How to Cite:
Kumar, S., Sham Kishore, K., Alva, A. B. R., Kumar, A., & Nambiar, S. (2022). An anatomical and morphological analysis of ligaments of talocrural joint and its articular surfaces. *International Journal of Health Sciences*, *6*(S4), 6215–6248. https://doi.org/10.53730/ijhs.v6nS4.9604

An anatomical and morphological analysis of ligaments of talocrural joint and its articular surfaces

Dr Shishir Kumar
Professor, Department of Anatomy, Kanachur Institute of Medical Sciences, Mangalore
Corresponding author email: dr.shishirkumar4142@gmail.com

Dr Sham Kishore K
Professor, Department of Forensic Medicine, G.R.Medical College, Mangalore

Dr Avin B R Alva
Assistant Professor, Department of Community Medicine, K.S.Hegde Medical Academy, Mangalore

Dr Arunachalam Kumar
Ex-HOD, Department of Anatomy, K.S.Hegde Medical Academy, Mangalore.

Dr Satheesha Nambiar
Ex-Professor, Department of Anatomy, K.S.Hegde Medical Academy, Mangalore.

***Abstract*---**Background: Talocrural joint is one of the most important joint that has evolved significantly. The entire weight of the body is taken up by these joints and that's why it had to evolve on an enormous scale. This study puts in a sincere effort to understand the anatomical and morphological aspect of the ligaments and its articular surfaces. Aims and Objectives: To study the anatomy and morphometry of a. Tibiotalar and fibulotalar articulations. b. Ligaments of the talocrural joint. Materials and Methods: Thirty formalin fixed human ankles were dissected which was available in the Department of Anatomy, which included nineteen male and eleven female specimen. Male and female ankles were categorized and also right from the left. Results: The morphometric analysis, squatting facets analysis and the radiological analysis has been done and reported. Conclusion: The results provide conclusive evidence that the difference is there in some aspects when compared to that of the other study.

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.
Manuscript submitted: 27 March 2022, Manuscript revised: 9 May 2022, Accepted for publication: 18 June 2022

***Keywords*---**morphometry, anatomy, talocrural, ankle, joint, ligaments.

Introduction

The talocrural joint is a major weight bearing joint of the body. The weight of the body is transmitted from the tibia and fibula to the talus which distributes the weight anteriorly and posteriorly within the foot. One sixth of the static load of the leg is carried by the fibula at the tibiofibular joint[1]. These require a high degree of stability which is determined by the passive and dynamic factors[2]. The passive stability depends on the contour of the articular surfaces, the integrity of the collateral ligaments, the integrity of the distal tibiofibular ligaments, the reticular system around the ankle and the crossing and attached tendon tunnels. The dynamic stability is conferred by gravity, muscle action, and the reaction between the foot and the ground.

Talocrural joint is an approximately uniaxial joint[3]. Although it is considered to be a simple hinge, its axis of rotation slightly changes, during dorsiflexion and plantar flexion. Starting from the plantigrade position, the normal range of dorsiflexion is 10° when the knee is straight and 30° with the knee flexed. The range of normal plantar flexion is 30°. Dorsiflexion results in the joint adopting the ‘close-packed' position[7], with maximal congruence and ligamentous tension; from this position. All major thrusting movements are exerted, in walking, running and jumping. The malleoli grip the talus, and even in relaxation no appreciable lateral movement can occur without stretch of the inferior tibiofibular syndesmosis and slight bending of the fibula. The superior talar surface is broader in front, and in dorsiflexion the malleolar gap is increased by slight lateral rotation of the fibula, by ‘give' at the inferior tibiofibular syndesmosis and gliding at the superior tibiofibular joint.

The lower end of tibia along with its medial malleolus and the lateral malleolus of the fibula form a deep recess to accommodate the body of talus. The mortise formed by the lower end of tibia and the fibula is usually considered syndesmosis. The tibiofibular joints permit only slight movement. Due to the varying slope of the talar lateral malleolar surface, the fibula rotates laterally a little bit during dorsiflexion at the ankle, the bones being also slightly separated. Slight bending or torsion of the fibular shaft may permit movements at the distal tibiofibular joint. The proximal tibiofibular joint also helps.

The empirical axis of ankle joint passes distal to tips of malleoli at 5 mm ± 3 mm range, (0 to 11 mm) distal to the tip of medial malleolus and 3 mm ± 2 mm range (0 to 12 mm) distal to and 8 mm ± 5 mm anterior to the tip of lateral malleolus[3]. The axis is inclined downwards and laterally in the frontal plane and is rotated posterolaterally in the horizontal or transverse plane. In the frontal plane, the angle between empirical axis of the ankle and midline of the tibia is 82.7 degrees ± 3.7 degrees, with a range of 74 to 94 degrees in the transverse plane, the angle of ankle axis with the transverse axis of the knee is 20 to 30 degrees. Some workers recognized two axis to the ankle joint[4,5,6,8]. A dorsiflexion axis inclined downwards and laterally and a plantar flexion axis included downward and medially. The changeover occurs within a few degrees of the neutral position of the talus.

Habitual squatting has long been recognized to alter the skeletal morphology of the lower limb. Squatting is a resting postural complex that involves hyperflexion at the hip and knee and hyperdorsiflexion at the ankle and subtalar joints. During locomotion, the foot is rarely dorsiflexed sufficiently to bring the anterior border of the inferior extremity of the tibia into contact with the dorsum of the neck of the talus. Thus modifications of the neck of the talus and the distal tibia indicating their habitual contact have been taken as evidence of the extreme dorsiflexion of the ankle that occurs in squatting[9].

It is important to know some basic anatomy of the distal part of tibia and fibula bones along with the talus since all the ligaments and articular surface involved in the formation of talocrural joint is situated in here.

Lower end of tibia: The distal end of the tibia is expanded slightly and has anterior, medial, posterior, lateral and distal surfaces. It also has inferomedial projection called as the medial malleolus. The smooth anterior surface bulges beyond the distal surface and is separated by a narrow groove. The capsule of the ankle joint is attached to an anterior groove near the articular surface. The medial surface is smooth, continuous above with the medial surfaces of the shaft and below with the medial malleolus and is subcutaneous. The posterior surface is smooth and extends to the posterior surface of the medial malleolus. It also is continuous with the posterior surface of the shaft. The lateral surface has a triangular fibular notch; its anterior and posterior borders converge proximally to the interosseous border. The anterior and posterior tibiofibular ligaments are attached to the edges of the notch. The distal surface, articulating with the talus, is wider in front, concave sagittally and transversely slightly convex, somewhat like a saddle-shape. Medially it continues as the malleolar articular surface. This articular surface may extend sometimes into a groove that separates it from the anterior surface of the shaft. Such groove like extensions, are squatting facets, and they articulate with reciprocal talar facets in extreme dorsiflexion. These features have been used in the evaluation of the racial origins of skeletal material.

Medial malleolus: The medial malleolus has a smooth lateral surface with a crescent shaped facet that articulates with the medial talar surface. The distal border is pointed anteriorly, posteriorly depressed and gives attachment to the deltoid ligament. The medial malleolus ends slightly higher than the lateral malleolus, and also more anteriorly than the latter. The capsule of the ankle joint is attached to its anterior surface.

Lower end of fibula: The distal end of the fibula forms the lateral malleolus which projects distally and posteriorly than the medial malleolus. Its lateral aspect is subcutaneous while its posterior aspect has a broad groove with a prominent lateral border. Its anterior border is continuous with the tibial inferior border. The medial surface has a triangular articular facet, convex vertically, its apex directed distally, and it articulates with the lateral articular surface of the talus. Behind this facet is a rough malleolar fossa. The posterior tibiofibular ligament proximally and the posterior talofibular ligament distally, are attached posterior to the fossa.

The anterior talofibular ligament is attached to the anterior surface of the lateral malleolus; the calcaneofibular ligament is attached to the notch just anterior to its apex.

Talus: The talus is the link between the foot and leg, through the ankle joint and it has the following parts:

Head is directed distally and somewhat inferomedially, the head has a distal surface; its long axis is also inclined inferomedially and articulates with the proximal navicular surface. The plantar surface has three articular areas, separated by smooth ridges. The posterior is the largest, is oval and slightly convex and rests on a shelf-like medial projection of calcaneus, the sustentaculum tali. Anterolateral to this articular surface and usually continuous with it, is a flat articular facet which rests on the anteromedial part of the dorsal calcaneal surface; distally it continues into the navicular surface. Between the two calcaneal facets, articular cartilage covered talar head is in contact with the plantar calcaneonavicular ligament.

The neck is a narrow, medially inclined region present between the head and body of talus. Its rough surface provides attachment to the ligaments. The capsule of the ankle joint is attached distally to its dorsal surface. A part of trochlear surface and medial articular facet of the talar body may extend onto the neck. The anterior talofibular ligament is attached on the lateral aspect of the neck, and spreads around the adjacent anterior border of the lateral surface. ‘Squatting facet' is commonly seen on the talar neck in those individuals who habitually adopt the squatting position and it articulates with the anterior tibial margin in extreme dorsiflexion and may be double.

The body is cuboidal, the trochlear surface articulates with the distal end of the tibia. It is convex anteroposteriorly, gently concave transversely, wide anteriorly and narrows posteriorly. The triangle shaped lateral surface is smooth and vertically concave for articulation with the lateral malleolus and is continuous with the trochlear surface. Proximally, the medial surface is covered by a comma-shaped facet, which is deeper in front and articulates with the medial malleolus. The plantar surface articulates with the dorsal calcaneal surface by an oval concave facet, its long axis is directed distolaterally at an angle of approximately 45° with the median plane. The medial border of the trochlear surface is straight. Its lateral border inclines medially in its posterior part and is often broadened into a small elongated triangular area which is in contact with the posterior tibiofibular ligament in dorsiflexion. Since our study is based upon the ligaments morphometry some basic anatomy of ligaments of ankle joint should be known.

