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Comparative Morphometric Analysis of Medial and Lateral Menisci in Cadaveric Knee Joints: Implications for Injury Mechanisms, Surgical Interventions, and Prosthetic Design

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Abstract

Background: The knee joint's functionality is significantly dependent on the structural integrity and morphometry of the medial and lateral menisci. These crescent-shaped cartilaginous structures play a pivotal role in load distribution, joint stability, and shock absorption. Variations in meniscal dimensions are crucial for understanding knee biomechanics, the etiology of meniscal injuries, and optimizing surgical interventions and prosthetic designs.

Materials and Methods: A cross-sectional study was conducted on 30 cadavers, analyzing 60 knee joints (30 right and 30 left) at the Department of Anatomy, SBKSMIRC, SVDU, Waghodia, Vadodara. Digital calipers were used to measure the distances between the anterior and posterior horns, the lengths (outer and inner circumferences), widths, and thicknesses at specified regions of the menisci. Data were analyzed using SPSS version 23, employing descriptive statistics, unpaired t-tests, and Pearson correlation coefficients to assess morphometric variations, with a significance level set at $p<0.05$.

Results: Significant differences were found in the morphometry of the medial and lateral menisci, particularly in their distances between horns, circumferential lengths, widths, and thicknesses across various segments. Notably, the medial meniscus exhibited greater distances between its horns and larger dimensions in both circumferences compared to the lateral meniscus. These morphometric variations underscore the necessity for personalized approaches in meniscal surgery and prosthetic design.

Conclusion: The detailed morphometric analysis of the menisci provides invaluable insights into knee joint anatomy, with significant implications for the diagnosis and treatment of meniscal injuries. Recognizing the variability in meniscal dimensions emphasizes the importance of tailored surgical and prosthetic interventions to enhance therapeutic outcomes. Despite the limitations related to cadaveric specimen variability, this study marks a critical step toward integrating anatomical precision into orthopedic practices.

Keywords: Knee Joint, Menisci, Morphometry, Orthopedics, Surgical Interventions, Prosthetic Design, Cadaveric Study.

Introduction

The complexity of the knee joint, being the largest synovial joint in the human anatomy, cannot be overstated. Its functionality hinges significantly on the menisci—crescent-shaped cartilaginous structures nestled between the femur and tibia. These menisci play a critical role in ensuring the joint's mechanical integrity, aiding in load distribution, facilitating smooth movement, and absorbing shock. The depth of our knowledge regarding the specific dimensions and characteristics of the menisci directly influences our understanding of knee biomechanics, the etiology of meniscal damage, and the strategic approach to clinical interventions.[1-4]

Injuries to the menisci are prevalent across various demographics, attributed to a range of causes from acute physical trauma to gradual wear and tear associated with aging. Such injuries compromise the knee's structural equilibrium and are a known precursor to the development of degenerative joint diseases, such as osteoarthritis. This causal relationship underscores the necessity for surgical precision in meniscal repair and transplantation, which, in turn, relies on an intimate acquaintance with meniscal morphology.[5-7]

While the knee is commonly classified based on its synovial nature and hinge-like function, this simplification masks the underlying anatomical and functional complexity of its internal constituents, notably the medial and lateral menisci. Each meniscus exhibits distinct physical properties and dimensions that are critical to the knee's biomechanical performance and its susceptibility to injury.[8,9]

The refinement of surgical techniques and the introduction of sophisticated diagnostic tools underscore the growing demand for precise morphometric data of the menisci. Such data are indispensable for tailoring prosthetic designs and optimizing surgical outcomes.[10,11]

Addressing the gap in literature concerning the comparative morphology of the knee's menisci, this investigation aims to meticulously analyze and document the morphometric nuances of the medial and lateral menisci within human cadaveric knee joints. By offering a granular view of these structures, the study aspires to enrich the orthopedic discourse with insights that could potentially transform diagnostic, therapeutic, and preventative modalities in knee joint care.

Aims & Objectives

Aim

To conduct an in-depth morphometric analysis of the medial and lateral menisci within cadaveric knee joints, with the objective of enhancing the foundational knowledge that informs clinical decisions in orthopedics, particularly in the realms of diagnosis, treatment, and surgical intervention for meniscal injuries.

