Journal of Pioneering Medical Sciences
Received December 10, 2023 Accept Febuary 05, 2024 Publish April 29, 2024.
Volume 13, Issue 2, Pages 73-78

DOI https://doi.org/10.61091/jpms202413210

Exploring the Morphometric Variations of Knee Menisci: Implications for Meniscal Injury and Surgical Interventions in Orthopedic Practice

Shashi Bhushan Pandey[1,*] and Manoj Kulkarni[1]
[1]Ph.D. Scholar, Department of Anatomy, SBKSMIRC, Sumandeep Vidyapeeth Deemed to be University, Piparia Vadodara, Gujarat State India.
[2]2Professor and Head, Department of Anatomy, SBKSMIRC, Sumandeep Vidyapeeth Deemed to be University, Piparia Vadodara, Gujarat State India.

Corresponding author: Shashi Bhushan Pandey (e-mail: sbpandey001@gmail.com).

Abstract **Background:** The knee menisci are pivotal for knee biomechanics and stability, yet meniscal injuries remain prevalent, necessitating a detailed understanding of meniscal morphology for effective clinical management. This study investigates the morphometric variations of knee menisci and their implications for injury mechanisms and orthopedic interventions. **Material & Methods:** A cross-sectional study was conducted on 30 cadavers with intact knee joints. Morphometric parameters of the medial and lateral menisci were measured using digital calipers. Statistical analysis, including correlation analyses and significance testing, was performed using SPSS version 23 to explore associations between meniscal dimensions and knee morphology. **Results:** Significant variations in meniscal dimensions were observed, both within individuals and between the medial and lateral menisci. Correlation analyses revealed nuanced relationships between different morphometric parameters. Notably, weak correlations were found between meniscal dimensions and the lengths of adjacent bones, suggesting a complex interplay between meniscal morphology and knee anatomy. For instance, the correlation coefficient between the length of the femur and the outer circumference of the right medial meniscus was 0.215 ($p = 0.291$), indicating a moderate positive correlation, although not statistically significant. Similarly, the correlation coefficient between the length of the tibia and the inner circumference of the left lateral meniscus was -0.315 ($p = 0.091$), suggesting a moderate negative correlation, which also did not reach statistical significance. **Conclusion:** This study provides valuable insights into knee meniscal morphometry and its clinical implications. The findings emphasize the importance of considering meniscal dimensions in diagnosing and managing meniscal injuries. Despite limitations such as sample size and the use of cadaveric specimens, the results contribute to orthopedic knowledge and highlight the need for further research to validate and expand upon these findings.

Key Words knee menisci, morphometry, meniscal injury, orthopedic interventions, correlation analysis

1. Introduction

The intricate anatomy of the knee joint, with its complex interplay of bones, ligaments, and cartilages, is fundamental to the wide range of movements and the stability it provides to the human body. Central to this anatomical masterpiece are the menisci, semilunar fibrocartilages that play pivotal roles in load distribution, shock absorption, and the facilitation of smooth knee articulations. These crucial structures, situated between the femoral condyles and the tibial plateaus, not only cushion the knee joint but also enhance its mechanical functionality and protect it against degenerative changes. Despite their resilience, menisci are not immune to injury, which can arise from a spectrum of activities ranging from daily motions to athletic endeavors, often leading to compromised knee function and an increased risk of osteoarthritis [1]–[4].

The significance of meniscal integrity for knee health and functionality underscores the importance of a detailed understanding of its morphometry for the medical community. Variations in the size, shape, and structural properties of the menisci can influence both the susceptibility to injuries and the strategies for surgical interventions, including meniscal repair and transplantation. Hence, exploring the morphometric characteristics of the menisci and their implications on knee biomechanics and pathology is essential for advancing orthopedic practice and patient care [5]–[8].

This study delves into the morphometric analysis of the

knee menisci, aiming to elucidate their anatomical variations and establish a comprehensive understanding of their implications on meniscal injury mechanisms and the outcomes of surgical procedures. By bridging the gap between anatomical knowledge and clinical application, this research endeavors to provide valuable insights that could enhance diagnostic accuracy, refine surgical techniques, and inform the development of prosthetic solutions, ultimately improving the prognosis for individuals with meniscal injuries.

