

Special Article

Anatomo-arthroscopic approach of the lateral ligament complex of the ankle

Jorge Pablo Batista¹ , Guillermo Arrondo² , Lucas Logioco¹ , Leandro Casola² ,
Lucía Verónica Cangiano¹ , Germán Matías-Joannas^{1,2,3} 

1. Centro Artroscopico Jorge Batista, CABA, Buenos Aires, Argentina.
2. Instituto Dupuytren, CABA, Buenos Aires, Argentina.
3. Instituto Barrancas, Quilmes, Buenos Aires, Argentina.

Abstract

Injuries of the lateral ligament complex of the ankle have become increasingly frequent over the last years due to increase in sports practice among the population. These injuries present with good outcomes when treated conservatively. However, 20-25% of patients experience persistent pain or instability and should be approached surgically. Countless open surgical techniques have been published over the last 50 years. Currently knowledge on superficial, deep, and arthroscopic anatomy of ankle has allowed for the development of completely arthroscopic procedures to treat chronic lateral instability of the ankle.

The aim of this article is to describe the superficial and deep anatomy of lateral ligament complex of the ankle, specifically from the arthroscopic point of view, for it to be applied to the multiple currently described surgical procedures.

Level of Evidence III; Therapeutic Studies; Comparative Retrospective Study.

Keywords: Arthroscopy; Ankle injuries; Lateral ligament, ankle; Fractures, bone.

Introduction

Injuries of the lateral ligament complex of the ankle are frequent in athletes, and numerous surgical treatments have been described over the last 50 years to treat both acute and chronic instability. Arthroscopic techniques have emerged and have been constantly developed over the last 20 years aiming to reestablish joint stability through minimally invasive approaches.

Increase in the use of these arthroscopic techniques, along with the development and technological advances in the industry, have led to significant changes in the therapeutic field of this type of diseases.

This increase has led ankle joint anatomy to be understood from an arthroscopic perspective. Descriptions of ankle ligaments have usually a classic 2-dimensional anatomic approach and are usually brief in most classic anatomy books^(1,2).

Several studies have been conducted over the last 15 years to assess the arthroscopic approach to the treatment of chronic ankle instability; however, few published works provide a detailed anatomical description⁽³⁾. Therefore, a new anatomo-arthroscopic approach has been widely developed by internationally anatomists over the last decades^(4,5).

The aim of this article is to present the superficial and deep anatomy of the lateral ligament complex of the ankle, specifically from the arthroscopic perspective, relating it with some surgical procedures^(6,7).

The 2 joints that participate in ankle configuration are the tibiotalar (tibioastragalar) and the subtalar (talocalcaneal) joints⁽⁸⁾ (Figure 1).

The tibiotalar joint (TTJ) is the most important and connects the distal extremities of the tibia and the fibula to the talus bone (Figure 2A-B).

Study performed at the Centro Artroscopico Jorge Batista, CABA, Buenos Aires, Argentina.

Correspondence: Jorge Pablo Batista. Av. Pueyrredón 2446, C1119ACU CABA, Argentina. **E-mail:** jbatista20@hotmail.com. **Conflicts of Interest:** none. **Source of funding:** none. **Date received:** March 1, 2022. **Date accepted:** April 15, 2022. **Online:** April 30, 2022.



The tibia and the fibula are firmly connected by strong ligaments forming a joint mortise or dome on which the trochlea or pulley of the talus is fitted. Therefore, this trochlear joint is formed by 3 bones: tibia, fibula, and talus, consisting of a joint with a triangular morphology and with a proximal base that accounts for 30% of ankle joint stability. This stability depends mainly on the shape of joint surfaces of the talus and the tibia (Figure 3A-B).

The subtalar joint (STJ) is formed by the inferior side of the talus and the superior side of the calcaneus. This joint is stabilized through a series of very strong ligamentous structures well adapted to bear load and forces exerted during gait. Traditionally, 2 joint compartments are described: one posterior or talocalcaneal compartments (trochoid), and other anterior or talocalcaneonavicular (enarthrosis).

The anatomy of the STJ is complex. In its inferior side, it presents 2 joint segments divided by an osseous canal that ends at the sinus tarsi. In the anterior region, the anterior and medial facets of the inferior side of the talus articulate with the anterior facet of the calcaneus, whereas, in the posterior region, the posterior facet of the talus articulates with the posterolateral facet of the calcaneus. Many ligamentous

structures originate from the sinus tarsi and the tarsal canal. Harper categorized these ligamentous structures into 3 well-defined groups: superficial, intermediate, and deep layers⁽⁹⁾.

The main ligament is the interosseous talocalcaneal ligament, a thick and strong band of 2 partially united fibers that connect the talus and the calcaneus. It is located medially in the tarsal canal and has the peculiarity of fusing with the medial root of the inferior extensor retinaculum (IER) at the level of the calcaneus in a V-shape configuration (Figure 4A-B).

The lateral interosseous talocalcaneal ligament, which is short and strong, connects from the lateral talus under the peroneal facet up to lateral calcaneus and runs parallel to the calcaneofibular ligament (CFL)^(10,11).

The medial interosseous talocalcaneal ligament extends from the medial tubercle of the talus up to the sustentaculum tali at the medial surface of the calcaneus.

Another important ligament of the STJ is the anterior capsular ligament. This thick flat ligament was defined by some authors as a thickened segment of the anterior joint capsule of the posterior talocalcaneal facet.

