The Journal of Foot & Ankle Surgery 58 (2019) 717–722

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Independent Attachment of Lateral Ankle Ligaments: Anterior Talofibular and Calcaneofibular Ligaments - A Cadaveric Study

Akira Kakegawa, PhD[1,2], Yusuke Mori, MD[3], Atsushi Tsuchiya, MD[4], Norimi Sumitomo, MT[5], Nanae Fukushima, MD, PhD[6], Tetsuji Moriizumi, MD, PhD[6]

[1] *Associate Professor, Faculty of Health Care, Teikyo Heisei University, Tokyo, Japan*
[2] *Lecturer, Department of Anatomy, Shinshu University School of Medicine, Nagano, Japan*
[3] *Orthopedic Surgeon, Toyohashi Ezaki Orthopedic Hospital, Aichi, Japan*
[4] *Orthopedic Surgeon, Sakudaira Orthopedic Clinic, Nagano, Japan*
[5] *Technological Assistant, Department of Anatomy, Shinshu University School of Medicine, Nagano, Japan*
[6] *Professor, Department of Anatomy, Shinshu University School of Medicine, Nagano, Japan*

ARTICLE INFO

Level of Clinical Evidence: 5

Keywords:
anatomy
ankle
anterior talofibular ligament
calcaneofibular ligament
connective fiber

ABSTRACT

Anatomic knowledge of lateral ligaments around the lateral malleolus is important for repair or reconstruction of ankle instability. The detailed structure of the connective fibers between the anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL) is unknown. To clarify the anatomic structure of ATFL and CFL and the connective fiber between the 2 ligaments, the lateral ligament was dissected in 60 ankles of formalin-fixed cadavers, and the distance was measured between bony landmarks and fibular attachment of ATFL and CFL using a digital caliper. All ankles had connective fibers between ATFL and CFL. The structure of connective fibers consisted of a thin fiber above the surface layer of ATFL and CFL; it comprised thin fibrils of the surface layer covering the lower part of ATFL and the front part of CFL. Both ATFL and CFL were independent fibers, and both attachments of the fibula were isolated. Single bands of ATFL were noted in 14 of 60 (23.3%) ankles, double bands that divided the superior and inferior bands were observed in 42 of 60 (70.0%) ankles, and multiple bands were observed in 4 of 60 (6.7%) ankles. A cord-like and a flat and fanning type of CFL was noted in 22 (36.7%) and 38 (63.3%) of the 60 ankles, respectively. Distances between ATFL/CFL and articular and inferior tips of the fibula were 4.3 ± 1.1 mm/7.6 ± 1.6 mm and 14.3 ± 1.9 mm/7.4 ± 1.7 mm, respectively (mean ± standard deviation). The results of this study suggest that knowledge of more anatomic structures of ATFL, CFL, and connective fiber will be beneficial for surgeons in the repair or reconstruction of the lateral ligament of the ankle.

Ankle ligament injury is a frequently occurring sports injury that often includes a damaged lateral ligament. Anterior talofibular ligament (ATFL) injury occurs most often and is likely to occur at the fibular side or substantial part of the ligament (1–6). Furthermore, if the calcaneofibular ligament (CFL) is ruptured along with ATFL, ankle joint (or subtalar joint) instability is more severe than in cases of isolated ATFL injury (1,3,7). Conservative functional therapy is generally performed for acute ankle ligament injury, often with good clinical results (8), but nonoperative functional treatment results in an ~10% failure rate and slower return to full activity (9). Such patients need operative repair or reconstruction of the lateral ligament because of chronic ankle instability (9–13). Knowledge of the ligament structure of the ankle is important for surgeons performing reconstruction or repair.

ATFL is an intra-articular ligament (capsular ligament) that connects the anterior lateral border of the lateral malleolar articular surface to the anterior portion of the lateral malleolus. There have been many reports on the anatomic structure of the lateral ligament of the ankle (14–23). Previous studies reported anatomic variation of the ATFL fiber bundle, including single, double, or triple (multiple) band forms (7,15,16,18,19,21,22). The frequency of the type of bundle patterns had been reported as mostly a single isolated fiber (20,22) and mostly double bundles that divided the superior band (SB) and inferior band (IB) (19). It remains controversial whether the ATFL consists of a single fiber or double bundles.

CFL is an extra-articular ligament. The fibular origin of CFL is just below the origin of ATFL, and the calcaneal origin is on the lateral surface of the calcaneus (24). Variations in the form of the CFL fiber have been reported, such as a cord-like band or a flat and fanning structure (21).

Financial Disclosure: None reported.
Conflict of Interest: None reported.
Address correspondence to: Akira Kakegawa, PhD, Faculty of Health Care, Teikyo Heisei University, 2-51-4 Higashi-ikebukuro, Toshima-ku, Tokyo 170-8445, Japan.
E-mail address: a.kakegawa@thu.ac.jp (A. Kakegawa).

https://doi.org/10.1053/j.jfas.2018.12.009

The fibular origins of ATFL, CFL, and the posterior talofibular ligament (PTFL) are concentrated in the lower part of the lateral malleolus. Because these 3 ligaments are partially connected with connective fiber, they are termed the "lateral ligamentous complex" (19). ATFL and CFL include the connective fiber, called "arciform fiber" (19); connection ligament (22); and bridging (21), although their detailed anatomic structure is unknown. The purpose of this study was to clarify the structure of the lateral ligament and connective fiber between ATFL and CFL and the positional relationship between attachment of ATFL and CFL of the fibula and bony landmarks.