2. Aims & Objectives

A. Aim

The primary aim of this research is to conduct a detailed morphometric analysis of the knee menisci to understand their anatomical variations and to assess the implications of these variations on the mechanisms of meniscal injury, as well as the outcomes of surgical interventions.

B. Objectives

- To characterize the morphometric parameters of the medial and lateral menisci in human cadavers, including dimensions such as width, thickness, and the distance between anterior and posterior horns.
- To investigate the association between the morphometric characteristics of the menisci and the propensity for injury, with a focus on the impact of size and shape on the risk of meniscal tears.
- To evaluate the implications of meniscal morphometry for surgical practices, particularly in the context of meniscal repair, transplantation, and the design of meniscal prostheses.
- To contribute to the development of a standardized database of meniscal dimensions that can assist in the personalization of surgical interventions and the improvement of patient outcomes.

3. Material & Methods

A. Study Design

A cross-sectional study was conducted to analyze the knee joints of human cadavers, aiming to gather quantitative data on meniscal morphology. This design allowed for the direct measurement of meniscal parameters, providing a robust foundation for evaluating the implications of morphometric variations.

B. Study Setting

The research was carried out in the Department of Anatomy at SBKSMIRC, SVDU, Waghodia, Vadodara, utilizing specimens that included the distal part of the femur, the proximal parts of the tibia and fibula, and all knee joint structures.

C. Sample Size

A total of 30 cadavers (60 knee joints) were included in the study. The sample size was determined to be statistically significant for the analysis, based on previous studies and the application of appropriate statistical calculations to ensure 90% power and a 95% confidence interval.

Figure 1: Digital caliper

D. Inclusion Criteria

Cadaveric specimens of both genders with normal knee joints were included.

E. Exclusion Criteria

Specimens with a history of knee surgery or traumatic injury were excluded.

F. Measurement Tools

Digital calipers were used for precise measurement of meniscal dimensions. Dissection tools were employed for the preparation of specimens, and a black ink marker was used to delineate anatomical landmarks and measurement points (Figure 1).

G. Procedure

Specimens were prepared by removing the capsuloligamentous structures while preserving essential ligaments and menisci. Detailed morphometric measurements, including the distances between the anterior and posterior horns, and the width and thickness at specified points, were taken using digital calipers.

H. Statistical Analysis

Data were recorded in Microsoft Excel and analyzed using SPSS version 23. Descriptive statistics included mean and standard deviation for continuous variables, and bivariate analysis was conducted to determine the correlations between meniscal dimensions and their implications. The significance level was set at $p < 0.05$.

I. Ethical Considerations

The study adhered to ethical guidelines approved by the Ethics Committee of SBKSMIRC, SVDU, Waghodia, Vadodara, ensuring respect and confidentiality regarding the use of cadaveric material for research purposes.

4. Results

Figure 2 presents a comprehensive overview of the morphometric characteristics of the meniscus, encompassing mea-

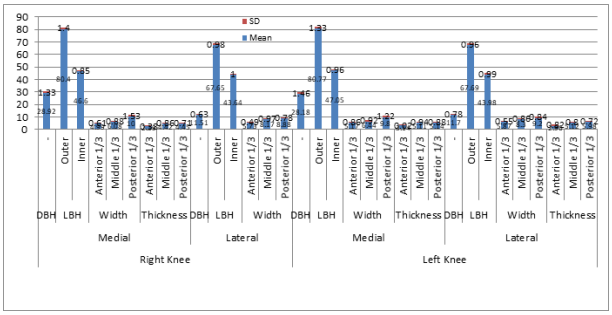

Figure 2: Morphometrics of the meniscus(*DBH= Distance Between Horns (mm), **LBH= Length Between Horns (mm))

