Original Article

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Anatomy Section

Morphological and Morphometric Characterisation of Lateral Ankle Ligament Complex in Human Cadavers: A Descriptive Cross-sectional Study

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ABSTRACT

Introduction: The lateral ankle ligaments are the most common to get involved in ankle sprains and problems related to ankle instability, and a precise knowledge of the morphological features of these ligaments would be highly beneficial for diagnosis and treatment.

Aim: To describe the attachments, and mean dimensions of the lateral ankle ligament complex.

Materials and Methods: A descriptive cross-sectional study was conducted in the Department of Anatomy, Government Medical College, Thiruvananthapuram, Kerala, India, from March 2022 to 2023. A total of 56 embalmed cadavers donated for teaching purposes were dissected to evaluate the lateral ankle ligaments. The three lateral ankle ligaments, namely Anterior Talofibular (ATFL), Calcaneofibular (CFL), and Posterior Talofibular (PTFL) were identified. Their positions with respect to external bony landmarks were defined. The morphology of the ligaments, their site of attachments, length, and width were documented. The stretching of the ligaments and their orientation with the long-axis of the fibula with dorsiflexion and plantarflexion of the foot was noted. The morphological observations were presented in percentages. Assuming the numeric measurements of the morphometric analysis to be normally distributed, the data were summarised in mean and standard deviation.

Results: The ATFL was found to consist of two bands in 32 (57.14%) ankles and a single band in 24 (42.86%) ankles. The CFL was cord like in 38 (67.9%) ankles and was single banded in 18 (32.1%) ankles. The lateral talocalcaneal ligament was observed to reinforce CFL in four ankles. The mean length of ATFL, CFL and PTFL were 19.24±2.31 mm, 28.16±3.56 mm, 25.03±3.53 mm, respectively and the mean width were 8.21±1.52 mm, 5.25±1.10 mm, 7.56±1.25 mm, respectively.

Conclusion: The detailed anatomical knowledge would be vital in diagnosis and arthroscopic reconstruction of the injured ankle ligaments In the era of minimally invasive surgeries, the study findings would be promising for clinical practice and research.

Keywords: Anterior talofibular, Calcaneofibular, Lateral talocalcaneal, Posterior talofibular

INTRODUCTION

The lateral ankle ligament complex includes the ATFL, PTFL, and CFL ligaments. While ATFL and PTFL restrain anterior and posterior displacement of the talus with respect to the tibia and fibula, CFL restrains the inversion of the calcaneus with respect to the fibula [1]. Hence, these ligaments form the lateral stabilisers of the ankle joint. In 85% of ankle sprains, these are the ligaments involved, with ATFL being the most frequently injured [2,3].

The majority of ankle sprains occur as a result of plantarflexion, adduction, and inversion of the foot [4]. With this mechanism of injury, ATFL is the initial site of disruption. If the mechanism of injury continues around the lateral aspect of the ankle, it leads to disruption of the CFL, followed by that of the PTFL [5]. The majority of patients with ankle sprains are successfully treated conservatively. However, residual symptoms like chronic pain, muscle weakness, and recurrent instability are encountered in around 30-40% of patients [6,7]. An understanding of the anatomy and biomechanics of this ligament complex will be helpful for orthopaedic surgeons while doing arthroscopic repair and radiologists in diagnosing injuries of these ligaments. During surgical repair of traumatised ligaments, any undue foreshortening of ligaments may reduce the range of motion at the ankle and subtalar joints and, in extreme cases, may even modify gait patterns and put undue stress on the foot [8]. The present study aimed to describe the morphology and attachments and determine the mean dimensions of these ligaments in cadaveric ankle specimens.

