Eklem Hastalıkları ve Cerrahisi
Joint Diseases and Related Surgery
Experimental Study / *Deneysel Çalışma*
Eklem Hastalık Cerrahisi
2010;21(3):153-158

Anatomy of the lateral complex of the ankle joint in relation to peroneal tendons, distal fibula and talus: a cadaveric study

Peroneal tendonlar, distal fibula ve talusla ilişkili olarak ayak bileğinin lateral kompleks anatomisi: Bir kadavra çalışması

Mahmut Uğurlu, M.D.,[1] Murat Bozkurt, M.D.,[2] İsmail Demirkale, M.D.,[3] Ayhan Cömert, M.D.,[4] Halil İbrahim Acar, M.D.,[4] İbrahim Tekdemir, M.D.[4]

[1]Department of 1st Orthopedics and Traumatology, Atatürk Training and Research Hospital, Ankara, Turkey
[2]Department of 3rd Orthopedics and Traumatology, Dışkapı Training and Research Hospital, Ankara, Turkey
[3]Department of Orthopedics and Traumatology, Siirt State Hospital, Siirt, Turkey
[4]Department of Anatomy, Medicine Faculty of Ankara University, Ankara, Turkey

Objectives: The anatomy of the lateral complex of the ankle joint comprises multiple ligaments and muscles. This study aims to demonstrate the complexity of the lateral ankle structures in detail.

Materials and methods: The study was performed on 11 cadavers (22 ankles) fixed in 10% formaldehyde, and 24 free talus specimens. The detailed course and attachments of each ligament was observed and noted with the ankle in neutral position. Talar measurements were applied to 46 specimens including the dissected cadavers and free talus ones. This study also investigated the relationships between these ligaments and gross morphologic pattern of lateral complex and talus, including the morphological pattern of the peroneal groove and the relationship between the peroneal tendons before and after the peroneal groove.

Results: The whole relationship of lateral ankle structures including anatomic and morphologic patterns and talus were evaluated. No morphologic variation was found concerning peroneus brevis and longus muscles. Although the existence of peroneus quartus muscle has been reported to be 6.6%, we detected it in two of our dissections (9%). We found a peroneus quinti in four of our dissections. We also found an extraordinary ligamentous structure that runs between the distal lateral process of the calcaneus and the inferior peroneal retinaculum in 12 of our dissections. A single form of the anterior talofibular ligament (ATFL) was observed in 23%, a bifurcate ATFL in 59% and the trifurcate ATFL in 18% of the dissected ankles in this study.

Conclusion: Understanding the detailed anatomy of lateral ligament complex of the ankle joint with their relationships to the osseous structures and biomechanics of the ankle can help increase the success of treatment on ankle pathologies.

Key words: Ankle joint; ankle ligaments; fibula; peroneal tendons; talus.

Amaç: Ayak bileğinin lateral kompleks anatomik yapıları birçok bağ ve kastan oluşmaktadır. Bu çalışmada ayak bileği lateral yapılarının karmaşıklığı ayrıntılı olarak gösterildi.

Gereç ve yöntemler: Bu çalışma %10 formaldehit ile tespit edilmiş 11 kadavra (22 ayak bileği) ve 24 serbest talus örneği kullanılarak yapıldı. Her bağın detaylı seyri ve yapışma yerleri gözlendi ve ayak bileği nötral pozisyonda iken kaydedildi. Talar ölçümler 46 disseke edilmiş kadavra ve bir serbest talus örneği üzerinde yapıldı. Çalışmada peroneal oluk öncesi ve sonrası, peroneal oluğun morfolojik modeli ile peroneal tendonlar arasındaki ilişkiler de dahil olmak üzere, lateral kompleks ve talusun büyük morfolojik modelleri ve bu bağlar arasındaki ilişkileri incelendi.

Bulgular: Anatomik ve morfolojik modeller ve talus dahil lateral ayak yapılarının tüm ilişkileri değerlendirildi. Hiçbir morfolojik değişim peroneus brevis ve longus kasları ile ilgili bulunmadı. Her ne kadar peroneus brevis ve longus ile ilgili morfolojik varyasyon %6.6 olarak bildirilmiş olsa da, peroneus quartus bizim iki diseksiyonumuzda %9 olarak bulundu. Bizim dört diseksiyonumuzdan birinde peroneus quinti bulundu. On iki diseksiyonda da kalkaneusun distal lateral çıkıntısı ile inferiyor peroneal retinakulum arasında seyreden olağanüstü ligamentöz yapı tespit edildi Bu çalışmada ayak bileği diseksiyonlarında %23 tek band anterotalofibuler bağ (ATFB), %59 ikili ATFB ve %18 üçlü ATFB bulundu.

