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Footprint of the Lateral Ligament Complex of the Ankle

Timothy B. Neuschwander, MD[1], Andrew A. Indresano, MD[1], Tudor Hughes, MD[2], and Bertil W. Smith, MD[3] [AQ: 1]

Abstract

Background: We describe the topographic anatomy of the lateral ligament complex of the ankle using 3-dimensional (3D) computed tomography (CT) imaging.

Methods: Dissection of the anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL) was performed on 8 unpaired fresh-frozen cadaver feet. Ligaments were sharply dissected from bone, and the footprint was outlined with radio-opaque paint. The specimen underwent a 0.625-mm slice CT scan of the ankle with 3D reconstructions. Software was used to determine the surface area of the ligament footprint as well as measure the distance from the peroneal tubercle to the center of the CFL footprint. Data are presented as mean ± standard error.

Results: Six specimens had a bifid ATFL. Seven ankles had a bifid ATFL footprint on the talus. All specimens had intact CFL fibers. The intact superior and inferior limbs of the ATFL measured 19.7 ± 1.2 mm and 16.7 ± 1.1 mm. The CFL measured 24.8 ± 2.4 mm. The area of the footprints of the superior ATFL and inferior ATFL on the talus measured 1.5 ± 0.26 cm^2 and 0.90 ± 0.07 cm^2. The CFL and ATFL origins on the fibula were continuous and measured 3.48 ± 0.39 cm^2. The CFL insertion on the calcaneus measured 2.68 ± 0.20 cm^2. The CFL was found 27.1 ± 1.0 mm posterior and superior from the peroneal tubercle.

Conclusions: In presumably uninjured specimens, both the ATFL and its footprint on the talus were bifid. The CFL and ATFL origins have a single confluent footprint on the anterior border of the distal fibula. The CFL footprint on the calcaneus is almost 3 cm posterior and superior to the peroneal tubercle.

Clinical Relevance: [AQ: 2]

Keywords: lateral ligament complex, anterior talofibular ligament, ATFL, calcaneofibular ligament, CFL, footprint, topography

Lateral ankle sprain is the most common injury in sport.[5,16] Among professional basketball players, ankle injuries were responsible for almost 10% of game-day injuries.[18] Twenty percent of players who medically failed the National Football League Combine sustained ankle sprains.[1] The mechanism of injury is typically an inversion force on an unloaded ankle, since the bony mortise contributes to loaded stability. Eighty percent of patients will tear their anterior talofibular ligament (ATFL), whereas the other 20% will tear both the ATFL and calcaneofibular ligament (CFL).[2] Approximately 20% of patients with a first-time ankle sprain will develop chronic ankle instability.[9,13] In these patients, surgical repair or reconstruction may be indicated. Of the many procedures described, Broström's description of direct repair of the ATFL and CFL remains the gold standard.[2] Good to excellent results in approximately 80% of patients and a low complication rate have demonstrated that the Broström procedure is superior to peroneal tenodesis procedures.[8,10] In the 20% of patients who continue to sprain their ankles after direct repair of the ligaments, "larger" athletes in whom a more robust construct is needed, patients with congenitally lax ligaments, or patients with multiple, severe sprains who may have unrepairable ligaments, anatomic reconstruction with allograft or autograft may be indicated.[4]

To perform an anatomic reconstruction, the anatomy must be well understood. Although several excellent descriptions of the ankle lateral ligament complex exist in the literature, none of these studies provide an in-depth description of the footprint of the lateral ligament complex.[7,21] When performing

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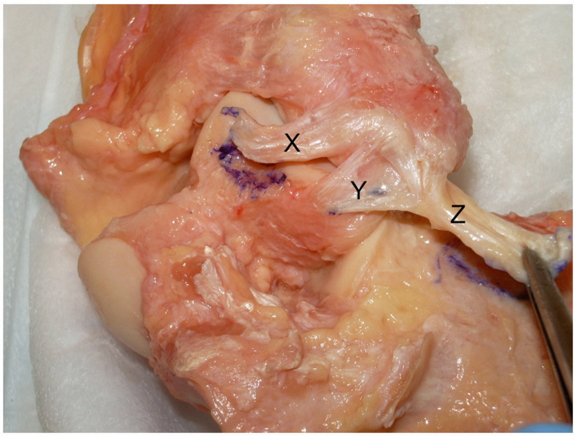

Figure 1. Sharp dissection of the superior anterior talofibular ligament (ATFL) (X), inferior ATFL (Y), and calcaneofibular ligament (Z). Footprints were outlined with a surgical marker during dissection under loupe magnification.

