Int. J. Morphol.,
30(1):162-169, 2012.

Morphometric Study and Anatomical Variations of the Medial Ligament of the Talocrural Joint

Estudio Morfométrico y Variaciones Anatómicas del Ligamento Medial de la Articulación Talocrural

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SEPÚLVEDA, P. R.; CAPURRO, S. B.; MORENO, T. R.; GIESEN, F. L.; IBARRA, M. C.; SILVA, D. P.; TELIAS, N. A. & VEGA, P. E. Morphometric study and anatomical variations of the medial ligament of the talocrural joint. ***Int. J. Morphol., 30(1)***:162-169, 2012.

SUMMARY: The aim of this study was to perform a descriptive study of the morphology, anatomical variations and morphometry of medial talocrural (or deltoid) ligament. We dissected 27 lower limbs obtained from amputations without histories of age, sex or disease. The measurements were made with a caliper, compass and ruler, expressing the results in millimeters. We described the superficial layer morphology of the medial ligament, measuring the size and ligament's thickness. For the deep layer we described and measured the length (l), width (w) and thickness (t). Results: Superficial layer: trapezoid form=66.7% (anterior margin=30.5 mm; posterior margin=27.6 mm; top margin=22.6 mm; bottom margin=50.5 mm), rectangular form=19% (anterior margin=19.3 mm; posterior margin=27.2 mm; top margin=24.4 mm; bottom margin=29.8 mm), triangular form=14.3% (anterior margin=37 mm; posterior margin=37.8 mm; bottom margin=48.3 mm). The average thickness of the superficial layer was 3.6 mm. Deep layer of the medial ligament: l=6.9 mm, w=11 mm, t=5.7 mm; presented rectangular form in 100%. In 76.2% of the specimens, the deep layer was covered completely by the superficial layer; however, in 23.8% the coverage is incomplete, showing the deep layer by posterior angle. The literature is contradictory regarding the anatomy and variations of the medial ligament of the ankle. There are important differences in morphology, attachments, subdivisions and relationships between the two layers of the deltoid ligament. Conclusions: We found significant anatomical variations in the morphology and the relationship between the superficial and deep layers of the deltoid ligament.

KEY WORDS: Ligament; Medial; Ankle; Anatomy.

INTRODUCTION

The ligaments of the talocrural joint are essential anatomical structures for the stability of the joint. This ligament apparatus should resist tension forces that occur regularly during foot movement as well as abnormally higher tensions that could jeopardize its integrity.

It is estimated that 15-20% of all sports injuries involve the ankle (Garrick & Requa, 1988; Barr & Harrast, 2005). Of all ankle sprains, medial (or deltoid) ligament injury may occur in up to 18% (Lin *et al.*, 2006). 20-40% of ankle injuries will lead to a chronic instability and disability (Renstrom, 1994).

Due to the high prevalence of ankle injuries and their clinical implications, have been sought the main factors determining the stability of the ankle. It is known that the stability of the ankle depends on two factors: the anatomical configuration and ligamentous support (Jolin *et al*., 1991).

There have been attempts to establish which the most important component in stabilizing the ankle. Stormont *et al.* (1985), in a study he sectioned the lateral ligaments, and found that ankle joint surfaces gave 30% stability for the rotation and 100% for inversion movement. Therefore the real role of the lateral ligaments in the stability of the talocrural joint would be questionable. Hintermann *et al.* (1995) found in a study *in vitro,* that section of the lateral ligaments did not significantly influence the movement of internal or external rotation or dorsal or plantar flexion. However, the section of the deltoid ligament caused a noticeable functional compromise in these actions, mainly plantar flexion. It was also found that the integrity of the talocrural joint depends much more than an intact deltoid ligament (Hintermann *et al*.). The deltoid ligament would be essential to limit the talar abduction (Close, 1956; Grath, 1960). It has been determined that the main stabilizer of the ankle is the deep layer of the deltoid ligament, avoiding the lateral shift and eversion of the talus (van den Bekerom *et al.*, 2009).

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Injuries to these ligaments are very common, and thus, of critical clinical importance. Defects can lead to functional limitation in flexion and extension, complex regional pain syndrome, local pain, swelling, stiffness after exercise and osteoarthritis (Jolin *et al*.). Furthermore, myositis ossificans secondary to medial ligament injury (Muir *et al.*, 2010), has been described.

