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Original Research Article

A Study on the Morphometric Measurement and Intrinsic Innervation of the Knee Meniscus in Adult Burmese Population

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ABSTRACT

Introduction: Understanding the dimensions of the knee joint menisci is crucial for arthroscopic surgery and the management of injuries. Menisci's size, shape, and composition play roles in determining the structural and material properties of the tissue allograft. The present study aims to describe the morphometric measurement and intrinsic innervation of the knee meniscus in Myanmar's adult population.

Methods: The length, width, thickness, and other morphometric factors of 160 menisci from twenty male and twenty female autopsy bodies were measured. Five menisci from fresh cadavers were dissected, stained with Marsland, Glees, and Erikson's staining methods, and examined under a light microscope.

Results: The average length of the medial and lateral meniscus was 8.49 cm and 7.98 cm, respectively. The average width of the anterior horn, body, and posterior horn of medial menisci were 0.64 cm, 0.63 cm, and 1.25 cm, and that of lateral menisci were 0.94 cm, 0.89 cm, and 0.95 cm. The average thickness of the anterior horn, body, and posterior horn of medial menisci was 0.38 cm, 0.45 cm, and 0.47 cm, and that of lateral menisci were 0.25 cm, 0.42 cm, and 0.39 cm. Ruffini's corpuscles, Paccinian corpuscles, and Golgi tendon organs with fibrous capsules were observed under the light microscope at the anterior and posterior horns of the menisci.

Conclusions: The present study provides a good understanding of the knee meniscus in the Myanmar adult population, which will help morphologists and orthopaedic surgeons design prostheses and perform knee joint arthroscopy with a high success rate.

KEYWORDS: Measurements, innervation, human, knee meniscus

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INTRODUCTION

The menisci of the knee joint play a crucial role in the knee's ability to function properly by enhancing joint congruence, distributing loads, reducing stress on the knee joint, and preventing the development of osteoarthritis [1]. The knee joint makes the tibia and femoral condyles more congruent, resulting in efficient joint lubrication, reducing contact stresses between the bones, and preventing damage to the articular cartilage.

Meniscal injuries are prevalent in various settings, such as the workplace, sports, and everyday activities, and they can have severe consequences. Meniscal injuries in children and adolescents are being seen with increased frequency [1-3]. Removing the entire medial meniscus can lead to a bow-legged deformity and medial joint arthritis, while the absence of the lateral meniscus can cause a knock-knee deformity and lateral joint arthritis [2,3]. Meniscal lesions are the most common knee disorders encountered by practicing orthopaedic surgeons. Advances in the knowledge of the anatomy and function of the meniscus and the development of arthroscopic surgery have led to the foundation of contemporary meniscal treatment. The surgical philosophy has matured from routine excision to preservation and restoration. A fundamental and expanded knowledge of meniscal anatomy, biomechanics, and function is crucial to understanding meniscal pathology and treatment [4].

Height, weight, and gender directly relate to meniscal tissue dimensions and successful meniscal transplantation. Female menisci are generally smaller than males, and the lateral meniscus is comparatively smaller than the medial one [5]. Menisci's size, shape, and composition plays a vital role in determining the structural and material properties of the tissue allografts, which are significant for ensuring biomechanical function [6]. Surgical interventions like resection of 16% to 34% of the meniscus results in more than a 3-fold increase in contact forces in the knee. Even partial meniscectomies resulted in significant articular cartilage and bone changes within 5 to 15 years. Without the meniscus, the concentration of force on a small area of the articular cartilage could damage the surface, leading to a degenerative condition called osteoarthritis. The round femoral condyle would also slide on the flat tibial surface [7]. Meniscal size and shape determination become essential in designing therapies for an implant or an articular repair system. These treatments encompass meniscal repair, articular repair, and arthroplasty, consisting of biological materials such as tissue scaffolds, plastic, metal, or metal alloys or combinations [6]. The normal lateral meniscus is morphologically more variable than the medial meniscus. The abnormal lateral meniscus, which varies in size, shape, and stability, is commonly seen in patients of all ages. The underlying causes of lateral meniscal abnormalities are multifactorial [2]. The knowledge of morphology and intrinsic innervation of knee menisci would greatly benefit.

Meniscus studies are deficient among the Burmese population. This research is intended to determine the morphometric measurements and intrinsic afferent innervation of knee menisci among the Myanmar population.

