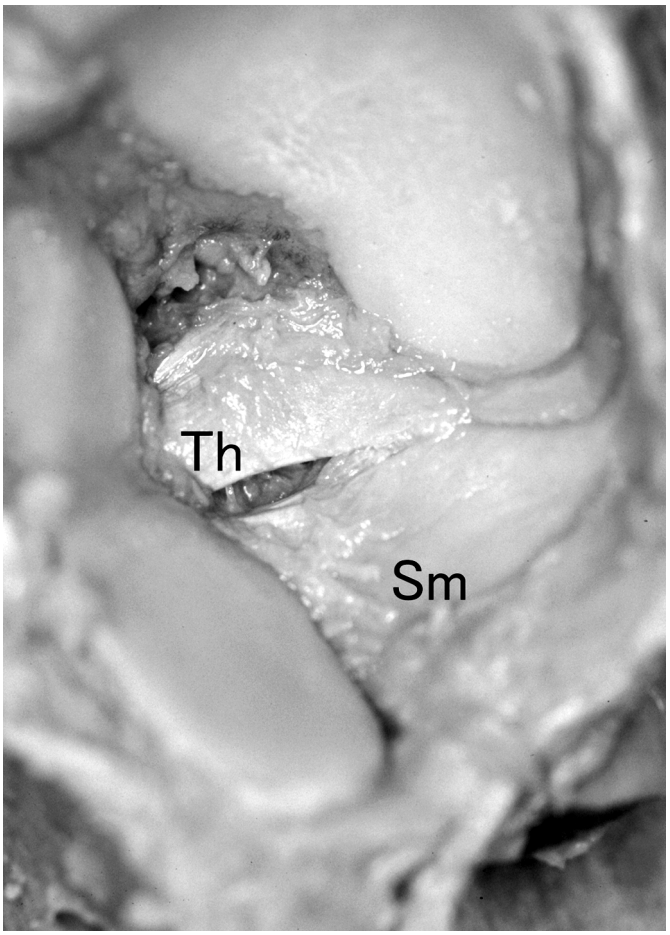

Fig. 1-B

After removal of the articular cartilage covering the spring ligament fibrocartilage complex, the fibers of the third ligament (Th), running from the notch between the anterior and middle calcaneal facets to the navicular beak, become visible. Sm = superomedial calcaneonavicular ligament.

TABLE I Measurements of the Components in the Spring Ligament Fibrocartilage Complex in Forty-eight Feet*

	Superomedial Calcaneonavicular Ligament†					
	Whole Ligament	Origin	Midpoint	Terminus	Central Region of Articular Surface	Medial Margin Bordering on Third Ligament
Length *(mm)*	33.5 ± 3.8 (22.7-42.7)					
Width *(mm)*		18.9 ± 3.1 (12.5-29.0)	13.3 ± 2.4 (9.0-20.3)	8.4 ± 2.3 (4.4-13.6)		
Thickness *(mm)*					4.8 ± 1.4 (1.9-8.2)	2.5 ± 0.8 (1.4-4.6)

*See Figure 3 for measurements schematic. †The values are given as the mean and standard deviation, with the range in parentheses.

Results

The results of the measurement of the components of the spring ligament fibrocartilage complex are shown in Table I.

The superomedial calcaneonavicular ligament, constituting the medial part of the spring ligament, is triangular and hammock-shaped, with its deep surface covered with fibrocartilage, to form an articular surface against the head of the talus. The central region of the articular surface of the ligament is thicker than the medial margin bordering on the third ligament (4.8 compared with 2.5 mm). When the fibrocartilaginous surface is removed, sparse fibers are found to originate from the entire anterior margin of the middle articular facet of the calcaneus. The fibers of the superomedial calcaneonavicular ligament bypass the tubercle of the navicular to insert on top of the medial margin of its talar articular surface (Fig. 2). The superficial fibers of the superomedial calcaneonavicular ligament attach to the tendinous sheath of the posterior tibial tendon vertical to the course of the tendon.