Materials and Methods

We studied 72 ankles from 36 formalin-fixed Japanese cadavers (16 male [44%] and 20 female [56%]), with a median age of 87.5 years (range, 66 to 99 years) at the time of death. Twelve ankles were excluded for the following reasons: 9 left ankles had already been dissected at the joint during anatomic practice by medical students, 2 left ankles had severe osteoarthritis, and 1 left ankle had an avulsion fracture of the lateral malleolus. A total of 60 ankles (36 right [60%] and 24 left [40%]) were amputated 10 cm above the ankle. Each ankle was cut in half along the sagittal plane. The skin and soft tissues were carefully removed for detailed dissection of lateral ligamentous structures from inside and outside the ankle joint.

ATFL

We carefully dissected ATFL and CFL from outside and inside the ankle joint. ATFL was classified into 3 bundle types (single, double, or multiple). A single-band type consisted of an isolated band. The double-band type was divided by superior and inferior fibers. The multiple-band type was divided by triple bands or more.

CFL

CFL was classified into 2 types according to the bundle shape, that is, a cord-like or a flat and fanning-like structure. The cord-like structure was identified by the circular shape of the cross-section of CFL, whereas in the flat and fanning-like structure, the cross-section was a flat shape at a point 10 mm distal from the lateral malleolus.

Connective Fiber Between ATFL and CFL

We examined the presence of connection fibers between ATFL and CFL. When a connection fiber existed, we investigated the positional relationship between ATFL and CFL and the connective fiber and judged whether the connective fiber was a converged fiber that firmly combined as 1 fiber or a covered fiber that consisted of a thin fascia covering only the surface layer of both ligaments. We also investigated whether there were continuous fibers with ATFL from the ankle joint.

Table 1
Characteristics of anterior talofibular ligament, calcaneofibular ligament, and lateral talocalcaneal ligament (N = 60 ankles)

Characteristic	n (%)
ATFL	
Single type	14 (23.3)
Double type	42 (70.0)
Multiple type	4 (6.7)
CFL	
Cord type	22 (36.7)
Flat and fan type	38 (63.3)
LTCL	
Presence	31 (51.7)
Absence	29 (48.3)

Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; LTCL, lateral talocalcaneal ligament.
ATFL and CFL are classified according to the shape of the ligament fiber. The frequency of occurrence of LTCL and, when LTCL was present, the proportion of connecting fibers between ATFL and CFL are shown.

Lateral Talocalcaneal Ligament

We investigated the presence of lateral talocalcaneal ligament (LTCL), which was not a connective fiber between ATFL and CFL at the fibular side but was an isolated fiber that generally connected the calcaneus to the talus of the lateral ankle. If LTCL existed, we investigated whether the LTCL fiber from the calcaneus side was converged to ATFL at the central region of ATFL.

Distance From Bony Landmarks

Inferior tips (IT) and articular tips (AT) of the fibula (a landmark of the bone) were plotted from the bottom side of the ankle mortise (Fig. 1*A*). After confirming the structure of lateral ligaments, ATFL and CFL were cut at the center of each fiber and removed from the fibula. Then, fibula attachments of both ligaments were outlined with a pencil, and the approximate center of the attachment of each ligament was plotted (Fig. 1*B*). The distance from the bony landmark to the fibular attachment of ATFL and CFL was measured using a digital caliper (Fig. 1*C, D*). All measurements were performed by a single investigator (A.K.); 2 average values were used in this study.

Results

Type of ATFL

On classifying ATFL, a single isolated band was noted in 14 of the 60 ankles (23.3%; Table 1; Fig. 2*A*), double bands that divided SB and IB were noted in 42 of the 60 ankles (70.0%; Fig. 2*B*), and multiple bands were