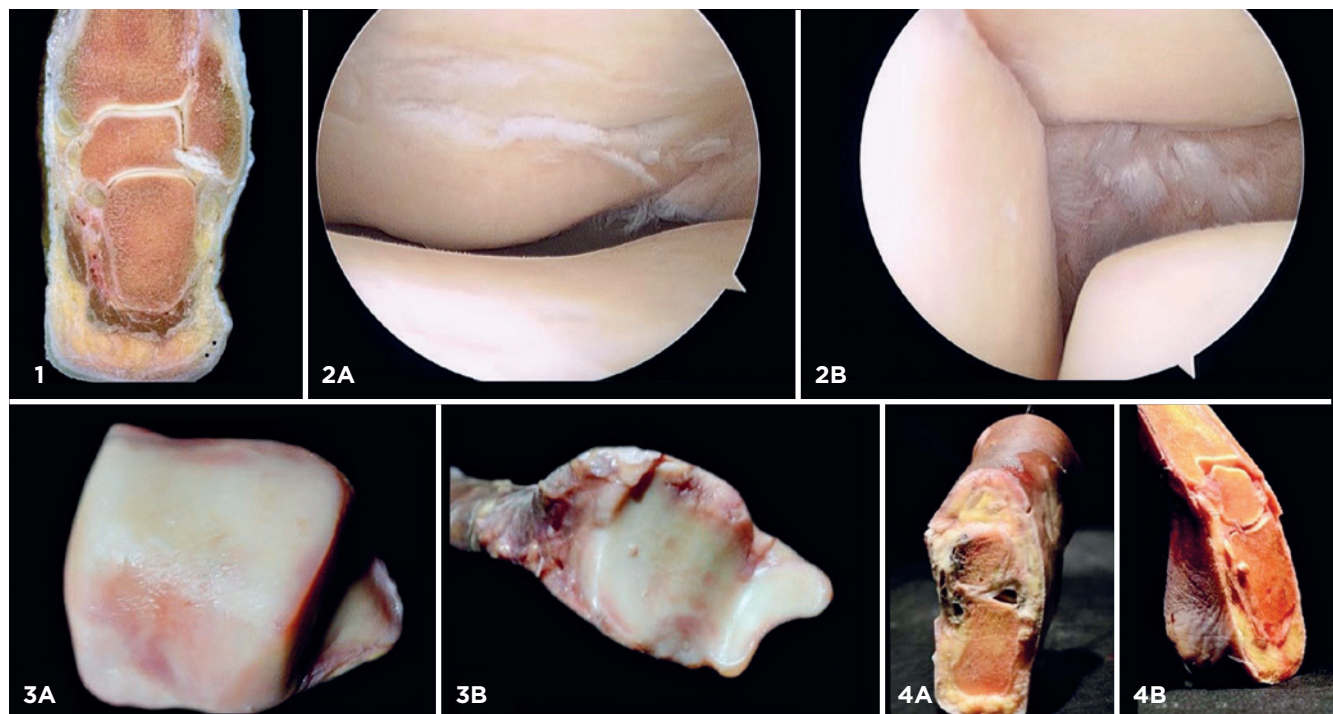


Figure 1. Anatomical slice of the frontal plane of the ankle showing tibiotalar and subtalar joints. **Figure 2.** A) Arthroscopic image of the tibiotalar joint. B) Arthroscopic image showing the tibia (above), the talus (below) and the fibula laterally. **Figure 3.** A) Anatomical piece of the talus visualized from above (talar dome). B) Anatomical piece of the joint facet of the tibia (tibial plafond). **Figure 4.** A) Frontal anatomical slice showing the interosseous talocalcaneal ligament. B) Oblique anatomical slice showing the interosseous talocalcaneal ligament.

The TTJ presents a joint capsule that is superiorly inserted into the anterior side of the tibia at nearly 8 to 10 millimeters from the cartilaginous lining. It is worth highlighting that it slightly expands to fatty tissue attachments between the distal epiphysis of the extremities of the tibia and the fibula, it is prolonged up to the inferior tibiofibular joint (tibiofibular syndesmosis). Similarly, it is inserted into the neck of the talus at nearly 6 to 8 millimeters from the cartilaginous line (Figure 5).

The lateral joint capsule of the ankle is supported by the anterior talofibular ligament (ATFL), the posterior talofibular ligament (PTFL), and the CFL.

These structures, together with superior and inferior retinaculi and the medial collateral ligament, are important static stabilizers of the ankle⁽¹²⁾ (Figure 6).

The joint capsule is relaxed in ankle dorsiflexion and is flattened in ankle plantar flexion. Therefore, in anterior arthroscopic procedures of the ankle, surgeons will benefit from operating with the patient in the dorsiflexed position, since it will expand the surgical site, will move neurovascular structures away from potentially hazardous instruments such as shaver or other sharp elements, and will prevent possible iatrogenic talar dome injuries by hiding the joint surface under the tibiofibular mortise.

Anterior talofibular ligament (ATFL)

The ATFL is flat and quadrilateral, according to early descriptions made by Testut⁽¹³⁾, and relatively thin, being the weakest lateral ligamentous structure. It is inserted in the anterior edge of the lateral malleolus of the fibula and courses towards the lateral side of the talus, being immediately inserted under a triangular area, whose identification is extremely important in procedures of anatomical reconstruction or capsular augmentation in chronic ankle instabilities^(2,8,14) (Figure 7A-E).

This ligament has an approximate length from 15 to 20mm, width from 6 to 10mm, and thickness of 2mm^(15,16).

In thin individuals with no history of sprains, it is possible to identify the ATFL and the CFJ by visualization and palpation. Visualization and palpation of the ATFL are improved in plantar flexion and supination, whereas the CFJ is better palpated in ankle inversion (Figure 8A-C).

The ATFL plays an important role in limited anterior translation of the talus over the tibia and in plantar flexion of the ankle (Figure 9).

The 2 traditional maneuvers to assess its integrity are the anterior drawer test, which assesses the degree of ATFL integrity through anterior translation of the knee, and the Tilt test, which assess the integrity of both ligaments, primarily the CFL, and the degree of restriction of ankle inversion.