The inferior calcaneonavicular ligament, which constitutes the lateral part of the spring ligament fibrocartilage complex, is a strip-like bundle of wide and short fibers that originates in the notch between the anterior and middle facets of the calcaneus and terminates on the navicular beak.

In all specimens examined in this study, we observed a third bundle of fibers running independently of the other two ligaments under the fibrocartilaginous surface. The fibers consistently originated in the notch between the anterior and middle facets of the calcaneus and terminated at the navicular tuberosity. We have termed this structure *the third ligament*. In five specimens, its fibers were found to have a fibrocartilaginous surface (Fig. 4), whereas in the other specimens, the fibers were distinct from the fibrocartilaginous surface. These fibers of the third ligament are strip-like in shape, attach laterally to the navicular tuberosity, and are clearly distinct from the superomedial calcaneonavicular ligament.

Discussion

According to Hollinshead[8], the plantar calcaneonavicular ligament is a very important component of the medial side of the arch of the foot, contains a considerable number of elastic fibers, and is often known as *the spring ligament*. Woodburne and Burkel[9], in their anatomy atlas, noted that the plantar calcaneonavicular ligament is called *the spring ligament* because of its elasticity under weight-bearing pressure from the head of the talus. However, according to Gray[10], there is no real evidence that the spring ligament is particularly resilient, and Hardy[11] reported that the plantar calcaneonavicular ligament is a purely collagenous ligament and does not possess elastic properties. Kitaoka et al.[12] stated that, among the six stabilizing ligaments, the spring ligament contributes the least to the stabilization of the arch of the foot. Davis et al.[2] stated that the function of the spring ligament complex is to provide a sling function for the talar head. Differences of opinion concerning the functional role of the spring ligament may be due in part to confusion surrounding the definition of the term *spring ligament* itself[2,5]. The plantar calcaneonavicular ligament is termed *the spring ligament*[9,10,12-14]; however, it is not clear whether this means the whole spring ligament fibrocarti-

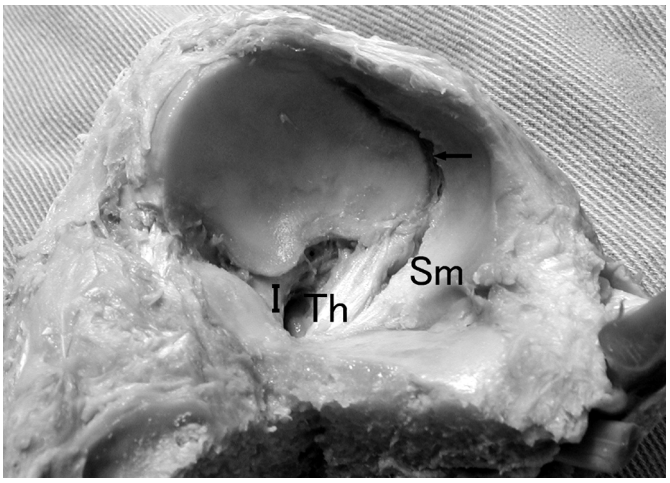

Fig. 2

The fibers of the third ligament (Th) are distinct from both the superomedial calcaneonavicular ligament (Sm) and the inferior calcaneonavicular ligament (I). Note that the superomedial calcaneonavicular ligament runs along the medial margin of the talonavicular articular surface and does not attach to the tubercle of the navicular (arrow).