Capsule of the talocrural joint: The fibrous capsule is thin in front and behind. It is attached proximally to the borders of the tibia, medial and the lateral malleolus, and distally to the talus near the margins of its trochlear surface, except anteriorly where it reaches the dorsum of the talar neck. The capsule is strengthened by strong collateral ligaments in the sides.

Ligaments of the inferior tibiofibular joint

Anterior tibiofibular ligament: It is a flat fibrous ligament. It originates from the longitudinal tubercle on the anterior border of the lateral malleolus and from the lower segment of the anterior border of the shaft of the fibula and are inserted on the anterior edge of the triangular fibular notch. Some fibres reach the anterior surface of the tibia. The fibres are directed upwards and medially.

Posterior tibiofibular ligament: It has two components, superficial and deep. The superficial component originates from the posterior border of the tubercle located above. The fibres are directed upward and medially and are inserted on the posterolateral tibial tubercle. The deep component is the transverse ligament. It has a twisted arrangement. It originates from the round posterior fibular tubercle located above the digital fossa. The fibres are directed upwards, medially and posteriorly. At the posterior border of the tibial articular surface, the fibres change the direction and have a transverse arrangement. It is inserted on the lower part of the posterior border of the tibial articular surface and reaches the medial border of the medial malleolus.

Lateral ligaments of the ankle

Anterior talofibular ligament: It is a flat, quadrilateral and a relatively strong ligament. It has two bands separated by some vascular branches. The ligament originates from the inferior oblique segment on the anterior border of the lateral malleolus. It courses anteromedially and inserts on the talar body just anterior to the lateral malleolar articular surface.

Posterior talofibular ligament: It is a very strong ligament and has a near horizontal position. The ligament originates on the medial surface of the lateral malleolus from the lower segment of the digital fossa. It courses horizontally and is inserted on lateral surface of the talus in a groove along the posteroinferior border of the lateral malleolus up to its mid segment and also to the posterior surface of talus.

Calcaneofibular ligament: It is a strong, cordlike or flat oval ligament. It originates from the lower segment at the anterior border of the lateral malleolus. In neutral position of the foot it runs posteriorly, inferiorly and medially. It is inserted on a small tubercle located on the posterior aspect of the lateral calcaneal surface.

Medial ligament of the talocrural joint: The medial collateral ligament also called as the deltoid ligament is a strong, triangular band, attached to the apex and to the anterior and posterior borders of the medial malleolus. Of its superficial fibres, the anterior also called the tibionavicular, passes forward to the navicular tuberosity, behind they blend with the medial margin of the plantar calcaneonavicular ligament. Intermediate also called the tibiocalcaneal fibres descend almost vertically to the entire length of the sustentaculum tali. Posterior fibres also called the posterior tibiotalar, passes posterolaterally to the medial side of the talus and its medial tubercle. The deep fibres (anterior tibiotalar) pass from the tip of the medial malleolus to the non-articular part of the medial talar surface.

Almost in all living primates, there is a general tendency for erect posture and some bipedalism. This tendency is mainly associated with sitting, leaping, standing and occasionally bipedal walking. The advantage of bipedal locomotion is that, the hands are freed for carrying the objects and has become an efficient means of covering long distances. A flexible, generalized limb anatomy, allows most primates to practice a number of locomotion behaviors that have been lost in some specialized mammals.

Bipedalism is certainly a feature that evolved fairly early in human history. A tibia attributed to *Australopithecus anamensis* is around 4 million years old and indicates that this species was bipedal[10]. An efficient bipedal adaptation has been obtained by altering the foot to act as a stable support instead of a grasping limb. It has been examined that, the form and function of the ankle in a variety of species and this knowledge is used this to draw some inferences about locomotion in early hominins. The relevant bones (tibia and talus) in great apes, humans, and extinct hominins ranging from *Australopithecus anamensis* to *Homo erectus* were studied and found that the ankle morphology was different in humans. The modern human ankle suggests that they were better adapted for upright walking than to climb trees.

Modern humans are the only known obligate bipedals, where the body weight is transmitted to the ground through the lower limbs; each of them sharing 50% of the body weight in upright posture. The problem with bipedal walking is to maintain the balance of the body as well as to provide stability to the lower limb especially when one limb is off the ground. In this regard the role of the talocrural joint cannot be ignored.

The ankle joint is one of the most frequently injured joint[11]. The ankle injuries occur in the plantar flexed position of the foot. The lateral ligament is injured more often when compared to medial. A sprained ankle results due to tear of anterior talofibular and calcaneofibular ligaments when the foot is twisted in lateral direction. In forcible eversion of the foot the deltoid ligament may be torn. At times the deltoid ligament pulls the medial malleolus thereby causing avulsion fracture of the malleolus. Potts fracture occurs when the foot is caught in the rabbit hole in the ground and the foot is forcibly everted. In this condition at first there is an oblique fracture of shaft and lateral malleolus of fibula. The strong eversion pull on the deltoid ligament causes transverse fracture of medial malleolus. If the tibia is carried anteriorly, the posterior margin of the distal end of the tibia is also broken by the talus producing a trimalleolar fracture.

Conventionally X-ray techniques have been used to diagnose ligament injuries. Magnetic resonance (MR) imaging has opened new horizons in the diagnosis and treatment of many musculoskeletal diseases of the ankle and foot. It demonstrates abnormalities in the bones and soft tissues before they become evident at other imaging modalities. A limited account of studies is available on ligaments and articular surfaces of the talocrural joint. So in order to gather more information and to compare with the available data, a study of the above topic is helpful.

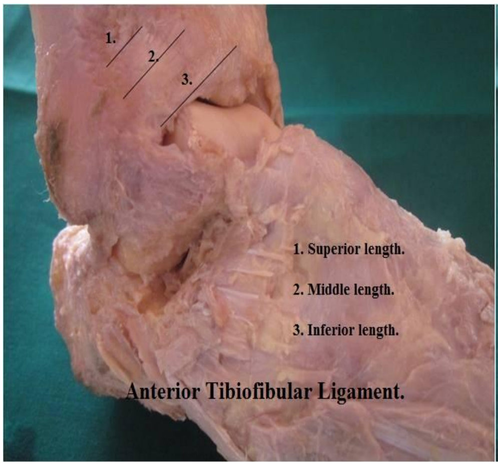
Aims and objectives of study

1. To study the anatomy and morphometry of
   a. Tibiotalar and fibulotalar articulations.
   b. Ligaments of the talocrural joint.
2. To study the variations, if any in the articular surface and ligaments in different specimen, as well as on the contralateral side and sexes.
3. To study the radiological features of normal and abnormal talocrural joint.
4. To compare the data with the standard data available.

Material and Methods

Thirty formalin fixed human ankles were dissected which was available in the department of anatomy, K.S.Hegde medical academy which included nineteen male and eleven female specimen. Male and female ankles were categorized and also right from the left. Incision was made on the anterior median plane and posterior median plane from caudal one third of leg to proximal one third of foot. Skin was reflected all around the talocrural joint till the meeting of dorsal surface and plantar surface. All the soft tissues including the muscles were dissected and reflected on the anterior, posterior, medial and lateral surfaces. The soft tissue tunnel which surrounds the tendons of muscles is in intimate relation with the underlying ligaments of the talocrural joint.

On the anterior, aspect the joint capsule was reflected and anterior tibiofibular ligament was exposed. The measurement was taken. The length was taken at three levels namely superior, middle and inferior. The breadth was taken at three different levels namely medial end, middle and at the lateral end. Then the thickness was measured.



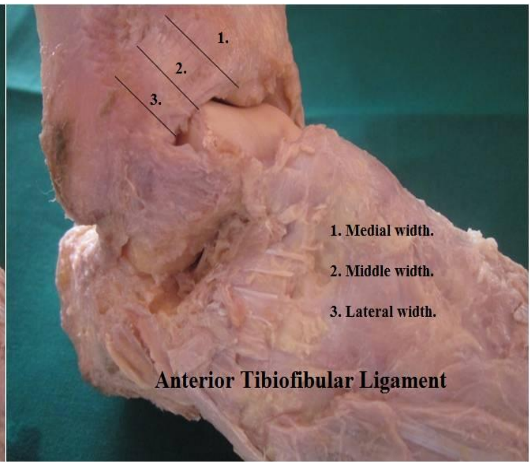
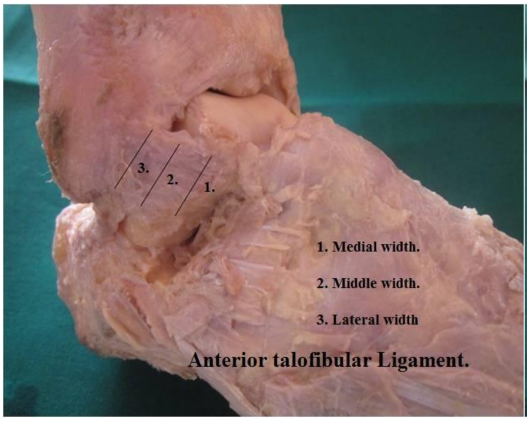


Image 1(left): Length measurements of anterior tibiofibular ligament taken at different levels.
Image 2(right): Width measurements of anterior tibiofibular ligament taken at different levels.

On the lateral aspect, anterior talofibular ligament was exposed and measurements were taken. The length was taken at three levels namely superior, middle and inferior. The breadth was taken at three different levels namely medial, middle and lateral part. The thickness was then measured.