Figure 2. Ligament footprints were outlined with surgical marker and painted with radio-opaque barium paint.

an anatomic reconstruction of the lateral ligament complex, the surgeon has little guidance on where to place bony tunnels. Current literature has focused on description of length, width, and bony landmarks of the ligaments.[19] Present techniques to describe human cadaveric ligament footprints use either 2-dimensional digital photography or 3-dimensional (3D) laser photography.[6,11]

In this study, we describe a new technique using radio-opaque paint and 3D computed tomography (CT) imaging to outline ligament footprints. Using this technique, we provide a pictorial, 3D description of the topography of the footprint of the lateral ligament complex of the ankle.

Materials and Methods

A superficial dissection of the lateral ligament complex in 8 unpaired fresh-frozen cadaver feet was performed. Under loupe magnification, the ligaments of the lateral ligament complex were isolated with sharp dissection (Figure 1). These included the ATFL and the CFL. The lateral talocalcaneal ligament and the posterior talofibular ligament were not included in this study. All soft tissue was removed from the specimen until only ligaments and bone remained. The ATFL and CFL were then measured with a ruler from approximate center to center of ligament attachments. It was noted whether the ATFL was bifid. Four left and 4 right ankles were dissected, and our sample was evenly matched between sexes. Average age of specimen at death was 56.3 ± 5.8 years.

Ligaments were sharply dissected from bone and the footprint was outlined with a surgical marker followed by radio-opaque paint (Figure 2). Paint was prepared by mixing 0.25 g Daler-Rowney Acrylic Artists Ink Scarlet #567 (Bracknell, England) per gram of EZ-HD 98% v/w Barium Sulfate (Lake Success, NY). The paint was then applied to the area of the footprint, and the specimen underwent a 0.625-mm slice CT scan of the ankle with 3D reconstructions. Vitrea (Vital Images, Minnetonka, MN) software was used to determine the surface area of the ligament footprint as well as measure the distance from the peroneal tubercle to the center of the CFL footprint. A single investigator (T.N.) performed all ligament dissections, footprint painting, and CT measurements. Data are presented as means ± standard error (SE).

Results

Six specimens had a bifid ATFL. Seven of 8 ankles had a bifid ATFL footprint on the talus, including the specimen with evidence of a healed talar neck fracture. All specimens had intact CFL fibers. One specimen (CT scan shown in Figure 3) had well-healed surgical scars medially and laterally over the talus, indicating history of open reduction and internal fixation for a talar neck fracture; this specimen had a bifid ATFL footprint but not a bifid ATFL as there was significant scar tissue between the superior and inferior limbs. No other specimens had evidence of surgical scars. One other specimen had evidence of prior injury with significant scarring of the ATFL and disorganized ligamentous fibers; this was the only specimen without a bifid ATFL footprint. These 2 specimens did not have a bifid ATFL.

The lengths of all ligaments were measured prior to dissection. The intact superior limb of the ATFL measured 19.7 ± 1.2 mm (scarred ATFL specimens excluded). The intact inferior limb of the ATFL measured 16.7 ± 1.1 mm (scarred ATFL specimens excluded). The CFL measured

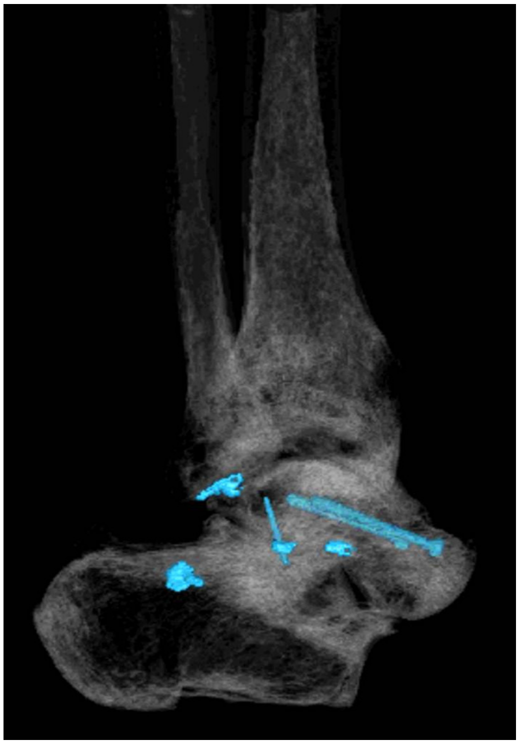

Figure 3. Specimen with evidence of prior treatment for a talar neck fracture. Vitrea presets for hardware are used to make bone transparent and hardware blue. The anterior talofibular ligament footprint on the talus in this case was bifid, despite evidence of scarring.

