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Deltoid Ligament Study in Terms of its Shape and Size

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Abstract: ***There are two major ligamentous complexes of ankle joint which are appreciated both in MRI and cadaveric dissections. They are medial and lateral collateral ligaments. The lateral ligaments have three discrete parts, Anterior Talofibular, Posterior Talofibular and Calcaneofibular ligaments. The medial collateral (deltoid) ligament is attached to the tip, anterior and posterior borders of medial malleolus. It has superficial anterior (tibionavicular), intermediate (tibiocalcaneal), posterior fibres (posterior tibiotalar) and deeper fibers anterior tibiotalar ligament. Ankle sprains are most common in atheletes and in other sports like basketball, soccer, football and volleyball. Study of ligaments interms of its shape and size is helpful to understand the mechanism and extent of injury. It may also reconstructive surgeries to replace the damaged ligament. Study was conducted on 60 formalin fixed adult cadaveric lower limbs, irrespective of sex from the Department of Anatomy, Kempegowda Institute of Medical Sciences, Bangalore. Superficial component of Deltoid ligament described three different shapes: trapezoidal- 43(71.66%), rectangular- 12(20%) and triangular shaped- 5(8.3%) specimens. The mean values of anterior and posterior borders of superficial deltoid ligament were found to be statistically significant between rectangle and triangular and also between trapezoidal and rectangle. Also there was significant difference between the mean values of top border between trapezoidal and rectangular forms of deltoid ligament. There are not much literature available of ankle ligaments on Indian population. Thus, further studies on the morphometric of ligaments of ankle are required to compare the values and to draw further conclusions.***

Keywords: deltoid ligament, ankle sprains, tibionavicular, calcaneonavicular, morphometry

1. Introduction

The deltoid ligament is composed of a fan- shaped, vertical superficial layer and a short and more horizontal deep layer. The **superficial part** consists of the tibionavicular ligament anteriorly, the tibiocalcaneal ligament in the middle (originating 1 to 2 cm above the tip of the medial malleolus and inserting into the sustentaculum tali of the calcaneus), and the superficial tibiotalar ligament posteriorly. The **horizontal deep layer** of the deltoid ligament consists of the strong anterior and posterior tibiotalar ligaments.

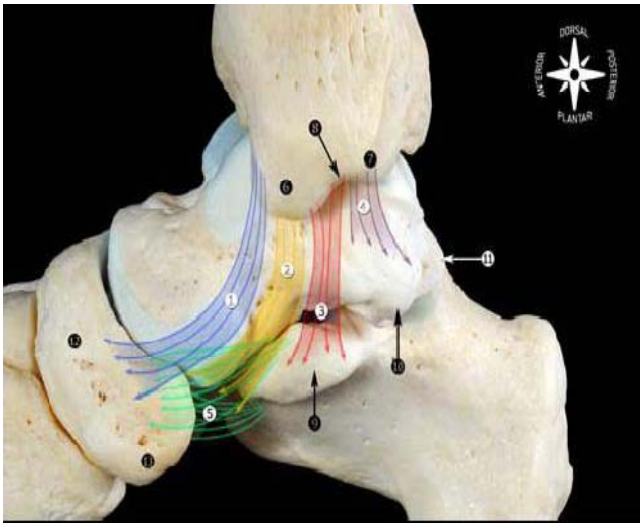


Figure 1: Schematic representation of the main components of the medial collateral ligament. 1.tibionavicular ligament, 2 tibiospring ligament, 3 tibiocalcaneal ligament, 4 deep posterior tibiotalar ligament , 5 spring ligament complex(plantar and superomedial calcaneonavicular ligaments) , 6 anteriro culliculus, 7 posterior culliculus, 8 interculliculus groove, 9 sustentaculum tali, 10 medial talar process, 11 lateral talar process , 12 navicular, 13 navicular tuberosity

The deep layer is more important to ankle stability than the superficial layer. During ankle motion, however all parts of the deltoid ligament function as a unit, giving static support to the ankle during abduction, eversion and pronation of the foot. The tibiocalcaneal and tibionavicular ligaments give medial ligamentous stability to both the talocrural and subtalar joints, whereas the deep tibiotalar ligaments are responsible for the medial stability of the talocrural joint only.