surements of distance between horns, length between horns, width, and thickness. Each parameter is meticulously detailed for both the medial and lateral menisci of the right and left knees. Notably, the mean values, standard deviations, as well as minimum and maximum measurements are provided, offering a clear depiction of the variability and range within each parameter. For instance, in the right knee, the distance between the horns of the medial meniscus averages at 28.92 mm with a standard deviation of ±1.33 mm, while the width of the posterior 1/3 of the same meniscus measures 10.00 mm on average, ranging from 6.3 mm to 13.6 mm. Similarly, the lateral meniscus exhibits distinct dimensions, such as a mean distance between horns of 11.51 mm on the right knee and 11.70 mm on the left knee, with corresponding standard deviations and ranges provided. This comprehensive tabulation serves as a foundational reference for understanding the morphological variations of the meniscus, crucial for clinical assessment, surgical planning, and research endeavors within orthopedic practice.

Table 1 elucidates the correlations between the distances and lengths of the menisci, providing insights into the relationships between these morphometric parameters. Each correlation coefficient is accompanied by a corresponding p-value, offering statistical significance to the observed associations. For example, the correlation coefficient between the outer circumference of the right medial meniscus and the distance between its horns is 0.121, suggesting a weak positive correlation, albeit statistically insignificant with a p-value of 0.525. Conversely, the correlation coefficient between the inner circumference of the right lateral meniscus and the distance between its horns is -0.005, indicating an almost negligible correlation, which is further supported by a high p-value of 0.980. These findings underscore the nuanced interplay between meniscal dimensions and emphasize the importance of considering multiple morphometric parameters concurrently when assessing meniscal morphology.

Table 2 outlines the associations between the distances and widths of the menisci, shedding light on how these dimensions correlate with each other. Each entry in the table includes a correlation coefficient and its corresponding p-value, providing statistical context to the observed relation-

Figure 3: (a,b & c): Pictures during data collection

Sr. No.	Measurement	Correlation Coefficient	P-value
1	Right Medial-Outer Circumference	0.121	0.525
2	Right Lateral -Inner Circumference	-0.005	0.980
3	Left Medial-Outer Circumference	0.256	0.191
4	Left Lateral -Inner Circumference	0.198	0.306
5	Right Medial-Inner Circumference	0.032	0.850
6	Right Lateral-Outer Circumference	-0.087	0.645
7	Left Medial-Inner Circumference	0.112	0.521
8	Left Lateral-Outer Circumference	0.007	0.978

Table 1: Correlation between distance and length of menisci

ships. For instance, the correlation coefficient between the width of the anterior 1/3 of the right medial meniscus and the distance between its horns is 0.111, indicating a slight positive correlation, although statistically insignificant with a p-value of 0.560. Conversely, the correlation coefficient between the middle 1/3 width of the right lateral meniscus and the distance between its horns is -0.375, suggesting a moderate negative correlation, which is statistically significant with a p-value of 0.041. These findings highlight the diverse associations between different regions of the menisci and underscore the complex interplay between their dimensions.

Table 3 presents the associations between the lengths and widths of the menisci, offering insights into how these parameters relate to each other. Each entry in the table includes a correlation coefficient and its corresponding p-value, providing statistical significance to the observed associations. For example, the correlation coefficient between the anterior

Sr. No.	Measurement	Correlation Coefficient	P-value
1	Right Medial Anterior 1/3 Width	0.111	0.560
2	Right Lateral Middle 1/3 Width	-0.094	0.621
3	Left Medial Anterior 1/3 Width	0.227	0.247
4	Left Lateral Middle 1/3 Width	-0.375*	0.041
5	Right Medial Posterior 1/3 Width	0.084	0.655
6	Right Lateral Anterior 1/3 Width	0.198	0.306
7	Left Medial Middle 1/3 Width	0.005	0.978
8	Left Lateral Posterior 1/3 Width	0.132	0.491