Objectives

a) To measure the lengths of the medial and lateral menisci (outer and inner circumferences) in both right and left knees, providing a comprehensive dataset on their size variations.

b) To ascertain the distances between the anterior and posterior horns of the menisci in both right and left knees, illuminating their spatial configurations for surgical reference.

c) To determine the widths of the menisci at their anterior, middle, and posterior thirds in both right and left knees, offering insights into their load-distributing capabilities.

d) To assess the thickness of the menisci at their anterior, middle, and posterior thirds in both right and left knees, which could influence meniscal functionality and vulnerability to injury.

e) To evaluate the bilateral asymmetry in the morphometry of the menisci between right and left knees, addressing potential implications for bilateral knee surgeries and therapies.

f) To compare the morphometric parameters between medial and lateral menisci in both knees, contributing to a nuanced understanding of their differential roles in knee biomechanics and injury patterns.

g) To integrate these morphometric findings into the broader context of meniscal health, injury prevention, and surgical innovation, aiming to refine current practices and pave the way for future advancements.

Material & Methods

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 facilitated direct measurement of meniscal parameters, providing a robust foundation for evaluating the implications of morphometric variations.

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.

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.

Inclusion Criteria:

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

Exclusion Criteria:

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

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: Digital Caliper

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.

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 $p < 0.05$.

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.

Results

The intricate study of meniscal morphometry within cadaveric knee joints, as delineated in our research, casts new light on the complex interplay between anatomical structure and clinical practice in orthopedics.

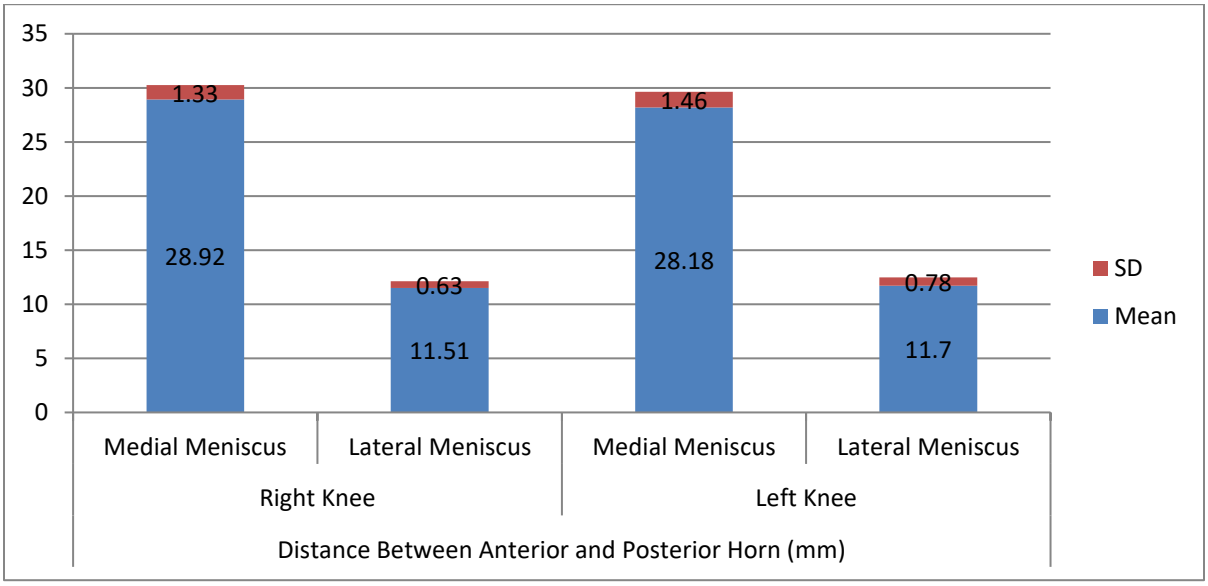

Figure-2: Morphometrics of Meniscus

This Figure-2 outlines the anterior-posterior distances of medial and lateral menisci, revealing a notable difference between them. Specifically, the medial meniscus shows an anterior-posterior distance of 28.92±1.33 mm in the right knee and 28.18±1.46 mm in the left knee. In contrast, the lateral meniscus measures 11.51±0.63 mm in the right knee and 11.70±0.78 mm in the left knee. This difference underscores the medial meniscus's larger size, potentially influencing its biomechanical role in the knee.