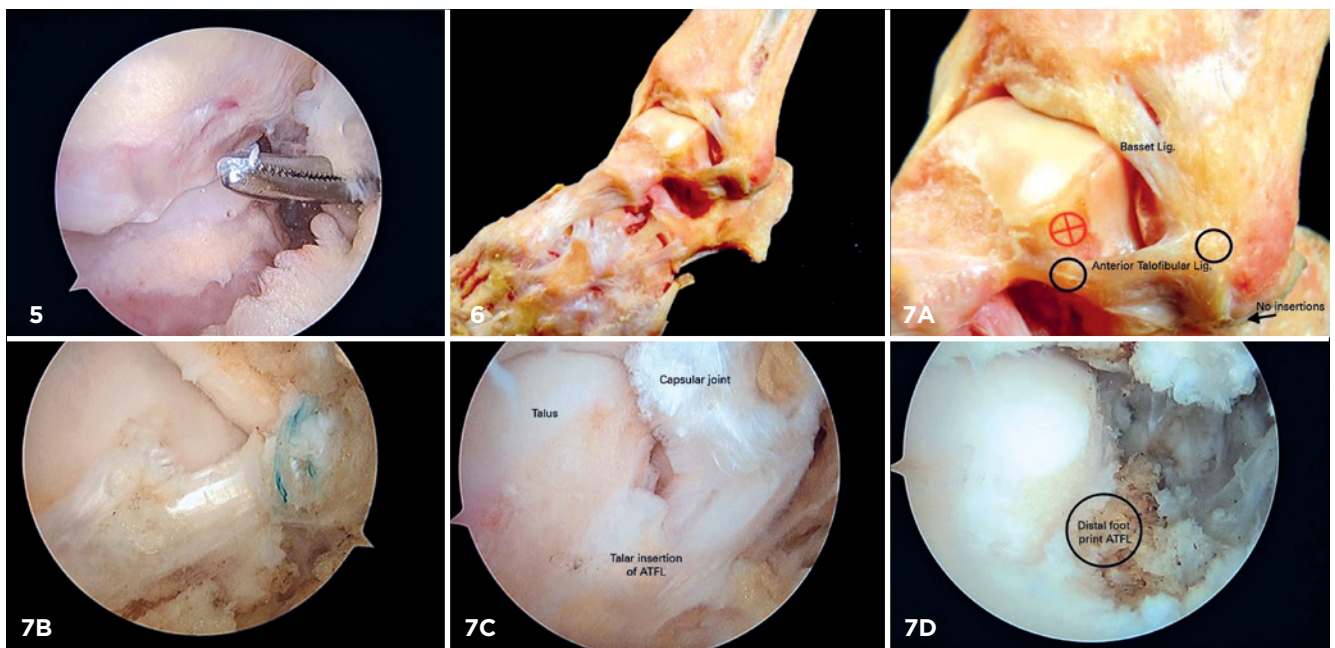


Figure 5. Arthroscopic image showing insertion of the joint capsule distant 8-10 mm from the joint cartilage of the tibia. **Figure 6.** Panoramic image of anatomical dissection of the anterolateral ligament complex of the ankle. **Figure 7.** Anatomico-arthroscopic images of proximal and distal insertions of the anterior talofibular ligament (ATFL). A) Image of anatomical dissection with sites of proximal and distal insertions of the ATFL indicated with black circles. The red circle shows the reference triangle below which the distal footprint of the ATFL is located. B) Arthroscopic image from the anterolateral portal showing normal distal insertion of a proximally repaired ATFL. C) Arthroscopic image of normal structures of the distal insertion of the ATFL. D) Arthroscopic image of the distal footprint of the ATFL.

In standing position, the ATFL runs parallel to the plantar support surface, but in ankle plantar flexion of the ankle, its orientation changes, it becomes more tense, and becomes aligned perpendicularly with the support surface; therefore, this is the position in which the ATFL is more vulnerable and more prone to injuries (Figure 10A-C).

In the 1950s and in the 1980s, 2 early cadaveric dissection studies^(12,17) showed that the ATFL was the main primary restrictor of supination and anterior talar translation in all positions. Rasmussen^(18,19) described that this ligamentous structure played a crucial role in controlling plantar flexion and internal rotation of the talus.

Stormont et al.⁽²⁰⁾ also determined that the ATFL was the major primary restrictor of internal rotation of TTJ. This finding, made 4 decades ago, was confirmed by contemporary authors such as Vega et al.^(21,22), who have shown the impact experienced by the medial axilla of the tibia, the medial segment of the talus and even, in certain occasions, the compromise of the anterior fascicle of the deltoid, turning a lateral instability into a rotational ankle instability with osseous or osteochondral sequelae in many cases (Figure 11A-C).

The ATFL presents 2 clearly defined bands, the superior and the inferior ones, which are separated by a small perforating peroneal artery that anastomoses with the lateral malleolar artery. This small branch is responsible for the bleeding and subsequent ecchymosis following an ankle sprain⁽⁵⁾ (Figure 12).

Some authors, such as Kelikian and Sarrafian⁽²³⁾, described 3 bands of the ATFL. However, Golano et al.⁽³⁻⁵⁾ and Kitaoka⁽²⁴⁾ were not able to systematically detect these 3 bands in their dissections. The superior band is the only one that can be arthroscopically visualized by directing the optical trocar towards the lateral gutter. This maneuver should be performed with the ankle flexed at 90° in this position superior band of the ATFL, the distal extremity of the fibula, and the lateral side of the talus can be clearly visualized, inspected, and palpated (Figure 13A-C).

It is extremely important not positioning the ankle in plantar flexion, because in this position, it is not able to visualize the fibula insertion of ATFL⁽²⁵⁾.

The tip of the peroneal malleolus is free of any insertions. The footprint of the ATFL is one centimeter above and in front of

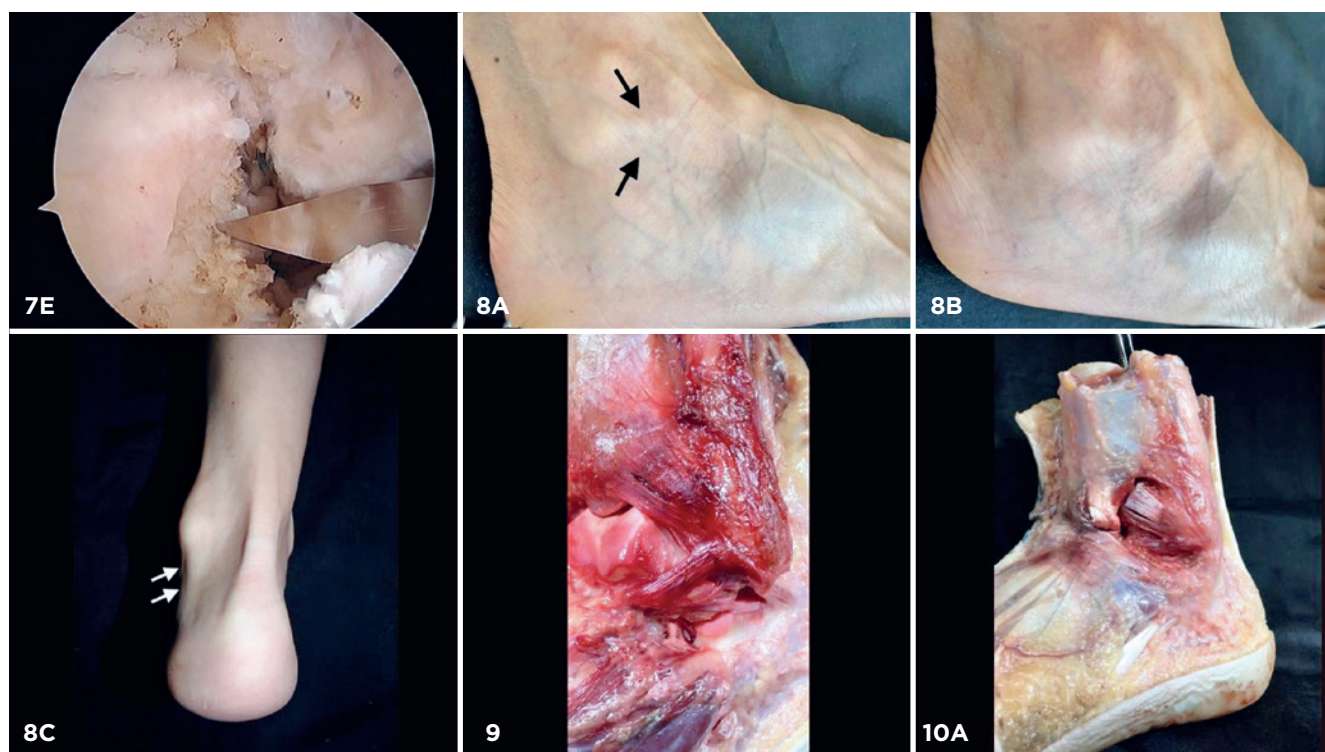


Figure 7. E) Site where a talar tunnel is carved in augmentations or reconstructions of the anterior talofibular ligament. **Figure 8.** Images of superficial anatomy of the ankle. A) Superficial anatomical image of the anterior talofibular ligament (ATFL). B) Superficial anatomical image of the ATFL in ankle inversion (the ligament is tensioned, thus improving its visualization and palpation). C) Superficial anatomical image of the ATFL visualized from a posterior view. **Figure 9.** Panoramic image of the anterior talofibular ligament (specimen with only 1 band). **Figure 10.** Anatomical images of the anterior talofibular ligament (ATFL) in relaxation, plantar flexion, and supination. A) Image of ankle at 90° with the ATFL relaxed.