Sonuç: Ayak bileğinin karmaşık lateral yapılarının ve bunların osseöz yapılarla olan ilişkisinin detaylı anatomisinin anlaşılması ve biyomekaniğinin bilinmesi ayak bileği patolojilerinin tedavisindeki başarıyı artıracaktır.

Anahtar sözcükler: Ayak bileği; ayak bileği bağları; fibula; peroneal tendons; talus.

- *Received: May 05, 2010 Accepted: July 07, 2010*

- Correspondence: Mahmut Uğurlu, M.D. Atatürk Eğitim ve Araştırma Hastanesi, 1. Ortopedi ve Travmatoloji Kliniğj, 06800 Bilkent, Ankara, Turkey. Tel: +90 312 - 291 25 25 Fax: +90 312 - 291 25 25 e-mail: drugurlu@yahoo.com

Lateral ankle sprain is the most common injury that is seen at the emergency departments.[1,2] Although conservative treatment usually improves the symptoms, some residual complaints may exist in some patients.[3] Understanding the detailed anatomy of the lateral ligament complex of the ankle joint and their relationships to the osseous structures not only can help decrease these residual complaints but also facilitates initial interpretation of severity of ligamentous injury and provides significant data for ligament reconstruction.

The anatomy of the lateral complex of the ankle joint is compsed osseochondral structures, multiple ligaments and muscles.[4,5] Important ones are the peroneal muscles and lateral collateral ligaments. The anterior talofibular ligament, the posterior talofibular ligament and the calcaneofibular ligament form the lateral ligamenteous complex. The peroneal tendons intersect these ligaments. Although some variations can be seen, the peroneus longus and brevis generally run distally after exiting the fibular groove. Also there are three more morphological variations of peroneal tendons which are peroneus tertius, quinti and quartus.[6-8] While considering ankle pathologies such as instability, degenerative arthrosis or other abnormalities, surgeons must also bear articular surfaces in mind besides ligament or tendon disorders. All these structures maintain ankle stability by anatomical and geometrical means.

The purpose of this study was to elucidate the morphology and detailed attachment regions of the lateral complex ligaments and peroneal muscles and its variations in relation to fibular groove and talar morphology and to give basic knowledge about the lateral ankle complex. We also calculated the ratio of detailed morphometrical data of length, width and angle of the individual lateral ankle ligaments and talar joint surfaces with some standard measurements.

MATERIALS AND METHODS

The study was performed on 11 cadavers (22 limbs) fixed in 10% formaldehyde and 24 free talus specimens. No legs had been dissected previously. Ankle specimens with evidence of previous surgical procedures, deformity and trauma were excluded. The lateral ankle ligaments were carefully dissected. A surgical microscope (OPMI 9; Carl Zeiss AG, Oberkochen, Germany) was used for magnification of some regions.

After removing the skin and subcutaneous tissue, the lateral ligament complex and peroneal tendons were exposed in a standard fashion. The dissection was carried to the distal-lateral tip of calcaneus and the dorsum of the foot in order to identify the variations of the peroneal tendons. Then the superior and inferior peroneal retinaculum was incised to expose the ligaments. The detailed morphology of each ligament was observed and noted with the ankle in neutral position (Table I). Talar measurements were applied

TABLE I

Morphology and measured distances of the lateral ankle ligaments (average)

Variations	Orientation	Width (mm)	Length (mm)
ATFL Single band form (23%)	–	7.61	20.84
Bifurcate form with two bands (59%)	Superior	5.39	18.74
	Inferior	4.92	15.33
Trifurcate form with three bands (18%)	Superior	4.05	14.38
	Intermediate	4.44	14.46
	Inferior	4.48	16.12
Calcaneofibular ligament	–	4.57	26.67
Posterior talofibular ligament	–	5.09	24.12
Anterior inferior tibiofibular ligament	2 bands (42%) Superior	8.98	9.96
	Inferior	3.74	18.43
	3 bands (58%) Superior	4.03	15.11
	Intermediate	5.74	18.23
	Inferior	3.43	18.02

ATFL: Anterior talofibular ligament

Figure 1. The angle between anterior talofibular ligament and calcaneofibular ligament.

to 46 specimens including dissected cadavers and free ones. After measuring ligaments and angles in neutral position, the ankles were disarticulated and the length, height and width of the talus were measured. The width of the talar articular surface was measured separately as fascies superior posterior and superior anterior. All distances were measured by a digital caliper (Casio, Japan, accuracy value 0.01 mm). Angular measurements were taken using a goniometer (Universal goniometer, UG).