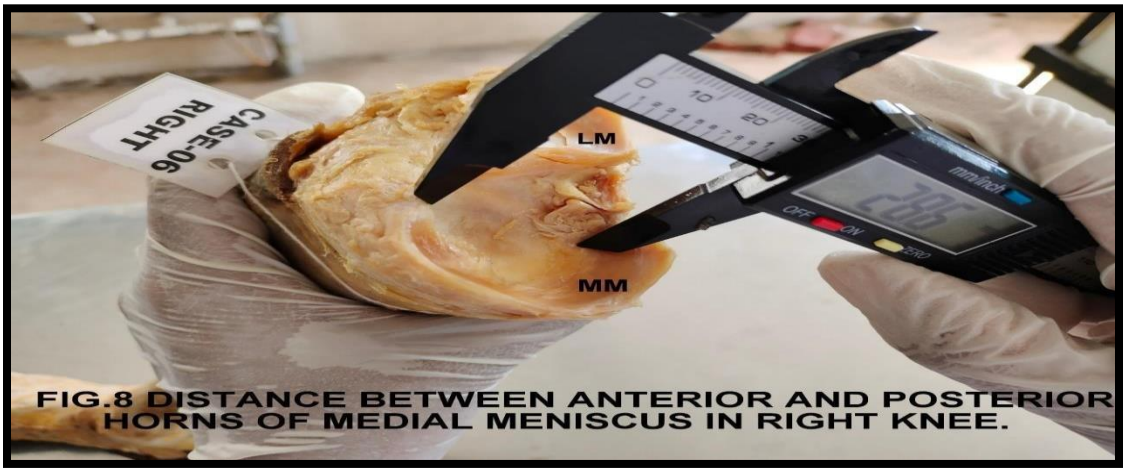

FIG.8 DISTANCE BETWEEN ANTERIOR AND POSTERIOR HORNS OF MEDIAL MENISCUS IN RIGHT KNEE.

(a)

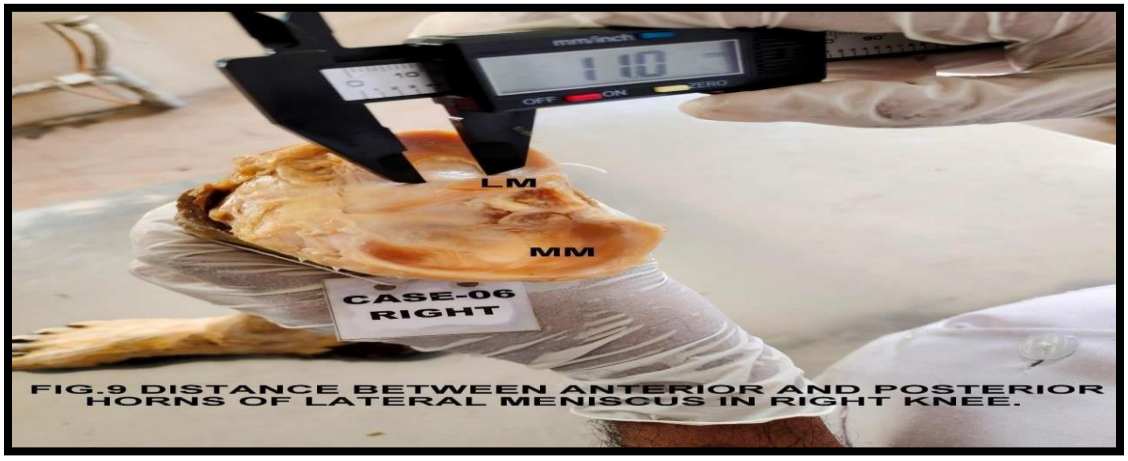

FIG.9 DISTANCE BETWEEN ANTERIOR AND POSTERIOR HORNS OF LATERAL MENISCUS IN RIGHT KNEE.