TABLE I *(continued)*

Inferior Calcaneonavicular Ligament†	Third Ligament†				
	Central Region	Min. Length of Lat. Part	Max. Length of Med. Part	Origin	Max. Portion
4.4 ± 1.8 (1.8-11.5)		11.1 ± 2.6 (4.9-18.7)	18.0 ± 3.6 (11.1-24.0)		
4.1 ± 1.0 (1.9-6.2)				5.3 ± 1.3 (2.6-8.5)	7.7 ± 2.0 (3.6-13.5)
3.4 ± 0.8 (1.5-4.8)	3.5 ± 1.0 (1.9-6.2)				

laginous complex, only the inferior calcaneonavicular ligament, or only the superomedial calcaneonavicular ligament as depicted in *Grant's Atlas of Anatomy*[15]. Deland[3] reported that the term *spring ligament* could be confusing because various authors, usually clinicians, have used it to refer only to the superomedial calcaneonavicular ligament, whereas others, particularly in descriptions of anatomy, have used it to refer to the inferior calcaneonavicular ligament. Gazdag and Cracchiolo[5] reported on eighteen tears of the spring ligament that were associated with dysfunction of the posterior tibial tendon; however, they mentioned that the described tears were within the superomedial calcaneonavicular ligament. In contrast, Sarrafian[1] and Callander[16] defined the inferior calcaneonavicular ligament as the spring ligament. Recently, the opinion of Davis et al.[2]—that the spring ligament is composed of the superomedial calcaneonavicular and inferior calcaneonavicular ligaments—has become the consensus; however, those investigators did not examine the anatomy of the complex beneath the fibrocartilaginous surface.

Once the fibrocartilage was removed in our study, the third ligament was seen to be clearly distinct from the superomedial calcaneonavicular ligament. Moreover, the inferior calcaneonavicular ligament and the third ligament were definitely separated by fatty tissue and showed completely different running patterns.

Sarrafian[1] indicated that the strongest fibers of the inferior calcaneonavicular ligament terminate on the beak of the navicular, and Murata and Sakai[17] observed a similar bundle of fibers within the inferior calcaneonavicular ligament. The authors of both reports regarded these fibers as a component of the inferior calcaneonavicular ligament. However, we propose that these fibers be classified as a distinct ligament that might play a distinct role because they are definitely separated from the other two ligaments by fatty tissue and they exhibit a completely different running pattern.

On the basis of the present results, it is most likely that the ligamentous components of the spring ligament fibrocartilage complex should be defined as the inferior calcaneonavicular

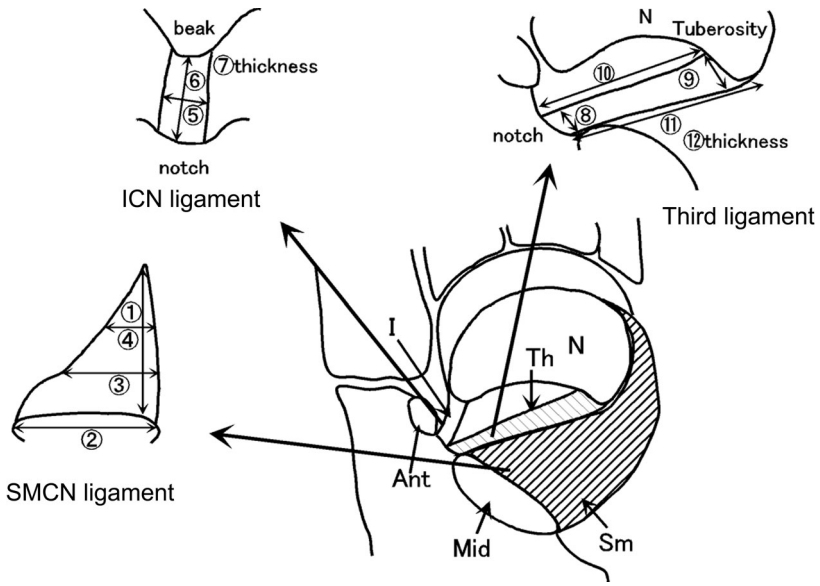

Fig. 3

Schema of the acetabulum pedis. Ant = anterior articular facet of the calcaneus, Mid = middle articular facet of the calcaneus, Sm = superomedial calcaneonavicular ligament, I = inferior calcaneonavicular ligament, Th = third ligament, and N = navicular. The measured elements of the expanded superomedial calcaneonavicular ligament were the length from the origin to the insertion (1), the width at the origin (2), and the width at the trisection points between the origin and the insertion (3 and 4). The measured elements of the inferior calcaneonavicular ligament were the length (5), the width (6), and the thickness (7). The measured elements of the third ligament were the width at the origin (8), the maximum width (9), the minimum length (10), the maximum length (11), and the thickness (12).