the tip of the peroneal malleolus⁽²⁶⁾. This anatomic detail can be clearly seen during arthroscopic exploration of the ankle and should be considered when carving a tunnel in the fibula during ligament repair or reconstruction (Figure 14).

The proximal insertion of these bands are different. The superior band reaches the origin of the ATFJ (Bassett's ligament), whereas the proximal insertion of the inferior band connects with fibers of the calcaneofibular and talocalcaneal ligaments through arciform fibers in its malleolar origin⁽¹¹⁾.

The superior band of the ATFJ is the first structure to be injured during an inversion trauma of the ankle, presenting an injury incidence of 80%, according to bibliography^(27,28).

In magnetic resonance imaging (MRI) studies with 22 patients with no history of ankle sprain, Delfaut et al.⁽²⁹⁾ found that the ATFJ was monofasciculated in 9% of the cases, bifasciculated in 55%, and striated in 36%.

Calcaneofibular ligament (CFL)

Unlike the ATFL, which acts only on the TTJ⁽¹⁹⁾, the CFL is extracapsular and plays an important role in the stability of the TTJ and the STJ. Morphologically, it has a thick and cord-like shape. Moreover, it is inserted on the anterior side of the

vortex of the lateral malleolus, immediately below, and very close to the insertion of the ATFL, to which it is usually joined by arciform fibers^(13,30) (Figure 15A-B).

It measures approximately 4 to 8 mm in diameter and has a length of nearly 20mm and width of 4 to 5.5mm^(19,31,32).

Its direction is oblique, towards posterior and distal, inserting on the lateral side of the calcaneus, 15mm or 20mm dorsally and posteriorly in relation to the lateral tubercle of this osseous structure, involving itself in its medial surface with the lateral talocalcaneal ligament (LTCL) (Figure 16). Immediately over its anterior edge and separated by a thin, and fatty tissue which sometimes goes unnoticed, we find the talocalcaneal ligament, separates the CFL from the STJ. The CFL is superficially crossed by the peroneal tendons and their sheaths, and only about 1cm of the ligament is uncovered. It is proximally fused with the fibers that form the floor of peroneal tendon retinaculum (Figure 17A).

During the plantar flexion of the ankle, the CFL is set horizontally; meanwhile, when flexed, it is set vertically, though, in both cases, it is tensed throughout during the arc of motion. This is a very strong ligament, and the only ankle movements during which it is relaxed is the ankle valgus position and the ankle eversion. In some situations of varus stress, the CFL is

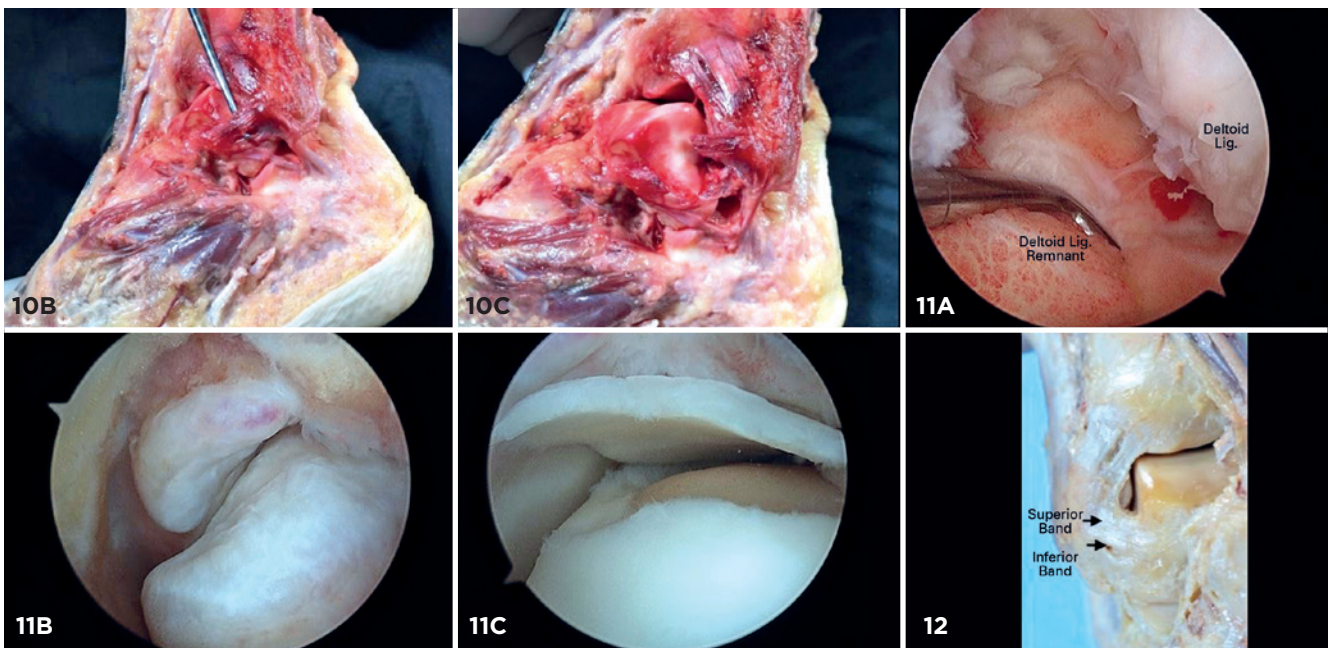


Figure 10. B) Image of the ankle in plantar flexion with the ATFL tensed at palpation. C) Anatomic image with the ATFL sectioned showing increased internal rotation and anterior translation of the ATFL. **Figure 11.** Impairment of the medial compartment of the ankle in patients with chronic lateral instability. A) Injury of the anterior fascicle of the deltoid ligament. B) Mirrored mushroom-shaped injury at the level of medial axilla of the tibia. Medial tibiotalar exostosis developed as a sequela of chronic lateral instability. C) Chondral flap in the anteromedial portion of the talus in a patient with chronic lateral instability of the ankle. **Figure 12.** Anatomical image of the anterior talofibular ligament with its 2 bands: superior (intra-articular) and inferior (extra-articular).

tensioned and may be injured event the ankle is not moving in flexion-extension (Figure 17B-C).