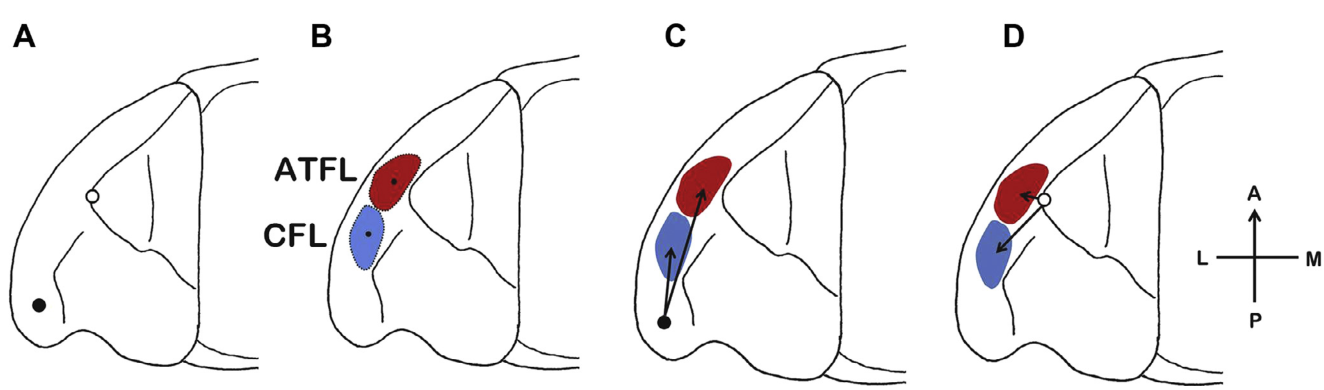

Fig. 1. Bottom views of the right ankle joint. (*A*) The distance from inferior tips (*black dot*) to articular tips (*white dot*) is measured, which constitutes a bony landmark of the intra- and extra-joint. (*B*) Outline of attachment of anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) is marked, and the center of each attachment is plotted. The distance between the center of the attachment of ATFL and CFL is measured. (*C*) The distance from inferior tips to the center of the attachment of ATFL/CFL is measured. (*D*) The distance from articular tips to the center of the attachment of ATFL/CFL is measured.

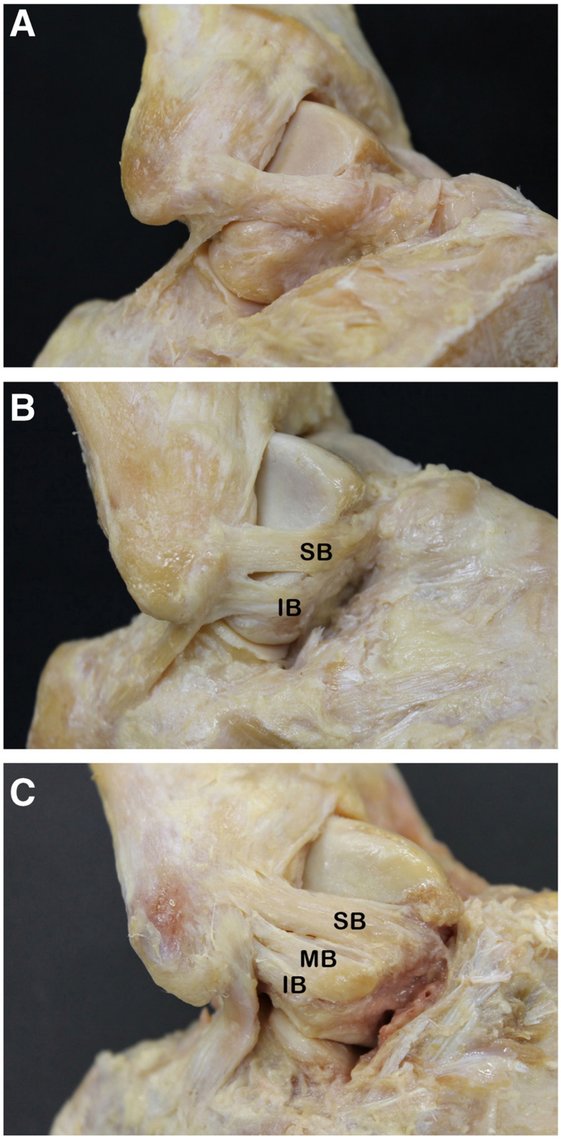

Fig. 2. Bundle type of anterior talofibular ligament. (*A*) Single type with isolated band. (*B*) Double type with divided superior band and inferior band. (*C*) Multiple type (triple type) with separated superior band, middle band, and inferior band.

noted in 4 of the 60 ankles (6.7%; Fig. 2*C*). In all 4 cases of multiple bands, ATFL consisted of 3 bundles (superior, middle, and inferior bundles).

CFL

The cylindrical cord-like type CFL, which was the same width over the entire length and circular cross-section, occurred in 22 of 60 ankles (36.7%; Fig. 3*A*). The flat and fanning type, which was spread widely toward the calcaneal bone and had a flat cross-section, occurred in 38 of 60 ankles (63.3%; Fig. 3*B*).

Connective Fiber Between ATFL and CFL

All 60 ankles had connective fiber between ATFL and CFL at the anterior inferior lateral malleolus (Fig. 4*A*). The connective fiber could be easily removed. After removal, the 2 ligament fibers were isolated from each other (Fig. 4*B, C*). The connective fiber covered the surface layer above the inferior part of ATFL and anterior part of CFL. When observed

