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Original Research Article

Morphological Study of the Menisci of the Knee Joint in Human Cadavers in Maharashtrian Population

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Abstract:

Background: The menisci of the knee joint are crucial for joint congruence, load distribution, and prevention of osteoarthritis. Meniscal injuries are common and can have severe consequences. Understanding the morphological variations, width, and thickness of menisci is essential for diagnosis and treatment.

Methods: This study examined 200 menisci of right and left lower limbs of 50 cadavers which include 100 medial and 100 lateral menisci. Morphological variations were categorized, and measurements were taken using a digital Vernier caliper. The menisci were dissected systematically, and data were recorded. Morphological and morphometric analyses were conducted for both medial and lateral menisci.

Results: The medial meniscus predominantly exhibited a crescent shape (96%), while the lateral meniscus was mostly C-shaped (94%). Incomplete discoid meniscus were rare (1%) and exclusively found in the lateral menisci. The medial menisci were thicker on average compared to the lateral menisci. The width of the lateral menisci were generally greater than that of the medial menisci.

Conclusion: This comprehensive study provides insights into the diverse anatomical characteristics of the human knee joint menisci. Predominant shapes, thickness, and width differences between the medial and lateral menisci were observed. These findings contribute valuable information for diagnosing meniscal issues and planning interventions.

Keywords: Menisci, Knee Joint, Morphological Variations, Cadaveric Study.

Introduction

The knee joint menisci form a crucial functional unit that enhances joint congruence and distributes loads, reducing stress on the knee and preventing osteoarthritis. These structures play various roles in ensuring the proper functioning of the knee. Injuries to the menisci are common in work settings, sports, and daily activities and their impact can be severe. [1]

The menisci, also known as semilunar cartilages, are crescent-shaped fibrocartilaginous structures located within the joint capsule. They widen and deepen the tibial articular surfaces to accommodate the femoral condyles. Comprising chondrocytes and fibroblasts, the meniscus consists of an extracellular matrix composed of collagen, proteoglycans, glycoproteins, and elastin. [2]

The inner edges of the menisci are slim and concave, while the thicker and convex borders are attached peripherally. Blood vessels from the fibrous capsule and synovial membrane supply blood to the outer regions, whereas the inner portions lack blood supply. Meniscal tears are common, especially in the inner avascular zones, and spontaneous healing is rare. Surgical intervention is often necessary, and in cases where removal is required, it is typically for meniscal tears in the avascular inner regions. Conversely, if surgery involves repair, tears in the vascularized peripheral zones can generally heal effectively. [3]

The menisci contribute to joint lubrication and provide cushioning to protect the underlying bone from the substantial forces generated during extreme flexion and extension. By enhancing the congruity of articulation, they play a crucial role in mitigating these forces. Additionally, the menisci offer proprioceptive feedback to further support joint function. The significance of structural anomalies and variations in the intraarticular structures of the knee joint has become more apparent with advancements in diagnostic techniques like arthroscopy, computed tomography (CT), and magnetic resonance imaging (MRI).

Notably, the absence of a meniscus significantly elevates the risk of developing arthritis in the knee. [4]

Utilizing allograft tissue for meniscus replacement proves beneficial in alleviating symptoms and reducing the likelihood of future arthritis. Precision in determining the appropriate size and shape is essential in the context of meniscal transplantation. Primary care physicians often encounter cases of knee pain attributed to meniscal tears in the community. [5]

Morphological variations in menisci increase the susceptibility to tears. This study aids family physicians in recognizing the significance of diverse meniscal structures and the role they play in causing knee issues through tears. Our study sought to achieve three primary objectives: (1) To examine the morphological variations in meniscal form, (2) to analyze the width and thickness of the menisci, and (3) to compare the characteristics of the medial menisci (MM) and lateral menisci (LM) within the knee joint.

Material and Methods

This study employed a cross-sectional design to investigate the morphological characteristics of the menisci of the knee joint in human cadavers within the Maharashtrian population.

The research utilized the following resources: Human adult knee joints sourced from the anatomy dissection hall were employed in the study. A total of 200 menisci which include 100 medial and 100 lateral menisci of both lower limbs obtained from 50 adult cadaver knee joints were included in the research. Measurements of the menisci were conducted using a digital Vernier caliper.