METHODS

Study design: A cross-sectional descriptive study was performed on forty adult embalmed bodies of both genders (20 males and 20 females) aged 18 to 65. Cadavers were dissected for gross and histological examination**.** The study was performed at the Anatomy Departments, University of Medicine 1 and 2, Yangon, Myanmar.

Data collection: The cadaveric dissection was done in a supine position, and a horizontal incision below the knee and two vertical incisions at the sides of the knee were made to obtain the menisci. The length of the meniscus was measured along its periphery by a measuring tape (**Figure 1b**). The obtained value was divided into four, establishing three points on the line: one anterior, one middle, and one posterior (**Figure 1a**). From each point, the width and thickness of the menisci were measured by using the outer measurements

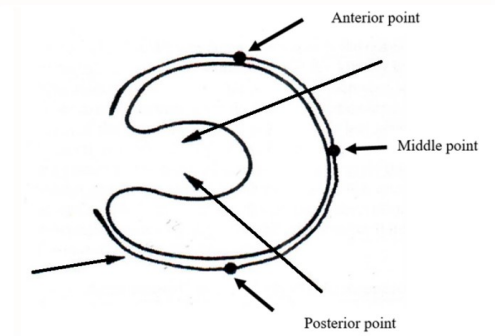

Figure - 1a

Figure - 1b

Figure - 1c

Figure - 1d

Fig. 1. a: Showing the measurement of the length of the right lateral meniscus and representing the three points of morphometric analysis of menisci in the anterior, medium, and posterior thirds [8], **b:** Measuring the length of the left medial meniscus with measuring tape, **c:** Measuring the width of the posterior horn of the left medial meniscus with Vernier calliper, **d:** Measuring the thickness of the anterior horn of the left medial meniscus with Vernier calliper.

of a pachymeter (Vernier caliper) **(Figure 1c and Figure 1d)** [8]. The values of width and thickness at these three points were recorded. For histological examination, meniscal tissue was taken from fresh cadavers within six hours after death. The anterior and posterior horns of medial and lateral menisci were embedded in paraffin wax, and the sections were stained with Marsland, Glees, and Erikson's staining method and studied under a binocular light microscope. The results were noted and photographed. After the dissection, the skin was stitched back thoroughly with minimal dis-figuration [9].

Inclusion and exclusion criteria: All menisci obtained from the cadavers of the Departments of Anatomy, University of Medicine 1, and University of Medicine 2, Yangon, Myanmar, were included in the study. Meniscal injuries, meniscectomy, severely injured knee joints, joint diseases such as osteoarthritis, rheumatic arthritis, rheumatoid arthritis, and musculoskeletal disorders related to cadavers were excluded to avoid study bias. Cadavers with a single limb, amputations above the knee, and surgical interventions in the knee were also excluded.

Sample size calculation: A simple random sampling method was adopted. The sample size calculated was 160 specimens (80 medial menisci and 80 lateral menisci) using $n=Z^2pq/d^2$ [n=the desirable estimated sample size; Z=the standard normal deviation with a 95% confidence interval; p=proportion of variants; q=0.5; d=degree of accuracy], based on a previous study [10].

Data analysis and variables: The outcome variables were the length, width, and thickness of the knee menisci's anterior horn, body, and posterior horn, and various mechanoreceptors for histological examination. The explanatory variables were gender and laterality. For descriptive statistics, frequency distribution and paired t-tests were done.

Ethical committee approval: The Ethical and Research Committee and Academic Committee of Anatomy, University of Medicine 2, Yangon, approved the research. The authors obtained informed consent from the next of kin before the dissection of the cadaver.

RESULTS

Table 1: Comparison of length of medial and lateral menisci.

Meniscus	Mean	Standard deviation	t-value	Significance
Medial meniscus	8.49 cm	1.053	4.279	0.000*
Lateral meniscus	7.98 cm			

*p <0.05, statistically significant

Table 1 explains the comparison of the lengths of the medial and lateral menisci. The average length of the medial meniscus was 8.49 cm, significantly higher than the lateral meniscus 7.98 cm (Table 1). (p<0.05).

Table 2: Comparison of length of medial and lateral menisci according to side and gender.

		Medial meniscus				Lateral meniscus			
		Mean (cm)	SD	t-value	Significance	Mean (cm)	SD	t-value	Significance
Side	Right side	8.55	0.734	1.141	0.261	8.05	0.67	1.322	0.194x
	Left side	8.42				7.91			
Gender	Male	8.91	1.067	-4.995	0	8.22	1.6	-1.877	0.068x
	Female	8.07				7.75			
Average		8.49				7.98			

xp >0.05, statistically not significant

Table 2 expedites the comparison of the length of medial and lateral menisci according to side and gender. The length of medial meniscus was significantly higher in males, measuring 8.91cm, than in females 8.07cm (p<0.05).