Perhaps the most important complication is the "medial instability" (Hintermann, 2003). Medial instability is a complication due to the incompetence of the deltoid ligament secondary to it injury. It is characterized by instability of the foot when walking, jogging, up and down stairs, pain at the anteromedial ankle zone, in the projection of the posterior tibial tendon and pain in the anterior portion of the lateral malleolus (Hintermann). The talus is in slight pronation, producing a deformation in talo-valgus (Hintermann). The clinical and stress imaging show the deformation, asymmetry and instability. The diagnostic criteria of medial instability are: a sense that the “foot is gone”, pain in the medial ankle zone and a valgus and pronation deformity of the foot that can typically be corrected by the action of tibialis posterior muscle (Hintermann).

The main causes of deltoid ligament injuries are sporting accidents (36%), traffic accidents (14%) and isolated falls (50%) (Jolin *et al*.). Of all the deltoid ligament injury, 89% had associated fractures; the most common fracture is the distal third of the fibula (Jolin *et al*.).

The injury mechanisms of the talocrural ligaments were described in a dynamic way by Lauge-Hansen (1949). The medial ligament injury is caused by pronation-abduction, pronation-eversion and supination-eversion. When the mechanism in pronation-abduction occurs isolated deltoid ligament injury (Jolin *et al*.). In mechanisms of pronation-eversion or supination-eversion, fractures of the fibular malleolus as well as rupture of the syndesmosis. The most frequent mechanism of injury is the supination-eversion (40-75%) (Jolin *et al*.; van den Bekerom *et al*., 2009). When the mechanism is supination-eversion; in Lauge-Hansen stage 2, there is no compromise of medial structures, but in stage 4 there are rupture of deep deltoid ligament and / or medial malleolus fracture, producing a incompetence of deltoid ligaments (van den Bekerom *et al*., 2009).

On bimalleolar fractures, the 26% of cases presents deltoid incompetence after malleolar fixation (Tornetta, 2000). Assessing the competence of the medial ligament is performed with a stress radiograph of the foot, in a front view (ligament resistance against gravity) (Close; Grath). Another useful diagnostic tool to confirm the clinically suspected medial ligament incompetence is the MRI (van den Bekerom *et al*., 2009) and arthroscopy (Hintermann).

A controversial aspect is the surgical repair of the medial ligament. When it is injured, there is a bringing of the posterior tibial tendon that prevents regeneration, so it must operate (Close). This is evidenced by the inability to reduce the space medial radiolucency on the radiograph of stress (Close). Ligaments heal better when they are repaired surgically (Close; Grath). Surgical exploration of the medial ligaments should be performed in all patients with symptomatic ankle instability or suspected clinically and confirmed by arthroscopy (Hintermann). Surgical repair improved the ankle function and in 89% of the cases with a good to excellent result (Hintermann), without sequelae, both objective and subjective (Jolin *et al*.).

However, despite extensive evidence that corroborates the importance of the deltoid ligament, as one of the key stabilizers of the ankle, we know very little about their anatomy and biomechanics (Boss & Hintermann, 2002; Hintermann). It is essential to understand the clinical implications, consequences, assessment and treatment; a good base of the medial ligament anatomy.

The magnitude and force that these ligaments withstand is considerable and the degree of injury varies in different people. This signifies that apart from the extent of the damage and magnitude of the external force, there are intrinsic properties of the ligament that determine the effectiveness of its resistance.

The lateral ligaments of the ankle where it has been well described (van den Bekerom *et al*., 2008; Telias *et al.*, 2010) but the medial ligament has not been similarly described. For that reason, this report will analyze the macroscopic variables and anatomical variations of the medial ligament of the talocrural joint by utilizing a descriptive morphometric study; for the distinct purposes of contributing information to be used for surgical treatment, and supplying a better understanding and clarification of the factors that affect its stability.

Anatomically, the medial ligament is described as a double structure. It presents a homogenous superficial layer with a trapezoid form (fan-shaped) and a wide distal attachment. Additionally, it contains a deep layer, separated by connective and adipose tissue (Testut & Latarjet, 1974; Close; Muhle *et al*., 1999; Klein, 1994; Mengiardi, 2007). The superficial layer originates from the anterior colliculus of medial malleolus (Close) and inserted into the talus, navicular, calcaneus, and the plantar calcaneonavicular and medial talocalcaneal ligaments. Its morphology is rectangular, triangular or trapezoid (Testut & Latarjet). Also, according to the same author, in order to get to the deep layer it is necessary to dismember the ankle laterally, since the superficial layer completely covers the deep layer. Netter and Schneck (Netter, 2006; Schneck *et al.*, 1992) shows the medial ligament as a structure comprised of 4 ligaments: the anterior tibiotalar ligament, the tibionavicular ligament, the tibiocalcaneal ligament, and the posterior tibiotalar ligament – each of which is completely separate from the other. Netter does not go further than to identify these 4 ligaments, and does not address the deep layer. Boss & Hintermann talk about a complex of deltoid ligament composed by the tibiospring (from tibia to lig. calcaneonavicular or spring), tibiocalcaneal, superficial posterior tibiotalar, deep anterior tibiotalar and deep posterior tibiotalar ligaments. Hintermann explains that the surface layer consists of a tibionavicular (which may also have fiber to the talus), tibiocalcaneal and tibiospring ligament. Tibiotalar ligament would be entirely the deep layer, divided into anterior and posterior portion. He also explained that the calcaneal navicular ligament would be very important in the biomechanics of the ankle and the strongest is the tibiotalar ligament (Hintermann). Other authors (Sarrafian, 1994; Milner & Soames, 1998) claim that calcaneus-navicular (or spring) ligament would be the strongest.