Morphological Study

The examination of the menisci involved the dissection of skin and muscles, followed by an anterior approach. This approach included making longitudinal incisions on each side of the joint capsule and transverse cuts of the patellar ligament and collateral ligaments. To expose the menisci, the joint capsule and intraarticular ligaments were incised, and the condyles were circumferentially separated from their soft tissue attachments. Subsequently, the condyles were excised to unveil the tibial plateau. The dissections were conducted systematically, and data were recorded on a standardized collection sheet. Menisci were observed and classified according to their morphological variations, including sickle-shaped, sided U-shaped, sides V-shaped, crescent-shaped, and C-shaped for the medial menisci (MM). The lateral menisci (LM) were categorized into three types: crescent (semilunar), C-shaped, and discoid-shaped. A meniscus is considered discoid when it covers the tibial plateau in a circular pattern. Crescent (semilunar) menisci were characterized by slender anterior and posterior horns along with thin bodies. Sickle-shaped menisci were identified by slender anterior and posterior horns and thicker bodies. Menisci exhibiting structural alterations, including injuries or advanced degenerative changes, were excluded from the study.

Morphometric Study

A digital Vernier caliper was employed to assess the width and thickness of the menisci. The breadth of the menisci was measured at three specific points: the anterior third, middle third, and posterior third. At each designated site, a line was drawn from the outer margin of the meniscus to the inner margin of the meniscus for measurement purposes. The cumulative measurement was calculated by considering the distances between the outer and inner margins at each designated breadth point. Similarly, for thickness assessment, measurements were taken exclusively between the upper and lower margins of the outer circumference at the same breadth points. The collected data were organized into tables and subjected to statistical analysis using Microsoft Excel. Mean values along with standard deviations were calculated for all measurements. Data analysis was performed using a Student's t-test.

Results and Discussion

Morphological Study of Menisci

The differentiation of menisci or the establishment of vasculature during early embryonic development may contribute to alterations in the meniscus's form. Morphological changes in the menisci could indicate the potential for damage. The distinctive contours and insertions of the lateral meniscus (LM) and medial meniscus (MM) play a significant role in injury processes. Abnormalities in meniscal form, such as hypoplasia or hyperplasia, have been identified in men. Particularly, meniscal hyperplasia, also referred to as discoid menisci, has been extensively researched due to its frequent association with symptomatic conditions. Parsons [6] observed that the medial meniscus (MM) typically exhibits a crescentic shape in primates, while the lateral meniscus (LM) can be either crescentic or disc-shaped. Vallois [7] supported and further explored this observation, conducting an anatomical study of the knee joint in primates.

Flick and Rudolph [8,9] characterized the medial meniscus (MM) as resembling half, two-thirds, or three-fourths of an ellipse, whereas the lateral meniscus (LM) was likened to an almost complete circle. On a different note, Charles classified the menisci by considering the relative size of the anterior and posterior horns as well as the curvature degree. Additionally, Young [10] documented the presence of a discoid lateral meniscus in a cadaver

specimen. The knee's meniscus, particularly the lateral meniscus (LM), displays a discoid shape instead of the typical semilunar form, representing an atavistic anomaly. The discoid meniscus is believed to be primarily a congenital deviation, with a tendency to occur more frequently on the lateral side. Moreover, it was observed that the discoid shape led to increased coverage of the tibia and was frequently associated with a greater thickness of the meniscus. This structural variation could potentially contribute to abnormal shearing stresses across the knee joint.

A discoid meniscus stands out as the most common congenital anomaly of the meniscus in men, with a prevalence ranging from 0.4% to 17%, and the majority of cases manifesting on the lateral side of the knee. This information is derived from a study conducted by Rao and Rao [11] in South India. Out of 3,167 knee arthroscopies conducted between 1993 and 2004, a total of 177 cases (5.59%) revealed the presence of a discoid lateral meniscus (discoid LM).

Nathan et al. [12] reported a frequency of 1.4–4.5% for discoid meniscus in the lateral meniscus (LM) and 0.3% for the medial meniscus (MM). However, the present study revealed an incomplete discoid meniscus in 1% of the lateral meniscus and none in the medial meniscus. In 2006, Kale et al. [13] identified six morphological categories of meniscus forms. Among the medial menisci (MM), 18.8% were crescent-shaped, 22.72% were sided V-shaped, 9.09% were sided U-shaped, 36.36% were sickle-shaped, 13.63% were C-shaped, and none were discoid-shaped. Notably, among the discoid shapes, 54.54% exhibited partial discoid forms, while 22.72% exhibited complete discoid shapes.