Table 3: Average width of menisci according to side.

Side	Medial meniscus			Lateral meniscus		
	Anterior horn (cm)	Body (cm)	Posterior horn (cm)	Anterior horn (cm)	Body (cm)	Posterior horn (cm)
Right side	0.64	0.65	1.29	0.91	0.89	0.96
Left side	0.63	0.61	1.2	0.96	0.89	0.93
Average	0.64	0.63	1.25	0.94	0.89	0.95

Table 3 shows the average width of medial and lateral menisci in the anterior horn, body and posterior horn in both right side and left side.

The average width of the anterior horn, body and posterior horn of the medial meniscus were 0.64 cm, 0.63 cm and 1.25 cm respectively. The average width of anterior, body and posterior horn of lateral meniscus were 0.94 cm, 0.89 cm and 0.95 cm respectively (Table 3).

Table 4: Average thickness of menisci according to side.

Side	Medial meniscus			Lateral meniscus		
	Anterior horn (cm)	Body (cm)	Posterior horn (cm)	Anterior horn (cm)	Body (cm)	Posterior horn (cm)
Right side	0.36	0.44	0.47	0.25	0.42	0.41
Left side	0.4	0.46	0.46	0.24	0.41	0.37
Average	0.38	0.45	0.47	0.25	0.42	0.39

Table 4 shows the average thickness of medial and lateral menisci in anterior horn, body and posterior horn in both right side and left side.

The average thickness of anterior horn, body, and posterior horn of medial meniscus were 0.38 cm, 0.45 cm and 0.47 cm respectively. The average thickness of anterior, body and posterior horn of lateral meniscus were 0.25 cm, 0.42 cm and 0.39 cm respectively (Table 4).

Table 5: Comparison of the width and thickness of menisci (in cm).

Comparison of the width of menisci																
	Medial meniscus								Lateral meniscus							
	Right side				Left side				Right side				Left side			
	U (cm)	SD	t	S	U (cm)	SD	t	S	U (cm)	SD	t	S	U (cm)	SD	t	S
AH	0.64	0.126			0.63	0.125	1.072	0.290^{x}	0.91	0.267	0.444	0.659^{x}	0.96	0.208	2.074	0.045^{x}
B	0.65		-0.415	0.681^{x}	0.61				0.89				0.89			
B	0.65	0.297	-13.609	0.000*	0.61	0.282	-13.138	0.000*	0.89	0.287	-1.639	0.109^{x}	0.89	0.209	-1.189	0.242^{x}
PH	1.29				1.2				0.96				0.93			
AH	0.64	0.308	-13.284	0.000*	0.63	0.286	-12.461	0.000*	0.91	0.252	-1.392	0.172^{x}	0.96	0.206	1.892	0.378^{x}
PH	1.29				1.2				0.96				0.93			
Comparison of the thickness of menisci																
AH	0.36	0.145	-3.466	-0.001*	0.4	0.161	-2.597	0.013*	0.25	0.123	-8.422	0.000*	0.24	0.171	-6.27	0.000*
B	0.44				0.46				0.42				0.41			
B	0.44	0.121	-1.522	0.136^{x}	0.46	0.132	0.036	0.971^{x}	0.42	0.118	0.442	0.661^{x}	0.41	0.112	2.39	0.022*
PH	0.47				0.46				0.41				0.37			
AH	0.36	0.155	-4.432	0.000*	0.4	0.178	-2.323	0.025*	0.25	0.113	-8.705	0.000*	0.24	0.173	-4.648	0.000*
PH	0.47				0.46				0.42				0.37			

