Original Article

Comparative Morphological and Morphometric Study between Medial and Lateral Menisci in Aged Male and Female Human Cadavers

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Abstract

Background: The meniscal cartilages are fibrous discs that are important for knee structures and have the ability to bear weight and stabilize joints. However, morphological and standard data for the meniscus are limited. Therefore, this work will compare anatomical and histological parameters of meniscal cartilages. The results will be important for the different measurements that are necessary for knee joint surgery. **Materials and Methods:** A total of 24 aged cadavers (12 males and 12 females) were included. Knee joints were dissected and the menisci were excised and labeled as medial or lateral, right or left, male or female. Then, the menisci were kept in 10% formalin solution. Morphological variations of the meniscal shapes were macroscopically categorized. Different measurements, including the distance between anterior and posterior horns, outer and inner circumferences, width (breadth), and thickness, were done using a digital Vernier caliper and recorded manually. **Results:** 48 medial menisci (MMi) cartilages were studied, they were 54.6% crescent-shaped, 34.6% V-shaped, and 10.8% U-shaped. 48 lateral menisci (LMi) cartilages were studied, 41.6% were crescent-shaped, 56.4% were C-shaped, and 2% were disc-shaped articular cartilage. Findings included differences in their lengths and thickness. **Conclusion:** The findings of this study were significant in providing new information on various morphological and morphometric parameters of the MMi and LMi in aged males and females, which are necessary to require more precise and comprehensive fundamental data that will be helpful for many specialists for better diagnostic and therapeutic approaches; aiming to restore normal joint conditions in senile people complaining of different meniscal pathologies.

Keywords: Cadavers, cartilage, elderly, lateral meniscus, medial meniscus, morphometry

Introduction

The medial and lateral knee menisci are a pair of semilunar fibrocartilaginous structures, which are situated on the tibial plateau to receive the femoral condyles. The menisci's peripheral borders are thick and convex, while their inner borders are thin and concave. The superior meniscal surface is smooth and concave, making more substantial contact with the femoral condyles. In contrast, the inferior meniscal surface is flat and rests on the opposite surface of the tibia. The medial meniscus (MM) has a broad posterior horn, a narrow anterior horn, and a more open C-shaped form. The anterior and posterior horns of the lateral meniscus (LM) are almost the same width, and it has a tighter C-shaped appearance. MM covers 50%–60% of the medial tibial plateau, while LM covers 70%–80% of the lateral plateau.[1-3]

The menisci play critical load-bearing roles in the knee joint, such as joint stabilization, shock absorption, and articular cartilage protection from excessive stress.[4] They also deepen the articular surfaces of the tibia to improve the joint congruence, stability, and load distribution, thereby reducing the stress on the tibial condyles, a function that is considered primordial to protect the articular cartilage.[5] However, because the menisci serve these critical mechanical functions, they

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are frequently subjected to severe injuries and degenerative alterations.[6,7]

The anatomical, morphological and morphometric variables have been documented as significant determinants in determining the meniscal injury's probability, etiology, and type.[8] Furthermore, due to modern procedures such as arthroscopy, computed tomography (CT), and magnetic resonance imaging (MRI), these variances have recently become substantial. In addition, it is critical to investigate these variants for clinical diagnosis and surgical interventions to minimize or postpone the meniscal damage.[9]

Cellular and tissue aging have recently received much attention. In this sense, the knee menisci exhibit some alterations with age where gross examination revealed that the elderly menisci are more opaque, with a dark yellowish tint and rough surfaces than the younger menisci, which have translucent, smooth, and gleaming surfaces. Furthermore, as we age, the menisci become tougher and lose their flexibility.[10] Moreover, it was documented that the age-related changes could induce meniscal tissue vulnerability that eventually leads to permanent meniscal damage.[1,11]

Sex differences between men and women have long been known in terms of conditions affecting the human knee, where it has been long recognized that there was a greater susceptibility of knee joint injury in women compared to men.[12,13] Furthermore, it has been observed that there is a relationship between age and meniscal degeneration in both genders; in this view, the males have a greater risk of meniscal degeneration than females before the age of sixty, but females above the age of 70 showed increased degeneration.[14,15] A variety of potential factors have been suggested, such as muscle weakness, hormonal factors including postmenopausal remodeling of the cartilage, and a thinner cartilage thickness compared with men.[16-19] In addition, the life expectancy in women was longer than men, which is a worldwide phenomenon.[20,21]