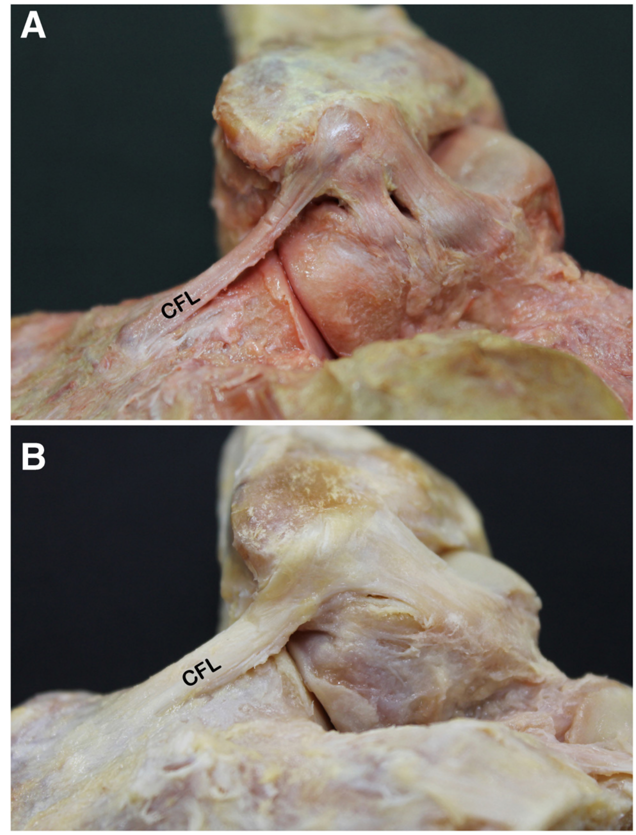

Fig. 3. Fiber type of calcaneofibular ligament. (*A*) Cord-like type structure. (*B*) Flat and fan type structure.

from the intra-joint, the deep-layer fiber of ATFL was continuous with PTFL (Figs. 4*D* and Fig. 5).

LTCL

LTCL was present in 31 (51.7%) and absent in 29 of the 60 ankles (Table 1). LTCL ran parallel to CFL and toward the inferior part of ATFL. Of the 31 ankles in which LTCL was present, 19 (61.3%) had a structure bridging the inferior part of ATFL and the anterior part of CFL (Fig. 6). In 12 ankles, no fiber connected ATFL and CFL, and LTCL ran parallel to CFL and inserted at the talus bone.

Distance of the Fibular Attachment of ATFL and CFL From Bony Landmarks

The distance (mean ± standard deviation) between the 2 bony landmarks, IT to AT, was 13.4 ± 1.5 (male, 13.9 ± 1.4; female, 13.0 ± 1.3) mm. The distance between the center of the fibular attachment of ATFL and that of CFL was 7.1 ± 1.4 (male, 7.3 ± 1.5; female, 7.0 ± 1.3) mm. Distances between IT and ATFL and that between IT and CFL were 14.3 ± 1.9 (male, 14.7 ± 1.6; female, 13.9 ± 2.0) and 7.4 ± 1.7 (male, 7.5 ± 1.5; female, 7.3 ± 1.8) mm, respectively, toward the anterior. Distances between AT and ATFL and that between AT and CFL were 4.3 ± 1.1 (male, 4.3 ± 1.1; female, 4.3 ± 1.1) mm toward lateral and slightly anterior and 7.6 ± 1.6 (male, 8.1 ± 1.5; female, 7.3 ± 1.6) mm toward posterior-lateral, respectively (Table 2).

Discussion

The most important finding of this study was that all ankles had connective fibers between ATFL and CFL, and their structures were clarified.

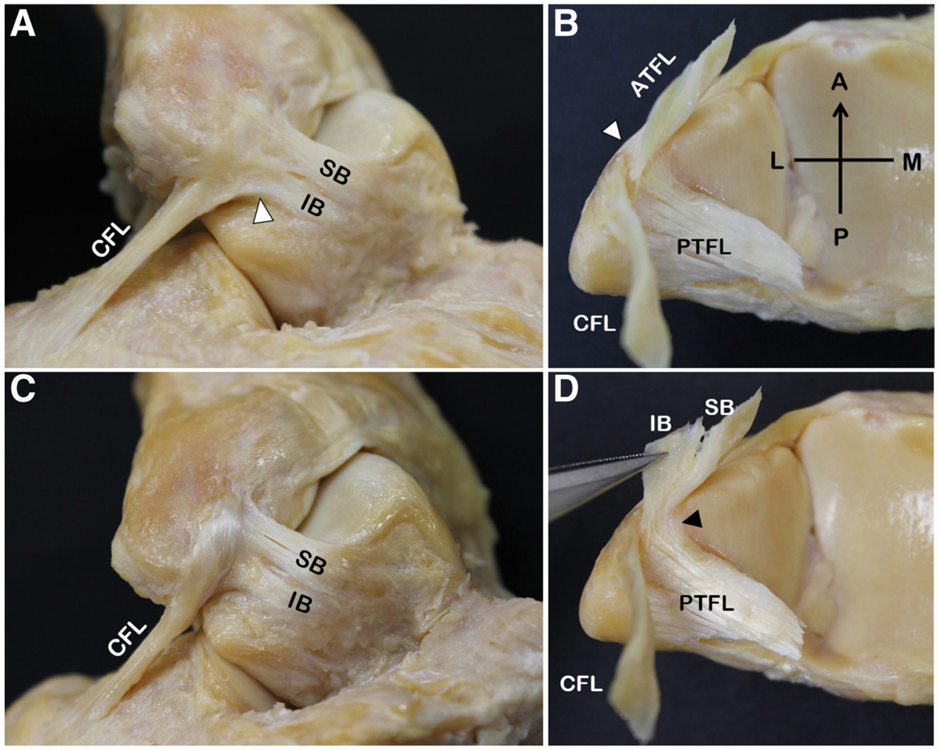

Fig. 4. Lateral view of the right ankle. (*A*) White arrowhead indicates the connective fiber between anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL). (*B*) After removal of the connective fiber, the ATFL and CFL fibers are independent of each other. (*C*) Bottom view of the right ankle joint. White arrowhead indicates the boundary of ATFL and CFL. (*D*) Black arrowhead shows continuous fiber between ATFL and posterior talofibular ligament.