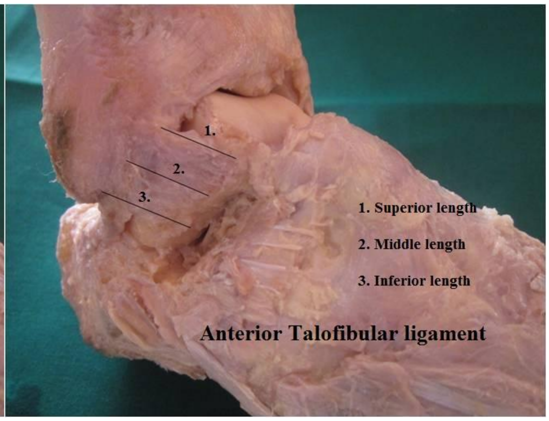
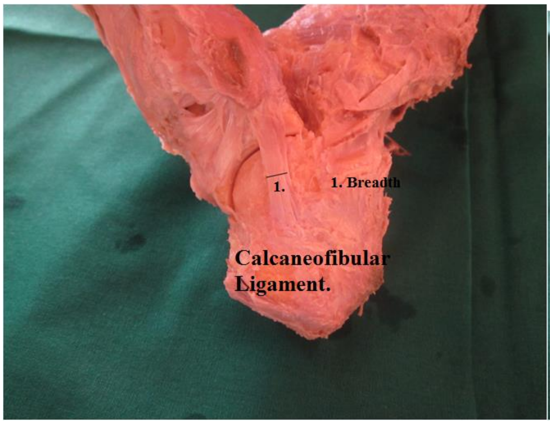


Image 3(left): Width measurements of anterior talofibular ligament taken at different levels.
Image 4(right): Length measurements of anterior talofibular ligament taken at different levels.

The calcaneofibular ligament was exposed and measurements were taken. It is a cord like ligament and the length, breadth and thickness was measured.



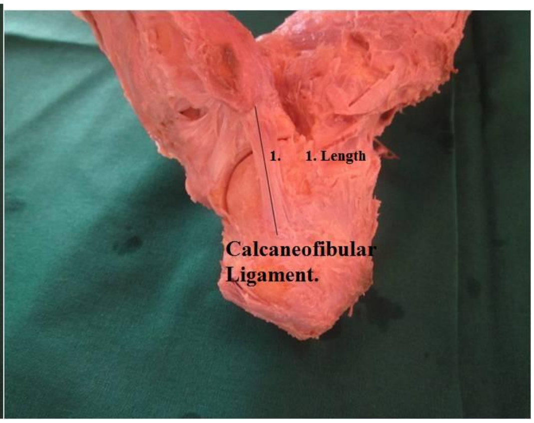
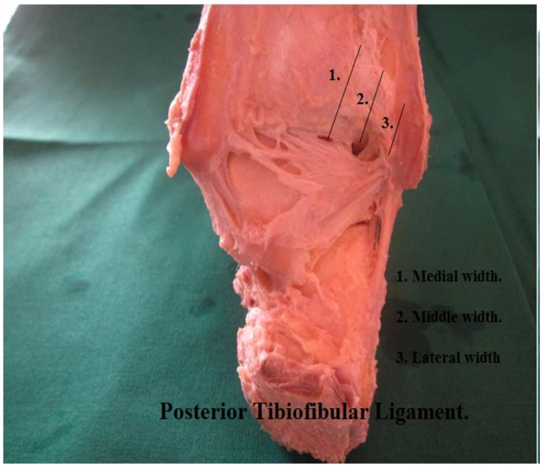


Image 5(left): Width measurement of calcaneofibular ligament.
Image 6(right): Length measurement of calcaneofibular ligament.

On the posterior aspect the capsule was reflected. The posterior tibiofibular ligament was exposed and measurements were taken. The length was taken at three levels namely superior, middle and inferior fibres. The breadth was taken at three different levels namely medial, middle and lateral aspect. Then the thickness was measured.



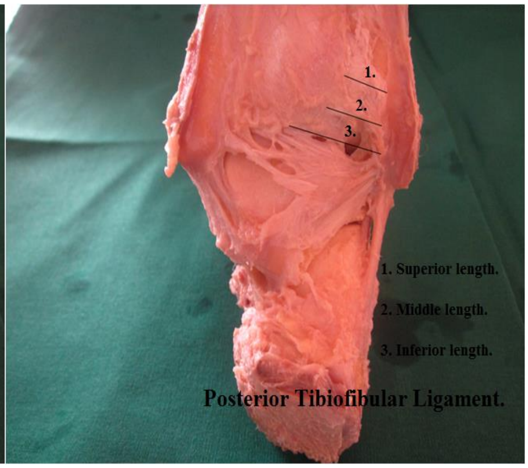
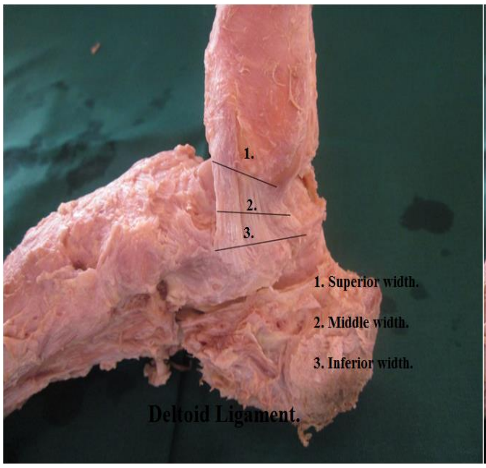


Image 7(left): Length measurements of posterior tibiofibular ligament taken at different levels.
Image 8(right): Width measurements of anterior tibiofibular ligament taken at different levels.

The posterior talofibular ligament was exposed and since it is a cord like ligament, the length, breadth measurements along with the thickness was measured.

Image 9(left): Length measurement of posterior talofibular ligament.
Image 10(right): Width measurement of posterior talofibular ligament.

On the medial aspect the deltoid ligament was exposed and all the three superficial components were measured and it was reflected partly to check the presence of the deep component. The thickness was also measured.



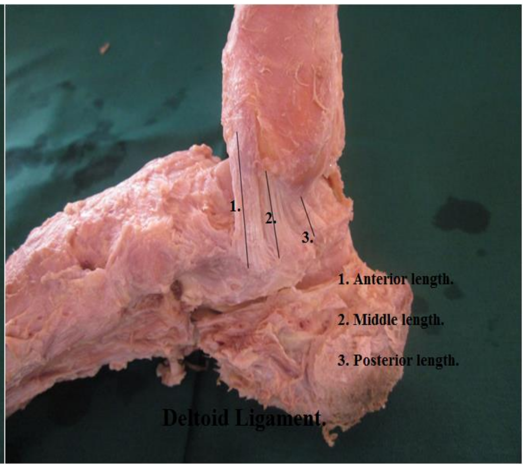


Image 11(left): Width measurements of deltoid ligament taken at different levels.
Image 12(right): Length measurements of deltoid ligament taken at different levels.

All the measurements were taken, using a digital calipers.

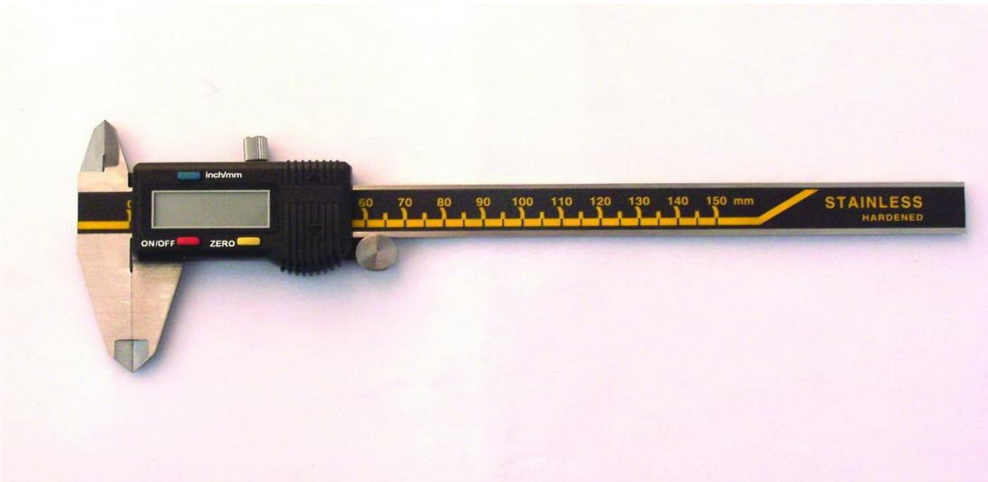
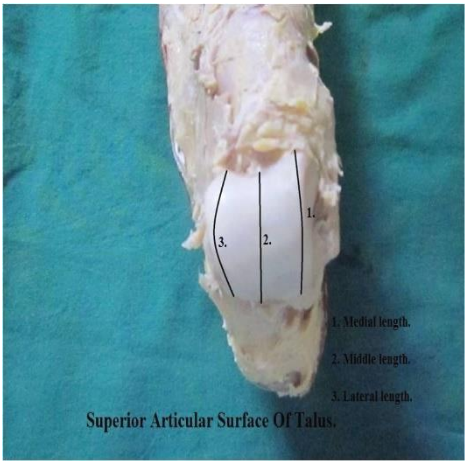


Image 13: Digital Calipers

The ligaments were detached to expose the articular surface of the tibiofibular mortise and the trochlear surface of talus in eleven specimens which included six female and five male specimens. All the measurements were taken using a thread and digital calipers. Presence of squatting facets on the mortise as well as on the talus was noted. Measurements were also taken on articulating surfaces of tibia, fibula and talus. Different measurements were taken using a thread and digital vernier calipers.

The measurements that were taken on the superior articulating surface are, medial side length, lateral side length, central length, anterior width, central width, posterior width, lateral side: central radius, lateral side: posterior radius, medial side: anterior height. The squatting facets were noted.



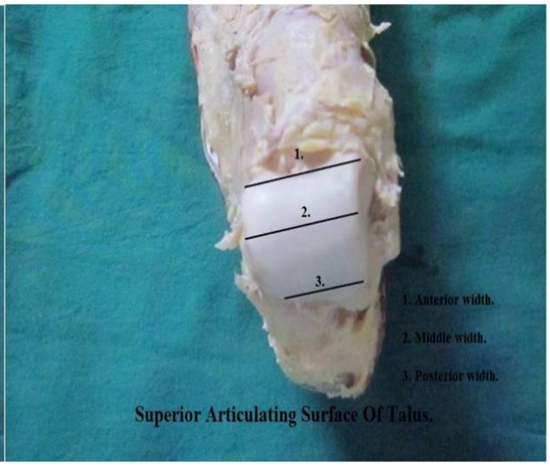


Image 14(left): Length measurements of superior articulating surface of talus taken at different levels.
Image 15(right): Width measurements of superior articulating surface of talus taken at different levels.