The medial collateral ligament (deltoid ligament) is a strong, triangular band, attached to the apex and the anterior and posterior borders of the medial malleolus.3 Similar to posterior talofibular ligament, the medial deltoid or medial collateral ligament is a mutifascicular ligament, originating from the medial malleolus to insert in the talus, calcaneus and navicular bone. The tendon of posterior tibial muscle covers the posterior and middle part of the deltoid ligament in much the same way as the peroneal tendon sheath is associated with the calcaneofibular ligament on the lateral side. The anatomical descriptions of the MCL (medial collateral ligament) vary widely in the literature, in general most of them agree that it is composed of two layers ; the superficial and deep.[1]

The ligament is crossed by the tendons of tibialis posterior and flexor digitorum longus. It is rarely injured alone, and when torn, is commonly associated with a fracture of the distal fibula. Chronic instability is rare. Isolated injuries to the deltoid ligament are very rare.

The superficial ligaments cross two joints, the ankle and the subtalar joint; the deep ligaments cross one joint, the ankle. The tibiocalcaneal ligament was described to constitute the superficial layer of the deltoid that spans the medial malleolus to the medial aspect of the calcaneus; the other three divisions, the anterior tibiotalar, posterior tibiotalar were described to attach the medial malleolus to the talus. Although the tibiocalcaneal ligament is extremely thin and

supports only negligible forces before failing, the tibiotalar ligaments are strong. Four components were superficial (tibiospring, tibionavicular, superficial posterior tibiotalar and tibiocalcaneal ligaments), of which only the tibiospring and tibionavicular ligaments were constant. Two bands were deep (deep posterior tibiotalar and deep anterior tibiotalar ligaments) , of which only deep posterior tibiotalar ligament was constant. tibiocalcaneal and tibiospring are the longest, tibiocalcaneal and posterior deep tibiotalar ligaments are the thickest of these ligaments.[2]

2. Aims, Materials And Methods

The main objective was to study the superficial fibers of **medial collateral (Deltoid) ligament** in terms of **its shape and size** by **dissection.**

Study was conducted on 60 formalin fixed adult cadaveric lower limbs, irrespective of sex from the Department of Anatomy , Kempegowda Insitute Of Medical Sciences, Bangalore

Cadavers with congenital abnormalities of ankle like club foot or congenital Talipus Equino Varus Shapes of the superficial component of medial deltoid ligament were also noted. The sizes of the superficial part of deltoid ligament interms of its borders were noted. Values were compared with previous studies for their statistical significance. The data obtained was analyzed by computing descriptive statistics like mean, standard deviation and percentages, arranged in tabular form and compared with the other studies available in the literature and conclusions were drawn.

3. Results

SUPERFICIAL LAYER: In the present study, superficial layer presented 3 distinct shapes: trapezoidal (or fan shaped), rectangular and triangular. Trapezoidal shape was found in 72%, the rectangular shape 20% and the triangular shape 8% of the study specimens. There was no other variation in the shape of the superficial layer.

Table 1: Number and Percentage of different shapes of Superficial layer of deltoid ligament