Based on the information presented above, it appears that knowledge of the morphological features and morphometric measurements of medial menisci (MMi) and lateral menisci (LMi) in elderly males and females is of high or critical importance in providing a database for some specialties such as orthopedists, radiologists, and arthroscopists, allowing them to make a more accurate judgment and management such patients. Owing to very limited studies that have been found in the literature regarding these issues, the current study was undertaken to investigate and compare the morphological features and morphometric parameters of both menisci in male and female elderly human cadavers.

Materials and Methods

Cadaveric material

In this study, 24 human embalmed cadavers (12 males and 12 females) were chosen from the dissection laboratory of the Department of Anatomy, Faculty of Medicine, King Abdulaziz University, Saudi Arabia. As shown in their files, the age range of male cadavers was 60–68, and female cadavers were 62–72. By inspection of their knee regions, no local abnormalities were seen. After removing the skin and muscles, the knee joints were opened anteriorly by a longitudinal incision on each side of the knee joint capsule, cutting the patellar ligament and the collateral ligaments transversely. To expose the menisci clearly, the joint capsule and the intra-articular ligaments (anterior and posterior cruciate ligaments) were cut to expose the tibial plateau. The menisci of right (Rt) and left (Lt) sides from male and female cadavers were excised gently by cutting their anterior and posterior attachments from the tibial plateau using a sharp scalpel. The collected menisci were numbered, coded, and kept in plastic containers containing 10% formalin solution for the following studies:

Macroscopic study

The menisci were firstly inspected to detect any degenerative changes, color changes, fraying, calcium deposition, fibrillations, and tears. Then, the menisci were photographed using a digital camera (Olympus BX60, Olympus Optical Co., Japan), where the various shapes were noted and classified as a sickle, sided U, sided V, crescentic and C-shaped for the MMi. For LMi, they were classified as a crescent, C-shaped, and discoid-shaped.

Morphometric study

All following measurements were measured as previously reported by many investigators:[8,22-25]

- The distance between the anterior and the posterior horns of the menisci (APD): Was measured between the apex of the anterior horn and the apex of the posterior horn of the meniscus using a digital vernier caliper in centimeter
- The outer (OCL) and the inner (ICL) circumferences of the menisci: Were measured with nonelastic cotton thread, which was placed across the outer or inner edges of the menisci from the apex of the anterior horn to the apex of the posterior horn
- The breadth (width) of the menisci was measured from the outer margin to the inner margin in the anterior (BA), middle (BM), and posterior (BP) thirds of each meniscus using a digital Vernier caliper in millimeter
- The thickness of the menisci was measured between the top and bottom in the anterior (TA), middle (TM), and posterior (TP) thirds of each meniscus using a digital Vernier caliper in millimeter
- Meniscal volume (mm^3) (V) was done by complete immersion of the meniscus in a 25 mL calibrated glass cylinder, graded with 0.5 mL increments, containing 15 mL of PBS. The difference in volume before and after placement was attributed to the total volume of the meniscus
- Meniscal surface area (mm^2) (SA) was determined from the photographs by copying the outlines onto squared graph paper so that the area of squares could be counted.

Data analysis

Data were presented as mean ± standard deviation and were analyzed using Statistical Package for the Social Sciences (SPSS) version 23 (IBM Corp., Armonk, NY, USA). Shapiro–Wilk test was used to evaluate normal data distribution.

Statistical comparisons of measured parameters between right and left MMi and LMi from male and female cadavers were made by unpaired Student's *t*-test. Results were considered statistically significant if $P < 0.05$.

Ethical approval

This study was approved by the Unit of biomedical Ethics Research Committee in the Faculty of Medicine, King Abdul-Aziz University (HA-02-J-008) Number of Registration at National Committee of Bio. and Med. Ethics (Reference No 152-21). The guidelines outlined in 16 the Declaration of Helsinki were followed.