For the current study not only anatomic patterns but also the relationship between these ligaments and gross morphologic pattern of lateral complex and talus were evaluated. The angles between the calcaneofibular ligament (CFL) and fibula, anterior talofibular ligament (ATFL) and CFL (Figure 1), ATFL and Anterior inferior tibiofibular ligament (AITFL), (Table II), morphologic pattern of the peroneal groove, and relationship between the peroneal tendons before and after the peroneal groove were evaluated.

RESULTS

The number, route and variations of the peroneal tendons were inspected. Peroneal tendons were evaluated before and after the peroneal groove. The structure of the groove (whether osseous or fibrocartilaginous) was also noted. We found 20 grooves to be in fibrocartilaginous form. No morphologic variation was found concerning the peroneus brevis and longus muscles. We dissected a peroneus tertius muscle in all of our dissections. Altough the existence of the peroneus quartus muscle has been reported to be 6.6%, we found it in two of our dissections (9%). The origin of the peroneus quartus was the muscle belly of peroneus brevis and it attached to the posterior part of the calcaneus. We found a peroneus quinti in four of our dissections.

A single band form, bifurcate form with two bands and trifurcate form with three bands of the ATFL were discerned in 23%, 59% and 18% of dissected specimens respectively (Figure 2). We concluded that this ligament had several morphological variations concerning the number of bands.

We also found an interesting ligamentous structure that ran between the distal lateral process of calcaneus and the inferior peroneal retinaculum in 12 of our dissections (Figure 3). This

TABLE II

Measured angles between the ankle ligaments (average)

The angle between	ATFL-CFL	ATFL-AITFL	CFL-AITFL
Degree	13	68	134

ATFL: Anterior talofibular ligament; CFL: Calcaneofibular ligament; AITFL: Anterior inferior tibiofibular ligament.

Figure 2. anterior talofibular ligament (three bundles).

ligament seemed to make an additional suspensory mechanism for the retinaculum which covers the peroneus longus. Advanced study seems to be necessary to investigate the exact purpose of this ligament.

Any morphological variation of the calcaneofibular and the posterior talofibular ligament was not seen. The fibular and talar insertion points of ATFL were nearly similar in all cases (except in one trifurcated form where the inferior band was inserted to calcaneus in co-existence with CFL).

While obtaining talar calculations, we also evaluated the difference of the most prominent anterior part of tibia and fibula, height of the lateral fascies of talus, the distance between distal tip of fibula and lateral part of neck of talus. The measurements are shown at table III.

In only one dissection was total rupture of the calcaneofibular ligament noted. The angle between calcaneofibular and anterior talofibular ligaments were noted. The mean angle was obtained as 113º (average, 123º-107º), as previously reported in the literature.

DISCUSSION

Most lateral ligament injuries respond to conservative treatment[9] but some residual complaints may be seen due to chronic instability, soft tissue impingement or peroneal tendon pathologies. Association of these pathologies are generally detected. Although both conservative and surgical treatment modalities of these pathologies are well described, knowing the detailed anatomy and some variations of the lateral ankle complex may provide better outcomes for treatment. It is important to document the variations of the ATFL because this ligament is the most commonly sprained ankle ligament and occasionally requires surgical intervention.[10]

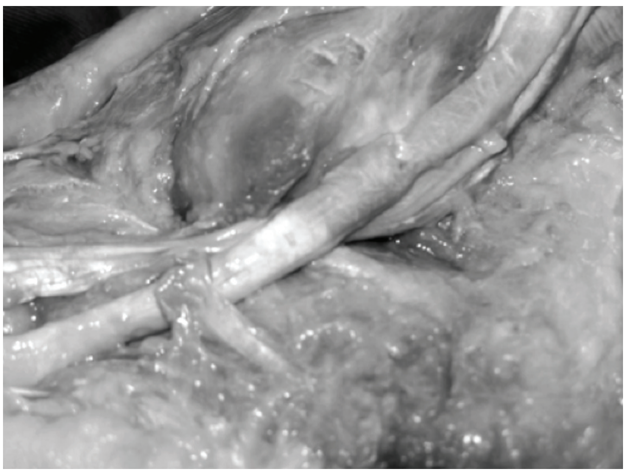

Figure 3. The ligament between inferior peroneal retinaculum and calcaneus.