This ligament is the second structure to become injured during an ankle sprain, with an injury incidence of approximately 20%. When the CFL is injured, the ATFL is usually injured as well^(10,26).

Posterior talofibular ligament (PTFL)

Testut describes the PTFL as a flat ligament that occupies the posterior region of the joint. However, anatomic dissections and arthroscopic visualizations represent it with a semi-cord-like shape and as the strongest and more resilient of the 3 ligaments^(8,13) (Figure 18).

It has a trapezoid aspect and measures 30mm in length, 5mm in width, and 5-8mm in thickness^(23,33).

This ligament is rarely injured, except in cases of peritalar ankle fracture or dislocation. Rasmussen and Tovborg-Jensen⁽¹⁶⁾ state that the PTFL plays a minor role in ankle stability when the rest of the lateral structures are intact. Golanó described this ligament arthroscopically in numerous occasions, highlighting that this is an intracapsular but extrasynovial ligament; therefore, it can be easily visualized during posterior ankle arthroscopy^(4,34,35) (Figure 19).

It inserts in the digital fossa, located in the medial, posterior part of the fibula and, from this point it runs medially, almost horizontally towards its insertion in the posterior area of talus. The footprint on this bone is quite large, which is why, descriptions of the surgical technique to resect the tail of the talus or an os trigonum show that is necessary to disinsert the fibers of this ligament that are inserted in the more distal area of the tail of the talus and to cut the retinaculum of the flexor hallucis muscle in order to resect the fragment in a technically appropriate manner^(35,36).

Some fibers originated from the superior part of the PTFL, near its origin, lie proximally and medially, inserting themselves into the posterior edge of the tibia, and are fused with the fibers of the deep layer of the posterior tibio fibular ligament.

In cadaveric dissections, it has been noted that these fibers reach, in more than 90% of the cases, the posterior surface of the medial malleolus, creating a true labrum on the posterior margin of the tibia. This cluster of fibers has been given different names: capsular reinforcement bundle, ascending or tibial bundle of the PTFL; however, following the concepts of Golanó et al.^(4,37) and Kitaoka⁽²⁴⁾, we prefer to use the term proposed by Paturet: posterior intermalleolar ligament (Figure 20).

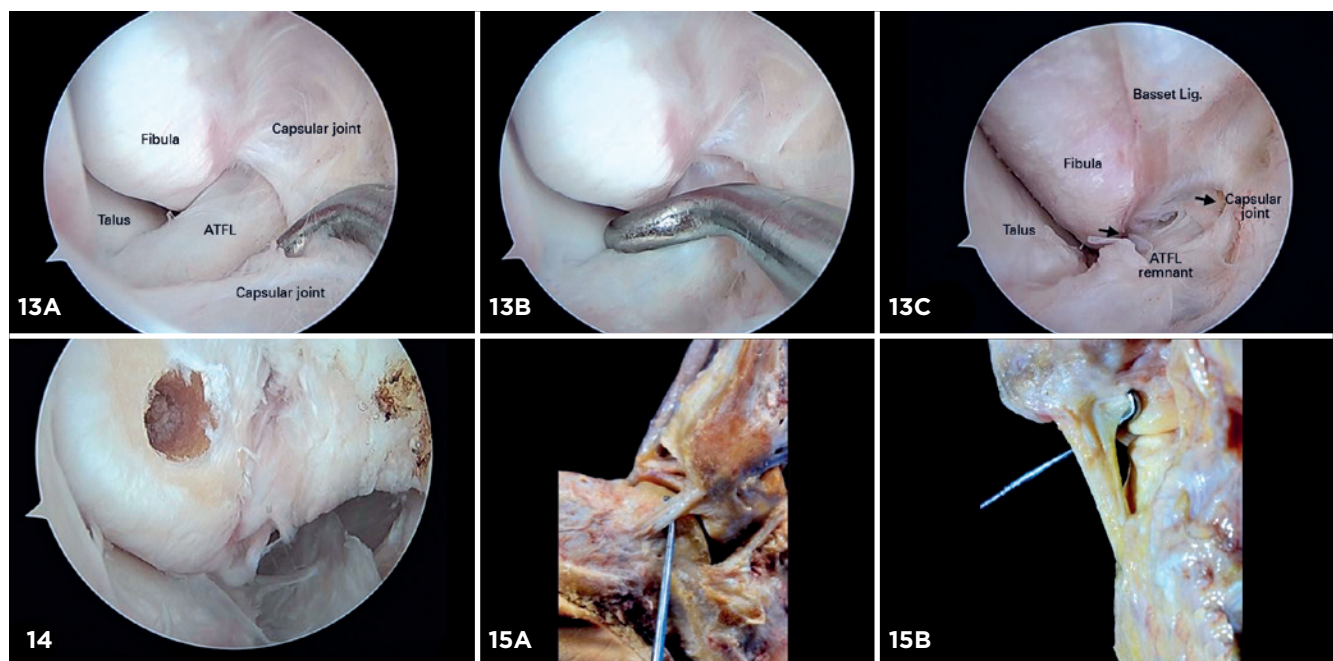


Figure 13. Arthroscopic images of the lateral gutter. A) Normal talofibular ligament (TFL) and joint capsule. B) Palpation of normal proximal insertion of the anterior TFL. C) Black arrows indicating proximal injury of the anterior TFL and of the joint capsule. **Figure 14.** Arthroscopic image showing normal tip of the peroneal malleolus with no ligamentous insertions and the hole where a tunnel is carved to perform arthroscopic repair of the anterior talofibular ligament. **Figure 15.** Anatomical images of the calcaneofibular ligament (CFL). A) Sagittal anatomical view of insertions of the CFL into the fibula and the calcaneus. B) Posterior anatomical image showing the CFL and fan-shaped arciform fibers.

Disinsertion of these distal fibers of the PTFL does not generate residual instability.

Arciform fibers

These fibers are an expansion of the regular, collagenous, and elastic dense connecting tissue, in the shape of a triangle or a semicircle, with an anteroinferior base that connects the inferior band of the ATFL with the LTCL and the CFL in a constant way. These structures have been clearly described by Kelikian and Sarrafian⁽²³⁾ in 2011, and has been confirmed by Golanó et al.^(5,14), but attracted attention again in recent years due to the critical role they play in endoscopic repairs of the ATFL⁽³⁵⁾ (Figure 21).

Arciform fibers are clearly identified in all cadaveric dissections and play a critical role within the lateral ligament complex of the ankle^(8,30).

We assessed the macroscopic and microscopic morphology of these arciform fibers, and found that the histological structure of these fibers is similar to that of ligamentous structures^(7,35) (Figure 22A-B).