Results

Morphological results

The macroscopic examination of MMi and LMi from males and females [Figures 1 and 2] showed that most of them were yellowish and opaque, with some of them appeared brown. Their surfaces were usually rough, with some degenerative lesions were observed in the form of fraying at inner borders, side fibrillations, partial tears, and some spots of calcium deposition.

The number and percentages of various morphological shapes of the MMiand LMi were shown in Tables 1 and 2, respectively.

Morphometric analysis

Comparisons of medial menisci and lateral menisci in males [Table 3]

Regarding the right MMi and LMi, the comparisons showed that APD, OCL, ICL, and TP were significantly higher in the right MMi versus right LMi ($P < 0.0001$, $P = 0.025$, $P < 0.0001$, and $P = 0.0005$). Meanwhile, BA, BM, and BP were significantly lower in the right MMi versus right LMi ($P < 0.0001$, $P = 0.037$, and $P = 0.003$, respectively). On the other hand, TM was insignificantly higher in the right MMi versus right LMi ($P = 0.140$). Also, there was insignificant higher value of meniscal volume $P = 0.592$) and insignificant lower value of SA ($P = 0.798$) between right MMi and LMi.

In the case of left MMi and LMi, the comparisons showed that APD, BM, and TP were significantly higher in left MMi versus left LMi ($P = 0.002$, $P = 0.044$, and $P = 0.0008$,

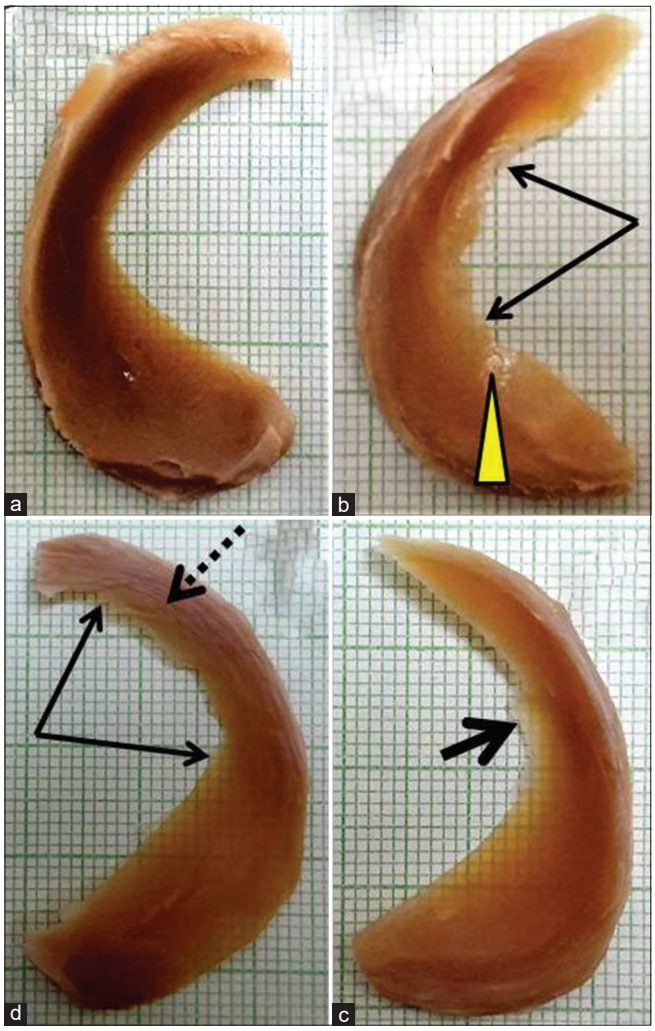

Figure 1: Representative photographs of male and female medial menisci showing (a) right male medial meniscus (MM) with brown color, (b) right female MM with fraying at inner borders (↑) and small calcium deposition (arrow head), (c) left male MM with fraying at inner borders (↑) and surface fibrillation (dashed arrow), (d) left female MM with radial tear (thick short arrow)