Shapes	N - 60	%
Trapezoidal	43	72
Rectangular	12	20
Triangular	5	8
Total	60	100

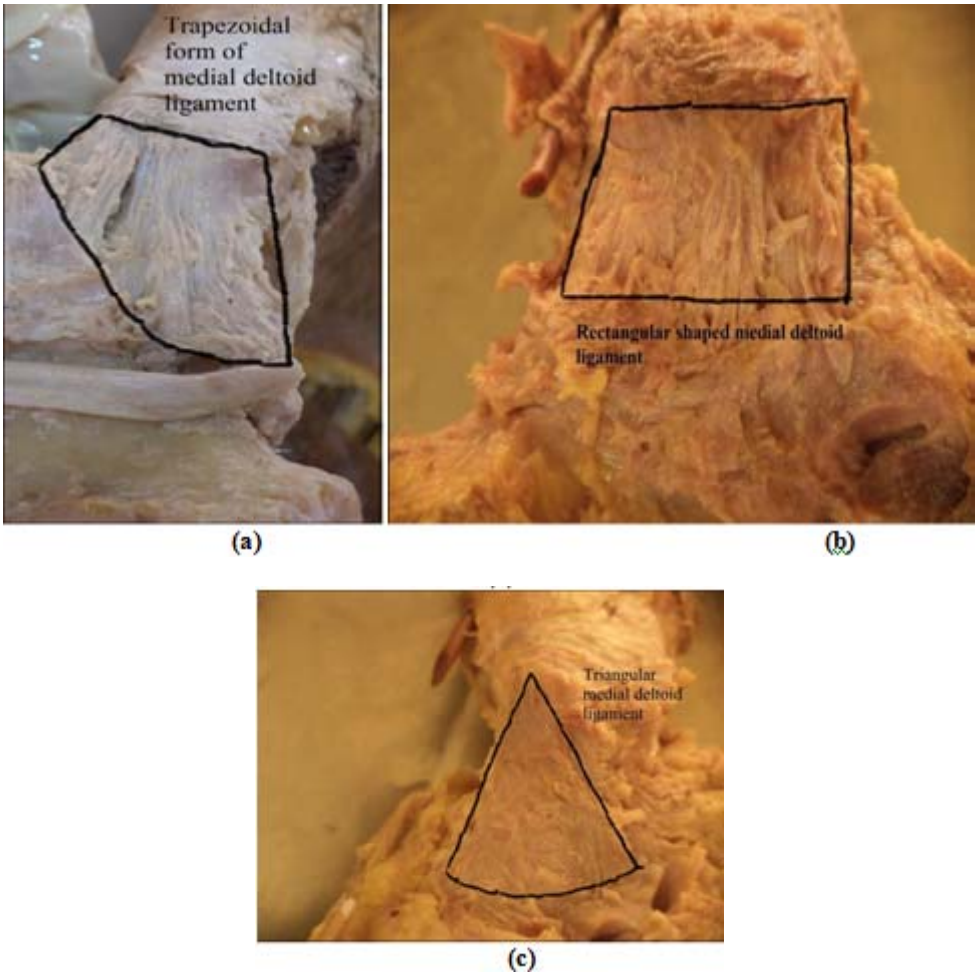
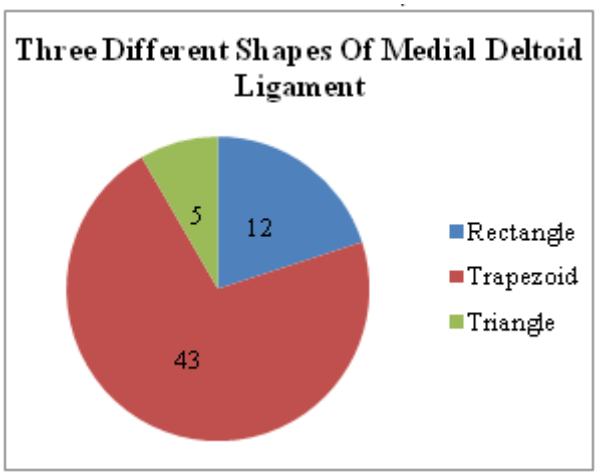


Figure 2: a) Trapezoidal shaped superficial medial deltoid ligament, b) Rectangular shape, c) Triangular shape



Representation 1: Pie diagram showing occurrence of different shapes of superficial layer of deltoid ligament

Proximal attachment : It is from the inferior margin of the tibial malleolus, and from there projects its fiber towards the inferomedial region and attaches from anterior to posterior - to the talus (anterior tibiotalar fibers), to the navicular (tibionavicular fibers), to the plantar calcaneonavicular ligament (tibiospring fibers), to the calcaneus (tibiocalcaneal fibers), posteriorly again to the talus (posterior tibiotalar fibers).These fibers are distributed homogeneously and they do not present clear subdivisions between one another, forming a continuous ligament with a wide distal attachment.

Distal attachment: the distal attachment was more extensive than proximal attachment for trapezoidal and triangular shaped. In rectangular shaped deltoid ligament, the fibers do not have a strong tendency to open up towards inferior.This superficial layer was closely related to the synovial sheaths of Tibialis posterior and Flexor Digitorum Longus tendons. The articular capsule was also very closely related to the superficial layer.