Connective fibers between ATFL and CFL covered the surface layer of the inferior part of ATFL and the anterior part of CFL. The connective fibers could be separated; ATFL and CFL fibers were subdivided as independent fibers. Although there are many reports on connective fibers, the illustrations are not clear, and it is difficult to understand which part is pointing to the connective fiber. The connective fiber between ATFL and CFL comprises 2 intermixed patterns; 1 is the fiber at the fibular side that is derived from the joint capsule, and the other is derived from LTCL. The connective fiber in this study is indicated by the fiber near the fibular attachment of ATFL and CFL and is part of the fibrous membrane of the joint capsule. Sarrafian and Kelikian (19) reported that the arciform fiber united CFL and IB of ATFL. Yıldız and Yalcın (22) observed the connecting ligament in 19 of 46 cases (41.3%) and suggested that this connecting ligament refers to LTCL. Burks and Morgan (14) reported that LTCL was divided into 3 patterns: 1) LTCL seemed to run combined with CFL and arched up toward ATFL, 2) LTCL was a completely discrete ligament from ATFL and CFL, and 3) LTCL was absent. LTCL has a role in subtalar instability, but its role is not totally understood. Wiersma and Griffioen (21) identified LTCL in 29 of 44 ankles (66%); when identified, it showed bridging of CFL and ATFL in 24 of 29 ankles (83%). This LTCL formed the connecting leg of the triangle between ATFL and CFL. However, often LTCL is a relatively thin fiber structure, and the control function of the subtalar joint is small. The insertion and relative position of ATFL and CFL are important for anterolateral stability of the ankle (subtalar) joint.

Using 3-dimensional computed tomography imaging, Neuschwander et al (18) reported that CFL and ATFL have a single confluent attachment on the anterior border of the distal fibula, but Wenny et al (20) reported that the insertion of the fibular of ATFL and CFL was clearly divided by connective tissue and fat as 2 ligaments. We found that ATFL and CFL were independent fibers and had independent attachment in cadavers.

Anatomic reconstruction or repair of injured lateral ankle ligaments requires detailed understanding of anatomic relative relationships. ATFL is the most frequently injured ligament of the ankle in cases of ankle sprains. This ligament has an important role in anterior displacement and internal rotation of the talus. There are many reports on the length (~12 mm–25 mm) and width (~6 mm–10 mm) of ATFL (17,19,20,24). In terms of bundle type of ATFL, Sarrafian and Kelikian (19) reported never finding a single ATFL band and that ATFL mainly consisted of 2 bands. Golanó et al (25) reported that most ATFLs commonly have a double-banded morphology. However, Wenny et al (20) noted a single ATFL band in all 17 specimens examined. Wiersma and Griffioen (21) reported a single band in 30 (68%) and a double band in 14 (32%) of 44 ankles. Yıldız and Yalcın (22) reported that the double band was formed by SBs and IBs bilaterally in 24.4% of 45 ankles; SB was longer than IB. Raheem and O'Brien (26) reported that 5 of 19 ankles (26%) had a 2-slip structure, and 14 of 19 ankles (74%) had 1 main ligamentous body. Khawaji and Soames (15) reported several ATFL band patterns, including a single band in 11 (23%), double bands in 27 (56%), and triple bands in 10 (21%) of 48 ankles. Some multiple bands had connections to other bands, but their distal insertion and fiber directions differed. In 42 of 60 ankles (70%) in our study, the double-band type was more prevalent than the single-band type. In all cases with double bands, SB and IB were separated by vascular branches from the perforating peroneal artery and its anastomosis with the lateral malleolar artery, similar to that observed by Golanó et al (25). SB of ATFL was more rigid than IB; therefore, SB was easy to visualize using ultrasonography, but it was difficult to evaluate IB of ATFL. In reconstruction or repair of the lateral ankle ligament, it is important to have accurate anatomic knowledge of the running of ATFL in the ankle joint. In the intra-articular view of the ankle, SB of ATFL travels horizontally at AT of the fibula and IB runs further under it (Fig. 5*A*).