*p <0.05, statistically significant ^{x}p >0.05, statistically not significant

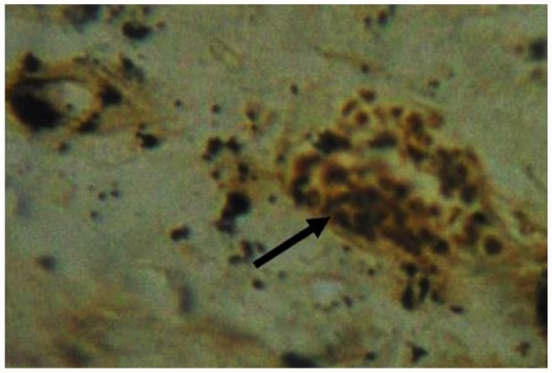

Figure - 2a

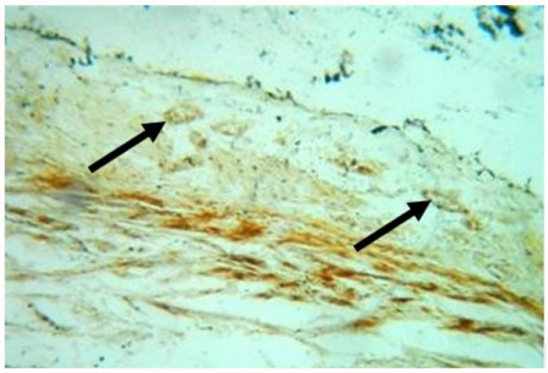

Figure - 2b

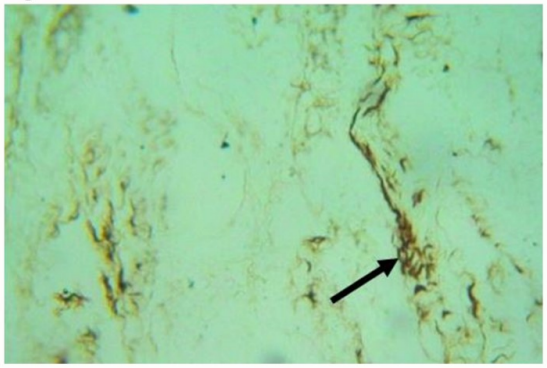

Figure - 2c

Figure - 2d

Fig. 2a: Photograph showing the type I mechanoreceptors (Ruffini's corpuscles) at the anterior horn of the menisco-capsular junction of the left lateral meniscus, longitudinal section, **b:** Photograph showing the type II mechanoreceptors (Paccinian's corpuscles) at the musculo-capsular junction of the left medial meniscus, longitudinal section; Glee's silver staining, 10X (Case 25), **c:** Photograph showing the type III mechanoreceptors (Golgi tendon organs) at the anterior horn of the right lateral meniscus in a male, longitudinal section; Glee's silver staining, 10X (Case 12), **d:** Photograph showing the type IV mechanoreceptors (Free nerve endings) at the anterior horn of left medial meniscus, longitudinal section; Glee's silver staining, 40X (Case 34)

Table 5 explains the comparison of width of anterior horn, body and posterior horn in both medial and lateral menisci as well as in right side and left side. The width of the medial meniscus was significantly higher in the posterior horn than body and anterior horn in both sides.

In comparison to the width of medial menis-cus, there were significant differences not onlybetween body and posterior horn but also anterior and posterior horns on both sides. In comparison to the width of lateral meniscus, there were no differences among anterior horn, body and posterior horn on both sides.

In comparison of thickness of meniscus, there were significant differences not only between anterior horn and body as well as anterior horn and posterior horn on both medial and lateral menisci and also on both sides.

DISCUSSION

Medial and lateral menisci length:

Previous researchers documented that the average length of medial menisci on the right and left side was 9.85 cm and 9.09 cm, and the average length of lateral menisci was 9.37 cm and 9.28 cm, both values are higher than our findings on the adult Mynamar population [2, 11]. The result may differ due to age, gender, ethnicity, geographical region, genetic variations, race differences, body size, and physical activity. The average length of medial and lateral menisci in this study were consistent with others [12-14]. We found the medial meniscus was larger than the lateral meniscus, dissimilar with others who did not find the difference in length between the medial and lateral meniscus [11].

Medial and lateral menisci width:

In this study, the width of the posterior horn of the medial meniscus was significantly higher than the rest, which agrees with other researchers [13, 14]. Our findings were less than those of Almeida et al., who mentioned the anterior horn, body, and posterior horn as 0.9 cm, 1.22 cm, and 1.74 cm, respectively [8].

The average width of the lateral menisci in this study was less than in previous research [15]. The width of the lateral meniscus in the anterior horn, body, and posterior horn was less than that of Almeida et al., who mentioned 11.86 mm, 11.97 mm, and 11.44 mm; Braz et al., who reported 11.32 mm, 11.16 mm, and 11.67 mm; Bhatt et al., who stated 11.30 mm, 11.66 mm, and 11.50 mm; and Hathila et al., who mentioned 11.82 mm, 12.53 mm, and 12.03 mm, respectively [8, 11, 16, 17].