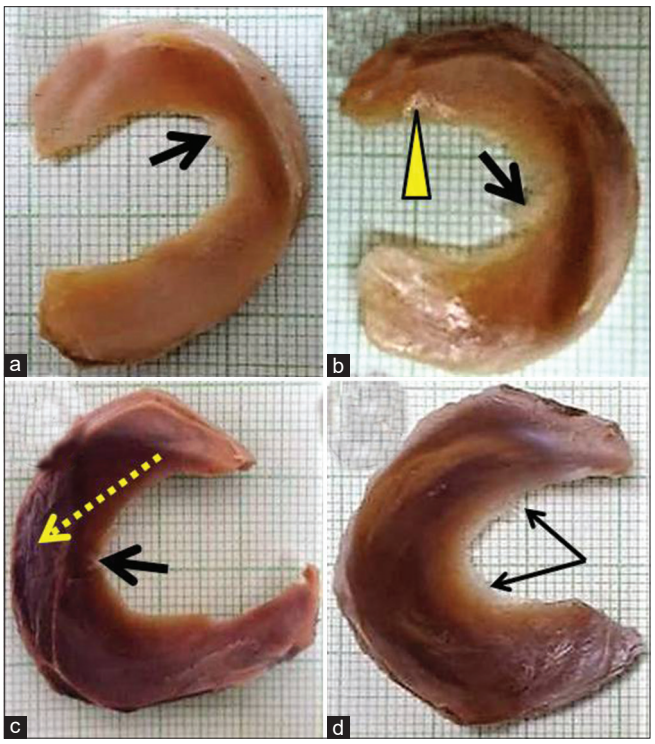

Figure 2: Representative photographs of male and female lateral menisci showing (a) right male lateral meniscus (LM) with radial tear (thick short arrow), (b) right female LM with radial tear and (thick short arrow) and small calcium deposition (arrow head), (c) left male LM with radial tear (thick short arrow) surface fibrillation (dashed arrow), (d) left female LM with fraying at inner borders (↑)

respectively). Meanwhile, there were insignificant changes regarding OCL, ICL, BA, BP, and TM ($P = 0.824$, $P = 0.638$, $P = 0.730$, $P = 0.592$, $P = 0.758$, $P = 0.145$, respectively). Regarding the meniscal volume and SA, there were insignificant lower values in MMi versus LMi ($P = 0.549$ and $P = 0.201$, respectively).

Table 1: Different shapes of medial menisci in males and females

Shape	Males ($n=24$), *n* (%)	Females ($n=24$), *n* (%)
Crescent-shaped	11 (45.8)	12 (50.0)
Sickle shaped	5 (20.8)	6 (25.0)
C-shaped	4 (16.6)	3 (12.5)
Sided U shaped	2 (8.3)	1 (4.2)
Sided V-shaped	2 (8.3)	2 (8.3)

Table 2: Different shapes of lateral menisci in males and females

Shape	Males ($n=24$), *n* (%)	Females ($n=24$), *n* (%)
Sided U shaped	7 (29.1)	8 (33.3)
Crescent-shaped	6 (25.0)	6 (25.0)
C-shaped	5 (20.8)	3 (12.5)
Sickle shaped	4 (16.6)	3 (12.5)
Sided V-shaped	2 (8.3)	4 (16.6)

Moreover, comparisons between right and left MMi showed that OCL was significantly higher in the right MMi as compared to left MMi ($P = 0.005$). While BM was significantly lower in the right MMI compared to the left MMI ($P = 0.038$). While, BA and TA were insignificantly lower in the right MMi compared to left MMi ($P = 0.441$, $P = 0.309$). In contrast, TM and TP were insignificantly higher in the right MMi compared to left MMi ($P = 0.663$, $P = 0.663$). Furthermore, there were insignificant changes regarding ICL, BP, and APD between right MMi compared to left MMi ($P = 0.0.595$, $P = 0.241$, $P = 0.937$, respectively). In addition, there were insignificant higher values between right and left MMi regarding volume ($P = 0.531$) and SA ($P = 0.213$).