On the other hand, Rouvière & Delmas (2005) describes the medial ligament as a structure composed of a superficial portion and a deep portion, showing the latter from the posterior margin of the ligament. Rouvière & Delmas (2005) also describes the superficial layer as a homogenous, trapezoid structure with attachments to the talus, navicular, calcaneus and calcaneonavicular ligament. In contrast, Standring (2008) describes the medial ligament as a structure composed of a superficial and deep layer. He describes the superficial layer as having a triangular shape, and attaching to the talus, calcaneus, navicular and plantar calcaneonavicular ligament. They also mentions that the deep layer is visible, but from the anterior angle of the superficial layer. Offering yet another approach, Moore & Dalley (2009) describes the ligament as a trapezoid structure that projects fibers towards the talus, navicular and calcaneus, forming the anterior tibiotalar, tibionavicular, tibiocalcaneus and posterior tibiotalar ligaments.

Sarrafian, Milner & Soames, Boss & Hintermann, Hintermann and Mengiardi *et al*. discusses the subdivision of the deep layer into an anterior portion and a posterior portion. Of these only the anterior portion would be unstable (Milner & Soames; Boss & Hintermann; Hintermann). Through this study we intend to clarify the anatomy of the medial ligament of the talocrural joint because of the many contradictions pertaining to its actual morphology, anatomical variations, and the existence or non-existence of certain ligaments or attachments. We will also morphologically analyze the layers of the ligament and obtain average measurements of their margins, thereby establishing a standardized description of the anatomy of the medial ligament and offering an explanation of the existing discrepancies.

MATERIAL AND METHOD

A descriptive study was performed utilizing 27 lower limbs obtained from amputations without background information indicating age, sex, or demographic data.

Only limbs that were unharmed in the medial ankle region were included in the study. Limbs with necrosis in the medial malleolus, calcaneus or other near-by regions were excluded.

The dissection protocol consisted of pulling back the cutaneous flap that covers the anterior and medial face of the limb and serves as a covering to protect the structures. The deepening was accomplished by the extraction of fasciae, retinaculum, capsule, tendons with their sheaths, adipose and connective tissue until the medial ligament was exposed. Good anatomical indicators that were used to find the ligament were the long flexor tendons of the toes and the posterior tibial tendon with its respective synovial sheaths; by removing those, the medial ligament could be seen. Then the authors proceeded to dissect and separate the ligament from the surrounding tissue without damaging them in order to take the measurements.

The samples did not include fixative which meant that the entire procedure had to be completed in one day - including the dissection, analysis and measurements.

The measurements were taken with one foot of professional metered measuring tape, a professional protractor, and a professional metallic millimeter ruler.

Superficial Layer: the morphology was described according to the existing information in the literature (Testut & Latarjet; Rouvière & Delmas; Standring; Moore & Dalley) fan-shaped or trapezoidal, rectangular, triangular, or other - in case another shape was discovered. Measurements were taken of each variation of the superficial portion in respect to its anterior, posterior, superior and inferior sides. The ligament thickness was also measured. The macroscopic anatomical variations of the ligament were noted.

Deep Layer: to measure the deep portion, the talocrural joint was dismantled through the lateral face, freeing the deep portion in order to measure and analyze it in the same fashion as the superficial portion. The length, width and thickness of this ligament were measured.

The measurements obtained were recorded and analyzed in Microsoft Office Excel. The average values for each measurement were calculated as well as their respective standard deviations.

RESULTS

The medial ligament is macroscopically composed of a superficial layer and a deep layer (Fig. 1).

