MORPHOMETRIC ANALYSIS OF THE MENISCI OF THE KNEE JOINT IN POPULATION OF EAST GODAVARI REGION OF ANDHRA PRADESHNarayan Rao¹, Anirban Das Gupta², A. V. Raju³**HOW TO CITE THIS ARTICLE:**

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ABSTRACT: The morphometrical data related to the menisci of the adults have been reported by few authors but data specific to the population of East Goadavari region have not been reported. The aims of the present study were to analyse the external circumference thickness, the width, peripheral and inner border lengths, and the distance between anterior and posterior horns of the menisci and to compare them with those which are available in the literature. The menisci from 100 knee joints of the formalin fixed cadavers which were obtained from the Anatomy department of Rangaraya Medical College, Kakinada and Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram were analysed. The cadavers which had musculoskeletal anomalies were excluded from the study. A vernier calliper of 0.02 mm accuracy and a non-elastic cotton thread were used for the morphometry. After comparing the meniscal dimensions of the present study with the other available literature, we established that there are some morphological differences of meniscus in this set of population.

KEYWORDS: Morphometry; Knee joint; Menisci.

INTRODUCTION: The incongruity of the joint faces of femur and tibia within knee joint can be "corrected" by wedge shaped medial and lateral meniscus.^[1] The meniscus plays an important role in load sharing, shock absorption, joint stability, joint nutrition and overall protection of articular cartilage.^[2] The menisci consist of cells such as chondrocytes and fibroblasts; the extracellular matrix is composed of collagen, proteoglycans, glycoproteins and elastin.^[3]

Meniscus injury is common in day to day life as well as in sports; they are exposed to injury which may occur as part of a rotational trauma, bending, joint degenerative process or spontaneous injury.^[5] Loss of a meniscus leads to a significant increase in the risk of developing arthritis in the knee. To reduce the process of knee degeneration after meniscectomy, meniscus allograft transplantation has been considered as a preferred choice.^[4]

A body and two horns can be distinguished in the menisci (anterior and posterior); these wider regions serve as the basis for the insertion of the meniscus. The load bearing function of meniscus depends on the firm bony insertion of its anterior and posterior horns.^[6]

Contour and the insertion of the medial and lateral menisci are important in determining the mechanism of injury.^[7] The outer edges of menisci are thick and attached to the fibrous capsule of the knee joint; the inner edges are non-fixed and sharp. Cuneiform in transversal cut, the menisci are firmly attached to the intercondylar area of tibia. The coronary ligaments are capsular fibers clinging to the margins of the menisci and tibial condyles.^[8]

The medial meniscus is wider anteriorly, fan-shaped and is attached to the tibial plateau about 6 to 7 mm anterior to the fixation of the anterior cruciate ligament.^[8,9]

ORIGINAL ARTICLE

Its posterior insertion attaches to the posterior intercondylar area of the tibia between the posterior insertion of the lateral meniscus and anteriorly to the fixation of the posterior cruciate ligament.^[1]

The lateral meniscus is almost circular, smaller and more freely movable than the medial meniscus. The anterior insertion of the lateral meniscus is attached to the anterior intercondylar fossa of the tibia, anteriorly to the lateral eminence of the tibia, and parts of its fibres blend with the anterior cruciate ligament.^[1]

The insertion of the posterior lateral meniscus is fixed in the tibia posterior to the insertion of the medial meniscus. In 50% of cases, the anterior fibres of the posterior insertion of the lateral meniscus are set out in the intercondylar notch of the medial condyle of the femur anterior to the origin of the posterior cruciate ligament.^[9,10]

For transplantation of menisci, vascularity and sizing of menisci is an important requirement. With regard to the menisci vascularization, the peripheral part is irrigated by vessels from its junction with the capsule and the anterior and posterior horns constituting the most vascular segments.^[11] Most commonly used method for sizing of the allograft is by plain radiographs.^[12]

Kohn and Moreno^[9] reports that, if bony fixation of a meniscal substitute should be attempted, the entire circumferential length of the meniscus plus both the insertion ligaments must be known. This length in the adult menisci has been described previously by Kohn & Moreno^[9] and McDermott et al.^[13] Cadaveric dissection can help in sizing the grafts accurately; hence, it is interesting to correlate the allograft sizing with dimensions of cadaveric menisci.

Meniscus size is subject to morphometric variation,^[14] moreover, there are marked differences in the contour and insertion between the lateral and the medial menisci which are important in relation to the injury mechanisms.^[15] According to Smillie,^[15] the morphological differences of menisci, in particular, the thickness and width can determine not only the possibility of an injury, but also the location and the kind of injury; this author also suggests that the narrow meniscus is less prone to ruptures than the wide.