Table 2: Mean values of anterior, posterior, top and bottom values of superficial layer in different shapes of medial collateral or deltoid ligament

	Trapezoidal	Rectangular	Triangular
Anterior	29.03±4.12	25.84±5.9	36.78±1.46
Posterior	29.12±5.2	26.42±5.08	35.4±2.16
Top	25.85±2.92	23.03±2.46	--
Bottom	48.49±5.4	27.79±8.08	49.92±2.86

From the values of the above table, it is confirmed that irrespective of the shape, all forms had a wider attachment at the bottom to one of the tarsal bone and narrow attachment at the top to the medial malleolus, giving it a fan shaped emerging fibers.

Table 3: Comparison Of Shapes Of Superficial Fibers Of Deltoid Ligament In Right And Left Ankles

Side	Trapezoidal		Rectangular		Triangular	
	n	%	n	%	n	%
Right	21	49	8	67	5	100
Left	22	51	4	33	-	-
Total	43	100	12	100	5	100

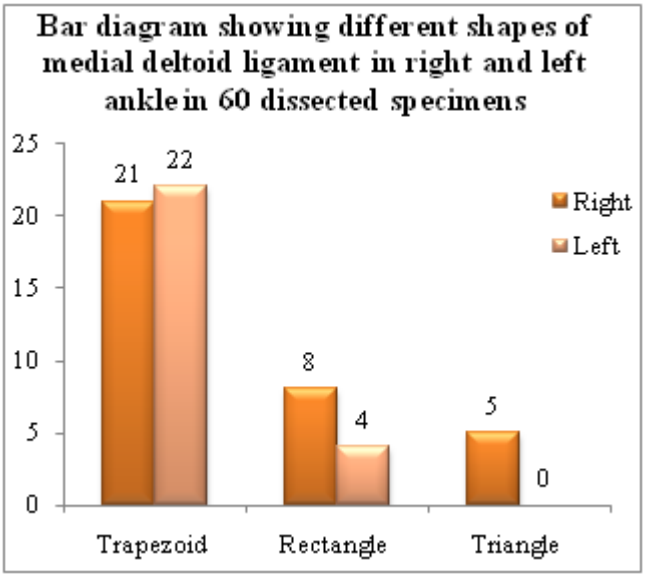
We found all five **triangular** shaped superficial component of deltoid ligament in **right ankle specimens**.

Table 4: Comparison of medial deltoid ligament parameters between left and right side

Parameter Medial deltoid ligament	*Side*	*n*	*Mean*	*Std dev*	*SE of Mean*	*Mean Difference*	*t*	*P - Value*
Anterior	Left	26	27.92	4.69	0.92	-1.962	-1.469	0.147
	Right	34	29.89	5.43	0.93			
Posterior	Left	26	29.15	6.41	1.26	0.057	0.041	0.968
	Right	34	29.10	4.42	0.76			
Top	Left	26	25.75	3.26	0.64	0.747	0.878	0.384
	Right	30	25.00	3.10	0.57			
Bottom	Left	26	46.01	9.46	1.85	2.887	0.062	0.293
	Right	33	43.12	11.02	1.92			

The mean difference of the mean values of anterior, posterior, top and bottom bordered values of superficial fibers of medial deltoid ligament between the right and left ankle was found to be 1.962, 0.057, 0.747 and 2.887 respectively.No significant difference was observed between left and right side with respect to the various medial deltoid ligament parameters (P>0.05)

Representation 3: Comparison of different shapes of deltoid ligament with right & left



Comparison of DIFFERENT BORDERS of medial deltoid ligament parameters among different shapes:

1. Comparison of Medial deltoid ligament – Anterior border

The highest value of anterior border of rectangle and trapezoidal forms was observed to be almost same.

Table 5: Descriptive statistics for the anterior border values of deltoid ligament in different shapes

Medial - Anterior	*n*	*Mean*	*Std Dev*	*SE of Mean*	*95% CI for Mean*		Min	Max
					Lower Bound	*Upper Bound*		
Rectangle	12	25.84	6.17	1.78	21.92	29.76	17.60	37.40
Trapezoid	43	29.03	4.17	0.64	27.74	30.31	20.10	37.50
Triangle	5	36.78	1.63	0.73	34.75	38.81	35.40	39.60

Higher mean Medial –Anterior was recorded in triangle shape followed by trapezoid and rectangular shape respectively. The difference in mean medial – anterior among the groups was found to be statistically significant (P<0.001).