There was no evidence of a discoid medial meniscus (MM), and 73% of the cadavers exhibited consistent meniscus morphology on both sides. In a study by Kale et al. [13] in 2006, six morphological types of meniscus forms were identified, including horseshoe, sickle, sided U-shaped, C-shaped, and discoid shapes. However, in the present investigation, horseshoe-shaped structures were not observed. The same study by Kale et al. [13] discovered discoid lateral menisci (LM) in 77% of cases and no discoid MM. This research was conducted on 11 neonatal cadavers with a total of 22 knee joints. Muralimanju et al. [14] identified four distinct morphological forms of menisci shapes in adult cadavers. Among the medial menisci (MM), 50% were crescent-shaped, 38.9% were V-shaped, and 11.1% were sided U-shaped. For the lateral menisci (LM), 61.1% exhibited a C-shaped morphology, while 38.9% were crescent-shaped, and no discoid forms were observed on either side. Interestingly, the study found that the MM shape differed on each side in 54.71% of the cadavers. In a study by Itagi et al. [15] in 2015, focusing on the morphology of 60 menisci from cadaveric adult knee joints, the findings revealed that 96.6% of medial menisci (MM) were crescentic in shape, 1.6% were sided V-shaped, and 1.6% were sickle-shaped. As for the lateral menisci (LM), 88.33% exhibited a C-shaped morphology, 6.66% were U-shaped, and 5% were classified as incomplete discoid shapes.

The morphological classification of menisci in this study revealed that crescent-shaped medial menisci (MM) constituted 96%, sided V-shaped MM accounted for 2%, sickle-shaped MM accounted for 2%, and no discoid MM were observed (2%). Regarding lateral menisci (LM) shapes, 94% were C-shaped, 4% were sided U-shaped, and 1% were classified as incomplete discoid. These findings are largely consistent with the observations made by Itagi et al. [15] [Tables 1 and 2].

Table 1: The incidence of different shapes of the MM (*n*=100)

Shape	Total and Percentage
Crescentic	96 (96%)
Sided V-shaped	2 (2%)
Sided U-shaped	2 (2%)

Table 2: The incidence of different shapes of the LM (*n*=100)

Shape	Total and Percentage
C Shaped	94 (94%)
Sided U Shaped	4 (4%)
Incomplete Discoid	2 (2%)

Morphometric Study of Menisci

Elevated body weight and a sedentary lifestyle have been associated with meniscus injuries and the subsequent development of osteoarthritis. The morphology of the menisci, particularly in terms of thickness and width, can influence the type of injury, treatment options, and prognosis. Due to the limited understanding of meniscal morphometry, this study aimed to explore variations in human meniscus morphology, contributing valuable insights to the field. The study also sought to correlate these morphometric variations with the likelihood, location, and type of meniscal lesions.

Over time, numerous authors have delved into the morphological characteristics of the knee joint's

menisci. In this current study, a comparative analysis was conducted on the morphological parameters of the knee joint's menisci, aligning the findings with observations made by other authors. The study encompassed diverse areas explored in previous research, including those conducted by Almeida et al [15], Braz and Silva [16], Bhatt et al. [17], and Hathila et al. [18]. [Tables 3 and 4].

Table 3: Comparison of Morphological Studies: MM Study vs. Other Study

Parameters	Present study	Almeida et al [16]	Braz and Silva [17]	Bhatt et al. [18]	Hathila et al. [19]
The thickness of MM (mm)					
Anterior 1/3	5.96±0.60	5.92±1.37	6.17±1.68	5.82±1.44	6.21±0.60
Middle 1/3	6.10±0.69	5.31±1.06	6.31±1.73	5.64±1.26	6.18±0.55
Posterior 1/3	6.20±0.60	5.91±1.13	5.18±1.55	5.86±1.06	6.30±0.42
Width of MM (mm)					
Anterior 1/3	8.60±0.63	9.02±1.59	7.68±1.36	8.78±2.12	9.05±0.70
Middle 1/3	11.24±1.17	12.16±2.58	9.32±2.24	12.08±2.52	11.10±0.45
Posterior 1/3	15.58±1.02	17.37±2.22	14.96±2.66	16.46±2.18	15.39±0.80