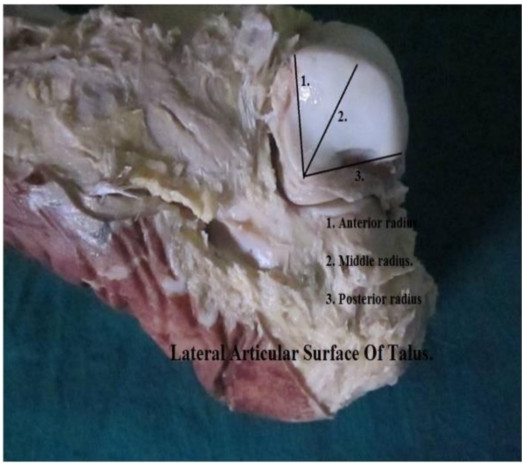
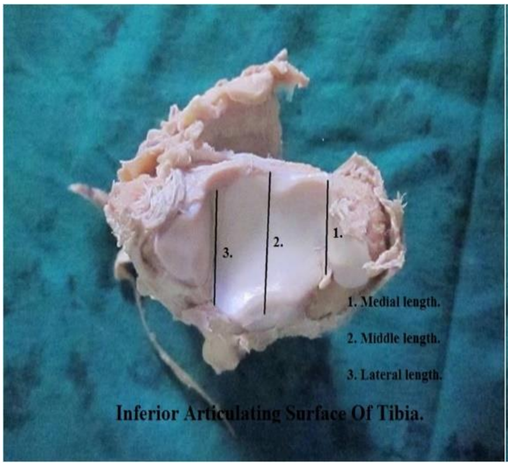


Image 16(left): Measurements of lateral articulating surface of talus taken at different levels.
Image 17(right): Measurements of medial articulating surface of talus.

The measurement that were taken on the articulating surface of tibia and fibula are, medial side length, central length, lateral length, anterior width, central width, posterior width, medial malleolos (wide width), medial malleolus (narrow width), medial malleolus (height), lateral malleolus (width), lateral malleolus (height).

The Squatting facets in the tibia were noted.



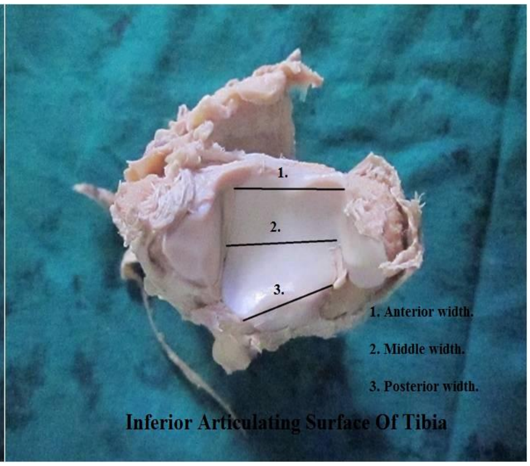
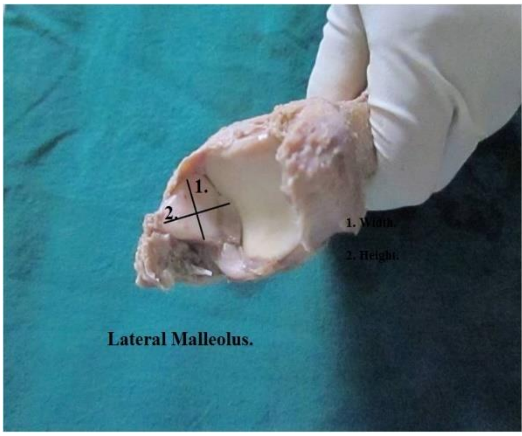


Image 18(left): Length measurements of inferior articulating surface of tibia taken at different levels.
Image 19(right): Width measurements of inferior articulating surface of tibia taken at different levels.



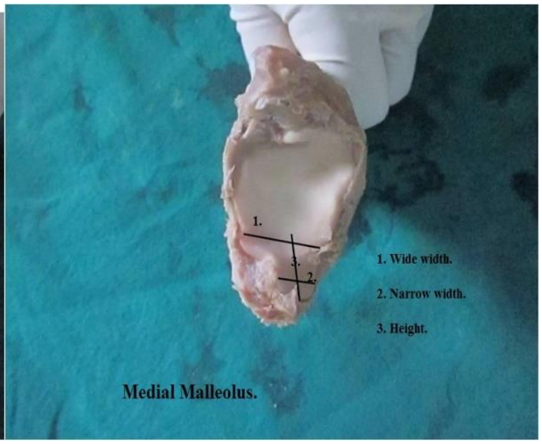


Image 20(left): Measurements of lateral malleolus.
Image 21(right): Measurements of medial malleolus.

Then the same measurements were taken on the articular surfaces that participate in the talocrural joint in thirty dry talus, tibia and fibula available in the department of anatomy, K.S.Hegde Medical Academy, Mangalore.

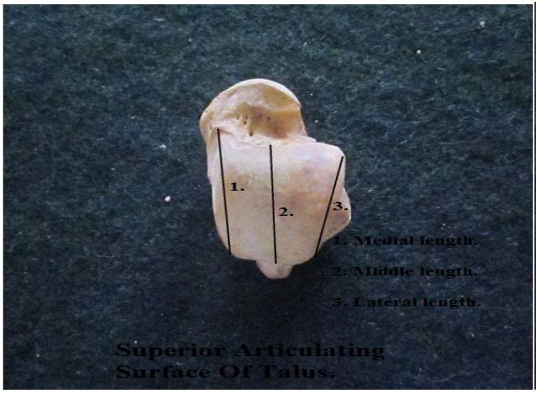
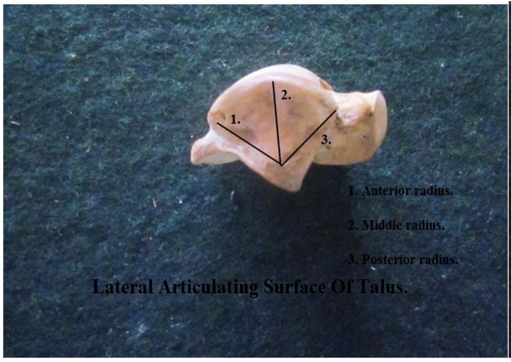


Image 22(left): Length measurements of superior articulating surface of talus taken at different levels.
Image 23(right): Width measurements of superior articulating surface of talus taken at different levels.



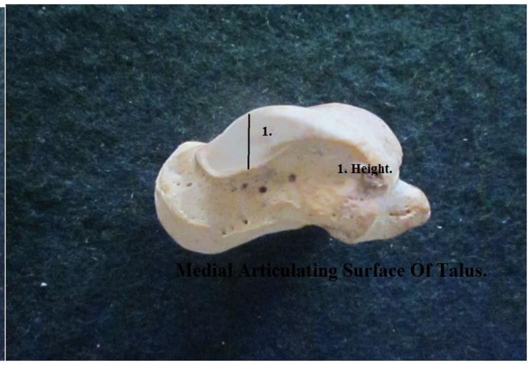
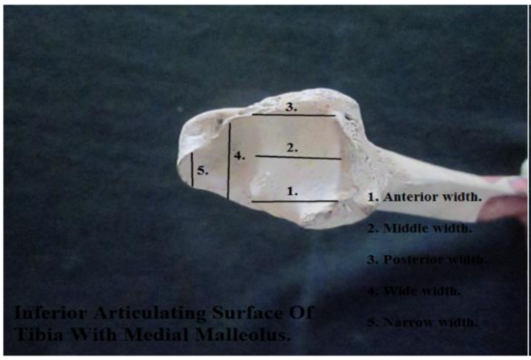


Image 24(left): Measurements of lateral articulating surface of talus taken at different levels.
Image 25(right): Measurements of medial articulating surface of talus taken at different levels.



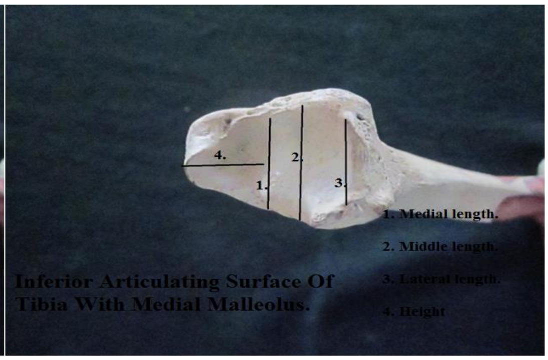


Image 26(left): Width measurements of inferior articulating surface of tibia and length measurements of medial malleolus taken at different levels.
Image 27(right): Length measurements of inferior articulating surface of tibia and medial malleolus taken at different levels.

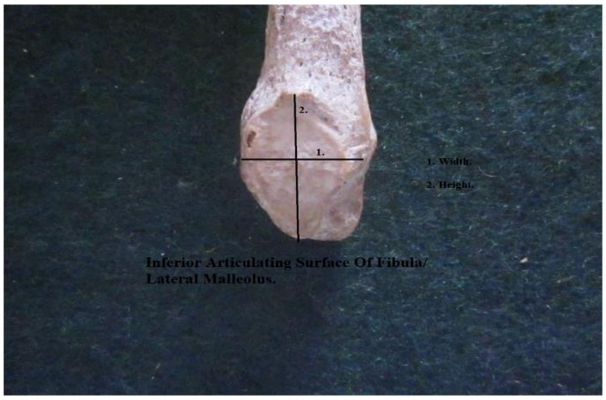


Image 28: Morphometry of inferior articulating surface of fibula (lateral malleolus).