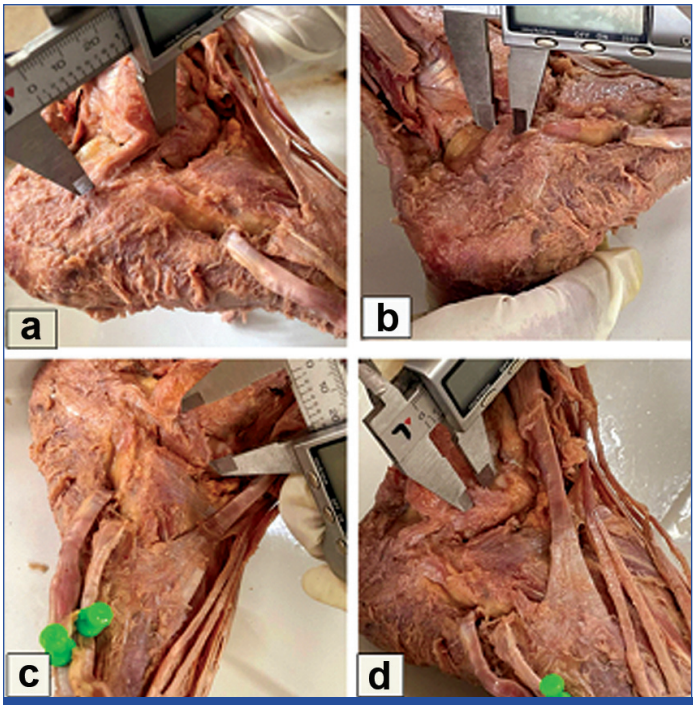
MATERIALS AND METHODS

A descriptive cross-sectional study was conducted in the Department of Anatomy, Government Medical College Thiruvananthapuram, Kerala, India, from March 2022 to 2023. The study was conducted after attaining Ethical Committee clearance (HEC NO:02/09/2022MCT).

Inclusion and Exclusion criteria: A total of 56 formalin-fixed specimens of lower limbs sectioned below the knee joint, at the level of the proximal third of the tibia and fibula were included and examined. They were obtained from cadavers of Indian origin donated for teaching and research purposes. Specimens with gross fractures of bones and deformities of leg and foot were excluded.

Study Procedure

The skin was reflected by putting an incision along the lateral aspect of the leg and foot. The deep fascia and retinacula were divided. The muscles and tendons in close contact with the ankle joint were displaced to visualise the lateral ankle ligament complex. The attachments of the ligaments and their morphology were studied. The length and width of the ligaments in the neutral position of foot were measured. The farthest fibers were considered while measuring length. The width was measured from the middle of each ligament [Table/Fig-1]. The ankle specimens were taped into position before taking the measurements. Measurements were carried out thrice using an electronic Vernier caliper with an accuracy of up to 0.01



[Table/Fig-1]: Measurement of length: (a) and width (b) of calcaneofibular ligament and length (c) and width (d) of Anterior Talofibular (ATFL) ligament.

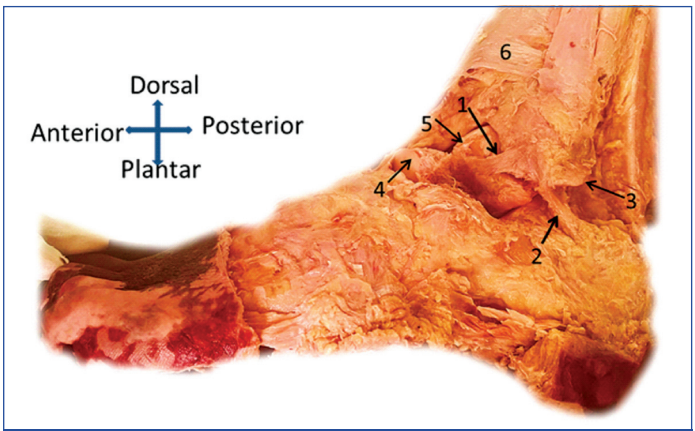
mm by independent researchers and the average of the 2 nearer values were documented. The yielding of the ligaments during dorsiflexion and plantar flexion were captured.

STATISTICAL ANALYSIS

The data obtained were entered in Microsoft Excel. Quantitative variables were described by mean, standard deviation, minimum and maximum. The morphological observations were presented in percentages.

RESULTS

Anterior Talofibular Ligament (ATFL): The ATFL was seen as a flat strip closely adherent to the ankle joint capsule. It originated from the anterior border of the lateral malleolus at a mean distance of 10.33±2.66 mm from its tip. It extended forwards and medially to the body of the talus immediately anterior to its articulation with the lateral malleolus [Table/Fig-2].

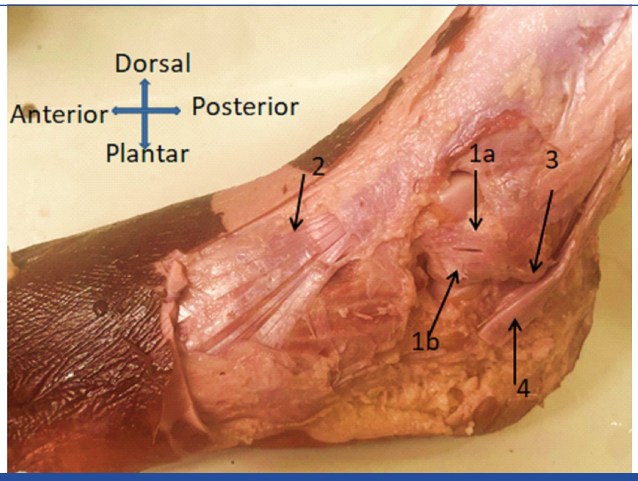


[Table/Fig-2]: Anterolateral view of the anatomic dissection of ankle ligaments.
1. Anterior talofibilar ligament; 2. Calcaneofibular ligament; 3. Tip of fibula; 4. Head of talus; 5. Body of talus; 6. Superior extensor retinaculum