Table 4: Comparison of Morphological Studies: LM Study vs. Other Study

Parameters	Present study	Almeida et al [16]	Braz and Silva [17]	Bhatt et al. [18]	Hathila et al. [19]
The thickness of LM (mm)					
Anterior 1/3	4.20±0.55	3.71±1.15	4.40±0.83	3.70±1.52	4.15±0.50
Middle 1/3	5.93±0.42	6.10±1.04	6.52±1.81	5.78±1.22	5.90±0.61
Posterior 1/3	5.50±0.35	5.29±0.78	5.46±1.19	5.20±0.98	5.63±0.60
Width of LM (mm)					
Anterior 1/3	11.56±0.82	11.86±1.81	11.32±1.46	11.30±1.30	11.82±0.81
Middle 1/3	12.12±0.95	11.97±2.56	11.16±1.64	11.66±1.48	12.53±0.72
Posterior 1/3	11.85±0.83	11.44±1.07	11.67±1.54	11.50±1.34	12.03±0.80

The present study noted that the anterior third (5.96 ± 0.60 mm) of the medial meniscus is the thinnest at the anterior, middle, and posterior locations, which contrasts with the findings of Almeida et al [15], Braz and Silva [16], Bhatt et al. [17], and Hathila et al. [18]. According to Almeida et al [15], the average thickness of the medial meniscus (MM) was 5.71 mm, while that of the lateral meniscus (LM) was 5.03 mm. Braz and Silva [16], reported an average thickness of 5.87 mm for the MM and 5.46 mm for the LM. In the study by Hathila et al. [18], the average thickness was 5.77 mm for the MM and 4.89 mm for the LM. Hathila et al. [18] found that the medial meniscus (MM) is 6.23 mm thick, and the lateral meniscus (LM) is 5.22 mm thick. In the current study, the average thickness was reported as 6.08 mm for the MM and 5.21 mm for the LM. This suggests that, on average, the MM tends to be thicker than the LM. In comparison to previous studies, the current study indicates that the thickness of both the medial meniscus (MM) and lateral meniscus (LM) is greater, with the exception of the study by Hathila et al. [18], which reported thickness values higher than those found in the current study.

According to Almeida et al [15], the average width of the medial meniscus (MM) was 12.85 mm, and that of the lateral meniscus (LM) was 11.76 mm. In the study by Braz and Silva [16], the average width was reported as 10.65 mm for the MM and 11.38 mm for the LM. As reported by Bhatt et al. [17], the average width of the medial meniscus (MM) was 11.48 mm, and that of the lateral meniscus (LM) was 12.44 mm. Hathila et al. [18] found an average width of 11.84 mm for the MM and 12.12 mm for the LM. The current investigation discovered the average width of the medial canal, but the specific measurement is not provided in the text.

Young [10] suggests that lateral menisci (LM) are wider than medial menisci (MM). Furthermore, he contends that morphological features, particularly thickness and width, can not only suggest the likelihood of injury but also indicate the location and type of injury. Young [10] found that a broader meniscus is more susceptible to rupture than a narrower one. Almeida et al [15] observed that the width of the middle third of the lateral meniscus (LM) was greater than the posterior third. In contrast, in the present study, the posterior third of the medial meniscus (MM) was found to be the broadest, while the anterior third was the narrowest. For the lateral meniscus, the middle third was the widest, while the anterior third was the narrowest. These differences in findings highlight variations in meniscal width across different studies.

The key findings from the present study include:

1. A predominant crescent shape was observed in the medial meniscus (MM) at 96%, while a dominant C-shaped configuration was noted in the lateral meniscus (LM) at 94%. Incomplete discoid meniscus was present in only 1% of

cases, exclusively in the LM and absent in the MM.

2. The medial meniscus (MM) demonstrated greater thickness compared to the lateral meniscus (LM) according to the data presented in Table 5.
3. The width of the lateral meniscus (LM) was found to be greater than that of the medial meniscus (MM). [Table 6 and Figures 1-2].