This supposition is justified because the narrow meniscus is liable to a less action of femoral condyle. According to Smillie^[15] and Farias Filho et al,^[16] the lateral meniscus covers a higher area of the tibial plateau, due to its semicircular format and the proximity between the insertions of its horns. Thus in this study, knees were dissected to expose menisci and dimensions of menisci were calculated by using vernier calliper. These parameters can be useful in accurate sizing of meniscus allograft for transplantation, especially for this region of East Godavari district.

MATERIAL AND METHODS: The embalmed human cadavers which were obtained from the anatomy department were used for the present study. The study included 100 knee joints (50 right & 50 left sides); as the limbs were already disarticulated, sex of the cadavers was not considered in this study. The cadavers were preserved in 10% formaldehyde solution. The cadavers which had musculoskeletal anomalies were excluded from the study.

After the dissection of skin and muscles, the menisci were approached anteriorly by a longitudinal incision on each side of the joint capsule, cutting the patellar ligament and the collateral ligaments transversely. In order to expose the menisci clearly, the joint capsule and the intra articular ligaments were cut, and the condyles were circumferentially detached from their soft tissue attachments, exposing the tibial plateau.

ORIGINAL ARTICLE

All dissections were performed in a systematic fashion and data were recorded on a standardized collection sheet. The measurements were done based on the methods described by Murlimanju BV et al.^[17] The peripheral lengths of the menisci were measured with the non-elastic cotton thread. The thread was placed along the periphery of the meniscus and held in place with metallic pins. The length of this thread from the most anterior part of the insertional area to the most posterior part was measured and was called "peripheral length."

In the same way, the inner free border length was measured by keeping the thread at the inner free edge. Then the menisci were divided into 3 equal parts using the thread and the parts are called anterior, middle and posterior 1/3 respectively. The width and thickness of the menisci were measured with the vernier caliper. The measurements of the thickness and width were done at the midpoint of the above mentioned 3 parts.

The distance between the anterior and posterior horn was also measured. These parameters were used to determine dimensions of the menisci. Statistical analyses between the sides were performed by using t-test; p-values < 0.05 were considered significant. The SPSS 15.0 program was used for statistical analysis and data was presented as mean $\pm$ SD.

RESULTS: Both lateral and medial menisci were consistently present in all the 100 knee joints studied. The arrangement and attachments of the medial menisci were in conformity with the standard text book description and they did not show any variations. The anterior horn of medial meniscus was attached to the anterior tibial inter-condylar area in front of the anterior cruciate ligament whereas the posterior horn was attached to the posterior tibial inter-condylar area between the attachments of the lateral meniscus and posterior cruciate ligament.

The anterior horn of lateral meniscus was attached in front of the inter-condylar eminence posterolateral to the anterior cruciate ligament whereas the posterior horn was attached behind the inter-condylar eminence in front of the posterior horn of the medial meniscus. The peripheral margins of the both menisci were attached to the capsule except in posterolateral aspect where it was grooved by the tendon of popliteus.

From the results obtained, it was observed that there was no statistically significant difference in the length of the outer circumference ($p > 0.05$) between the medial (86.4 ± 0.27 mm) and lateral meniscus (87.3 ± 0.65 mm). The distance between the anterior and posterior horn of the medial meniscus (31.8 ± 0.33 mm) was significantly higher than that of the lateral meniscus (12.6 ± 0.98 mm). With regard to the width of the lateral meniscus, there was no significant difference between the anterior (9.90 ± 1.16 mm), middle (9.70 ± 0.61 mm), and posterior thirds (9.80 ± 1.16 mm).

However, in the medial meniscus, the posterior third was the widest part (15.80 ± 2.35 mm) followed by middle third (10.50 ± 1.20 mm) and the anterior third (8.30 ± 1.06 mm). Comparing the width of the medial and lateral menisci, a statistically significant difference ($p < 0.05$) in three points was found. The middle third of the medial meniscus was thickest (5.60 ± 0.60 mm) followed by anterior and posterior thirds (5.40 ± 0.5 mm) showing an average of 5.47 mm. Similarly, in the lateral meniscus, the middle third was the thickest (5.90 ± 0.33 mm) followed by the posterior (5.70 ± 0.40 mm) and anterior (5.00 ± 0.56 mm) thirds, and their average value was 5.53 mm.

In the present study 46 of the medial menisci were found to be crescentic shape, 24 of the medial menisci were found to be sided V shape, 14 of the medial menisci were found to be sided U shape, 11 of the medial menisci were found to be C-shape and 5 of the medial menisci were found to be sickle shape. Discoid shape was not observed in medial menisci.