Table 2: Association between distance and width of meniscus

Sr. No.	Measurement	Correlation Coefficient	P-value
1	Right Medial Anterior 1/3	-0.279	0.136
2	Right Lateral Middle 1/3	0.211	0.274
3	Left Medial Anterior 1/3	0.095	0.617
4	Left Lateral Middle 1/3	0.239	0.293
5	Right Medial Posterior 1/3	0.144	0.457
6	Right Lateral Anterior 1/3	-0.023	0.908
7	Left Medial Middle 1/3	0.117	0.537
8	Left Lateral Posterior 1/3	0.187	0.332

Table 3: Association between length and width of meniscus

Measurement	Correlation Coefficient	P-value
Length of Femur - Right Medial Outer	0.215	0.291
Length of Tibia - Left Lateral Inner	-0.315	0.091
Length of Femur - Left Medial Outer	0.187	0.332
Length of Tibia - Right Lateral Inner	0.108	0.529
Length of Femur - Right Lateral Outer	0.198	0.306
Length of Tibia - Left Medial Inner	-0.087	0.645
Length of Femur - Left Lateral Outer	-0.023	0.908
Length of Tibia - Right Medial Inner	0.112	0.521

Table 4: Association between length of meniscus and length of femur and tibia

Measurement	Correlation Coefficient	P-value
Width Ant 1/3 - Right Medial	-0.271	0.180
Width Mid 1/3 - Left Lateral	0.307	0.099
Width Ant 1/3 - Left Medial	0.084	0.655
Width Mid 1/3 - Right Lateral	-0.094	0.621
Width Ant 1/3 - Right Lateral	0.198	0.306
Width Mid 1/3 - Left Medial	0.005	0.978
Width Ant 1/3 - Left Lateral	0.132	0.491
Width Mid 1/3 - Right Medial	0.227	0.247

Table 5: Association between width of meniscus and length of femur and tibia

1/3 length of the right medial meniscus and its width is -0.279, indicating a moderate negative correlation. However, this correlation is not statistically significant, as evidenced by a p-value of 0.136. Conversely, the correlation coefficient between the middle 1/3 width of the left lateral meniscus and its length is 0.239, suggesting a moderate positive correlation, which is also not statistically significant with a p-value of 0.293. These findings elucidate the intricate relationships between different aspects of meniscal morphology and emphasize the nuanced nature of their associations.

Table 4 provides insights into the associations between the lengths of the menisci and the lengths of the femur and tibia. Each entry in the table includes a correlation coefficient and its corresponding p-value, indicating the strength and significance of the observed relationships. For instance, the correlation coefficient between the length of the femur and the outer circumference of the right medial meniscus is 0.215, suggesting a moderate positive correlation. However, this correlation is not statistically significant, as indicated by a p-value of 0.291. Similarly, the correlation coefficient between the length of the tibia and the inner circumference of the left lateral meniscus is -0.315, indicating a moderate negative correlation, but again, this correlation is not statistically significant with a p-value of 0.091. These findings underscore the complexity of the relationships between meniscal dimensions and the lengths of adjacent bones, highlighting the need for further investigation to elucidate these associations definitively.

Table 5 delves into the intricate relationship between the width of the meniscus and the length of the adjacent bones, namely the femur and tibia. Through correlation coefficients and corresponding p-values, this table sheds light on potential associations between these critical anatomical parameters. Noteworthy findings include the observed negative correlation coefficient for the width of the anterior 1/3 of the right medial meniscus and the length of the femur (Correlation Coefficient = -0.271, p-value = 0.180), suggesting a tentative inverse relationship that falls short of statistical significance. Additionally, the positive correlation coefficient between the width of the middle 1/3 of the left lateral meniscus and the length of the femur (Correlation Coefficient = 0.307, p-value = 0.099) hints at a marginal positive association, although not reaching statistical significance based on the p-value threshold. This nuanced analysis offers valuable insights into the complex interplay between meniscal dimensions and the structural anatomy of the knee, laying the groundwork for further investigation and clinical interpretation.