ANOVA:

Table 6: ANOVA test to see the significance between and within the groups

Source of variation	*Df*	*Sum of Squares*	*Mean Square*	*F*	*P-Value*
Between Groups	2	422.297	211.149	10.390	<0.001*
Within Groups	57	1158.379	20.322	---	---
Total	59	1580.677	---	---	---

*denotes significant difference

Table 7: Mutiple comparisons using Bonferroni test for pair- wise significance of anterior border values in different shapes of deltoid ligament

(I) Shape	*(J) Shape*	*Mean Difference (I-J)*	*P-Value*	*95% CI for Mean Diff*	
				Lower Bound	*Upper Bound*
Rectangle	Trapezoid	-3.184	0.104	-6.81	0.45
	Triangle	-10.938	<0.001*	-16.86	-5.02
Trapezoid	Triangle	-7.754	0.002*	-13.01	-2.50

*denotes significant difference

The difference in mean medial – anterior was found to be statistically significant between rectangle and triangle (P < .001) as well as between trapezoid and triangle (P<0.01).

2. Comparison of medial deltoid ligament- posterior border

Table 8: Comparison of Medial deltoid ligament- posterior border parameters in different shapes

Medial - Posterior	*n*	*Mean*	*Std Dev*	*SE of Mean*	*95% CI for Mean*		Min	Max
					Lower Bound	*Upper Bound*		
Rectangle	12	26.43	4.26	1.23	23.72	29.13	19.80	33.50
Trapezoid	43	29.14	5.27	0.80	27.52	30.77	3.10	37.50
Triangle	5	35.40	2.41	1.08	32.40	38.40	32.60	38.20

Higher mean medial – posterior was recorded in **triangle shape** followed by trapezoid and rectangle shape respectively. The difference in mean medial – anterior among the groups was found to be statistically significant (P <0.01). Multiple comparisons using Bonferroni test for pair – wise significance is given below:

Table 9: Mutiple comparisons using Bonferroni test for pair- wise significance of posterior border values in different shapes of deltoid ligament

(I) Shape	*(J) Shape*	*Mean Difference (I-J)*	*P-Value*	*95% CI for Mean Diff*	
				Lower Bound	*Upper Bound*
Rectangle	Trapezoid	-2.719	0.291	-6.69	1.26
	Triangle	-8.975	0.004*	-15.46	-2.49
Trapezoid	Triangle	-6.256	0.029*	-12.01	-0.50

*denotes significant difference

The difference in mean medial- posterior was found to be statistically significant between rectangle and triangle also between trapezoidal and triangular (P<0.05).and not between rectangle and trapezoidal(P >0.05)

3. Comparison of medial deltoid ligament parameters- top border

Table 10: Comparison of Medial deltoid ligament- top parameters in different shapes

Medial - Top	*n*	*Mean*	*Std Dev*	*SE of Mean*	*95% CI for Mean*		Min	Max
					Lower Bound	*Upper Bound*		
Rectangle	12	23.03	2.57	0.74	21.40	24.66	19.40	27.30
Trapezoid	43	25.85	2.96	0.45	24.94	26.76	19.50	30.50
Triangle	5	----	---	---	---	---	---	---

Since there are no top bordered values for triangular shaped superficial component of medial deltoid ligament, only the trapezoidal and triangular forms are taken for comparison. Higher mean value is observed in trapezoidal shaped as compared to rectangular shaped.

Table 11: T test to check the level of significant difference if any between rectangle and trapezoidal shape of top values in different shapes of deltoid ligament

Shape	*N*	*Mean*	*Std dev*	*SE of Mean*	*Mean Difference*	*t*	*P-Value*
Rectangle	12	23.03	2.57	0.74	-2.820	-3.001	0.004*
Trapezoid	43	25.85	2.96	0.45			

*denotes significant difference

The level of difference in the top values between rectangular and trapezoidal forms of deltoid ligament was found to be statistically significant (P<0.01)

4. Comparison of medial deltoid ligament – bottom bordered values

Table 12: Comparison of medial bottom bordered values in different shapes of deltoid ligament

Medial - Bot	*n*	*Mean*	*Std Dev*	*SE of Mean*	*95% CI for Mean*		Min	Max
					Lower Bound	*Upper Bound*		
Rectangle	12	27.79	8.43	2.43	22.43	33.15	20.90	51.30
Trapezoid	42	48.48	5.54	0.85	46.75	50.21	29.50	58.90
Triangle	5	49.92	3.20	1.43	45.95	53.89	45.60	54.50

Higher mean bottom value was found in triangular form followed by trapezoidal and rectangular forms.