Table 5: Comparison of Thickness of MM and LM at Anterior, Middle and Posterior Third

Observation	Thickness					
	Anterior third		Middle third		Posterior third	
	MM	LM	MM	LM	MM	LM
Mean	5.96	4.20	6.10	5.93	6.20	5.50
Standard deviation	0.60	0.55	0.69	0.42	0.60	0.35
Statistical parameter	*t*-test 13.48, *P*<0.0001		*t*-test 1.45, *P*<0.15		*t*-test 7.24, *P*<0.0001	

Table 6: Comparison of Width of MM and LM at Anterior, Middle and Posterior third

Observation	Thickness					
	Anterior third		Middle third		Posterior third	
	MM	LM	MM	LM	MM	LM
Mean	8.60	11.56	11.24	12.12	15.58	11.85
Standard deviation	0.63	0.82	1.17	0.95	1.02	0.83
Statistical parameter	*t*-test 18.70, *P*<0.0001		*t*-test 3.62, *P*<0.001		*t*-test17.83, *P*<0.0001	

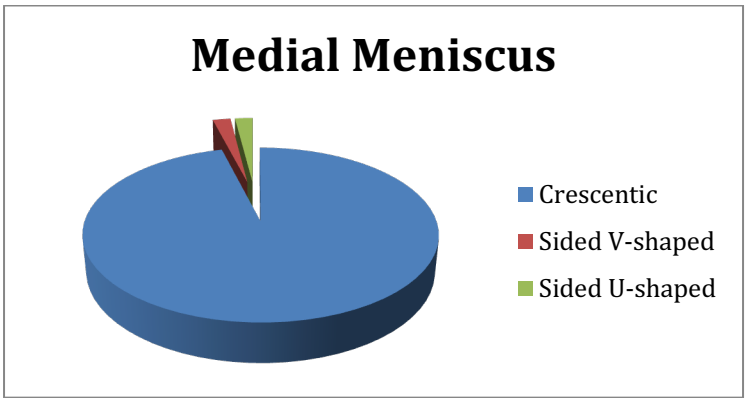

Figure 1: Pie diagram showing the incidence of different shapes of medial meniscus

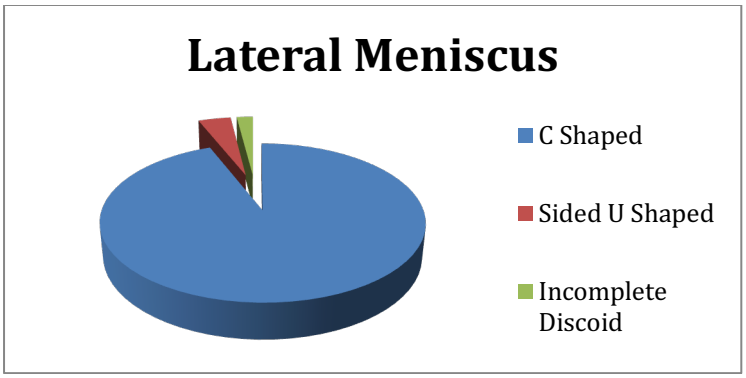

Figure 2: Pie diagram showing the incidence of different shapes of lateral meniscus

Conclusion

In conclusion, this comprehensive study investigated the morphological variations, width, and thickness of the medial and lateral menisci in the human knee joint. The findings highlighted the predominance of crescent-shaped medial menisci (MM) and C-shaped lateral menisci (LM), with minimal instances of incomplete discoid forms in the LM. The study revealed that the MM tends to be thicker on average compared to the LM, while the width of the LM is generally greater than that of the MM. These observations contribute valuable insights into the diverse anatomical characteristics of menisci.

Limitations

Despite the valuable insights gained from this study, certain limitations should be acknowledged.

The sample size, although sufficient for the study's scope, may not fully represent the entire population. Additionally, the study focused on morphological and dimensional aspects of menisci, excluding factors such as age, gender, and potential variations in individuals' daily activities, which could impact meniscal morphology. Future research could incorporate a more extensive and diverse sample, considering a broader range of demographic factors, to enhance the generalizability of findings. Moreover, the study primarily relied on cadaveric specimens, and caution should be exercised when extrapolating these findings to living individuals.

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Conflicts of Interest: The authors declare no conflicts of interest in relation to this research.

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