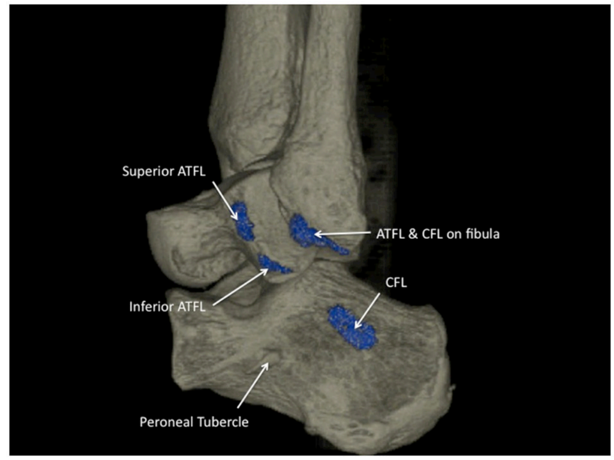

Figure 4. Detail of the superior and inferior anterior talofibular ligament (ATFL) footprints on the talus, ATFL and calcaneofibular ligament (CFL) footprint confluence on the fibula, CFL footprint on the calcaneus, and peroneal tubercle.

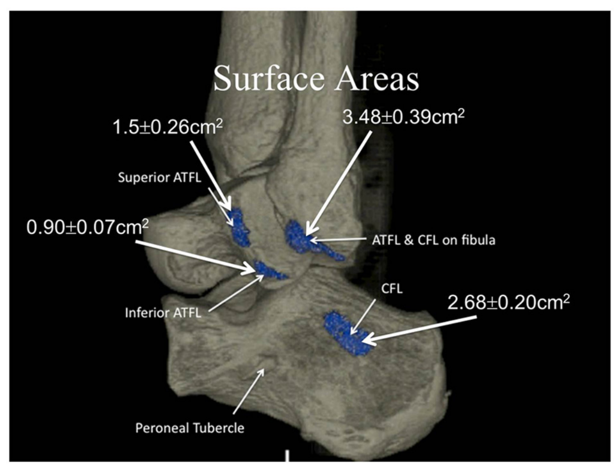

Figure 5. Surface areas of the superior and inferior anterior talofibular ligament (ATFL) footprints on the talus, ATFL and calcaneofibular ligament (CFL) footprint confluence on the fibula, and CFL footprint on the calcaneus.

24.8 ± 2.4 mm in all specimens. A specimen demonstrating typical ligament footprint topography is shown in Figure 4. Barium paint, much denser than bone, can be made to appear blue using Vitrea presets.

As seen in Figure 5, the surface area of the footprint of the superior ATFL on the talus measured 1.5 ± 0.26 cm^2 (nonbifid ATFL footprint specimen excluded). The surface area of the footprint of the inferior ATFL on the talus measured 0.90 ± 0.07 cm^2 (nonbifid ATFL footprint specimen excluded). The CFL and ATFL footprints on the fibula were confluent, and their surface area measured 3.48 ± 0.39 cm^2. The surface area of the CFL insertion on the calcaneus measured 2.68 ± 0.20 cm^2. The distance between the superior ATFL and inferior ATFL footprints on the talus, measured center to center, was 11.5 ± 1.0 mm. The center of the CFL was found 27.1 ± 1.0 mm posterior and superior to the peroneal tubercle (Figure 6).