In comparing the width of the lateral menisci, there were no statistically significant differences among the three parts of the lateral menisci. This finding was consistent with previous research [8]. The results differed from those of an earlier study, where the lateral meniscus was wider in the body [15].

The average widths of the medial and lateral menisci were similar to the findings of Smillie et al., who reported that the width of the lateral meniscus was broader and more uniform than that of the medial meniscus, which differs from another study [18] where the medial meniscus was slightly wider than the lateral meniscus [19].

Medial and lateral menisci thickness:

The average thickness of medial and lateral menisci in this study was consistent with that of Filho et al., who mentioned the average thickness as 0.4-0.5cm. [15] dissimilar to other findings with higher values of 0.7 cm and 0.6-0.8cm [8, 11, 19].

The morphometric measurements of the menisci were related to the possibility and type of injury. The results of correlations between the parts of the menisci could also be helpful for orthopaedic surgeons in the size matching of the menisci in the meniscal allograft. These data can be used in designing therapies such as implants or articular repair systems for treating knee joint diseases in Myanmar in the future.

Innervation of menisci:

Regarding the innervation of menisci, the results were consistent with those of Brindle et al., who described the concentration of meniscal mechanoreceptors as most remarkable in the horns [3].

However, contradictory findings were reported by Wilson et al., where innervations of human menisci were a subject of controversy, and penetration of neural elements was in the outer and medial third of the meniscal body [20]. The results followed those of other researchers, who observed it in the perimeniscal soft tissue but failed to identify any nerve supply within the meniscal tissue [21, 22]. On the other hand, Day et al. found that type II receptors, or Vater-Paccinian corpuscles, were found in the anterior horn of the lateral meniscus [23].

The current findings aligned with many previous findings that stated that meniscal horns possessed a rich neurovascular supply while the meniscal bodies did not [24, 25, 26]. The result was also consistent with Zimny et al., who noted that there were more nerve fibres at the horns of the knee menisci [27]. This knowledge is essential in treating a painfully injured meniscus as a denervation effect.

Limitations and future scope of the study:

The study should also include neonates, ages, and different races to investigate more variations. The sample size in this study fairly represents the population, so future studies are recommended with a larger sample. Variations in shape must be studied for more information about the knee menisci. Further analysis of variation in anterior and posterior horn attachments should be done among various races to compare the multiple races and be helpful in joint reconstruction. Moreover, modern methods for identifying innervation of the meniscus, such as immunohistochemistry (IHC), neuroimaging, fluorescence microscopy, immunofluorescence, and confocal microscopy, are recommended for future scopes.

Relevance of the study:

The meniscal-deficient knee was a common problem facing orthopaedic surgeons. Menisci's size, shape, and composition played roles in determining the structural and material properties of the tissue allograft. Intrinsic afferent innervation (mechanoreceptors) may provide proprioceptive information regarding joint function and position to the central nervous system. The morphological differences in thickness and width of menisci could determine the possibility of an injury and the location and kind of injury. The narrow meniscus was less prone to rupture than the wide. This supposition was justified because the thin meniscus was liable to less action from the femoral condyle. The rarity of injuries to the anterior third of the medial meniscus suggested higher evidence of rupture. Intrinsic afferent innervation (mechanoreceptors) is believed to be primarily mechanosensitive. This study will support meniscal anatomy concerning meniscus allografts and knee joint arthroscopy. It may be important not only for orthopaedic surgeons but also for morphologists. This study will help fulfil anatomical knowledge concerning the knee joint.

CONCLUSION

The average length of medial and lateral menisci was 8.49 cm and 7.98 cm, respectively, while the length comparison showed a significant difference between medial and lateral menisci. The width of the posterior horn was markedly higher than that of the anterior horn and body. The thickness of the anterior horn was the thinnest, and the posterior horn was the thickest. It can be confirmed by mechanoreceptors such as Ruffini's corpuscles, Paccinian corpuscles, Golgi tendon organs, and free nerve endings at the horns and periphery of the menisci. So, meniscectomy of a painful injured meniscus might be a method to treat pain relief as a denervation effect. This study will support meniscal anatomy concerning the surgical procedure and arthroscopy of the knee joint. It will help in the effective management of future rehabilitation for patients after meniscal injury and surgery. Meniscectomy of a painful injured meniscus may be one treatment method for pain relief as a denervation effect.

Data Availability: The dataset associated with this study can be made available on request from the corresponding author.

Conflicts of Interests:

All authors declare that they have no competing interests to declare.

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