Inferior extensor retinaculum (IER)

The IER is a very strong aponeurotic structure located in the anterior area of the ankle and the tarsus and is continui-

ty with the crural fascia. It can have different morphological shapes, but it commonly has a 'Y' or 'X' shape. This powerful retinaculum is responsible for preventing that the anterior tibial, extensor hallucis longus, extensor digitorum, and peroneus tertius tendons are dislocated to the anterior side of the ankle⁽²⁴⁾. The lying 'Y' shape, the most common one, is formed, from medial to lateral, by oblique superomedial and inferomedial bands, and continues through a single branch, the frondiform ligament (Figure 23).

This lateral part of the IER stem from the sinus tarsi and is divided into 2 branches at the extensor digitorum tendon: the oblique superomedial band, which runs proximally and end by inserting itself in the anterior portion anterior of the tibial malleolus, and the oblique inferomedial bands, which end by inserting itself into the abductor hallucis muscle and into the scaphoid and medial cuneiform bones.

The superomedial and inferomedial bands are located over the anteromedial region of the ankle, whereas the frondiform ligament is in the anterolateral region of the ankle and is the portion of the IER that could be used in augmentation surgical procedures to treat chronic ankle instability. It is worth highlighting that this structure is not close enough, nor crosses the ATFL, which could enable for it to be used in augmentation procedures.

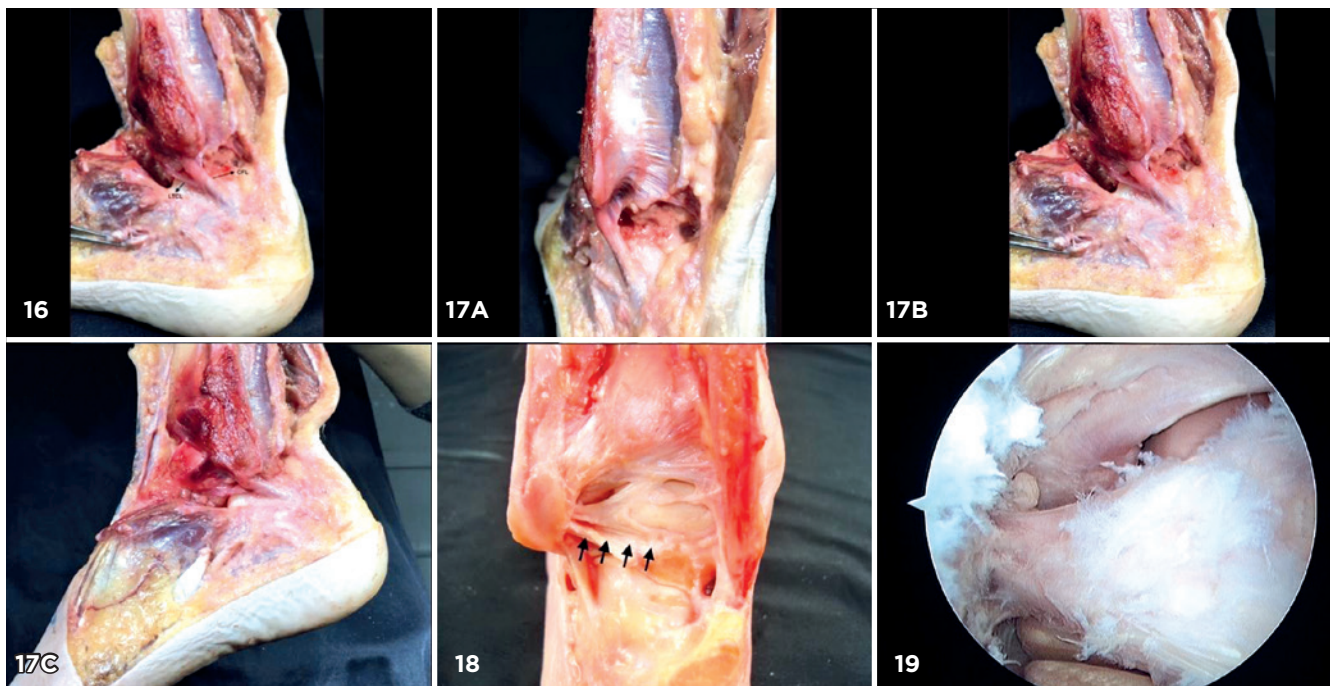


Figure 16. Anatomical image of the lateral talocalcaneal and the calcaneofibular ligaments. **Figure 17.** A) Anatomical image in which the fibula was removed. It is possible to visualize the continuity of the CFL with the floor of the peroneal tendon groove. B) Anatomy of the ankle in dorsiflexion. C) Anatomy of the ankle in plantar flexion. It bears noting that the calcaneofibular ligament is tensioned in both positions. **Figure 18.** Anatomical image of posterior dissection of the ankle. The black arrow shows the route of the posterior talofibular ligament. **Figure 19.** Arthroscopic image of the posterior talofibular ligament.

However, in 25% of the cases, some authors observed that oblique superolateral band varies considerably in shape and is responsible for the X-shape of the IER^(7,33,38) (Figure 24).

When this band is present, it crosses the ATFL and inserts into the lateral surface of the peroneal malleolus. Only this band should be used to perform IER augmentation following ATFL ligament repair.

Some fibers of this oblique superolateral band are in continuity with the superior peroneal retinaculum and run over the submalleolar portion of peroneal tendons. The IER have been often used by many surgeons worldwide over several decades to increase the repair of ATFL (Brostrom-Gould), a technique that is considered the gold standard by most of these surgeons, due to the excellent clinical and biomechanical outcomes obtained in large series with long-term follow-ups^(35,39).

Several authors have shown that advancing the IER and inserting it into the fibular periosteum promotes a function similar to the role played by CFL, thus stabilizing the STJ^(40,41).

As previously mentioned, the frondiform ligament crosses the STJ; sometimes, overtensioning of this structure during a surgical procedure of augmentation may lead to greater STJ stiffness and to plantar flexion deficit in these pa-

tients, which can be a problem, especially when dealing with athletes^(38,42).

Despite this last assumption, long-term studies did not show degenerative changes in the STJ among patients which chronic instability who were treated with these so-called “anatomical” techniques of repair and augmentation.

Conclusion

The ankle joint has been widely investigated from the anatomical, biomechanical, and surgical perspectives, producing a vast series of experimental observations.

The introduction of arthroscopy as a therapeutic element, along with the development of several completely arthroscopic techniques of ankle joint repair, augmentation and/or reconstruction have obliged surgeons to understand arthroscopic anatomy, which is nothing but a visualization different from the anatomy we all have studied.

Understanding the superficial, deep, and arthroscopic anatomy of the ankle allows for performing arthroscopic procedures to treat chronic lateral instability of the ankle in a systematized, reproducible, and safe manner.