Superficial Layer: The superficial layer presented 3 distinct shapes: trapezoidal (or fan-shaped), rectangular and triangular. The trapezoidal shape had a frequency of 70.4%; the rectangular shape 18.5% and the triangular shape 11.1%. There was no other variation in the shape of the superficial layer (Table I and figure 1). Its proximal attachment is from the inferior margin of the tibial malleolus, and from there it projects fibers towards the inferomedial region and attaches from the anterior to posterior in: the talus (anterior tibiotalar fibers), the navicular (tibionavicular fibers), the plantar calcaneonavicular ligament (tibiospring fibres), the calcaneus (tibiocalcaneal fibers) the medial tibiocalcaneal ligament and again through the talus (posterior tibiotalar fibers) (Fig. 2).

Table I. Variations on the surface layer of talocrural medial ligament.

Form	Number	Frequency
Trapezoid	19	70.4%
Rectangular	5	18.5%
Triangular	3	11.1%
	Total n=27	100%

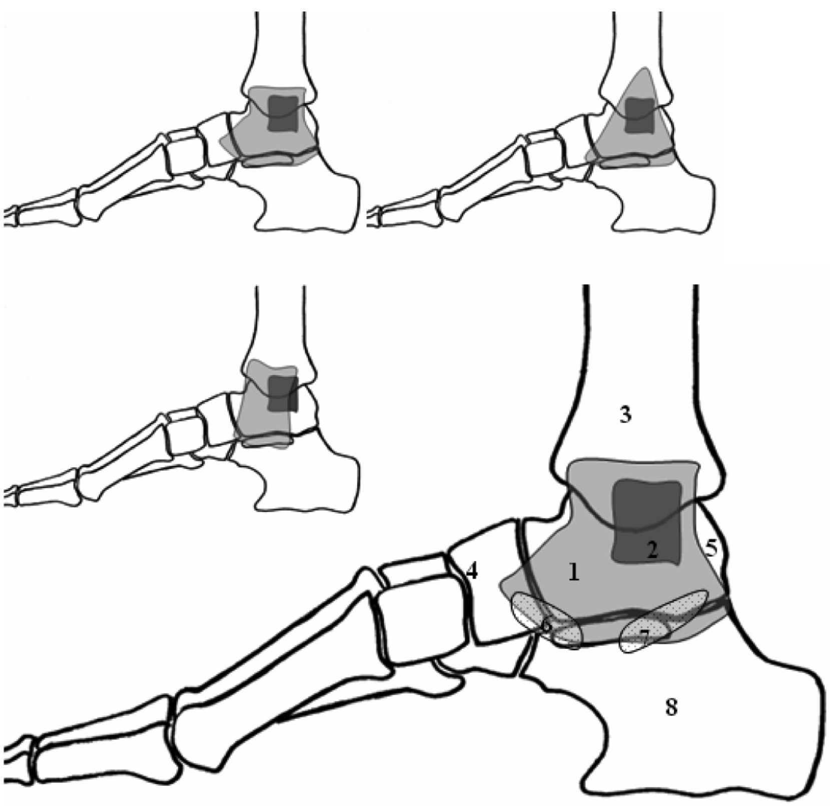

Fig. 1. Medial view diagram of right foot. Showing the different morphologies of the surface layer (trapezoid, triangular and rectangular). In the rectangular morphology shows a gap in coverage, leaving display for posterior the deep layer. 1. Surface Layer 2. Deep Layer 3. Tibia; 4. Navicular 5. Talus, 6. Plantar calcaneonavicular ligament (or tibiospring ligament) 7. Medial talocalcaneal ligament. 8. Calcaneus.

These fibers are distributed homogenously and do not present clear subdivisions between one another, forming a continuous ligament with a wide distal attachment.

Generally the distal attachment is more extensive than the proximal attachment (trapezoidal and triangular shaped), except in the rectangular shape where the fibers do not have a strong tendency to open up towards the inferior.

This superficial layer is closely related to the synovial sheaths of posterior tibial and flexor digitorum longus tendons. The articular capsule is also very closely related to the superficial layer, which looks more like a growth around the capsule but remains in an intracapsular position. The thickness of the superficial layer was on average 5.2 mm (SD 1.5 mm).

The average measurements of the sides of the trapezoidal shape were: anterior = 30.6 mm.; posterior = 28.5 mm.; superior = 22.5 mm. and inferior = 48.4 mm. Average sides of the rectangular shape of the superficial layer were: anterior = 21 mm; posterior = 24.8 mm.; su-