Thirty X - rays were also collected from the Department Of Radiology, K.S.Hegde Medical Academy and were measured for

- Talocrural Angle.
- Tibial overlap.
- Tibiofibular distance.
- Joint Space A.
- Joint Space B.

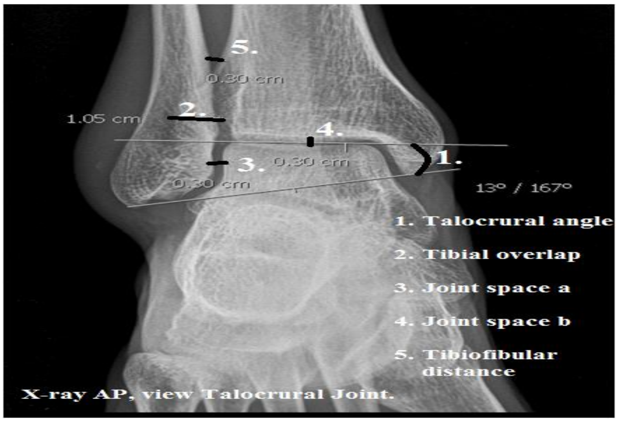


Image 29: X-ray, AP view measurements.

They were measured using, a computer software which was used in the department of radiology, K.S.Hegde Medical Academy. Thirty X- rays were also examined which had congenital defects and the difference in various measurements were only cross checked in comparison with that of normal X-rays.

Observation and Results

Morphometry of articular surface in wet talus

Table 1: Morphometry of each side and gender in wet talus

	Side	Mean	Std. Deviation	Sig.	Sex	Mean	Std. Deviation	Sig.2-tailed
ML	R	34.6	1.14	0.149	F	36.16	2.13	0.41
	L	36.5	2.58		M	35	2.34	
LL	R	36.2	2.04	0.423	F	35.66	1.50	0.904
	L	35.33	1.36		M	35.8	2.04	
CL	R	38	1	0.741	F	38	0.89	0.662
	L	38.16	0.40		M	38.2	0.44	
AW	R	30.2	1.64	0.649	F	30.16	1.47	0.535
	L	30.66	1.63		M	30.8	1.78	
CW	R	26.8	0.83	0.527	F	27.16	1.16	0.527
	L	27.16	0.98		M	26.8	0.44	
PW	R	21.2	0.44	0.576	F	21.33	0.81	0.766
	L	21.66	1.86		M	21.6	1.94	
AR	R	21.2	1.92	0.929	F	22.5	1.97	0.043
	L	21.33	2.73		M	19.8	1.78	
MR	R	22	1.73	0.378	F	23.33	1.86	0.238
	L	23.16	2.31		M	21.8	2.16	
PR	R	21.4	1.67	0.933	F	22.16	1.72	0.163
	L	21.5	2.07		M	20.6	1.67	
MH	R	14	0.70	1	F	13.66	0.51	0.392
	L	14	1.54		M	14.4	1.67	
Table. No. 1								

ML: medial length, LL: lateral length, CL: central length, AW: anterior width, CW: central width, PW: posterior width, AR: anterior radius, MR: middle radius, PR: posterior radius, MH: medial height.

Morphometry of articulating surface of wet tibia

	Side	Mean	Std.	Sig.	Sex	Mean	Std.	Sig.2
Medial length	R	23	1.41	1	F	23.16	1.16	0.675
	L	23	1.41		M	22.8	1.64	
Central length	R	26.4	1.14	0.69	F	26.16	0.75	0.198
	L	26.66	1.03		M	27	1.22	
Lateral length	R	26	1	0.71	F	26	1.54	0.662
	L	26.33	1.75		M	26.4	1.34	
Anterior width	R	29	1.22	0.75	F	28.5	1.87	0.5
	L	28.66	1.96		M	29.2	1.30	

Central Width	R	26.4	1.51	0.82	F	26.16	2.13	0.826
	L	26.16	1.83		M	26.4	0.89	
Posterior Width	R	21.4	1.14	0.77	F	21.83	1.72	0.497
	L	21.66	1.75		M	21.2	1.09	
MM (wide width)	R	22	1	0.18	F	22.33	1.50	0.554
	L	23	1.26		M	22.8	0.83	
MM (Narrow	R	11.6	1.14	0.81	F	11.5	1.87	0.606
	L	11.83	1.83		M	12	1	
MM (Height)	R	17.6	1.51	0.28	F	17.16	1.72	0.728
	L	16.5	1.64		M	16.8	1.64	
Table No. 2								

Table 2: Morphometry of each side and gender in wet tibia.

MM: medial malleolus.

Morphometry of articular surface in wet fibula

	Side	Mean	Std.	Sig.	Sex	Mean	Std.	Sig.
LM	R	19	1.41	0.823	F	18.83	1.47	0.82
Height.	L	18.83	0.98		M	19	0.70	
LM	R	19.4	1.14	0.337	F	19.66	1.21	0.68
Width.	L	20.16	1.32		M	20	1.41	
Table No. 3								

Table 3: Morphometry of each side and gender in wet fibula.
LM: Lateral Malleolus.

Squatting facets in wet talus

Table 4: Squatting facets in wet talus

		Absent	Present
SIDE	L	83.3%	16.7%
	R	80.0%	20.0%
SEX	F	83.3%	16.7%
	M	80.0%	20.0%
Table No. 4			

Table 5: Chi square test

Pearson Chi-Square	Value	Asymp. Sig. (2-sided)
Right vs Left	0.020	0.887
Male vs Female	0.020	0.727
Table No. 5		

Squatting facet in wet tibia

Table 6: Squatting facets in wet tibia

		Absent	Present
SIDE	L	50.0%	50.0%
	R	60.0%	40.0%
GENDER	F	50.0%	50.0%
	M	60.0%	40.0%
Table No. 6			

Table No 7: Chi-Square Test

Pearson Chi-Square	Value	Exact Sig. (2-sided)
Side	0.110	1.000
Gender	0.110	1.000
Table No. 7		

Morphometry of articular surface in talus (dry bone)

Table 8: Morphometry of each side in dry talus

	SIDE	Mean	Std.	P VALUE
Medial side length	LEFT	36.53	3.35	0.654
	RIGHT	36	3.09	
Lateral side length	LEFT	36.4	3.18	1
	RIGHT	36.4	2.41	
Central length	LEFT	37.4	2.41	0.486
	RIGHT	36.8	2.24	
Anterior width	LEFT	28.4	1.72	0.347
	RIGHT	27.87	1.30	
Central width	LEFT	26.67	1.87	0.924
	RIGHT	26.6	1.92	
Posterior width	LEFT	22.13	1.68	0.288
	RIGHT	21.47	1.68	
Anterior radius	LEFT	22.47	1.30	0.437
	RIGHT	22.13	0.99	
Central radius	LEFT	23.6	1.24	0.355
	RIGHT	23.2	1.08	
Posterior radius	LEFT	23.87	1.24	1
	RIGHT	23.87	0.99	
Anterior height	LEFT	13.07	1.03	1
	RIGHT	13.07	0.88	

Morphometry of articulating surface in tibia (dry bones)

Table 9: Morphometry of each side in dry tibia

	Side	Mean	Std. Deviation	Sig.
Medial side length	L	23.56	1.99	0.82
	R	23.71	1.54	
Central length	L	26.19	2.42	0.802
	R	26.43	2.79	
Lateral length	L	28.5	3.34	0.527
	R	27.71	3.36	
Anterior width	L	28.25	2.29	0.424
	R	28.93	2.26	
Central Width	L	25.25	1.98	0.429
	R	25.79	1.62	
Posterior Width	L	23	1.82	0.317
	R	22.36	1.59	
Medial Malleolos (wide width)	L	22.19	2.48	0.683
	R	21.86	1.79	
Medial Malleolus (Nar.Width)	L	11.56	1.50	0.346
	R	11.07	1.26	
Medial Malleolus (Height)	L	14.88	1.70	0.83
	R	15	1.41	
Table No. 9				

Morphometry of articular surface in fibula (dry bone)

Table 10: Morphometry of each side in dry fibula

	Side	Mean	Std.	Sig.
Lateral malleolus (width)	Left	19.94	1.181	0.816
	Right	20.07	1.9	
Lateral malleolus (height)	Left	19.25	1.528	0.632
	Right	18.93	2.093	
Table No. 10				

Squatting facets on dry talus bones

Table 11: Squatting facets in dry talus

		Absent	Present
Side	Left	60.0%	40.0%
	Right	80.0%	20.0%
Table No. 11			

Chi-square Test.		
	Value	Exact Sig. (2-sided)
Pearson Chi-Square	1.429	0.427
Table No. 12		

Squatting facets in dry tibia bones

Table 13: Squatting facets in dry tibia

Side	Absent	Present
Left	50.0%	50.0%
Right	78.6%	21.4%
Table No. 13		
CHI-SQUARE TEST.		
	Value	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.625	.105
Table No. 14		