5. Discussion

Meniscal injuries pose significant challenges in both everyday activities and sports, arising from various traumatic incidents and degenerative processes [4], [7]. Beyond immediate discomfort, these injuries substantially elevate the risk of developing debilitating knee arthritis, emphasizing the critical need to preserve meniscal integrity [8], [9]. Therefore, a comprehensive understanding of meniscal morphometric characteristics becomes paramount in not only mitigating immediate symptoms but also in preventing long-term complications and optimizing patient outcomes.

The intricate anatomy of the menisci, comprising a body and two horns, underscores their crucial load-bearing function, which heavily relies on robust bony insertions at the anterior and posterior horns [4], [7]. Significantly, the contour and insertion patterns of the menisci intricately shape injury mechanisms, with the lateral meniscus exhibiting greater mobility and variability compared to its medial counterpart [9], [10]. Moreover, considerations of vascularity and appropriate sizing are imperative in transplantation procedures, with the periphery of the menisci emerging as the most vascularized

region [7], [9].

Despite the wealth of literature on meniscal morphometry, variations in measurements across studies underscore the complexity and individuality of these structures [11], [12]. The present study contributes to this discourse by revealing significant associations between meniscal dimensions and knee morphology, particularly in the medial compartment. However, the weak correlations observed between these dimensions and femur/tibia length underscore the multifactorial nature of knee anatomy and injury susceptibility [7], [9].

Further exploration into the nuanced relationships between meniscal dimensions and knee morphology is warranted to inform more precise treatment strategies and surgical interventions [13], [14]. Additionally, the incorporation of advanced imaging techniques, such as MRI and CT scans, may offer deeper insights into meniscal morphometry and its clinical implications [15], [16]. By unraveling the intricate interplay between meniscal characteristics and knee function, clinicians can tailor interventions more effectively, ultimately enhancing patient care and outcomes in orthopedic practice.

Moreover, future studies should aim to investigate the biomechanical implications of meniscal morphometry, as understanding how these dimensions influence load distribution and joint stability can further refine treatment approaches [7], [9]. Additionally, exploring the impact of age, sex, and ethnicity on meniscal dimensions may provide valuable insights into population-specific variations and susceptibility to injury [7], [17].

Furthermore, longitudinal studies tracking changes in meniscal dimensions over time and in response to different interventions can elucidate the dynamic nature of meniscal morphology and its implications for disease progression and treatment outcomes [15], [18]. Additionally, investigating the relationship between meniscal morphometry and functional outcomes, such as pain, range of motion, and activity levels, can inform patient-centered care and rehabilitation strategies [4], [16].

A comprehensive understanding of meniscal morphometry is essential for optimizing treatment strategies and improving outcomes in patients with meniscal injuries. By integrating insights from morphometric studies with biomechanical, clinical, and longitudinal data, clinicians can tailor interventions to individual patient characteristics, ultimately enhancing the effectiveness of meniscal preservation and reconstruction techniques.

6. Limitation

The present study has several limitations that should be acknowledged. Firstly, the study utilized cadaveric specimens of unknown age and sex, potentially introducing variability into the measurements. Additionally, the specimens may have been preserved for varying durations, which could impact the accuracy of the measurements. Moreover, the study relied solely on linear measurements of the menisci, neglecting potential nonlinear characteristics. Lastly, the sample size was limited, and the study was conducted in a single geographical location, limiting the generalizability of the findings. Future research should address these limitations by incorporating larger sample sizes, diverse populations, and a combination of linear and nonlinear measurement techniques to provide a more comprehensive understanding of meniscal morphometry.

7. Conclusion

In conclusion, this study sheds light on the complex relationship between meniscal dimensions and knee morphology, providing valuable insights for clinical practice. By elucidating these associations, healthcare professionals can better tailor treatment strategies and surgical interventions to optimize patient outcomes. Despite the study's limitations, the findings underscore the importance of considering meniscal morphometry in the management of knee injuries and highlight the need for further research to validate and expand upon these findings. Ultimately, a deeper understanding of meniscal anatomy and its variations will contribute to improved patient care and outcomes in orthopedic practice.

Conflict of interest

The authors declare no conflict of interests. All authors read and approved final version of the paper.