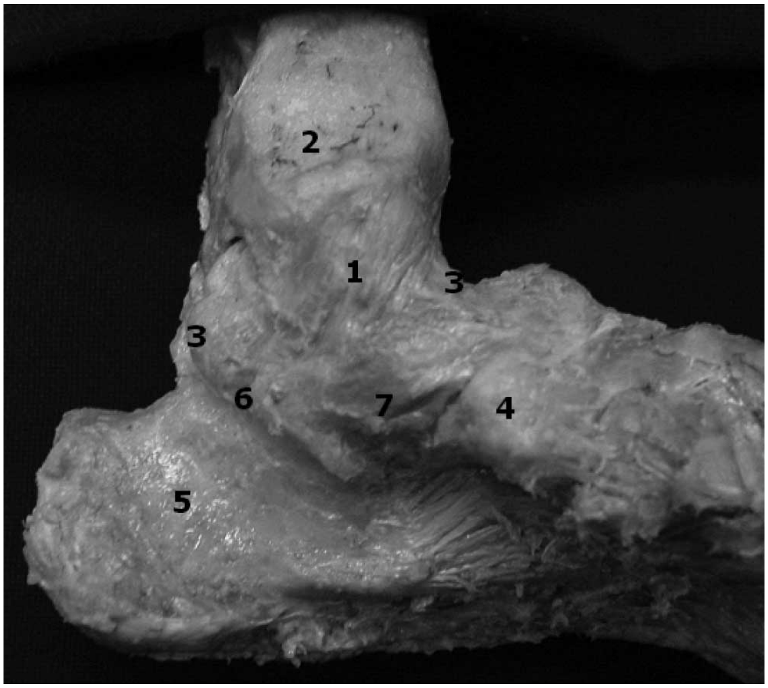

Fig. 2. Medial view of left foot. 1. Superficial layer of medial talocrural ligament, 2. Tibia, 3. Talus, 4. Navicular, 5. Calcaneus, 6. Medial talocalcaneal ligament, 7. Plantar calcaneonavicular ligament (or tibiospring ligament).

perior = 22.7 mm. and inferior = 28.2 mm. Average sides of the triangular shape of the superficial layer were: anterior = 37 mm.; posterior = 37.8 mm. and inferior = 48.3 mm. (there is no superior side because the ligament is triangular shaped) (Table II).

Table II. Average measurements of the edges of the surface layer (standard deviation).

	Trapezoid	Rectangular	Triangular
Anterior	30.6 (±10.3)	21 (±7.2)	37 (±10.6)
Posterior	28.5 (±8.5)	24.8 (±7.3)	37.8 (±3.9)
Top	22.5 (±3.7)	22.7 (±6.9)	---
Bottom	48.4 (±8.9)	28.2 (±7.6)	48.3 (±6.4)

In 74.1% of the cases, the covering of the superficial layer over the deep layer was complete, while 25.9% of the cases showed insufficient covering. Where the covering was incomplete, the deep layer could be observed through the posterior side, but never through the anterior (Fig. 3).

The shape of the superficial layer that was more frequently related to insufficiency in the covering was the rectangular shape (60% of the rectangular samples), while only 21% of the trapezoidal and 0% of the triangular presented incomplete covering.

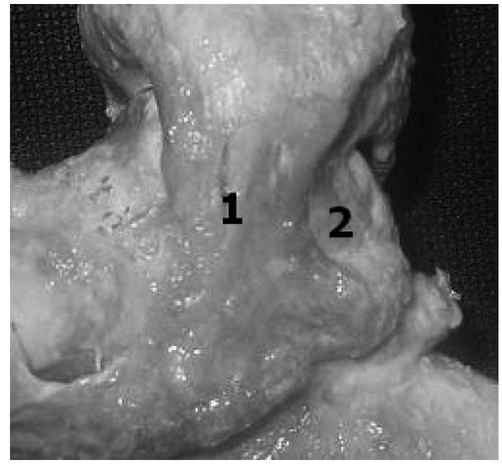

Fig. 3. Medial view of right foot. 1. Superficial layer of medial talocrural ligament, 2. Deep layer of medial talocrural ligament.

Deep Layer: Its macroscopic shape was rectangular in 100% of the cases, separated by connective and adipose tissue – in great contrast to the superficial layer. No subdivision was found that delineated the anterior portion from the posterior.

Its origin is in the internal face of the inferior side of the tibial malleolus, exactly in the medial osseous region of the hyaline cartilage that contains the articular inferior face of the tibia. It is directed towards the inferior and inserted in the internal face of the talus (Fig. 4).

The average thickness of this layer was 5.4 mm; length 6.7 mm. and a width of 10.9 mm. In contrast to the superficial layer, the deep layer was very consistent in its anatomy. Access to this is made disarticulating the ankle by lateral.