(b)

Figure-3: (a &b): Picture During Data Collection

Table 1: Comparison of the Lengths Between the Anterior and Posterior Horns of the Medial and Lateral Meniscus

Sr. No.	**Meniscus**	**Circumference**	**Length Between Anterior and Posterior Horn (mm)**	**t value**	**P value**
1	Medial Meniscus	Outer Circumference	Right Knee: 80.40±1.40, Left Knee: 80.77±1.33	-5.058	<0.001
		Inner Circumference	Right Knee: 46.60±0.85, Left Knee: 47.05±0.96	-5.070	<0.001

Sr. No.	Meniscus	Circumference	Length Between Anterior and Posterior Horn (mm)	t value	P value
2	Lateral Meniscus	Outer Circumference	Right Knee: 67.65±0.98, Left Knee: 67.69±0.96	-0.457	0.651
		Inner Circumference	Right Knee: 43.64±1.00, Left Knee: 43.98±0.99	-2.501	0.018

Table 1 delves into the lengths of menisci, where the outer circumference of the medial meniscus spans 80.40±1.40 mm in the right knee and 80.77±1.33 mm in the left knee, with a significant P value (<0.001). Similarly, the inner circumference measures 46.60±0.85 mm (right) and 47.05±0.96 mm (left), also showing significant differences. These variations are clinically crucial, as they hint at the necessity for tailored surgical approaches to account for individual anatomical differences.

Table 2: Comparison of the Distance Between the Anterior and Posterior Horns

Sr. No.	Meniscus	Distance Between Anterior and Posterior Horn (mm)	t value	P value
1	Medial Meniscus	Right Knee: 28.92±1.33, Left Knee: 28.18±1.46	3.490	0.002
2	Lateral Meniscus	Right Knee: 11.51±0.63, Left Knee: 11.70±0.78	-1.546	0.133

The distances between the horns of the medial and lateral menisci, presented in Table 3, show statistical significance for the medial meniscus between right and left knees (P=0.002), highlighting anatomical asymmetry that could impact surgical planning and rehabilitation strategies.

Table 3: Width of Medial and Lateral Meniscus

Sr. No.	Meniscus	Side	Width of Meniscus (mm)	t value	P value
1	Medial Meniscus	Anterior 1/3	Right Knee: 4.99±0.61, Left Knee: 5.17±0.86	-1.289	0.208
		Middle 1/3	Right Knee: 6.08±0.88, Left Knee: 6.44±0.92	-2.103	0.044
		Posterior 1/3	Right Knee: 10.00±1.53, Left Knee: 9.80±1.22	0.727	0.473

Sr. No.	Meniscus	Side	Width of Meniscus (mm)	t value	P value
2	Lateral Meniscus	Anterior 1/3	Right Knee: 5.73±0.49, Left Knee: 5.87±0.55	-1.704	0.099
		Middle 1/3	Right Knee: 8.17±0.97, Left Knee: 8.30±0.86	-0.862	0.396
		Posterior 1/3	Right Knee: 8.88±0.78, Left Knee: 9.20±0.84	-2.297	0.029

Table 3 details the width of the menisci, where the medial meniscus's middle third is significantly wider in the left knee (6.44±0.92 mm) compared to the right (6.08±0.88 mm), with a P value of 0.044. This difference, though subtle, could affect the joint's load distribution capabilities and vulnerability to injury.

Table 4: Thickness of Medial and Lateral Meniscus

Sr. No.	Meniscus	Side	Thickness of Meniscus (mm)	t value	P value
1	Medial Meniscus	Anterior 1/3	Right Knee: 2.39±0.38, Left Knee: 3.14±1.02	-3.879	<0.001
		Middle 1/3	Right Knee: 4.42±0.86, Left Knee: 5.11±0.94	-4.133	<0.001
		Posterior 1/3	Right Knee: 4.45±0.71, Left Knee: 5.14±0.88	-4.325	<0.001
2	Lateral Meniscus	Anterior 1/3	Right Knee: 2.43±0.59, Left Knee: 2.96±0.82	-3.300	0.003
		Middle 1/3	Right Knee: 5.11±0.80, Left Knee: 5.12±0.80	-0.026	0.980
		Posterior 1/3	Right Knee: 5.77±0.77, Left Knee: 5.98±0.72	-2.180	0.038

Focusing on thickness, Table 4 shows the anterior third of the medial meniscus is significantly thicker in the left knee (3.14±1.02 mm) than in the right (2.39±0.38 mm), with a P value <0.001. Similar patterns of significance are observed in the posterior third of both the medial and lateral menisci, indicating variations that could influence meniscal function and injury risk.