Discussion

Our technique for imaging ligament topography was easily performed using barium paint and a CT scanner. The accuracy of our technique depended on how accurately the ligament footprints were painted by hand since the CT scanner performed high-resolution 0.625-mm slices. Inter- and intraobserver reliability were not calculated since the least accurate step, outlining and painting the ligament insertions by hand, could only be performed once. Three-dimensional laser photography was used to image posterior cruciate ligament topography accurate up to 0.0008 mm.[6,11] Our study was similar in that the ligament was dissected from its footprint by hand and the footprint was marked with ink

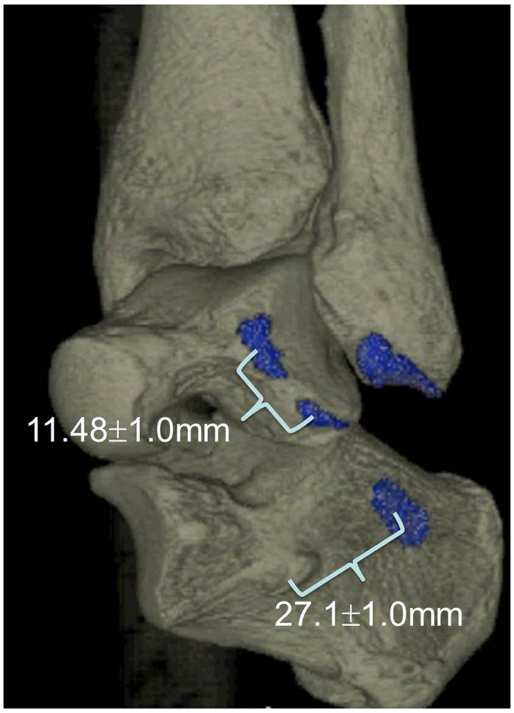

Figure 6. Mean distance between the superior and inferior anterior talofibular ligament (ATFL) footprints on the talus, and mean distance between the peroneal tubercle and the calcaneofibular ligament (CFL) footprint.

or paint. Therefore, there is likely no difference in accuracy between the 2 techniques since both of them involve outlining ligament footprints by hand prior to imaging. Despite the accuracy of the CT scanner, determining the outline and center of a ligament footprint was ultimately up to the discretion of the investigator and a potential source of bias. Other limitations of our study include the possibility of a spectrum of anatomical variation that was not seen given our small sample size. Although we noted a variation in the size of specimens, objective measurements of footprint size were not performed as part of this study. Subjectively, no specimens were noted to be outside the range of normal. Finally, 1 specimen with a nonbifid ATFL footprint on the talus was excluded from this data set with the assumption that the ATFL was previously injured. Although it had the gross appearance of scar tissue, we have no such history from the specimen or histologic data to confirm this.

We demonstrated that the CFL and ATFL have a single confluent footprint on the anterior border of the distal fibula. The CFL footprint on the calcaneus was almost 3 cm posterior and superior to the peroneal tubercle, which could be used as an osseous landmark during ligament reconstruction. In presumably uninjured specimens with a grossly intact ATFL, both the ATFL and its footprint on the talus are bifid. This is a well-established finding in the literature despite many textbooks showing the ATFL as a single band.[3,12,14,15] Sarrafian[17] suggested that the purpose of the split fibers is to allow penetration of the vascular branches of the anterior fibular artery. Van den Bekerom et al[21] believe there is a biomechanical purpose to the double bundle of the ATFL, with the superior ATFL taut in plantarflexion and the inferior ATFL taut in dorsiflexion, but there have been no biomechanical studies demonstrating this phenomenon. Based on the distance between the inferior and superior footprints of the ATFL on the talus seen in our study, it makes sense to assume a biomechanical purpose of the 2 bundles. A 2-bundle ATFL reconstruction may be more anatomic, but to our knowledge, this has not been performed. Since the superior ATFL probably restricts inversion in plantarflexion, the most common position of the foot at the time of injury, it may be the more important of the 2 bundles. Based on our results, the superior ATFL footprint is larger than the inferior ATFL footprint, and although our study did not assess the diameter of the ligaments, other studies have demonstrated the superior band to be the larger of a bifid ATFL.[20] Based on previous excellent results, reconstruction of a single limb of the ATFL is probably adequate to prevent recurrent instability.[4] The superior band of the ATFL inserts at the body-neck junction of the talus and is probably an easier location to place a bone tunnel and interference screw. At this time, we recommend reconstruction of the superior limb of the ATFL as we believe this represents a durable, anatomically correct construct that will prevent recurrent instability and provide near-normal ankle biomechanics.

In conclusion, this study provides a topographical description of the lateral ligament complex of the ankle and may assist surgeons in performing anatomic reconstruction of these ligaments.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.[AQ: 3]

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