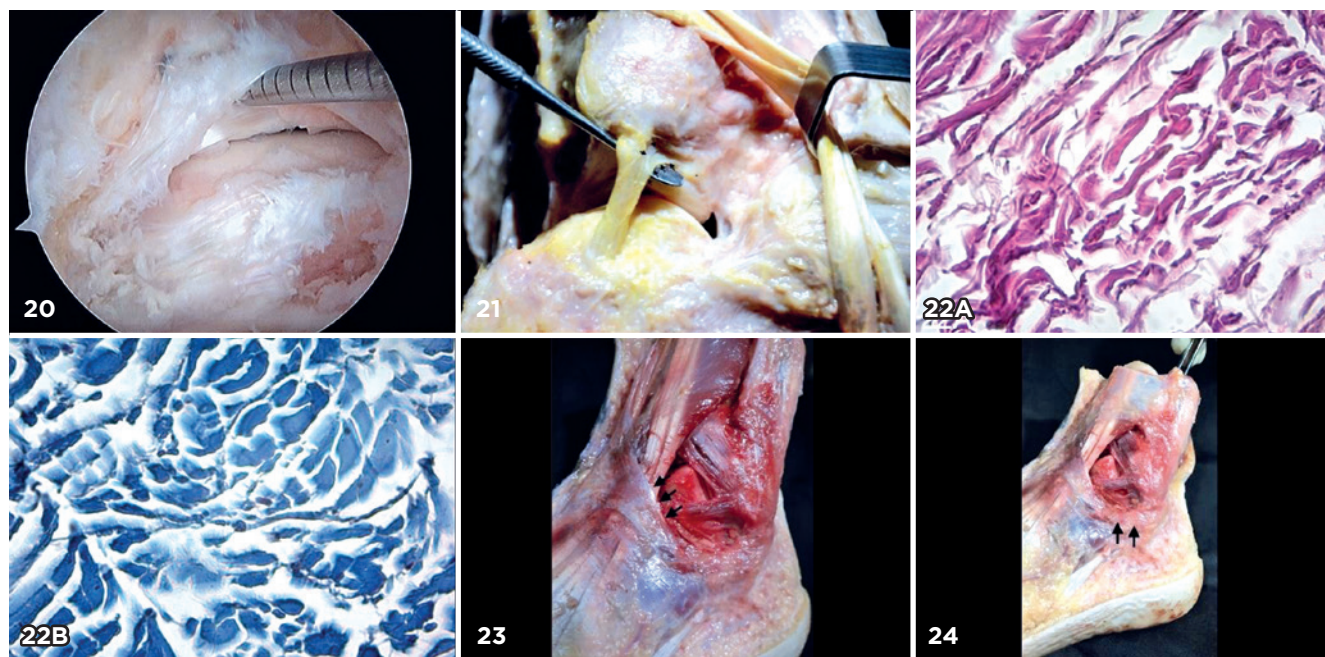



Figure 20. Arthroscopic image of the posterior intermalleolar ligament. **Figure 21.** Anatomical image of arciform fibers that connect the calcaneofibular and anterior talofibular ligaments. **Figure 22.** Images of histological slices of hematoxylin and eosin. A) And of Masson's trichrome stain. B) Showing the histological composition of arciform fibers similar to the calcaneofibular and anterior talofibular ligaments. **Figure 23.** Frondiform ligament (component of inferior extensor retinaculum). **Figure 24.** Superolateral band of the inferior extensor retinaculum identified in 25% of the cases.

Authors' contributions: Each author contributed individually and significantly to the development of this article JPB *(<https://orcid.org/0000-0003-0910-4140>) Conceived and planned the activities that led to the study, performed the surgery; GMA *(<https://orcid.org/0000-0003-4767-5489>) Data collection, bibliographic review; GMJ *(<https://orcid.org/0000-0001-9998-190X>) Interpreted the results of the study; LC *(<https://orcid.org/0000-0003-1187-0864>) Interpreted the results of the study, participated in the review process; LL *(<https://orcid.org/0000-0001-9094-7609>) Clinical examination, survey of the medical records, bibliographic review; LVC *(<https://orcid.org/0000-0002-0202-9603>) Clinical examination, survey of the medical records, bibliographic review. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) 