Among 56 specimens of ankle joints dissected, double bands of ATFL were observed in 32 specimens and single bands in 24 specimens. In the specimens with double bands, the bands were separated by a pad of fat and vascular twigs [Table/Fig-3,4]. The widths of the two bands together were almost equal to the width of a single band in single-banded ATFL specimens indicating that the variations in the number of bands do not modify its function. During

Ligaments	Length (Mean±SD, mm)	Breadth (Mean±SD, mm)
ATFL		
Single band	19.24±2.31	8.21±1.52
Double band		
Superior band	18.36±1.51	5.05±0.74
Inferior band	14.28±2.32	3.63±1.14
CFL	28.16±3.56	5.25±1.10
PTFL	25.03±3.53	7.56±1.25

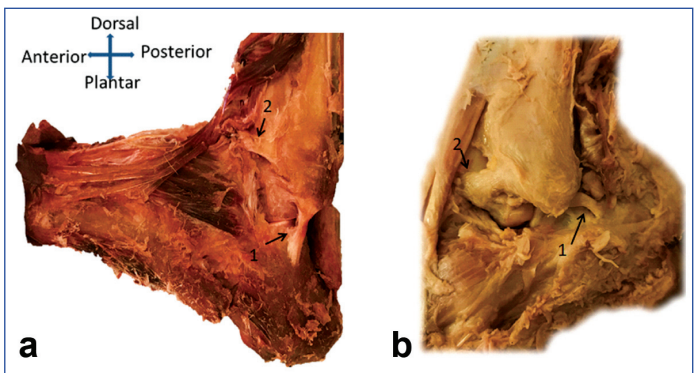
[Table/Fig-3]: The mean dimensions of lateral ankle ligaments (mm).



[Table/Fig-4]: Anatomic dissection of lateral region of foot showing double bands of Anterior Talofibular (ATFL) ligament. 1a) Superior band of Anterior Talofibular (ATFL) ligament; 1b) inferior band of ATFL ligament; 2) tendons of extensor digitorum longus; 3) tip of fibula; 4) tendons of peroneus longus and brevis (cut).

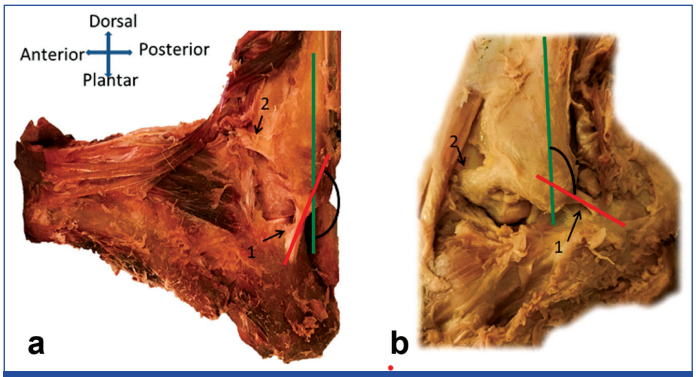
dorsiflexion, the lower band was found to get taut, while in plantar flexion, the upper band was found to be taut.

Calcaneofibular Ligament (CFL): The CFL was a thick bundle of ligament separate from the ankle joint capsule. Among 56 ankles dissected, 38 were cord-like, while 18 were single quadrangular bands. It originated from the anterior border of the lateral malleolus close to the origin of ATFL and ran downwards and backwards, making an obtuse angle with the ATFL and got attached to the posterior part of the lateral surface of the calcaneus above and behind the calcaneal tubercle [Table/Fig-2]. The ligament was almost entirely covered by the tendons of the peroneus longus and brevis. On dorsiflexion, the ligament became more vertically oriented and the angle between ATFL and CFL decreased [Table/Fig-5a]. On plantarflexion, the ligament became horizontal and the angle between ATFL and CFL became more obtuse [Table/Fig-5b]. The CFL was observed to get stretched and become taut during dorsiflexion, while it got relaxed in plantarflexion [Table/Fig-5a,b]. A decrease in the angle between the long axis of CFL