Morphometry of ligaments on the lateral side

		Side	Mean	Std. Dev	Sig.	Sex	Mean	Std. Dev	Sig.
Anterior Talofibular	SUPERIOR LENGTH	L	17.8	1.47	0.20	M	17.36	1.44	0.829
		R	16.9	2.12		F	17.54	2.47	
	MIDDLE LENGTH	L	16.8	1.18	0.57	M	16.84	1.28	0.39
		R	16.4	1.98		F	16.31	2.09	
	INFERIOR LENGTH	L	16.2	2.12	0.95	M	16.69	2.04	0.366
		R	16.3	3.15		F	15.63	3.45	
	MEDIAL	L	14.2	1.86	0.15	M	13.54	2.09	0.381
		R	13.2	1.98		F	14.20	1.72	
	MIDDLE	L	13.3	2.41	0.36	M	12.70	2.59	0.42
		R	12.5	2.25		F	13.42	1.82	
	LATERAL WIDTH	L	13.6	2.22	0.18	M	13.03	2.32	0.872
		R	12.5	1.94		F	13.16	1.81	
	THICKNESS	L	3.04	0.60	0.39	M	3.11	0.56	0.821
Posterior talofibular		R	3.22	0.51		F	3.16	0.56	
	LENGTH	L	22.5	2.68	0.62	M	23.47	2.93	0.155
		R	23.1	3.55		F	21.79	3.24	
	WIDTH	L	8.29	1.15	0.81	M	8.26	1.16	0.626
		R	8.41	1.45		F	8.50	1.53	
	THICKNESS	L	4.96	1.02	0.85	M	5.31	1.00	0.041
		R	5.03	1.22		F	4.46	1.13	
Calcaneofibular	LENGTH	L	25.7	2.40	0.28	M	25.18	2.54	0.729
		R	24.8	2.42		F	25.51	2.30	
	WIDTH	L	7.83	1.19	0.47	M	7.42	1.31	0.174
		R	7.49	1.36		F	8.08	1.12	
	THICKNESS	L	4.99	1.11	0.67	M	5.21	0.92	0.564
		R	5.19	1.44		F	4.87	1.75	

TABLE NO. 15

Table 15:

Variations in the anterior talofibular ligament

Table 16: Variations in the anterior talofibular ligament

SEX		Single SLIP	Three	Three
Gender	F	0.0%	10%	90%
	M	15%	0.0%	85%
Side	L	6.7%	0.0%	93.3%
	R	13.3% 13.3%	6.7% 6.7%	80.0%
Table No. 16				

	Value	Exact Sig. (2-sided)
Fisher's Exact	2.950	.224
Pearson Chi-	3.701	.126
TABLE NO. 17 CHI-SQUARE TEST.		

Variations in the posterior talofibular ligament

Table 18: Variation in the posterior talofibular ligament

			Nil	slip to tibia	Total
Gender	F	% within GENDER	81.8%	18.2%	100.0%
	M	% within GENDER	100.0%	0.0%	100.0%
Side	L	% within SIDE	100.0%	0.0%	100.0%
	R	% within SIDE	86.7%	13.3%	100.0%
Table No. 18					

Pearson Chi-Square	Value	Exact Sig. (2-sided)
Gender	3.701[a]	0.126
Side	2.143	0.483
Table 19: Chi-square test.		

Morphometry of ligaments on the medial side (deltoid ligament)

Table 20: Morphometry in each side and gender in the deltoid ligament

Deltoid	Side	Mean	Std.	Sig.	Sex	Mean	Std.	Sig.
MID LENGTH	R	21.98	3.39	0.435	M	20.70	1.96	0.116
	L	21.08	2.81		F	22.95	4.16	
ANT LENGTH	R	25.09	2.88	0.176	M	24.94	3.12	0.099

	L	23.72	2.47		F	23.47	1.58	
POST LENGTH	R	17.61	1.92	0.299	M	17.56	2.45	0.219
	L	16.79	2.27		F	16.57	1.17	
SUP WIDTH	R	18.71	3.22	0.029	M	20.77	2.94	0.057
	L	21.17	2.60		F	18.51	3.07	
MID WIDTH	R	21.75	2.99	0.083	M	23.29	2.54	0.057
	L	23.43	1.98		F	21.39	2.45	
INF WIDTH	R	26.79	3.59	0.27	M	28.81	3.11	<0.001
	L	28.11	2.76		F	25.11	1.74	
THICKNESS	R	7.01	0.71	0.631	M	7.05	0.81	0.348
	L	6.87	0.91		F	6.75	0.79	
Table no. 20								

Morphometry of ligaments of tibiofibular mortise

Table 21: Morphometry in each side and gender

Ant tibio fibular	Side	Mean	Std	Sig	SEX	Mean	Std	Sig
SUPERIOR	R	14.19	2.917	0.951	M	14.02	3.37	0.768
	L	14.11	4.00		F	14.42	3.75	
MIDDLE LENGTH	R	17.81	2.69	0.67	M	17.72	3.14	0.695
	L	17.29	3.72		F	17.22	3.47	
INFERIOR	R	24.67	2.79	0.386	M	24.33	3.67	0.567
	L	23.40	4.78		F	23.44	4.46	
MEDIAL LENGTH	R	19.03	1.84	0.882	M	19.15	1.89	0.516
	L	18.91	2.39		F	18.61	2.53	
MIDDLE WIDTH	R	16.40	1.89	0.202	M	16.21	1.83	0.314
	L	15.52	1.80		F	15.46	1.95	
LATERAL WIDTH	R	12.75	1.57	0.62	M	12.98	1.50	0.071
	L	12.44	1.81		F	11.81	1.79	
THICKNESS	R	3.53	0.90	0.387	M	3.93	0.75	0.017
	L	3.813	0.84		F	3.14	0.88	
POSTERIOR								
SUPERIOR	R	15.53	2.92	0.574	M	16.28	3.66	0.37
	L	16.24	3.85		F	15.09	2.72	
MIDDLE LENGTH	R	18.22	3.26	0.743	M	18.76	3.81	0.481
	L	18.65	3.83		F	17.78	2.87	
INFERIOR	R	25.19	3.53	0.68	M	25.94	3.60	0.276
	L	25.72	3.32		F	24.49	2.79	
MEDIAL LENGTH	R	21.76	2.81	0.503	M	22.67	2.46	0.064
	L	22.39	2.18		F	20.88	2.23	
MIDDLE WIDTH	R	17.64	3.39	0.52	M	18.57	2.81	0.087
	L	18.3	1.97		F	16.75	2.26	
LATERAL WIDTH	R	13.10	1.60	0.21	M	13.69	1.76	0.425

	L	13.90	1.85		F	13.13	1.76	
THICKNESS	R	4.75	1.00	0.89	M	5.05	1.01	0.016
	LEFT	4.70	1.16		F	4.08	0.88	
Table no. 21								

Radiological Measurements

Table 22: Morphometry in each side and gender

	Side	Mean	Std. Deviation	Sig. (2-tailed)	Sex	Mean	Std. Deviation	Sig. (2-tailed)
Talocrural angle°	R	13.4	1.59	0.57	M	13.26	1.62	0.91
	L	13.06	1.57		F	13.2	1.56	
Tibial overlap	R	10.85	0.74	0.165	M	10.5	0.54	0.166
	L	10.5	0.60		F	10.85	0.79	
Joint space a	R	2.98	0.39	0.528	M	3.03	0.49	0.967
a	L	3.08	0.46		F	3.02	0.36	
Joint Space b	R	3.06	0.36	0.963	M	3.11	0.43	0.479
b	L	3.06	0.39		F	3.01	0.32	
Tibio Fibular Distance	R	3.56	0.36	0.776	M	3.64	0.29	0.274
space	L	3.6	0.25		F	3.52	0.32	
Table No.22								

Discussion

Morphometry of the articular surface in wet talus

In males, the measurements are similar to that of females except in the anterior radius of lateral articulating surface there is a statistically significant difference. The female measurement is higher than the males. (p=0.043). This may be an indication of the fact that females in our society work more in their household work by stressing on their talocrural joint. This may be because of the difference in gait that is present in females when compared to males and also according to S.G. McLean et al.[30] the effect of gender on lower extremity kinematics during rapid direction changes: an integrated analysis of three sports movements, females had increased initial knee valgus and peak knee valgus, when compared to males, in three sports movements linked to non-contact ACL injury. According to Andrew R. Fauth et al.[12] on the study of anatomical based investigations on the total ankle arthroplasty, The study is in agreement with the study of Adrew. R .Fauth et al.[12] except the measurements of trochlear surface of the talus in females are more in the study when compared to the study by Adrew. R .Fauth et al.[12] In the study conducted by, Adrew. R .Fauth et al.[12] the measurements in males are uniformly more than than that of females. The difference found in our specimens, could be a characteristic of our population, but no previous studies exist to compare our findings.

Morphometry of articulating surface of wet tibia

According to Andrew R. Fauth et al.[12] on the study of anatomical based investigations on the total ankle arthroplasty. The study is in agreement with that of Adrew. R. Fauth et al.[12] except the tibial plafond measurements in the study are higher in females than the study conducted by Adrew. R. Fauth et al.[12] In the study conducted by Adrew. R. Fauth et al.[12] the measurements are uniformly more in males when compared to females.This may be because of the fact that, the study conducted in our studies is in "South Indian West Costal Population". The difference found in our specimens could be a characteristic of our population, but no previous studies exist with which to compare our findings.

Morphometry of articular surface in wet fibula

According to Andrew R. Fauth et al.[12] on the study of anatomical based investigations on the total ankle arthroplasty, The measurements in the study is in agreement with the study of Andrew R. Fauth et al.[12]

Squatting facets on the superior articular surface of wet TALUS

Inderbir Singh[9] in 1959 conducted a study of Squatting facets on the talus and tibia in Indians. Using 200 tibia and 200 tali (dry bones), 92 tibia and 100 talus (wet cartilage covered bones). The author mentioned that, out of 292 tibia which were studied, 231 tibia had squatting facets indicating an incidence of 79.1%. Of the 300 talus which were studied, 86 talus had squatting indicating an incidence of 28.6%. According to Charles RH[47] on the study of influence of function as exemplified on the morphology of the lower extremity of Punjabi, 34 out of 53 talus was found to have squatting facets showing an incidence of 63 percent. The observation in my studies is not in agreement with the other studies. It may be because of the difference in population chosen for the study. The study was conducted on south west coast Indians and the other study was based on north Indians.

Squatting facet superior articular surface of tibia

Inderbir Singh[9] in 1959 conducted a study of Squatting facets on the talus and tibia in Indians. Using 200 tibia and 200 tali (dry bones), 92 tibia and 100 talus (wet cartilage covered bones). The author mentioned that, out of 292 tibia which were studied, 231 tibia had squatting facets indicating an incidence of 79.1%. Of the 300 talus which were studied, 86 talus had squatting indicating an incidence of 28.6%. The observation in my studies is not in agreement with the other study when compared. It may be because of the difference in population chosen for the study. The study was conducted on south west coast Indians and the other study was based on north Indians.