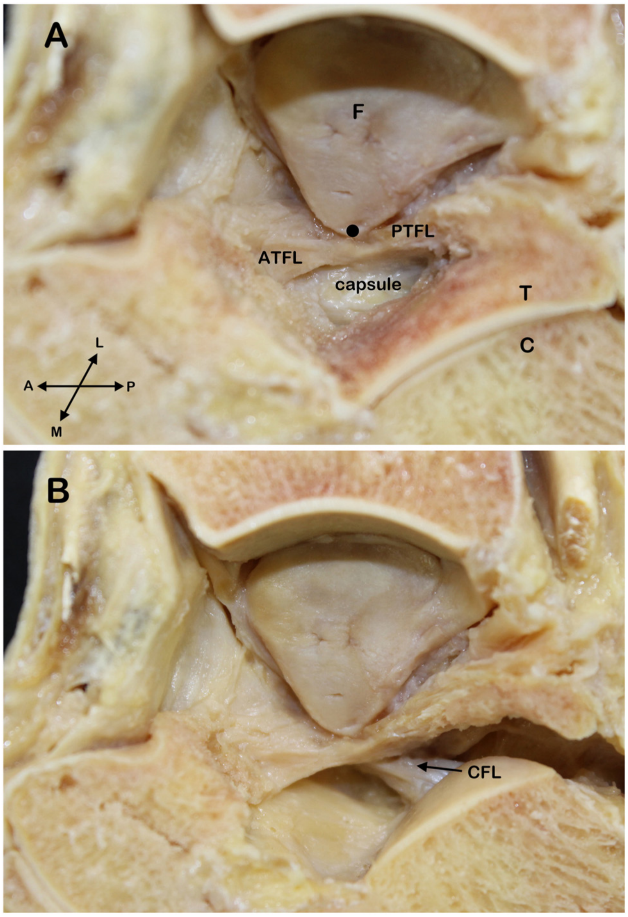

Fig. 5. (*A*) Intra-articular view of the right ankle joint (a part of the talus had been removed). Anterior talofibular ligament and posterior talofibular ligament have continuous fiber in the deep layer. (*B*) The capsule and tarsal bone are removed piece-by-piece from the intra-articular position and calcaneofibular ligaments are revealed from the intra-articular position.

CFL is the only lateral ligament bridging the subtalar and talocrural joints. ATFL and CFL rupture occurs in 20% of ankle sprains, but isolated ruptures of CFL are very rare (27). Patients with combined injuries of ATFL and CFL have unsatisfactory clinical results compared with those with an isolated ATFL injury (3).

There are many reports on the length (~20 mm–35 mm) and width (~4 mm–7 mm) of CFL (14,17–19,24,28). CFL is a single band, with a mean angle of 133° with the axis of the fibula (14). Wiersma and Griffioen (21) reported that the ligament pattern of CFL showed a single cord-like structure in 29 (66%) and a flat and fanning out structure in 15 (34%) of 44 ankles. CFL was identified to be extracapsular in 30 (68%) and to be a capsular reinforcing structure in 14 (32%) of 44 ankles (14). The flat and fanning-out type of CFL was more often a capsular reinforcing than an extracapsular structure (21). In our study, we did not examine whether it was the capsular or extracapsular ligament, but the flat-type CFL was found in 63% of ankles (38 of 60).

Because twist and tension of CFL change according to the motion of the ankle joint, it is necessary to clarify the change in the shape of the ligament fiber owing to movement of the ankle. It is difficult to find the exact attachment of ATFL and CFL. Therefore, a bony landmark is useful to make a bone tunnel during reconstruction of the lateral ligament. Matsui et al (29) reported the existence of the fibular obscure tubercle as a clinically reliable bony landmark of the ATFL and CFL origin location of the fibula. They reported that centers of fibular attachment of ATFL and CFL were located 3.7 mm proximal and 4.9 mm distal, respectively, from the obscure tubercle. The intersection point, which was the convergence of the inferior fiber of ATFL with the anterior fiber of CFL, was also located 2.4 mm posterior from the obscure tubercle. The obscure tubercle is a useful landmark of ATFL and CFL from the body surface. Khawaji and Soames (15) used the tip of the lateral malleolus as a bony landmark. The distance of ATFL originating from the lateral malleolar tip was ~10 mm anterosuperior. Thès et al (30) also used the tip of the lateral malleolus as a bony landmark. Centers of fibular attachment of ATFL and CFL were ~16 mm and 4 mm, respectively, from the tip of the fibula. Similarly, Clanton et al (31) used IT of the lateral malleolus as a bony landmark. In case of a single band, the fibular attachment averaged 13.8 mm from IT of the lateral malleolus at the anterior fibular border. In case of double bands, the average of SB of ATFL was 16.3 mm and that of IB was 10.2 mm. Wenny et al (20), Haytmanek et al (32),

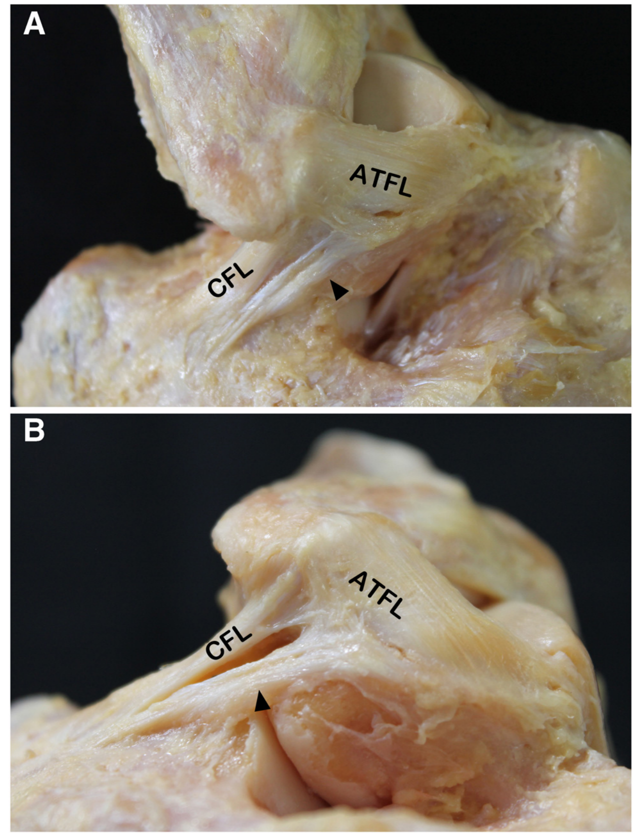

Fig. 6. (*A*) Lateral talocalcaneal ligament (*arrowhead*) is a fiber connecting the anterior talofibular ligament and calcaneofibular ligament in the distal part on lateral view. (*B*) Bottom view of lateral talocalcaneal ligament.