Deep Components of Medial Deltoid Ligament

The anterior and posterior tibiotalar ligaments are the deep components of medial deltoid ligament complex. Only after the complete removal of the superficial component of the deltoid ligament is the deep component visible. Or the ankle joint has to be disarticulated for its morphometric analysis. As our objective was to study only the superficial component, we didn't extend our dissection to disarticulate the joint. However, the deep components were partially visible only from the posterior aspect of the superficial component of the medial deltoid ligament.

4. Discussion

In contrast to the lateral ligaments of the ankle which have been well described, studies on medial deltoid ligament are limited. This study will analyze and contribute information which is to be used for surgical treatment. The medial ankle ligaments are important stabilizers not only against valgus forces but also against rotator forces and their insufficiency may lead to degenerative joint disease in the ankle. The description of the superficial and deep components of the medial deltoid ligament by various studies has been tabulated in the table below.

Table 13: Comparison of descriptions of superficial and deep components of medial deltoid ligament of present study with the previous studies

Studies	*Superficial component*	*Deep component*	*Morphology*
Testut & Latarjet (1974)	Homogeneous, trapezoidal or fan shaped with wide distal attachment	Present. Separated from the superficial component by connective and adipose tissue	Rectangular, triangular and trapezoidal
Hintermann (2003)	Tibionavicular, tibiospring and tibiocalcaneal ligaments	Anterior and posterior tibiotalar ligaments	
Rouviere & Delmas (2005)	Homogeneous, trapezoidal structure with attachments to talus, navicular, calcaneus and calcaneonavicular ligament.		
Standring (2008)	Triangular shape attaching to the talus, calcaneus, navicular and plantar calcaneonavicular ligament	Visible from the anterior angle of the superficial layer.	
Moore and Dalley (2009)			Trapezoidal structure that projects fibres towards the talus, navicular and calcaneus forming anterior tibiotalar, tibionavicular, tibiocalcaneus and posterior tibiotalar ligaments. But doesnot differentiate as superficial or deep components
Present study	Tibionavicular, tibiocalcaneal and tibiospring ligaments	Anterior and Posterior Tibiotalar ligaments	Trapezoidal, rectangular and triangular

Hintermann explains tibiotalar as the strongest ligament whereas Sarrafian, Milner & Soames claim that Calcaneonavicular or spring ligament would be the strongest. In a very recent report of long term results of ankle fractures at thirteen years, deltoid ruptures were found to have better prognosis than medial malleolar fractures.[3]

In a study on 27 lower limbs, superficial morphology of the medial deltoid ligament was described measuring the size and its thickness. The deep layer was described and the length (l), width (w) and thickness (t) was measured. Superficial layer was trapezoidal in 70.4%, rectangular in 18.5% and triangular in 11.1%. The average anterior, posterior, top and bottom margin values are measured. Deep layer of the medial deltoid ligament was rectangular form in 100% of the cases. The length, width and thickness were measured. In 76.2% of the specimens, the deep layer was covered completely by the superficial layer, however, in 23.8% the coverage is in complete, showing the deep layer by posterior angle.[4]

Table 14: Different shapes of superficial component of medial deltoid ligament as described by various authors their study compared with the present study

Studies	*Shapes of superficial layer*
Rodrigo Sepulveda P et al (2012)	Trapezoidal , rectangular and triangular
Testut & Latarjet (1974)	Trapezoidal, rectangular and triangular
Standring (2008)	Triangular
Rouviere & Delmas (2005)	Trapezoidal
Moore & Dalley (2009)	Trapezoidal
Present study	Trapezoidal, rectangular and triangular

With regard to the shape of the superficial layer of deltoid ligament, Standring mentions only triangular shape, Rouviere & Delmas and Moore & Dalley only discussed the trapezoidal or fan shaped. Thus, our findings coincided with Testut & Latarjet and Rodrigo Sepulveda et al who mentions about trapezoidal, rectangular and triangular shapes.[5]