The precise morphometric data outlined in these tables emphasize the inherent anatomical variability of the knee menisci. The significant differences in dimensions between right and left knees, and between medial and lateral menisci, highlight the critical need for personalized diagnostic and therapeutic approaches in orthopedic practice. This nuanced understanding of meniscal anatomy not only enhances our grasp of knee joint biomechanics but also informs the development of more effective, individualized treatments for meniscal injuries, promising improved outcomes for patients.

Discussion

Our comprehensive morphometric analysis of the menisci within cadaveric knee joints advances our understanding of the intricate relationship between meniscal anatomy and its implications for orthopedic practice, particularly in addressing meniscal injuries, enhancing surgical precision, and guiding prosthetic design.

The study's findings reinforce the central role of the menisci in knee biomechanics, highlighting how variations in meniscal dimensions could influence injury susceptibility. Similar to conclusions drawn by Smillie et al[12], who emphasized the biomechanical implications of meniscal morphology on injury risk, our analysis suggests that the thickness and width of the menisci are crucial parameters that may predispose these structures to specific patterns of tears and degeneration. This aligns with the work of Almeida et al[13], who noted marked differences in the contour and insertion points of the menisci, further underscoring the role of anatomical nuances in the etiology of meniscal injuries.

The data presented here, particularly regarding the distances between the anterior and posterior horns and the overall dimensions of the menisci, are invaluable for refining meniscal allograft transplantation techniques. This specificity in graft selection and alignment is echoed in the recommendations by Braz et al[14], who underscored the importance of morphometric compatibility in transplantation success. The variations we observed, especially the bilateral asymmetry noted between right and left knees, advocate for a more individualized approach to meniscal surgery, potentially enhancing post-operative outcomes and joint functionality, a concept that is gaining traction as evidenced by the work of Rao et al[15] and Rohila et al.[16]

The quest for anatomically accurate meniscal prostheses is significantly influenced by the detailed morphometric data unearthed in our study. These findings, providing a quantifiable blueprint of meniscal anatomy, echo the sentiments of Hathila et al[17], who highlighted the potential for such data to inform the design of next-generation prosthetic devices. The distinct morphometric profiles of the medial and lateral menisci, along with the bilateral variations identified, underscore the potential for developing side- and patient-specific prosthetic solutions, a frontier that is yet to be fully explored.

Linking meniscal morphology with clinical outcomes, particularly in the context of osteoarthritis progression post-meniscectomy, presents a promising avenue for future research. This study lays

the foundational groundwork for such investigations, aiming to build upon the findings of Rashmi et al[18] and Itagi et al[19], who have begun to explore the clinical implications of meniscal morphometry. Understanding these relationships could lead to targeted interventions designed to mitigate the risk of degenerative joint diseases.

In synthesizing our findings with the broader corpus of existing literature, it becomes evident that the nuances of meniscal anatomy hold profound implications for orthopedic surgery, diagnosis, and rehabilitation. This study not only contributes to the rich tapestry of knowledge regarding knee joint anatomy but also underscores the critical importance of incorporating morphometric analysis into clinical decision-making processes. As the field advances, the integration of detailed anatomical insights with clinical practice promises to enhance patient care and pave the way for innovations in the treatment of meniscal and knee joint pathologies

Limitations

One of the primary limitations of this study is the reliance on cadaveric specimens, which, while providing invaluable anatomical insights, may not fully replicate the living knee joint's dynamic conditions. The specimens' age and sex were unknown, potentially obscuring age-related morphometric changes or gender-specific variations in meniscal size and shape. Furthermore, the preservation state of the cadavers could have influenced the meniscal measurements, introducing variability. The study's methodology, focusing solely on linear measurements, may not capture the complete three-dimensional complexity of meniscal anatomy. These limitations underscore the need for complementary studies, incorporating advanced imaging techniques and a broader demographic spectrum, to validate and expand upon our findings.

Conclusion

This study elucidates the critical morphometric variations between the medial and lateral menisci within cadaveric knee joints, offering profound implications for orthopedic practice. By providing detailed measurements that highlight significant differences in meniscal dimensions, our research underscores the necessity of individualized approaches in diagnosing meniscal injuries, planning surgical interventions, and designing prosthetic devices. The findings serve as a valuable resource for clinicians and researchers alike, fostering advancements in the treatment and understanding of knee joint pathologies. Despite its limitations, this study marks a significant step forward in bridging the gap between anatomical research and clinical application, paving the way for future investigations aimed at enhancing patient outcomes in orthopedics.