ORIGINAL ARTICLE

In the present study 36 of the lateral menisci were found to be crescentic shape, 52 of the lateral menisci were found to be C-shape, 8 of the lateral menisci were found to be incomplete discoid and 4 of the lateral menisci were found to be complete discoid shape.

DISCUSSION: There has been an association of meniscus injury and consequent osteoarthritis with increased weight; with sedentary lifestyle in the verge of increasing meniscus injury has become a very important and common event. Variations of form and in particular, thickness and width of the menisci can determine the possibility and the kind of injury.^[13] The data related to the morphology of the menisci in this area are scarce; therefore, the main objective of this study was to analyze the morphometric variations present in the human meniscus of East Godavari region.

Study by Greis et al mentions that medial meniscus is C shaped; posterior horn is larger than anterior horn in anteroposterior dimension.^[18] Studies by Pollard et al^[19] and Shaffer et al^[20] describes medial meniscus as semicircular in shape with the posterior horn wider than the anterior horn. Study done by Brantigan et al^[21] and Miller et al^[22] says that the medial meniscus is much larger in diameter and thinner at the periphery. Didio^[23] reported that the posterior region of medial meniscus is quite wide whereas the anterior extremity is sharp and thin. Miller^[21] explained that the lateral meniscus is smaller in diameter, thicker about the periphery, and usually wider than medial. These observations about the width of medial meniscus as well as thickness of both menisci are confirmed by the present study.

In present study, the average length of the outer circumference is 86.4 mm for the medial meniscus and 87.3 mm for the lateral meniscus. There was no statistically significant difference between the length of the outer circumference of lateral and medial menisci; this finding do not corroborate with previous studies, which reveals that lateral meniscus is smaller than the medial.^[8]

This discrepancy can be explained by the next finding of our study; the distance between the anterior and posterior horns of the lateral meniscus is 12.6 mm and the distance between the anterior and posterior horns of the medial meniscus is 31.8 mm which correlates with study done by Kapandji et al^[24] and Miranda.^[25]

The larger interruption between the horns of medial meniscus indicates that the medial meniscus is more like a half-moon and the lateral meniscus resembles an almost complete ring thereby compensating for the difference in size of tibial plateau bordered by the menisci; this can explain why the outer circumference measures of the adjacent meniscus showed no significant difference. This finding is a very important clinical aspect whereby the close proximity of the two horns of lateral meniscus makes lateral meniscus less prone to injury.

The average width of lateral meniscus and medial meniscus in the present study was documented as 9.9 mm and 10.6 mm respectively; this finding do not corroborate with study done by Motta Filho et al^[26] and Hayashi et al.^[27] where the lateral meniscus was found to be 12-13 mm wide. Figueroa et al.^[28] observed that the lateral meniscus is more variable in its general configuration than the medial meniscus, appearing frequently wider in the body.

According to Smillie,^[15] the lateral meniscus exhibits a width higher and more uniform than the medial meniscus. However, Testut & Latarjet^[29] and Didio^[23] mentioned that the medial meniscus is a little wider than the lateral meniscus.

Moreover, no significant variations were found in the width between the 3 parts of the lateral meniscus but the posterior third of the medial meniscus was proved to be the widest followed by the

ORIGINAL ARTICLE

middle and anterior third; this corroborates with the findings documented by Almeida et al.^[7] and Moore et al.^[8]

In the present study, the anterior one third region of the lateral meniscus was wider than the medial and the posterior third region was wider in the medial than lateral. In the middle third region there was no statistically significant difference found between the medial and lateral compartments; this finding corroborates with findings of Almeida et al.^[7]

In the present study, the average thickness of lateral menisci were 5.53 mm which did not corroborate with the study done by Motta Filho et al.^[26] and Hayashi et al.^[27] According to Motta et al the lateral meniscus has an average thickness of 4-5 mm although Hayashi et al states that the normal meniscus is 6-8 mm thick; this may be attributed to morphological variation.

The middle third of the medial meniscus was thickest (5.60 ± 0.60 mm) followed by anterior and posterior thirds (5.40 ± 0.5 mm); this finding did not corroborate with study done by Almeida et al.^[7] which stated that the middle third was the thinnest followed by the anterior and posterior thirds. This difference may be explained by the fact that the three points used to perform the measures did not coincide during the data collection.

The lateral meniscus, in the present study exhibited thickest middle third (5.90 ± 0.33 mm) followed by the posterior (5.70 ± 0.40 mm) and anterior (5.00 ± 0.56 mm) thirds. This finding corroborates with Almeida et al. report^[7] which states that the middle third region of the lateral meniscus was the thickest in their specimens.