DISCUSSION

Our findings regarding the anatomy of the medial ligament of the talocrural joint coincided with those described by Testut & Latarjet. The ligament is composed of 2 layers, one deep and the other superficial. It begins in the inferior side of the tibial malleolus and projects towards the inferior and medial, where it inserts in the talus, navicular, calcaneus and

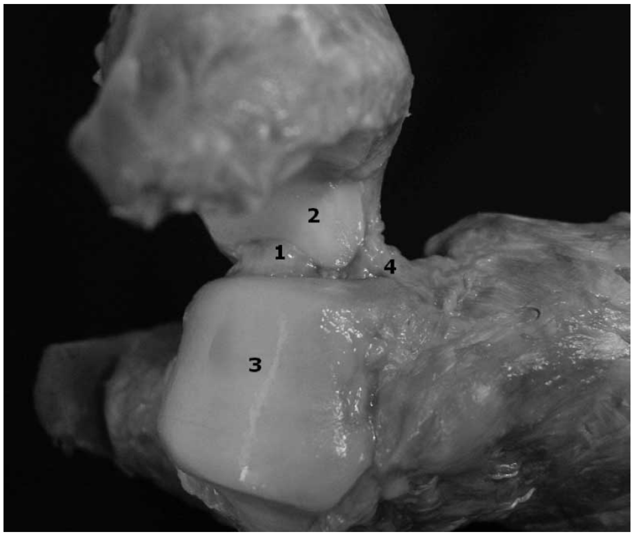

Fig. 4. Superior view of disarticulated right foot by lateral side. 1. Deep layer of medial talocrural ligament, 2. Tibia articular surface, 3. Talus articular surface, 4. Tibiotalars fibers of the superficial layer of medial talocrural ligament.

plantar calcaneonavicular and medial talocalcaneus ligaments (see Figure 1). Exactly as is described in the majority of the relevant literature, the superficial layer is a homogenous ligament (Testut & Latarjet; Close; Muhle *et al*.; Klein; Mengiardi *et al*.; Standring; Moore & Dalley).

Many authors describe the surface layer as a structure composed of several ligaments (Netter; Schneck *et al.*; Boss, 2002; Hintermann & Hintermann; Sarrafian; Milner & Soames), they all have disagreements and difficulties in establishing subdivisions. This situation is due to an attempt to create subdivisions which do not exist. The surface layer is a homogeneous ligament that has a large insertion and its fibers projecting to the navicular bone, talus, calcaneus and plantar calcaneonavicular and talocalcaneal ligaments.

In regards to the shape of the superficial layer, Testut & Latarjet describe the variations as fan (trapezoidal), rectangular and triangular shaped; Standring mentions only the triangular shape, and Rouvière & Delmas and Moore & Dalley only discuss the trapezoidal or fan shaped. Again, what we found coincided with Testut & Latarjet.

However, there were discrepancies with respect to the deep layer. Rouvière & Delmas describes the deep layer as being visible from the posterior side of the ligament. We found that only 25.9% of the cases corresponded to Rouvière & Delmas description, while in the rest, the deep layer was not visible without the dismemberment of the extremity. Standring describes the deep layer as being visible through the anterior side of the ligament; however, none of our samples complied with that assessment, and every deep layer was visible through the posterior side.

With regard to measurements, there are no studies to perform exactly the same measurements, but Boss & Hintermann measured the subdivisions of the deltoid complex on 12 cadaveric pieces. Making a rough comparison we can see differences: the anterior edge of the surface layer, measured on average, 29.5 mm (SD 10.5 mm), while the anterior tibiotalar ligament of Boss AP, 16.1 mm (SD 6.8 mm). The posterior edge measured 26.9 (SD 8.6 mm) and according to Boss AP 20mm (SD 4.3 mm).

Some authors mention a subdivision of the deep layer in anterior and posterior (Sarrafian; Milner & Soames; Boss & Hintermann; Hintermann; Mengiardi *et al.*), in our samples showed no subdivision, with the layer deep very consistent in their anatomy.

This "invariability" of the anatomy of the deep layer may be based on the fact that it is the main stabilizer of the ankle (van den Bekerom *et al*., 2009). A structure that plays an essential role in ankle function should remain constant.

The anatomy of the superficial layer could directly affect the rupture of deep layer, as it is an essential reinforcement to resistant potentially lesion. It is possible that those ligaments with incomplete coverage on the deep layer, delivering a lower resistance, giving this function exclusively to the deep layer, and thus increasing the likelihood of breakage. It would be seen more frequently in the rectangular shapes of the surface layer, who would have a greater tendency to medial instability in ankle injury. Further studies are needed to confirm this possibility.

Currently the deep layer structure is not accessible surgically, but the surface layer should be restored when it is injured by the possibility to generate sequels and the good postoperative results (Jolin *et al*.; Hintermann). Studies that discredit the surgical resolution (Strömsöe *et al*., 1995) do not have a long-term monitoring of patients.