References

- Latarjet M, Ruiz Liard A. Anatomía humana. 4ª. ed. Buenos Aires: Editorial Médica Panamericana; 2004. Available from: <https://books.google.co.ve/books?id=Gn64RKVTw0cC&printsec=frontcover&hl=es#v=onepage&q&f=false>
- Johna S. Gray's Anatomy: The Anatomical Basis of Clinical Practice Elsevier / Churchill Livingstone, 2005, ISBN 0-443-06676-0 [Internet]. Vol. 30, World Journal of Surgery. 2006. p. 1624-5. Available from: <http://dx.doi.org/10.1007/s00268-006-0109-2>
- Golanó P, Forcada P, Carrera A, Rodríguez M, Sáenz I, León M, et al. Arterias potencialmente. Cuadernos de Artroscopía [Internet]. 1996;3(12):50-7. Available from: https://fondoscience.com/sites/default/files/articles/pdf/fs_03206.fs9610007.arterias-potencialmente-lesionables.pdf
- Golanó P, Mariani PP, Rodríguez-Niedenfuhr M, Mariani PF, Ruano-Gil D. Arthroscopic anatomy of the posterior ankle ligaments. *Arthroscopy*. 2002;18(4):353-8.
- Golanó P, Vega J, de Leeuw PA, Malagelada F, Manzanares MC, Götzens V, et al. Anatomy of the ankle ligaments: a pictorial essay. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(5):557-69.
- Pijnenburg AC, Bogaard K, Krips R, Marti RK, Bossuyt PM, van Dijk CN. Operative and functional treatment of rupture of the lateral ligament of the ankle. A randomised, prospective trial. *J Bone Joint Surg Br*. 2003;85(4):525-30.
- Dalmau-Pastor M, Malagelada F, Kerkhoffs GM, Karlsson J, Guelfi M, Vega J. Redefining anterior ankle arthroscopic anatomy: medial and lateral ankle collateral ligaments are visible through dorsiflexion and non-distraction anterior ankle arthroscopy. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(1):18-23.
- Johnson EE, Markolf KL. The contribution of the anterior talofibular ligament to ankle laxity. *J Bone Joint Surg Am*. 1983;65(1):81-8.
- Harper MC. The lateral ligamentous support of the subtalar joint. *Foot Ankle*. 1991;11(6):354-8.
- Michels F, Matricali G, Vereecke E, Dewilde M, Vanrietvelde F, Stockmans F. The intrinsic subtalar ligaments have a consistent presence, location and morphology. *Foot Ankle Surg*. 2021; 27(1):101-9.
- Poonja AJ, Hirano M, Khakimov D, Ojumah N, Tubbs RS, Loukas M, et al. Anatomical Study of the Cervical and Interosseous Talocalcaneal Ligaments of the Foot with Surgical Relevance. *Cureus*. 2017;9(6):e1382.
- Golanó P, Pérez-Carro L, Saenz I. Anatomía de los ligamentos del tobillo (Comunicación oficial 1 (SECOT, Madrid, octubre 2004)). *Rev Ortop Traumatol*. 2004;48(Supl 3):35-44.
- Testut L, Latarjet A, Others. Tratado de anatomía humana. Barcelona: Salvat; 1964.
- Golanó P, Dalmau-Pastor M, Vega J, Batista JP. Anatomy of the Ankle. In: D'Hooghe PPRN, Kerkhoffs GMMJ, editors. *The ankle in football*. Paris: Springer; 2014. p. 1-24.
- Prins JG. Diagnosis and treatment of injury to the lateral ligament of the ankle. A comparative clinical study. *Acta Chir Scand Suppl*. 1978;486:3-149.
- Ludolph E, Hierholzer G, Gretenkord K, Ryan U. Research into the anatomy and X-ray diagnostics of the fibular ligaments at the ankle joint. *Arch Orthop Trauma Surg*. 1984;103(5):348-52.
- Attarian DE, McCrackin HJ, DeVito DP, McElhaney JH, Garrett WE Jr. Biomechanical characteristics of human ankle ligaments. *Foot Ankle*. 1985;6(2):54-8.
- Rasmussen O, Tovborg-Jensen I. Anterolateral rotational instability in the ankle joint. An experimental study of anterolateral rotational instability, talar tilt, and anterior drawer sign in relation to injuries to the lateral ligaments. *Acta Orthop Scand*. 1981;52(1):99-102.
- Rasmussen O. Stability of the ankle joint. Analysis of the function and traumatology of the ankle ligaments. *Acta Orthop Scand Suppl*. 1985;211:1-75.
- Stormont DM, Morrey BF, An KN, Cass JR. Stability of the loaded ankle. Relation between articular restraint and primary and secondary static restraints. *Am J Sports Med*. 1985;13(5):295-300.
- Vega J, Dalmau-Pastor M, Malagelada F, Fargues-Polo B, Peña F. Ankle arthroscopy: an update. *J Bone Joint Surg Am*. 2017; 99(16):1395-407.
- Vega J, Allmendinger J, Malagelada F, Guelfi M, Dalmau-Pastor M. Combined arthroscopic all-inside repair of lateral and medial ankle ligaments is an effective treatment for rotational ankle instability. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(1):132-40.
- Kelikian AS, Sarrafian SK, editor. Sarrafian's anatomy of the foot and ankle: descriptive, topographic, functional. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2011.
- Kitaoka HB. Anatomy of the foot and ankle. descriptive, topographic, functional. *J Bone Joint Surg*. 1993;75(12):1886.
- Vega J, Malagelada F, Manzanares Céspedes M-C, Dalmau-Pastor M. The lateral fibulotalocalcaneal ligament complex: an ankle stabilizing isometric structure. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(1):8-17.
- Michels F, Cordier G, Burssens A, Vereecke E, Guillo S. Endoscopic reconstruction of CFL and the ATFL with a gracilis graft: a cadaveric study. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(4):1007-14.
- Karlsson J, Lansinger O. Lateral instability of the ankle joint. *Clin Orthop Relat Res*. 1992;(276):253-61.
- Kim ES, Lee KT, Park JS, Lee YK. Arthroscopic anterior talofibular ligament repair for chronic ankle instability with a suture anchor technique. *Orthopedics*. 2011;34(4).
- Delfaut EM, Demondion X, Boutry N, Cotten H, Mestdagh H, Cotten A. Multi-fasciculated anterior talo-fibular ligament: reassessment of normal findings. *Eur Radiol*. 2003;13(8):1836-42.
- Rouvière H, Canela Lazaro M. Le ligament peroneo-astragalocalcaneen. *Ann Anat Pathol*. 1932;7(9):745-50.

31. Milner CE, Soames RW. Anatomy of the collateral ligaments of the human ankle joint. *Foot Ankle Int.* 1998;19(11):757-60.
32. Milner CE, Soames RW. Anatomical variations of the anterior talofibular ligament of the human ankle joint. *J Anat.* 1997; 191(Pt 3):457-8.
33. Dalmau-Pastor M, Yasui Y, Calder JD, Karlsson J, Kerkhoffs GM, Kennedy JG. Anatomy of the inferior extensor retinaculum and its role in lateral ankle ligament reconstruction: a pictorial essay. *Knee Surg Sports Traumatol Arthrosc.* 2016;24(4):957-62.
34. van Dijk CN, Vuurberg G, Batista J, d'Hooghe P. Posterior ankle arthroscopy: current state of the art. *J ISAKOS.* 2017;2(5): 269-77. Available from: [https://www.jisakos.com/article/S2059-7754\(21\)00253-4/fulltext](https://www.jisakos.com/article/S2059-7754(21)00253-4/fulltext)
35. Gould N, Seligson D, Gassman J. Early and late repair of lateral ligament of the ankle. *Foot Ankle.* 1980;1(2):84-9.
36. van Dijk CN. Hindfoot endoscopy. *Foot Ankle Clin.* 2006;11(2):391-414.
37. Golanó P, Vega J, Pérez-Carro L, Götzens V. Ankle anatomy for the arthroscopist. Part I: The portals. *Foot Ankle Clin.* 2006;11(2):253-73.
38. Prisk VR, Imhauser CW, O'Loughlin PF, Kennedy JG. Lateral ligament repair and reconstruction restore neither contact mechanics of the ankle joint nor motion patterns of the hindfoot. *J Bone Joint Surg Am.* 2010;92(14):2375-86.
39. Kakwani R., Siddique M. Sprained Ankles. VI. Surgical treatment of chronic ligament ruptures. In: Banaszkiwicz P, Kader D, editors. *Classic papers in orthopaedics.* London: Springer; 2014. Available from: https://doi.org/10.1007/978-1-4471-5451-8_57
40. Nery C, Raduan F, Del Buono A, Asaumi ID, Cohen M, Maffulli N. Arthroscopic-assisted Broström-Gould for chronic ankle instability: a long-term follow-up. *Am J Sports Med.* 2011;39(11):2381-8.
41. Lee KT, Park YU, Kim JS, Kim JB, Kim KC, Kang SK. Long-term results after modified Brostrom procedure without calcaneofibular ligament reconstruction. *Foot Ankle Int.* 2011;32(2):153-7.
42. Guillo S, Bauer T, Lee JW, Takao M, Kong SW, Stone JW, et al. Consensus in chronic ankle instability: aetiology, assessment, surgical indications and place for arthroscopy. *Orthop Traumatol Surg Res.* 2013;99(8 Suppl):S411-9.