Hence, comparing the average thickness value of the medial menisci (5.47 mm) with the value of the lateral menisci (5.53 mm), it was observed that, in general lateral meniscus was thicker than medial meniscus ($p < 0.05$) but, the anterior third of the medial meniscus was significantly thicker ($p < 0.05$) compared to the lateral meniscus. According to Almeida et al.^[7] in the anterior and posterior third regions, the medial meniscus was the thickest.

From the above findings it can be said that the width and thickness were inversely related. The greater the width of one part, the smaller was the thickness, while the opposite was also true.

The findings of present study and previous studies have been compared and tabulated in table no. 1 & 2.

	THICKNESS (in mm)	WIDTH (in mm)
Testut et al. ^[29]	8(LM); 6(MM)	-----
Motta Filho et al. ^[26]	12(LM); 5(MM)	-----
Cailliet ^[19]	12-13(LM)	-----
Hayashi et al. ^[27]	6-8	12-13
Nimje BP et al. ^[30]	5 (MM); 6 (LM)	9 (MM); 9 (LM)
Present study	5.47 (MM); 5.53 (LM)	10.6 (MM); 9.9 (LM)

TABLE NO. 1: COMPARISON OF WIDTH AND THICKNESS OF PRESENT AND PREVIOUS STUDIES

LM=LATERAL MENISCUS; MM= MEDIAL MENISCUS.

According to the table 1, thickness of medial meniscus observed in present study approximates that of the studies of Testut et al.^[29] Motta Filho et al.^[26] Nimje BP et al.^[30] and Hayashi et al.^[20] Thickness of lateral meniscus observed in present study approximates that of the studies of

ORIGINAL ARTICLE

Testut et al.^[21] and Hayashi et al.^[27] Thickness of lateral meniscus observed in present study contradicts that of the studies of Motta Filho et al.^[26] and Cailliet^[31] which is almost half of their studies. Width of menisci, do not corroborate with those of Nimje BP et al.^[30] and Hayashi et al study.^[27]

Parameters	Braz et al (14)		Almeid et al (7)		Present study	
	MM (mm)	LM (mm)	MM (mm)	LM (mm)	MM (mm)	LM (mm)
Distance between 2 horns	25.88	12.55	29.7	12.7	31.8	12.6
Outer margin	91.85	92.8	NA	NA	86.4	87.4
Inner margin	NA	NA	NA	NA	50.1	44.2
A 1/3 (w)	7.68	11.32	9.02	11.86	8.4	10.0
M 1/3 (w)	9.32	11.16	12.16	11.97	8.4	10.0
P 1/3 (w)	14.96	11.67	17.37	11.44	15.0	9.8
A 1/3 (t)	6.17	4.40	5.92	3.70	5.4	5.0
M 1/3 (t)	6.31	6.52	5.31	6.10	5.6	5.9
P 1/3 (t)	5.18	5.46	5.91	5.29	5.4	5.7
TABLE 2: COMPARISON OF PARAMETERS OF MEDIAL AND LATERAL MENISCI IN PREVIOUS AND PRESENT STUDIES						

Abbreviations used: MM = Medial Meniscus, LM = Lateral Meniscus, NA = Not Available; t = thickness; w = width; A = anterior; P = posterior; M = middle.

Wider area of meniscus allows greater exposure with the femoral condyles; this indicates that narrower part of meniscus is less prone to injury when compared to the wider parts. Literature reveals that anterior third of the meniscus is least prone to injury^[32,33] whereas the middle and posterior third of meniscus is maximally prone to injury. This fact is substantiated in the present study by documenting that anterior third of the meniscus (both medial and lateral) is narrowest.

The menisci are fixed at the horns and mobile in the middle third; this makes the middle third of meniscus more prone to injury which further justifies the thick nature of middle third of both the meniscus. The same finding is documented in the present study.

Of the two menisci, middle third of lateral meniscus was comparatively thicker than that of the medial meniscus making the later more prone to stress.

The study also revealed that the distance between the two horns of lateral meniscus is lesser than that of medial meniscus; this allows lateral meniscus to adjust with the moving femoral condyle more than its counterpart; this indicates lateral meniscus is less prone to injury.

The limitation of this study includes the simplistic technique of relying on linear measurement of a nonlinear structure.^[17] Implications for future study would involve studying the radius of curvature or measurement of volume of the meniscus with software like scion image analyzer. We believe that our study will provide extra edge to the literature concerning the surgical procedures and arthroscopy of the knee joint and will be of help to orthopaedic surgeons and morphologists.

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ORIGINAL ARTICLE

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