Morphometry of articular surface in talus (dry bone)

According to the study by Rosdi Daud et al.[13] on three dimensional morphometric study of the trapezium shape of the trochlear tali, the anterior width and the posterior width was measured in 99 participants (49 females and 50 males). In the study of ankle morphometry on 3D-CT images by Andrea Hayes et al.[14] in 21 subjects (10 females and 11males), the mean width on the anterior part was 29.9 mm with a standard deviation of 2.6 mm, in the middle the mean width in the middle measured to be 27.9 mm with a standard deviation of 3 mm and on the posterior part it measured 25.2 mm with a standard deviation of 3.7 mm. The study is in agreement with the study of Andrea Hayes et al.[14]

Squatting facets on dry talus bones

Baykara et al. [45] conducted a study to learn the daily activities of the medieval societies in the Van region through studying of squatting facets. Adult skeletons from Dilkaya and Van Kalesi-Eski Vanehri societies dating to the Medieval Age were investigated (65 tibia and 82 tali from Dilkaya, 61 tibia and 52 tali from Van Kalesi-Eski Vanehri). The squatting facet had high ratios in both societies. The tibial squatting facet found on females and males of Dilkaya was 97.2% and 96.9%, respectively, and on females and males of Van kalesi Eski Vanehri was 87.5% and 89.2 %, respectively. The talus squatting facet found on females and males of Dilkaya was 72.1% and 51.3%, respectively, and on females and males of Van kalesi Eski Vanehri was 91.2% and 83.7%, respectively. It is evident that it is found more in females than in males. The study is not in agreement with that Baykara et al.[45] Multiple factors may contribute for the formation of squatting facets. And this difference may be because of study in different population, or difference in life style. According to Ari et al.[46] Different factors can play a role in the modifications of the distal tibia surface, articulating with the talus.

Morphometry of articulating surface in tibia (dry bones)

Mandela Pamela et al.[15] in their study on “Estimation of the length of the tibia from dimensions of the distal articular surfaces of the tibia in adult Kenyans” Out Of 156 tibiae the mean measurements of the following were; Misiani Musa et al.[16] studied the Sexual dimorphism in the morphometric characteristics of the tibial plafond and medial malleolus. The measurements in our study are in agreement with the study of Mandela Pamela et al.[15] and Misiani Musa et al.

Squatting facets on dry tibia

According to the study of Ari et al.[46] they investigated 125 tibia from adult male skeletons from the late Byzantine period (13th century) to observe the presence or absence of squatting facets. Thirty-one talus pairing tibia bones were also investigated concerning their relationship with the squatting facets of these bones. There recorded that 64 right (51.2%) and 61 left (48.8%) tibia and squatting facets were observed on 30 right (46.9%) and 30 left (49.2%) tibia. Among the 25 paired tibia investigated, squatting facets were seen on 9 (36%) pairs and they found was no evidence of side predilection. On the right side, squatting facets occurred on 3 (20%) tibia-talus; on the left side they were present on 7 (43.7%) tibia-talus, and only one tibia had the squatting facet and talus had none. They concluded that different factors can play a role in the modifications of the distal tibia surface, articulating with the talus.

According to a study of Baykara et al.[45] to learn the daily activities of the medieval societies in the Van region through studying of squatting facets. Adult skeletons from Dilkaya and Van Kalesi-Eski Van ehri societies dating to the Medieval Age were investigated (65 tibia and 82 tali from Dilkaya, 61 tibia and 52 tali from Van Kalesi-Eski Vanehri). The squatting facet had high ratios in both societies. The tibial squatting facet found on females and males of Dilkaya was 97.2% and 96.9%, respectively, and on females and males of Van kalesi Eski Vanehri was 87.5% and 89.2 %, respectively. The talus squatting facet found on females and males of Dilkaya was 72.1% and 51.3%, respectively, and on females and males of Van kalesi Eski Vanehri was 91.2% and 83.7%, respectively. The study is not in agreement with the other study. Multiple factors may contribute for the formation of squatting facets. And this difference may be because of study in different population, or difference in life style.

Morphometry of articular surface in fibula dry (bone)

The measurements are similar on both sides.

Morphometry of ligaments on the lateral side

Anterior talofibular ligament

According to the study conducted by Mkandawire et al.[17] (2005) on foot and ankle ligament morphometry, the anterior talo-fibular ligament mean length was measured to be 24.09 ± 8.03 mm. According to a study conducted on diagnosis and treatment of injury to the lateral ligament of ankle by Prins JG et al[37] (1978), it measures about 15 mm x 8 mm x 20 mm. According to the study conducted by Ruth CJ et al[38] (1961) on the surgical treatment of injuries of the fibular collateral ligaments of the ankle, the mean measurements were 12 mm x 5 mm x 2 mm. According to the study on anatomy of the collateral ligaments of the human ankle joints by Milner et al[39] the mean length measurements was 13 mm with a standard deviation of 3.9 mm and mean width of 11 mm with a standard deviation of 3.3 mm.

Mahmut Ugurlu et al.[18] studied on the anatomy of the lateral complex of the ankle joint in relation to peroneal tendons, distal fibula and talus in 22 formalin fixed ankles and the mean. In bifurcate forms the mean length was 18.74 mm in the superior band. In the inferior band, the mean length was 15.33 mm. According to Taser et al.[31] the anterior talo-fibular length was 22.37 mm with a standard deviation of 2.5 mm and the width was 10.77 mm with a standard deviation of 1.6 mm.

According to the study on the lateral ankle ligaments by Muzaffer Sindel et al.[19] in 24 ankles, the anterior talo-fibular ligament was determined of having two bands. Superior band had average length of 19.1 mm with a standard deviation of 2.28 mm and the average width was 6.7 mm with a standard deviation of 1.06 mm. the mean length of the inferior band was measured as 15.2 mm with a standard deviation of 2.62 mm and the mean width as 4.5 mm with a standard deviation of 1.06 mm.

The study is in agreement with other studies in length measurements. The study is also in agreement with the studies of Prins J G et al.[37], Milner C et al.[39] and Taser et al. [31]in width measurements. The study is not in agreement with the studies of Ruth C J et al, Mahmut Ugurlu et al.[18] and Muzaffer Sindel et al.[19] in mean width measurements. It may be due to the population difference.

Variations in the anterior talofibular ligament

According to the study on anatomical variations of the anterior talo-fibular ligament of the human ankle joint by Milner et al.[32] in 26 ankle specimens, they observed two variations. The single slip variation was observed in 38 percent and the trifurcate form in 12 percent. Mahmut Ugurlu et al.[18] studied on the anatomy of the lateral complex of the ankle joint in relation to peroneal tendons, distal fibula and talus in 22 formalin fixed ankles the single band form was seen in 23 percent, bifurcate forms in 59 percent and trifurcate forms 18 percent. The study is not in agreement with that of other studies. It may be due to the population difference or difference in the participation of activities.

Posterior talofibular ligament

According to Milner et al.[32] on the antomy of collateral ligaments of human ankle joint (1998), the mean length was 23 mm, with a standard deviation of 7 mm and the mean width was measured to be 5.5 mm with a standard deviation of 2.5 mm. According to Taser et al.[31] the mean length was measured to be 21.66 mm with a standard deviation of 4.8 mm and mean width was 5.55 mm with a standard deviation of 1.3 mm.

On the anatomy of lateral ankle ligaments by Muzaffer Sindel et al.[19] the posterior talo-fibular ligament, the mean length was 20.7 mm with a standard deviation of 2.15 mm; the mean width was 6.1 mm with a standard deviation of 0.77 mm. Chimba Mkandawire et al.[17] (2005) in their study on “The Foot and ankle ligament morphometry.”in 121 bone- ligament- bone preparations from 26 cadaver feet. Posterior talofibular mean length was measured to be 27.74 ± 3.41 mm. On a study of anatomy of lateral complex of the ankle joint in relation to peroneal tendons, on the distal fibula and talus by Mahmut Ugurulu et al.[18] the posterior talofibular mean length was measured to be 24.12 mm and the mean width of 5.09 mm The study is in agreement with the other studies.

Variations in the posterior talofibular ligament

The inter malleolar ligament (a part of posterior talo-fibular ligament) was found in 81.8 percent of the specimen, according to Pau Galeno et al.[27] in his study of anatomy of ankle ligaments. The study is not in agreement with the other study. It may be due to the population difference or difference in activities in different population.

Calcaneofibular ligament

Chimba Mkandawire et al.[17] (2005) in their study on "The Foot and ankle ligament morphometry." in 121 bone- ligament- bone preparations from 26 cadaver feet. Calcaneofibular mean length was measured to be 35.44 ± 6.31 mm. According to the study by Testul et al.[48] the length ranged from 30 mm to 40 mm and width ranged from 4 mm to 5 mm.

According to Prins J G et al.[37] on the diagnosis and treatment of injury to the lateral ligament of ankle, the mean length measured 20mm, the mean width measured 5mm and mean thickness measured 3mm. According to Mahmut Ugurlu et al.[18] on the anatomy of lateral complex of the ankle joint in relation to peroneal tendons, distal fibula and talus, the calcaneo-fibular ligament measured a mean length of 26.67 mm and a mean width of 4.57 mm. According to Milner et al.[39] the mean length measured 19.5 mm with a standard deviation of 3.9 mm; the mean width measured 5.5 mm with a standard deviation of 1.6 mm.

According to Taser et al.[31] the mean length measured 31.94 mm with a standard deviation of 3.7 mm and the mean width measured 4.68 mm with a standard deviation of 1.3 mm. According to P Kitsoulis et al.[20] on morphological study of calcaneo-fibular ligament of in 72 cadaveric lower limbs, the mean length is 31.83 mm, the mean width was 4.42 mm and the mean thickness was 1.58 mm. According to Muzaffer Sindel et al.[19] on the anatomy of lateral ankle ligaments, the calcaneo-fibular ligament measured a mean length of 26.8 mm and a mean width of 6 mm. The study is in agreement with that of other studies.