References

1. Rohila J, Rathee SK, Dhattarwal SK, Kundu ZS. Morphometric analysis of menisci of adult human knee joint in North Indian population. Int J Res Med Sci 2017;5:569-73.

2. Messner K. and GAO J. The menisci of the knee joint. Anatomical and functional characteristics and a rationale for clinical treatment. Journal of Anatomy.1998; 193: 161-78.
3. Gray JC. Neural and vascular anatomy of the menisci of the human knee. Journal of Orthopaedics & Sport Physical Therapy. 1999; 29(1):23-30.
4. Yu JK, Yu CL, Ao YF, Gong X, Jiang D, Xie X, et al. Arthroscopy-assisted Allograft Meniscus Transplantation (With report of 4 cases′ following up for more than 20 months). Chin. J. Sports Med. (Chin.). 2007; 26: 261-5.
5. Gao J., Öqvist G. and Messner K. The attachment of the rabbit medial meniscus. A morphologica investigation using image analysis and immunohistochemistry. Journal of Anatomy. 1994; 185: 663-7.
6. Almeida SKS., De Moraes ASR., Tashimiro T., Neves SE., Toscano AE. and De Abreu RRM. Morphometric study of menisc of the knee joint.International Journal Morphology.2004; 22(3): 181-4.
7. Kohn D. and Moreno B. Meniscus insertion anatomy as a basic for meniscus replacement: a morphological cadaveric study. Arthroscopy. 1995; 11: 96-103.
8. Cohen, M., Abdalla, RJ., Barreto, FAQM., Bouchabki, ET., Oliveira, EV. and Ejnisman, B. study of radiographic experimental devascularization of the meniscos humans. Revista Brasileira de Ortopedia. 1993; 28: 263-72.
9. Shaffer B, Kennedy S, Klimkiewicz J, Yao L. Preoperative sizing of meniscal allografts in meniscus transplantation. Am. J. Sports Med. 2000; 28: 524-33.
10. Braz, P.R.P. and Silva, W.G. 2010. Meniscus morphometry study in humans.J. Morpho. Sci.2010; 27(2): 62-66.
11. Murlimanju, N.N., Shakuntala, R.P., Mangala, M.P., Gupta, C., Vishal Kumar.and Thejodhar Pulakunta, B.V. Morphometric analysis of the menisci ofthe knee joint in south Indian human fetuses. J. Morphol. 2010; 28(4):1167-1171.
12. Smillie, I. S. Injuries of the knee Joint. 1975; 4 ed. London, Living Stone.
13. Almeida SKS., De Moraes ASR., Tashimiro T., Neves SE., Toscano AE. and De Abreu RRM. Morphometric study of menisc of the knee joint. InternationalJournal Morphology. 2004; 22 (3): 181-4.
14. Braz PRP and Silva WG. Meniscus morphometric study in humans J. Morphol. Sci. 2010; 27(2):62-6.
15. Rao, Anirban Das Gupta, A. V. Raju. 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 2014; 3(34): 8972-8979.
16. Jyoti Rohila, Suresh Kanta Rathee, Suresh Kumar Dhattarwal, Zile SinghKundu. Morphometric analysis of menisci of adult human knee joint in North Indian population. Int J Res Med Sci. 2017 Feb;5(2):569-573.
17. Shital Bhishma Hathila, Kintukumar K Vyas, V. H. Vaniya, Bhavin B Kodiyatar. Morphological Study of Menisci of Knee Joint in Human Cadavers. International Journal

of Anatomy, Radiology and Surgery. 2018 Oct;7(4):AO10-AO14.

18. Rashmi BN, Dakshayani KR, Vadiraja N. Morphometric Study Of Menisci Of KneeJoints In Adult Cadavers. Int J Anat Res 2016; 4(4):2973-78.
19. Veeresh Itagi, Jayasudha Katralli, Veereshkumar Somalingappa Shirol. Morphometric study of medial menisci of the adult knee joint. ndian Journal of Clinical Anatomy and Physiology. April-June;2017;4(2):231-234.