Table 2
Distance between the bony landmark and fibular attachment of anterior talofibular ligament and calcaneofibular ligament (N = 60 ankles)

Measurement Point	Distance (mm)		
	Total	Male (n = 24)	Female (n = 36)
IT–AT	13.4 ± 1.5	13.9 ± 1.4	13.0 ± 1.3
ATFL–CFL	7.1 ± 1.4	7.3 ± 1.5	7.0 ± 1.3
IT–ATFL	14.3 ± 1.9	14.7 ± 1.6	13.9 ± 2.0
IT–CFL	7.4 ± 1.7	7.5 ± 1.5	7.3 ± 1.8
AT–ATFL	4.3 ± 1.1	4.3 ± 1.1	4.3 ± 1.1
AT–CFL	7.6 ± 1.6	8.1 ± 1.5	7.3 ± 1.6

Abbreviations: AT, articular tips; ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; IT, inferior tips.
Data are mean ± standard deviation.

and Burks and Morgan (14) also used IT of the lateral malleolus as a bony landmark.

Many reports adopted IT of the lateral malleolus, but in our anatomic study, AT of the fibula was used as a landmark. AT of the fibula located more proximal to IT and AT corresponded to the obscure tubercle (16). Because AT of the fibula could be observed using arthroscopy, it is useful as a landmark during arthroscopic surgery.

The distance between AT of the fibula and the center of the attachment of ATFL/CFL was ~4 mm toward anterior-lateral and ~8 mm toward posterior-lateral. These data are useful for estimating the insertion of ATFL and CFL. However, CFL was difficult to visualize arthroscopically. When the synovial membrane and capsule were removed from inside the ankle joint, CFL could be visualized beyond ATFL and PTFL (Fig. 5*B*). Fig. 5*B* (intra-articular view) helps to image the anatomic structure of the lateral ligament in arthroscopic reconstruction or repair of chronic lateral ankle instability.

In this study, we used the bottom view to indicate the fibular attachment. To accurately image the attachment, we believe that not only the front and outside but also the bottom views are necessary.

The limitations of this study are that subjects were limited to the elderly (mean age, 85.1 years) and the trauma history of the ankle was unknown. Our study demonstrates the structure of the connective fiber between ATFL and CFL. The fibular insertion of CFL was located behind the fibular insertion of ATFL on a side view. ATFL and CFL fibers are independent from each other. In the ultrasonography examination, it was reported that it was difficult to evaluate CFL because CFL was in the deep layer (5), but the fibular side of CFL is in the shallow layer of the lateral ankle. It is conceivable that the end of the fibular side of the ATFL short-axis image corresponds to the long-axis image of the front of the CFL from an anatomic viewpoint.

In conclusion, it is important to understand the relative positional relationship of these ligaments during palpation and ultrasonographic examination and reconstruction of the lateral ligament. The connective fiber covered the superficial inferior part of ATFL, and the anterior part of CFL was covered with a thin fiber capsule. ATFL and CFL fibers were isolated from each other and had divided fibular attachment. AT of the fibula was useful in estimating fibular attachment. In this study, we clarified an important anatomic structure in ankle repair or reconstruction surgery.