Morphometry of ligaments on the medial side (deltoid ligament)

According to Rodrigo Sepulveda et al.[21] Study (2012) on morphometric study and anatomical relations of the medial ligament of the talo-crural joint, it was found that three forms of the superficial deltoid ligament were present, namely the trapezoid, rectangular and triangular forms. In trapezoid form, the mean anterior and posterior length was 30.6mm with a standard deviation of 10.3 mm and 28.5 mm with a standard deviation of 8.5 mm. The mean superior width was 22.5 mm with a standard deviation of 3.4 mm and inferior width was 48.4 mm with a standard deviation of 8.9 mm.

In rectangular form, the mean anterior and posterior length was 21 mm with a standard deviation of 7.2 mm and 24.8 mm with a standard deviation of 7.3 4mm. The mean superior width was 22.7 mm with a standard deviation of 6.9 mm and inferior width was 28.2 mm with a standard deviation of 7.6 mm. In triangular form, the mean anterior and posterior length was 37 mm with a standard deviation of 10.6 mm and 37.8 mm with a standard deviation of 3.9 mm. The mean superior width was 00 mm with a standard deviation of 00 mm and inferior width was 48.3 mm with a standard deviation of 6.4 mm.The deep layer is present in 100 percent of cases.

Boss et al.[23] (2002) measured sub-divisions of deltoid complex and the mean anterior length measured 29.5 mm with a standard deviation of 10.5 mm, the middle mean length was 16.1 mm with a standard deviation of 6.8 mm and the mean posterior length was measured to be 26.9 mm with a standard deviation of 8.6 mm. In a study of medial collateral ligament complex of the ankle by Bernanrd Mengiardi et al.[22] the mean thickness of deltoid ligament in females was found to be 9.2 mm with a range of 7 to 12 mm. In men it was 10.8 mm with a range of 7 to 15 mm. In the total population it was measured to be 10.2 mm with a range of 7 to 15 mm.

In the study it closely resembles the trapezoid variety in majority of the cases but the measurements were very less when compared to the study of Rodrigo Sepulveda et al.[21]This may be due to population difference.This may also be due to the fact that our study was in formalin embalmed cadavers and the study by Rodrigo Sepulveda et al.[21] were on embalmed bodies.
The study is in agreement with that of other studies.

Morphomerty of ligaments of tibiofibular mortise

Chimba Mkandawire et al.[17] (2005) in their study on "The Foot and ankle ligament morphometry." in 121 bone- ligament-bone preparations from 26 cadaver feet. Anterior tibiofibular mean length was measured to be 18.89 ± 2.97 mm. According John J Hermans et al.[24] on a study of anatomy of distal tibio-fibular syndesmosis in adults, the anterior tibio-fibular ligament measured 6 mm to 8.9 mm in length and 4 mm to 4.9 mm in width and 1.8 mm to 3 mm in thickness. In the middle it measured 12 mm to 15.5 mm in length, 8.3 mm to 10 mm in width and 2.6 mm to 4 mm in thickness. The lower part measured 17 mm to 20.6 mm in length, 3.8 mm to 4 mm in width and 2 mm to 2.2 mm in thickness. In the study the measurements are consistently more in every aspect than the study by John J Hermans et al.[24] This may be due to practice of habitual squatting by the Indian population which exerts a stress effect on the ligaments of the tibiofibular mortise in extreme dorsiflexion. The study is in agreement with the study of Chimba Mkandawire et al.[17]

Posterior tibiofibular ligament

According John J Hermans et al.[24] on a study of anatomy of distal tibio-fibular syndesmosis in adults, the posterior tibio-fibular ligament's mean length was measured to be 21.8 mm with a standard deviation of 7.5 mm and range from 6.4 mm to 32.5 mm. The mean width of the ligament measured 17.4 mm with a standard deviation of 3.5 mm and range from 11.1 mm to 21.2 mm. The thickness measured 6.4mm with a standard deviation of 1.9 mm. The measurements in both the studies are congruent expect in the thickness. In our study the thickness is less when compared to the John J Hermans et al. This may be because of the sample population difference used in the study.Chimba Mkandawire et al.[17] (2005) in their study on "The Foot and ankle ligament morphometry." in 121 bone- ligament- bone preparations from 26 cadaver feet. Posterior tibiofibular mean length was measured to be 26.68 ± 4.49 mm. The study is in agreement with that of other studies.

Radiological measurements

Image 53: X–ray, AP view of talocrural joint.

M.S. Patil et al.[25] in their study on anthropometric measurements of ankle mortise for evaluating mortise fracture reductions with an aim to develop contoured implants measured the talocrural angle, tibiofibular clear space, tibiofibular overlap and compared joint clear space at two places. Anteroposterior radiographs, of both Ankles in 20 adult individuals formed the material. They agree with that the talocrural angle of two ankles of a given individual does not vary by more than 2 degrees. Tibiofibular clear space on Anteroposterior radiographs measured a mean value of 2.4 mm with a standard deviation of 1.3 mm. Tibiofibular overlap on Anteroposterior radiographs was measured as 11.2 mm with a standard deviation of 4.4 mm. Joint spaces at two levels were almost equal.

The study on Three-dimensional morphological characteristics measurement of ankle joint based on computed tomography image post-processing by Chen Yan-xi et al.[26] The mean talocrural angle (10.01±0.38°) was measured to be 10.1 degrees with a standard deviation of 0.38 degrees. Tibiofibular clear space mean measurements were 2.78 mm, with a standard deviation of 0.19 mm. They were not significance correlated with gender, height and weight (*P* >0.05) in 100 cases in 50 males and 50 females. The study is in agreement with the other studies.

Congenital abnormalities as seen in radiographs

The X-Ray findings of congenital abnormalities of ankle joints were examined. It was observed that the measurements when compared with that of normal ankle joint did not correlate with each other. The variations in measurements show us that it depends on the degree of malformation present in the congenital abnormalities.

Conclusion

Morphometry of the articular surface in wet talus: The lateral length measurement is higher than the other length measurements. Articular surface is wider in front and narrows posterior. The measurements are similar on both sides. In males, the measurements are similar to that of females except females had significantly (p=0.043) longer anterior radius when compared to males in articulating surface of wet talus.

Morphometry of articulating surface of wet tibia: The lateral side measurement is higher than the other length measurements. The articular surface is wider in front and narrows posterior. The measurements are similar on both sides. The measurements are similar in both sexes.

Morphometry of articular surface in wet fibula: The measurements are similar on both sides. In measurements are similar in both sexes.

Squatting facets on the superior articular surface of wet talus: The percentage of presence of squatting facets is 18.18 percent. Squatting facets are found more on the right side. It is also found more in males.

Squatting facets in superior articular surface in wet tibia: The percentage of presence of squatting facets on the tibia is 45.46 percent. The squatting facets are more on the right side. The squatting facets are more in the females.

Morphometry of articular surface in talus (dry bone): The lateral length measurement is higher than the other length measurements. Articular surface is wider in front and narrows posterior. The measurements on both sides are similar.

Morphometry of articulating surface in tibia (dry bones): The lateral length measurement is higher than the other length measurements. Articular surface is wider in front and narrows posterior. The measurements are similar on both sides.

Morphometry of articular surface in fibula (dry bone): The measurements are similar on both sides.

Squatting Facets on dry talus bones: The percentage of presence of squatting facets is 30 percent. It is present more on the right side.

Squatting facets on dry tibia: The percentage of presence of squatting facets is 36.66 percent. The squatting facets are present more on the left side.

Morphometry of ligaments on the lateral side

Anterior talofibular ligament: It is rectangular in shape. The measurements are similar on both sides. The measurements in both sexes are similar.

Variations in the anterior talofibular ligament: The one slipped variety is present in 6.7% in left side and 13.3% in right side. The three slipped variety is found in 6.7% in the right side. The one slipped variety is present in 15% of males. The three slipped variety is found in 10% of females.

Posterior talofibular ligament: It is a cord like ligament. measurements are similar on both sides. The measurement is similar in both sexes except, males had significantly (p=0.041) thicker ligament when compared to females in morphometry of posterior talofibular ligament.

Variations in the posterior talofibular ligament: It is found in 13.3% on the right side. It is found in 18.2% in females.

Calcaneofibular ligament: It is a cord like ligament. The measurements are similar on both sides. The measurements are similar in both sexes.

Morphometry of ligaments on the medial side (deltoid ligament): The superficial part trapezoid in shape wide anterior and narrow posterior measurements. It is also narrow superiorly where it arises and broad inferiorly where it gets inserted. There is a statistically significant difference between right and left side in superior width of deltoid ligament. The left side measurement is more than the right. (P=0.02). The right and the left side measurements are almost similar on both sides other aspects. There is also a significant difference between the male and female in inferior width of deltoid ligament. The male measurement is more than the female. (P=<0.01). The male and female measurements is similar in other aspects.

Morphomerty of ligaments of talofibular mortise

Anterior tibiofibular ligament: It is a flat laminar, multi vesicular flat ligament. The measurements are almost similar on both sides. The male measurements are similar to that of females except, there is a statistically significant difference in the thickness between the male and the female. The male measurement is more than the female. (p=0.017).

Posterior tibiofibular ligament: The measurements are similar on both sides. The male measurements are similar to that of females except, there is a statistically significant difference in the thickness between the male and the female. The male measurement is more than the females. (p=0.016).

Radiological measurements: The measurements are similar on both sides. The male and the female side measurements are similar.

Role of Authors

1. Dr Shishir Kumar: Principle Investigator
2. Dr Sham Kishore: Help to identify the gap in the knowledge and Statistics
3. Dr Avin BR Alva: Statistics
4. Dr Arunachalam Kumar: Co-Guide
5. Dr Satheesha Nambiar: Guide.

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