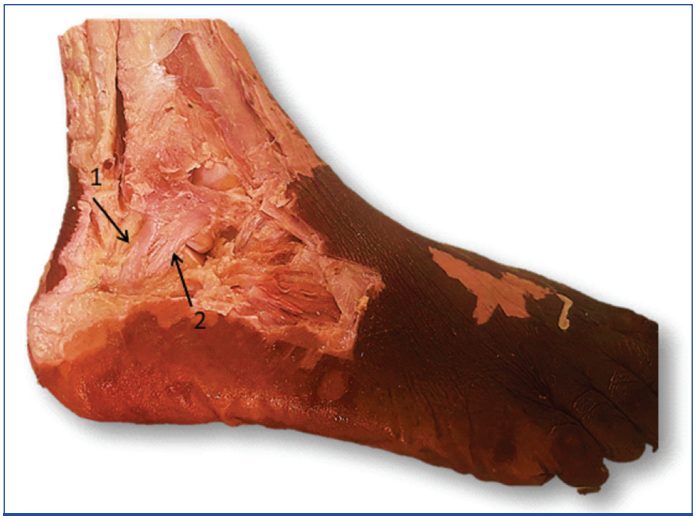


[Table/Fig-5]: Demonstration of the change in the angle between the Anterior Talofibular (ATFL) and the calcaneofibular ligaments during a) dorsiflexion b) plantarflexion of the ankle.
1 calcaneofibular ligament; 2 Anterior Talofibular (ATFL) ligament.
Note the calcaneofibular ligament becoming taut and vertically oriented in dorsiflexion (a) and relaxed and horizontally oriented in plantar flexion (b) of ankle.

and a line parallel to the fibular shaft was noted during the arc of motion from dorsiflexion to plantar flexion [Table/Fig-6a,b]. The mean dimensions of CFL are shown in [Table/Fig-2]. In four out of 56 specimens, lateral talocalcaneal ligament was found to reinforce the CFL [Table/Fig-7].

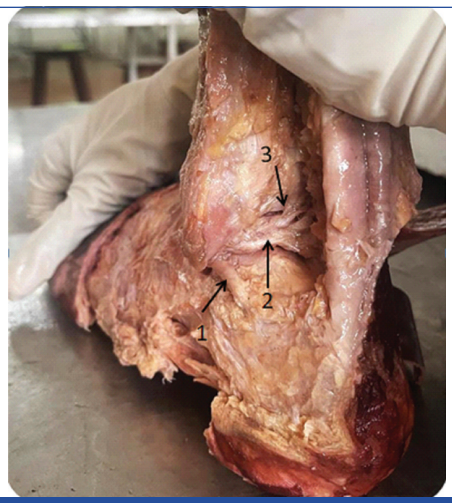


[Table/Fig-6]: Dorsiflexion (a) and plantar flexion (b) of ankle: angle between long axis of calcaneofibular ligament (red) and a line parallel to fibular shaft (green). Note the decrease in the angle between long axis of CFL and a line parallel to fibular shaft during the arc of motion from dorsiflexion to plantar flexion.



[Table/Fig-7]: Band-like calcaneofibular ligament 1; reinforced by lateral talocalcaneal ligament 2.

Posterior Talofibular Ligament (PTFL): The PTFL was found to be multifascicular with its proximal attachment on the malleolar fossa and distal attachment on posterolateral tubercle of talus. It was characterised by the absence of a distinct banded morphology. It was found to run horizontally just inferior to the posterior intermalleolar ligament [Table/Fig-8]. The ligament was observed to become tense during dorsiflexion.



[Table/Fig-8]: Posterior view of anatomic dissection of lateral ankle ligaments: 1 calcaneofibular ligament; 2 posterior talofibular ligament; 3 posterior intermalleolar ligament.