Authors Contribution

All authors contributed equally in this paper.

References

[1] Jiakuo, Y., Changlong, Y., & Yingfang, A. (2007). Arthroscopy-assisted Allograft Meniscus Transplantation (With Report of 4 Cases' Following up for More Than 20 Months. *Chinese Journal of Sports Medicine, 26*(3), 261.

[2] Rohila, J., Rathee, S. K., Dhattarwal, S. K., & Kundu, Z. S. (2017). Morphometric analysis of menisci of adult human knee joint in North Indian population. *Int J Res Med Sci, 5*, 569.

[3] Messner, K., & Gao, J. (1998). The menisci of the knee joint. Anatomical and functional characteristics, and a rationale for clinical treatment. *The Journal of Anatomy, 193*(2), 161-178.

[4] da Silva Almeida, K. S., Arruda de Moraes, S. R., Tashiro, T., da Silveira Neves, E., Toscano, A. E., & Rocha de Abreu, R. M. (2004). Morphometric study of menisc of the knee joint. *Int J Morphol, 22*(3), 181-4.

[5] Kohn, D., & Moreno, B. (1995). Meniscus insertion anatomy as a basis for meniscus replacement: a morphological cadaveric study. Arthroscopy: *The Journal of Arthroscopic & Related Surgery, 11*(1), 96-103.

[6] Shaffer, B., Kennedy, S., Klimkiewicz, J., & Yao, L. (2000). Preoperative sizing of meniscal allografts in meniscus transplantation. *The American Journal of Sports Medicine, 28*(4), 524-533.

[7] Braz, P. R. P., & Silva, W. G. (2011). Meniscus morphometric study in humans. *Braz. J. Morphol. Sci*, 62-66.

[8] Murlimanju, B. V., Nair, N., Pai, S. R., Pai, M. M., Gupta, C., Kumar, V., ... & PULAKUNTA, T. (2010). Morphometric analysis of the menisci of the knee joint in South Indian human fetuses. *Int J Morphol, 28*(4), 1167-1171.

[9] Rao, N., Gupta, A. D., & Raju, A. V. (2014). Morphometric analysis of the menisci of the knee joint in population of east Godavari region of Andhra Pradesh. *J Evol Med Dent Sci, 3*, 8972-8979.

[10] Smillie, I. S. (1946). Injuries of the knee joint. *Annexe Thesis Digitisation Project 2019* Block 22.

[11] Testut, L., & Latarjet, A. (1975). *Tratado De Anatomia Humana.* 10 ed. Barcelona, Salvat.

[12] Rao, N., Narayan, Das Gupta, A., & Raju, V. (2014). Morphometric analysis of the menisci of the knee joint in population of East Godavari region of Andhra Pradesh. *Journal of Evolution of Medical and Dental Sciences, 3*, 8972-8979.

[13] Rico, E. G. C., & Ayala, C. E. A. (1997) Localización de las rupturas meniscales en nuestro medio. *Rev. Mex. Ortop. Traumatol., 11*(1), 10-13.
[14] Hathila, S. B., Vyas, K. K., Vaniya, V. H., & Kodiyatar, B. B. (2018). Morphological study of menisci of knee joint in human cadavers. *Int J Anat Radiol Surg, 7,* 2973-2978.
[15] Hayashi, L. K., Yamaga, H., Ida, K., & Miura, T. (1988). Arthroscopic meniscectomy for discoid lateral meniscus in children. *JBJS, 70*(10), 1495-1500.
[16] Nimje, P. B., & Bhuiyan, P. S. (2014). A Morphometric study of menisci of knee joint in human cadavers. *Int J, 6,* 3807-3809.
[17] Motta Filho, L. A. J., Motta, L. A. J., & Motta Filho, G. R. (1999). Menisco lateral discóide: correlação anátomo-clínica. *Rev. Bras. Ortop,* 457-460.
[18] Cailliet, R. M. D. (1976). *Sindromes Dolorosas.* Joelho: dor e incapacidade. Rio De Janeiro, Manole.