References

1. van den Bekerom MP, Oostra RJ, Golanó P, van Dijk CN. The anatomy in relation to injury of the lateral collateral ligaments of the ankle: a current concepts review. Clin Anat 2008;21:619–626.
2. Brostrom L. Sprained ankles I: anatomic lesions in recent sprains. Acta Chir Scand 1964;128:483–495.
3. Samoto N, Sugimoto K, Takaoka T, Fujita T, Kitada C, Takakura Y. Comparative results of conservative treatments for isolated anterior talofibular ligament (ATFL) injury and injury to both the ATFL and calcaneofibular ligament of the ankle as assessed by subtalar arthrography. J Orthop Sci 2007;12:49–54.
4. Kumai T, Takakura Y, Rufai A, Milz S, Benjamin M. The functional anatomy of the human anterior talofibular ligament in relation to ankle sprains. J Anat 2002;200:457–465.
5. Kemmochi M, Sasaki S, Fujisaki K, Oguri Y, Kotani A, Ichimura S. A new classification of anterior talofibular ligament injuries based on ultrasonography findings. J Orthop Sci 2016;21:770–778.
6. Petersen W, Rembitzki IV, Koppenburg AG, Ellermann A, Liebau C, Brüggemann GP, Best R. Treatment of acute ankle ligament injuries: a systematic review. Arch Orthop Trauma Surg 2013;133:1129–1141.
7. Sugimoto K, Samoto N, Takaoka T, Takakura Y, Tamai S. Subtalar arthrography in acute injuries of the calcaneofibular ligament. J Bone Joint Surg Br 1998;80:785–790.
8. Prado MP, Mendes AA, Amodio DT, Camanho GL, Smyth NA, Fernandes TD. A comparative, prospective, and randomized study of two conservative treatment protocols for first-episode lateral ankle ligament injuries. Foot Ankle Int 2014;35:201–206.
9. Takao M, Miyamoto W, Matsui K, Sasahara J, Matsushita T. Functional treatment after surgical repair for acute lateral ligament disruption of the ankle in athletes. Am J Sports Med 2012;40:447–451.
10. White WJ, McCollum GA, Calder JD. Return to sport following acute lateral ligament repair of the ankle in professional athletes. Knee Surg Sports Traumatol Arthrosc 2016;24:1124–1129.
11. Lynch SA, Renström PA. Treatment of acute lateral ankle ligament rupture in the athlete. Conservative versus surgical treatment. Sports Med 1999;27:61–71.
12. Strauss JE, Forsberg JA, Lippert FG 3rd. Chronic lateral ankle instability and associated conditions: a rationale for treatment. Foot Ankle Int 2007;28:1041–1044.
13. Karlsson J, Lansinger O. Chronic lateral instability of the ankle in athletes. Sports Med 1993;16:355–365.
14. Burks RT, Morgan J. Anatomy of the lateral ankle ligaments. Am J Sports Med 1994;22:72–77.
15. Khawaji B, Soames R. The anterior talofibular ligament: a detailed morphological study. Foot 2015;25:141–147.
16. Matsui K, Takao M, Tochigi Y, Ozeki S, Glazebrook M. Anatomy of anterior talofibular ligament and calcaneofibular ligament for minimally invasive surgery: a systematic review. Knee Surg Sports Traumatol Arthrosc 2017;25:1892–1902.
17. Milner CE, Soames RW. Anatomy of the collateral ligaments of the human ankle joint. Foot Ankle Int 1998;19:757–760.
18. Neuschwander TB, Indresano AA, Hughes TH, Smith BW. Footprint of the lateral ligament complex of the ankle. Foot Ankle Int 2013;34:582–586.
19. Sarrafian SK, Kelikian AS. Syndesmology. In: Sarrafian SK, Kelikian AS, eds. *Sarrafian's Anatomy of the Foot and Ankle: Descriptive, Topographic, Functional*, 3rd ed, Lippincott Williams & Wilkins, Philadelphia, 2011:163–222.
20. Wenny R, Duscher D, Meytap E, Weninger P, Hirtler L. Dimensions and attachments of the ankle ligaments: evaluation for ligament reconstruction. Anat Sci Int 2015;90:161–171.
21. Wiersma PH, Griffioen FMM. Variations of three lateral ligaments of the ankle. A descriptive anatomical study. Foot 1992;2:218–224.
22. Yıldız S, Yalcın B. The anterior talofibular and calcaneofibular ligaments: an anatomic study. Surg Radiol Anat 2013;35:511–516.
23. Edama M, Kageyama I, Kikumoto T, Nakamura M, Ito W, Nakamura E, Hirabayashi R, Takabayashi T, Inai T, Onishi H. Morphological features of the anterior talofibular ligament by the number of fiber bundles. Ann Anat 2018;216:69–74.
24. Taser F, Shafiq Q, Ebraheim NA. Anatomy of lateral ankle ligaments and their relationship to bony landmarks. Surg Radiol Anat 2006;28:391–397.
25. Golanó P, Vega J, de Leeuw PA, Malagelada F, Manzanares MC, Götzens V, van Dijk CN. Anatomy of the ankle ligaments: a pictorial essay. Knee Surg Sports Traumatol Arthrosc 2016;24:944–956.
26. Raheem OA, O'Brien M. Anatomical review of the lateral collateral ligaments of the ankle: a cadaveric study. Anat Sci Int 2011;86:189–193.
27. Broström L. Sprained ankles. V. Treatment and prognosis in recent ligament ruptures. Acta Chir Scand 1966;132:537–550.
28. Lopes R, Noailles T, Brulefert K, Geffroy L, Decante C. Anatomic validation of the lateral malleolus as a cutaneous marker for the distal insertion of the calcaneofibular ligament. Knee Surg Sports Traumatol Arthrosc 2018;26:869–874.
29. Matsui K, Oliva XM, Takao M, Pereira BS, Gomes TM, Lozano JM, ESSKA AFAS Ankle Instability Group, Glazebrook M. Bony landmarks available for minimally invasive lateral ankle stabilization surgery: a cadaveric anatomical study. Knee Surg Sports Traumatol Arthrosc 2017;25:1916–1924.
30. Thès A, Klouche S, Ferrand M, Hardy P, Bauer T. Assessment of the feasibility of arthroscopic visualization of the lateral ligament of the ankle: a cadaveric study. Knee Surg Sports Traumatol Arthrosc 2016;24:985–990.
31. Clanton TO, Campbell KJ, Wilson KJ, Michalski MP, Goldsmith MT, Wijdicks CA, LaPrade RF. Qualitative and quantitative anatomic investigation of the lateral ankle ligaments for surgical reconstruction procedures. J Bone Joint Surg Am 2014;96:e98.
32. Haytmanek CT, Williams BT, James EW, Campbell KJ, Wijdicks CA, LaPrade RF, Clanton TO. Radiographic identification of the primary lateral ankle structures. Am J Sports Med 2015;43:79–87.