In a study on 27 lower limbs, superficial morphology of the medial deltoid ligament was described measuring the size and its thickness. The deep layer was described and the length (l), width (w) and thickness (t) was measured. Superficial layer was trapezoidal in 70.4%, rectangular in 18.5% and triangular in 11.1%. The average anterior , posterior, top and bottom margin values are measured. Deep layer of the medial deltoid ligament was rectangular form in 100% of the cases. The length, width and thickness was measured. In 76.2% of the specimens, the deep layer was covered completely by the superficial layer, however, in

23.8% the coverage is in complete, showing the deep layer by posterior angle.[4]

Table 14: Average measurements (mean ±SD in mm) of the edges of the superficial component of the deltoid ligament of the present study compared with Rodrigo Sepulveda study results.

	Trapezoid		Rectangular		Triangular	
Studies	Rodrigo Sepulveda P	Present study	Rodrigo Sepulveda P	Present study	Rodrigo Sepulveda P	Present study
Anterior	30.6(±10.3)	**29.03±4.12**	21(±7.2)	**25.84±5.9**	37(±10.6)	**36.78±1.46**
Posterior	28.5(±8.5)	**29.12±5.2**	24.8(±7.3)	**26.42±5.08**	37.8(±3.9)	**35.4±2.16**
Top	22.5(±3.7)	**25.85±2.92**	22.7(±6.9)	**23.03±2.46**	--	--
Bottom	48.4(±8.9)	**48.49±5.4**	28.2(±7.6)	**27.79±8.08**	48.3(±6.4)	**49.92±2.86**

As we compare the values, the measurements of the borders of trapezoidal shaped deltoid ligament of the present study were almost in accordance with the previous study. But the values of the **rectangular** shaped deltoid in the present were **lesser** and the values of the **triangular** shaped were **greater** than the previous studies.

Regarding measurements, there were not much studies. Boss & Hintermann measured the subdivisions of the deltoid complex on 12 cadaveric specimens. Making a rough comparison, we see the differences, the anterior edge of the surface layer, measured on average 29.03mm (SD-) which was roughly same as Rodrigo Sepulveda P which measured on average 29.5mm (SD 10.5mm), while the anterior tibiotalar ligament of Boss AP measured 16.1mm (SD 6.8 mm). The posterior edge measured 29.12 mm (SD) and according to Rodrigo Sepulveda P 26.9mm (SD 8.6mm) and according to Boss AP 20mm (SD 4.3mm).[5]

However, with respect to the deep layer, there were discrepancies. Rouviere & Delmas describes the deep layer as being visible from the posterior side of the ligament. But, we found only partial appearance of the deep layer from the posterior side in around 10% of the cases. In the rest of the specimens, 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 was in favour of it. Every deep layer which was visible was through the posterior side only.[6]

The deep layer of the deltoid ligament is known for its **invariability,** based on the fact that it is the main stabilizer of the ankle. Superficial layer of the deltoid ligament is an essential reinforcement to resistant potential lesion. Hence, in those ankles where superficial layer was incompletely covering the deep layer, the function of resisting the force of lesion completely falls on deep layer, thus it increases the likelihood of breakage of ligament.[5]

Presently the deep layer of the ligament is not accessible surgically, but the surface layer should be restored when it is injured. Our study has a number of samples that are not representative of the population, but they are suitable for the anatomical studies.

5. Conclusion

Superficial component of Deltoid ligament described three different shapes: trapezoidal- 43(71.66%), rectangular- 12(20%) and triangular shaped- 5(8.3%) specimens.

The mean values of anterior and posterior borders of superficial deltoid ligament were found to be statistically significant between rectangle and triangular. Also, between trapezoidal and rectangle. Also there was significant difference between the mean top bordered values between trapezoidal and rectangular forms of deltoid ligament.

Few fibres of superficial component of deltoid attached to the navicular are called tibionavicular ligament. Few fibres blended with the calcaneonavicular ligament. These are called tibiospring ligament. Few fibres reached distally to the calcaneum. These fibers are called tibiocalcaneal ligament. The dimensions of medial collateral ligaments determined in this study are in general agreement with those reported by other investigators with minimal variations. This suggests that they are a reasonable reflection of population values present in the average population.

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