The mean values of the lateral ligaments observed in this study are compared to the values reported by Siegler et al.,[11] Milner and Soames,[12,13] and Taser et al.[14] in table IV. We found similar results except those of Milner and Soames[13] who found the CFL to be shorter. The average lengths of the ATFL, CFL and posterotalofibular ligament (PTFL) were 18.41, 26.67 and 24.12 mm, and widths of the ATFL, CFL and PTFL were 11.39, 4.57 and 5.09 mm, respectively.

Burks and Morgan[10] observed that a distinct inferior band of the ATFL was occasionally present, i.e. that the ATFL consisted of one or two bands, but did not mention the trifurcate form. Milner and Soames[13] reported bifurcate and trifurcate forms of the ATFL along with a single major band of ligament. However, the attachments of different bands were very close to each other on longitudinal tubercle of the lateral malleolus and the anterior border of the lateral articular facet on the neck of the talus. Sarraffian[15] reported that two bands of ATFL had always been present along with occasional presence of three bands. Milner and Soames[13] found a single band form in 38% of their specimens.

Taser et al.[14] studied insertion points of lateral ankle ligaments and their relationship to bony landmarks. They concluded that precise knowledge of the location of the ligaments show the way to surgeons during ligament repair and is significant to reconstruct the normal anatomy insofar as is possible.

We observed that the trifurcate form is a rare variation, as well as its unilateral distribution.

TABLE III

Talar morphology (average)

	(mm)
Length	49.88
Width	42.07
Height	29.05
Fascies superior posterior	23.13
Fascies superior anterior	30.05

TABLE IV

Comparison of mean dimensions of the lateral ankle ligaments

Ligament	Present study	Siegler et al.[11]	Milner and Soames[12]	Taser et al.[14]	Burks and Morgan[10]
ATFL length (mm)	14.38-20.84	17.81±3	13.0±4	22.37±2.5	24.8
ATFL width (mm)	7.61-12.98	–	11.0±3.3	10.77±1.6	7.2
CFL length (mm)	26.67	27.69±3.3	19.5±3.9	31.94±3.7	35.8
CFL width (mm)	4.57	–	5.5±1.6	4.68±1.3	5.3
PTFL length (mm)	24.12	21.16±3.9	23.0±7.0	21.66±4.8	24.1
PTFL width (mm)	5.09	–	5±2.5	5.55±1.3	–

ATFL: Anterior talofibular ligament; CFL: Calcaneofibular ligament; PTFL: Posterior talofibular ligament.

It is obvious that there are some variations in the anatomy of the ATFL of the human ankle joint. Additionally there are some variations concerning the peroneal muscles that are similar to those previously documented in the literature.

The contribution of the distal fibula to the stability of ankle has been pointed out previously by many authors. The amount of external rotation, anteroposterior translation and lateral displacement of the lateral malleolus during dorsiflexion has also been reported.[16,17] The axis of rotation runs between the tips of the malleolus in dorsiflexion. The depth and the osseous or fibrocartilagineous structure of the distal fibular groove may play a complementary role between ligamentous and osseous structures for ankle stability.

Both the profiles of the trochlea tali and surface contact area of the talus were examined. Leardini et al.[17] concluded that the apex of talus is directed medially. Kura et al.[18] had noticed that chronic ankle instability causes a decrease in central and lateral zone contact area.

Although the ankle is accepted as a simple hinge joint, it also everts, pronates or externally rotates during motion. These extra motions, width difference and curvature of the trochlea tali together determine load distribution at dorsiflexion and plantarflexion. Impairment of this mechanism may predispose the ankle to disorders such as impingement, osteochondritis dissecans or instability.[4,19,20]

Contact area changes with plantar flexion, pronation or supination. But some acquired or congenital ankle deformities such as ankle malunions, flat foot or hindfoot varus-valgus deformities also alter dynamic and passive stabilizers of the ankle joint.

Ankle pathologies involving the lateral complex may cause many different entities. Even the shape of the talus besides the structure of the fibular groove and anatomy of ligaments can effect the progress of instability. In conclusion, knowing not only normal bony anatomy but also ligament, muscle, ankle mortise and distal fibular groove variations and effect of ankle deformities to ankle biomechanics can help increase the success of the treatment.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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