DISCUSSION

Based on cadaveric dissection, the morphology, dimensions, attachments, and variations of the lateral ankle ligaments were determined. Double bands of ATFL were observed in 57.14% (32 out of 56 ankles) and single bands in 42.85% (24 out of 56 ankles). Triple bands were not detected. This was in complete accordance with the dissected studies conducted by Inchai C et al., [9]. They also identified double-banded ATFL as the major type (57.14%), and triple bands were not identified. Uğurlu M et al., in their study on dissected ankles reported, 23% ATFL formed single bands, 59% double bands and 18% triple bands [10]. MR arthrography studies conducted by Delfaut EM et al., on 22 patients with no history of ankle sprains, found a single band of ATFL in 9% of cases, double bands in 55% and a striated appearance in 36% [11]. The mean length of ATFL was measured to be 19.24±2.31 mm (range 24.9-15.06 mm) in the present study. In specimens with double bands, the ATFL was found to be slightly shorter [Table/Fig-2]. Yildiz S and Yalcin B also observed the same and suggested that during plantar flexion ATFL formed by single bands are stronger than those formed by double bands [12]. The ATFL originated from the anterior border of the lateral malleolus at a mean distance of 10.33±2.66 mm proximal to the tip of the fibula. The average width of ATFL when measured from the middle of the ligament was 8.2±1.52 mm in ankles with single bands. In those with double bands, the upper band measured 5.05 ± 0.74 mm and the lower band 3.63±1.14 mm. According to previous studies, the width ranged between 4 mm and 12.98 mm [13]. ATFL was found to get taut in plantarflexion. In specimens with double bands, the superior band became tauter in plantarflexion compared to the inferior.

Ruzik K et al., in their study on anatomical variations of CFL classified the ligament into four types based on its morphology [14]. Single-banded CFL was classified as type 1, Y- shaped band as type 2, V-shaped band as type 3 and if additional bands were present along with the main band, it was classified as type 4. Type 1 was the most common as per their study. In 9.2% of cases, an additional band originated from the talus and was inserted into the lateral surface of the calcaneus (lateral talocalcaneal ligament) along with CFL. They classified it as subtype 4b. In the present study, CFL was cord-like in 38 (67.9%) ankles and was single-banded in 18 (32.1%) ankles. Lateral talocalcaneal ligament was observed in 4 (7%) ankles along with CFL. The cord-like morphology of CFL was described in the previous studies done by Ruzik K et al., Boonthathip M et al., [14,15]. The mean length was 28.16±3.56 mm (range 20.78-34.43 mm) and the width was 5.25±1.10 mm (range 3.32-6.77 mm) in this study. Szaro P et al., in their MRI studies on CFL, reported its mean length as 27.5±0.5 mm; and width as 5.6±0.3 mm [16]. Previous cadaveric studies on morphology of CFL reported the mean length as 31.8 mm [17], 26.67 mm [10] and mean width as 4.1 mm [18], 4.57 mm [16]. CFL was observed to get taut and vertically oriented on dorsiflexion while it got relaxed and horizontally oriented during plantarflexion. Changes in the position of the foot also resulted in variations in the angle formed between the axis of the fibula and CFL. The strain pattern in ATFL and CFL during movement of the foot was studied by Renstrom P et al., who concluded that foot position affected the strain pattern. In dorsiflexion, CFL gets taut and stabilises the talus laterally while in plantarflexion ATFL gets taut and takes over the function of lateral stabilisation of the talus [18]. The couple effect of ATFL and CFL in preventing talar tilt during motion was stressed by Inman [19]. The present study also displayed similar findings. CFL was found to get taut in dorsiflexion and ATFL in plantarflexion. In specimens with double banded ATFL, the lower band was tauter in dorsiflexion while the upper band became tauter in plantar flexion.

PTFL coursed horizontally from the malleolar fossa of the lateral malleolus to the posterolateral talus. It was observed to consist of

multiple fascicles and some of its fibers intermingled with those of the posterior intermalleolar ligament which was seen just above PTFL. The mean length was found to be 25.03±3.53 mm and width 7.56±1.25 mm. It's mean length and width was reported as 27.8±3.6 mm and 8.7±3 mm, respectively in MR studies conducted by Boonthathip M et al., [15]. Cadaveric dissections done by Inchai C et al., reported the mean length as 26.11 mm and width as 7.65 mm [20]. The PTFL braces the talus posteriorly thereby preventing posterior talar displacement with respect to the tibia and fibula. Rasmussen O et al., analysed the function of PTFL and showed that PTFL has no independent role in maintaining ankle stability when the other ligaments are intact [21]. But, once ATFL and CFL rupture, PTFL plays a pivotal role in restricting talar tilt.

Limitation(s)

As the study was performed on embalmed cadavers, there may be slight variations in the measurements when compared to living individuals, due to stiffening or contracture. Comparison between ligaments of the right and left side as well as that between males and females were not carried out.

CONCLUSION(S)

The comprehensive knowledge provided by the present study would be vital for surgeons and radiologists in diagnosing and treating ankle sprains, which are the most common among ankle injuries encountered by athletes and even in the common man. Moreover, the data would help in graft selection and accurate placement in reconstructive surgeries. In the era of minimally invasive surgeries, the study findings would be promising for clinical practice and research.

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