The deltoid ligament is probably injured with less frequency since it is a large, strong ligament with a wide attachment. Moreover, the osseous anatomy of the articulation contributes by limiting the abduction movement and external rotation.

Our study has a number of samples that are not representative of the population, but suitable for anatomical studies. It provides an important approach to clarify the current controversies that exist about the anatomy of the talocrural medial ligament.

CONCLUSION

Talocrural medial ligament is a structure strong, broad and have a large insertion. It is composed of a superficial and deep layer.

Important anatomical variations were found in the superficial layer of the deltoid ligament, from its morphology to its relation to the deep layer. It is a homogenous structure, without clearly-defined subdivisions and presents 3 types of shapes: trapezoidal, triangular and rectangular. The deep layer is consistent in its anatomy, rectangular shaped and, in the majority of cases, it is completely covered by the superficial layer.

There are many contradictions in the literature regarding the anatomy of the talocrural medial ligament, but most agree that it is an essentialstructure for stabilization and joint function.

ACKNOWLEDGEMENTS

The team would like to thank Juan Carlos Lopez MD, Mr. Marcos Valenzuela and Prof. Reinhard Putz MD, for your support, comments and assistance in carrying out this work.

SEPÚLVEDA, P. R.; CAPURRO, S. B.; MORENO, T. R.; GIESEN, F. L.; IBARRA, M. C.; SILVA, D. P.; TELIAS, N. A. & VEGA, P. E. Estudio morfométrico y variaciones anatómicas del ligamento medial de la articulación talocrural.***Int. J. Morphol., 30(1)***:162-169, 2012.

RESUMEN: El objetivo fue realizar un estudio descriptivo de la morfología, variaciones anatómicas y la morfometría del ligamento talocrural medial (o deltoídeo). Se disecaron 27 miembros inferiores obtenidos de amputaciones sin antecedentes de edad, sexo, ni morbilidad. Las mediciones se realizaron con un pie de metro, regla y compás, expresando los resultados en milímetros. Se describió la morfología del ligamento medial en su capa superficial, midiendo el tamaño y grosor del ligamento. Para la capa profunda se describió y midió la longitud (l), ancho (a) y espesor (e). Resultados: En la capa superficial se observó: forma trapezoidal = 66,7% (margen anterior = 30,5 mm; margen posterior = 27,6 mm; margen superior = 22,6 mm; margen inferior = 50,5 mm), forma rectangular= 19% (margen anterior = 19,3 mm; margen posterior = 27,2 mm, margen superior = 24,4 mm; margen inferior = 29,8 mm), forma triangular = 14,3% (margen anterior=37 mm, margen posterior = 37,8 mm; margen inferior = 48,3 mm). El espesor promedio de la capa superficial fue de 3,6 mm. La capa profunda del ligamento medial: l = 6.9 mm, a = 11 mm, e = 5,7 mm, presentó forma rectangular en el 100% de los casos. En el 76,2% de las muestras, la capa profunda estaba completamente cubierta por la capa superficial, sin embargo, en 23,8% la cobertura fue incompleta, mostrando la capa profunda por el ángulo posterior. La literatura es contradictoria respecto a la anatomía y variaciones del ligamento medial del tobillo. Existen importantes diferencias en su morfología, inserciones, subdivisiones y las relaciones entre las dos capas del ligamento deltoídeo. Conclusiones: Se encontraron importantes variaciones anatómicas en la morfología y la relación entre las capas superficial y profunda del ligamento deltoídeo.

PALABRAS CLAVE: Ligamento medial; Articulación talocrural; Anatomía.

REFERENCES

Barr, K. P. & Harrast, M. A. Evidence-based treatment of foot and ankle injuries in runners. *Phys. Med. Rehabil. Clin. N. Am., 16*:779-99, 2005.

Boss, A. P. & Hintermann, B. Anatomical study of the medial ankle ligament complex. *Foot Ankle Int., 23*:547-53, 2002.

Close, J. R. Some applications of the functional anatomy of the ankle joint. *J. Bone Joint Surg. Am., 38*:761-81, 1956.

Garrick, J. G. & Requa, R, K. The epidemiology of foot and ankle injuries in sports. *Clin. Sports Med., 7*:29-36, 1988.

Grath, G. B. Widening of the ankle mortise. A clinical and experimental study. *Acta Chir. Scand. Suppl., 263*:1-88, 1960.

Hintermann, B. Medial ankle instability. *Foot Ankle Clin., 8*:723-38, 2003.

Hintermann, B.; Sommer, C. & Nigg, B. M. Influence of ligament transection on tibial and calcaneal rotation with loading and dorsi-plantarflexion. *Foot Ankle Int., 16*:567-71, 1995.