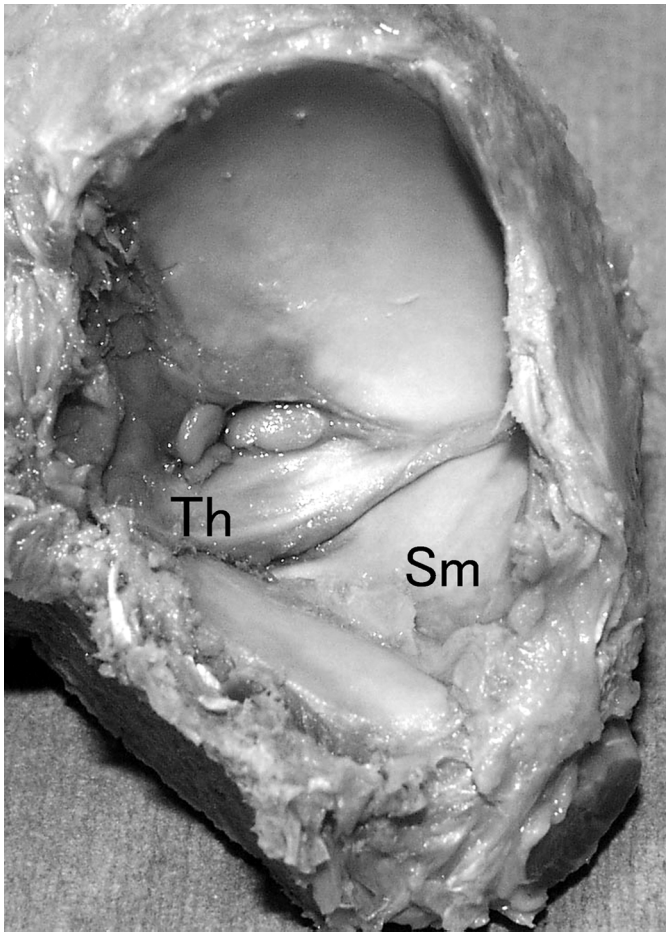

Fig. 4

In some specimens, the third ligament was found to have a fibrocartilaginous surface. Sm = superomedial calcaneonavicular ligament, and Th = third ligament.

ligament, the third ligament, and the superomedial calcaneonavicular ligament because (1) the inferior calcaneonavicular ligament and the third ligament are separated by fatty tissue, (2) the third ligament is clearly distinct from the superomedial calcaneonavicular ligament and terminates at a different locus, and (3) the different direction in which the fibers of the third ligament run suggests that the biomechanical role of this ligament differs from those of the inferior calcaneonavicular and superomedial calcaneonavicular ligaments. Dynamic mechanical testing is necessary to clarify the specific mechanical roles of the three components of the spring ligament fibrocartilage complex in the longitudinal arch of the foot.

It is possible that our measurements deviate from those of normal healthy tissue because the ligaments were obtained from preserved cadavers. To minimize this possibility, measurements were performed without applying any tension to the ligaments. Another limitation of this study is that the shape of the superomedial calcaneonavicular ligament was altered during measurement since the ligament, which has a curved surface, needed to be expanded to a flat plane for measurement.

In conclusion, we detailed the anatomy of the spring ligament fibrocartilage complex, which is composed of three distinct medial, lateral, and intermediate fiber groups, and we defined these groups as the superomedial calcaneonavicular ligament, inferior calcaneonavicular ligament, and third ligament, respectively. ■

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