Jolin, T.; Ribes, J.; Segura, F. & Subias, A. Rotura del ligamento deltoideo del tobillo. Evaluación clínico-quirúrgica. *Rev. Esp. Cir. Ost., 26*:307-11, 1991.

Klein, M. A. MR imaging of the ankle: normal and abnormal findings in the medial collateral ligament. *AJR Am. J. Roentgenol., 162*:377-83, 1994.

Lauge-Hansen, N. Ligamentous ankle fractures. Diagnosis and treatment. *Acta Chir. Scand., 97*:544-50, 1949.

Lin, C. F.; Gross, M. L. & Weinhold, P. Ankle syndesmosis injuries: anatomy, biomechanics, mechanism of injury, and clinical guidelines for diagnosis and intervention. *J. Orthop. Sports Phys. Ther., 36*:372-84, 2006.

Mengiardi, B.; Pfirrmann, C. W.; Vienne, P.; Hodler, J. & Zanetti, M. Medial collateral ligament complex of the ankle: MR appearance in asymptomatic subjects. *Radiology, 242*:817-24, 2007.

Milner, C. E. & Soames, R. W. The medial collateral ligaments of the human ankle joint: anatomical variations. *Foot Ankle Int., 19*:289-92, 1998.

Moore, K. L. & Dalley, A. F. *Clinically Oriented Anatomy*. 6th Ed. Philadelphia, Lippincott Williams & Wilkins, 2009.

Muhle, C.; Frank, L. R.; Rand, T.; Yeh, L.; Wong, E. C.; Skaf, A.; Dantas, R. W.; Haghighi, P.; Trudell, D. & Resnick, D. Collateral ligaments of the ankle: high-resolution MR imaging with a local gradient coil and anatomic correlation in cadavers. *Radiographics, 19*:673-83, 1999.

Muir, B. Myositis ossificans traumatica of the deltoid ligament in a 34 year old recreational ice hockey player with a 15 year post-trauma follow-up: a case report and review of the literature. *J. Can. Chiropr. Assoc., 54*:229-42, 2010.

Netter, F. H. *Atlas of Human Anatomy*. 4th Ed. Philadelphia, Saunders, 2006.

Renstrom, P. A. Persistently painful sprained ankle. *J. Am. Acad. Orthop. Surg., 2*:270-80, 1994.

Rouvière, H. & Delmas, A. *Anatomía Humana Descriptiva, Topográfica y Funcional.* 1a Ed. Barcelona, Masson, 2005.V.

Sarrafian, S. K. *Anatomy of foot and ankle.* 2nd ed. Philadelphia, Lippincott, 1994.

Standring, S. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 40th Ed. New York, Churchill Livingstone, 2008.

Stormont, D. M.; Morrey, B. F.; An, K. N. & Cass, J. R. Stability of the loaded ankle. *Am. J. Sports Med., 13*:295-300, 1985.

Strömsöe, K.; Höqevold, H. E.; Skjeldal, S. & Alho, A. The repair of a ruptured deltoid ligament is not necessary in ankle fractures. *J. Bone Joint Surg. Br., 77*:920-1, 1995.

Schneck, C.; Mesgarzadeh, M.; Bonakdarpour, A. & Ross, G. MR imaging of the most commonly injured ankle ligaments. Part I Normal anatomy. *Radiology, 184*:499-506, 1992.

Testut, L. & Latarjet, A. Anatomía Humana. 9a ed. Barcelona, Salvat, 1974. V. I.

Telias, A.; Moreno, R.; Ibarra, C.; Giesen, L.; Capurro,B.; Silva, P.; Sepúlveda, R. & Vega, E. Estudio morfométrico y variaciones anatómicas del ligamento talocrural lateral. *Int. J. Morphol., 28*:503-8, 2010.

Tornetta, P. 3rd. Competence of the deltoid ligament in bimalleolar ankle fractures after medial malleolar fixation. *J. Bone Joint Surg. Am., 82*:843-8, 2000.

van den Bekerom, M. P.; Mutsaerts, E. L. & van Dijk, C. N. Evaluation of the integrity of the deltoid ligament in supination external rotation ankle fractures: a systematic review of the literature. *Arch. Orthop. Trauma Surg., 129*:227-35, 2009.

van den Bekerom, M. P.; Oostra, R. J.; Alvarez, P. G. & van Dijk, C. N. The anatomy in relation to injury of the lateral collateral ligaments of the ankle: a current concepts review. *Clin. Anat., 21*:619-26, 2008.

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Received: 02-12-2011
Accepted: 29-12-2011