Furthermore, comparisons between right and left LMi revealed that APD was significantly lower in the right LMi compared to left LMi ($P = 0.016$). Meanwhile, there were insignificant lower values in the right LMi compared to left LMi regarding OCL, ICL, TA, and TM ($P = 0.696$, $P = 0.099$, $P = 0.232$, $P = 0.568$, respectively). Furthermore, BA, BM, and BP were significantly higher in the right LMi compared to left LMi ($P < 0.0001$, $P = 0.047$, $P = 0.074$), while TP was insignificantly higher in the right LMi compared to left LMi ($P = 0.5388$). Furthermore, there were insignificant changes in meniscal volume and SA in right versus left LMi ($P = 0.609$ and $P = 0.415$, respectively).

Table 3: Comparison of all measured parameters between right and left medial and lateral menisci in males

Meniscal parameters	Right MMi	Right LMi	Left MMi	Left LMi
Distance between APD (cm)	4.42±0.93	3.04±0.56	4.45±0.75	3.55±0.24
Significance (*P*)		0.0008[a]	0.9376[c]	0.002[b]; 0.0164[d]
OCL (cm)	8.63±0.83	7.36±0.79	7.43±0.87	7.53±1.10
Significance (*P*)		0.0250[a]	0.0055[c]	0.824[b]; 0.6961[d]
ICL (cm)	4.43±0.67	3.02±0.53	4.22±1.03	3.57±0.85
Significance (*P*)		<0.0001[a]	0.5955[c]	0.141[b]; 0.0996[d]
BA (cm)	0.61±0.18	1.24±0.17	0.67±0.16	0.71±0.21
Significance (*P*)		<0.0001[a]	0.4410[c]	0.638[b]; <0.0001[d]
BM (cm)	0.72±0.14	0.90±0.21	1.02±0.40	0.73±0.14
Significance (*P*)		0.037[a]	0.038[c]	0.044[b]; 0.0472[d]
BP (cm)	0.98±0.35	1.47±0.28	1.22±0.52	1.28±0.15
Significance (*P*)		0.003[1]	0.2416[3]	0.730[b]; 0.0748[d]
TA (mm)	3.49±0.84	3.06±0.42	3.82±0.54	3.34±0.58
Significance (*P*)		0.165[a]	0.3098[c]	0.0715[b]; 0.2322[d]
TM (mm)	5.22±0.77	4.74±0.61	5.08±0.64	4.96±1.03
Significance (*P*)		0.140[a]	0.6636[c]	0.7579[b]; 0.5683[d]
TP (mm)	5.78±0.59	4.42±0.83	5.62±0.98	4.23±0.48
Significance (*P*)		0.0005[a]	0.6635[c]	0.0008[c]; 0.5388[d]
Volume (mm^3)	3.25±0.20	3.20±0.21	3.19±0.22	3.25±0.22
Significance (*P*)		0.592[a]	0.5314[c]	0.5496[b]; 0.6095[d]
SA (mm^2)	4.81±1.34	4.95±1.05	4.16±0.86	4.62±0.68
Significance (*P*)		0.798[a]	0.2131[c]	0.2012[b]; 0.4151[d]

[a]*P*: Significance right MMi versus LMi, [b]*P*: Significance left MMi versus LMi, [c]*P*: Significance right and left MMi, [d]*P*: Significance right and left LMi, Data were expressed as mean±SD, Difference between groups was made using unpaired Student's *t*-test. LMi: Lateral menisci, MMi: Medial menisci, SD: Standard deviation, OCL: Outer circumferential length, ICL: Inner circumferential length, BA: Breadth anterior one-third, BM: Breadth middle one-third, BP: Breadth posterior one-third, TM: Thickness middle one-third, TP: Thickness posterior one-third, TA: Thickness anterior one-third, SA: Surface area, APD: Anterior and posterior ends

Comparisons of medial menisci and lateral menisci in females [Table 4]

Comparisons between right MMi and LMi showed that APD and TP were significantly higher in the right MMi compared to right LMi ($P < 0.0001$ and $P < 0.005$, respectively). While, BA, BM, and BP were significantly lower in the right MMi compared to right LMi ($P < 0.0002$, $P < 0.0002$, $P = 0.033$, respectively). There were insignificant changes between the right MMi compared to right LMi regarding OCL, ICL, TA, TM ($P = 0.166$, $P = 0.101$, $P = 0.605$, $P = 0.060$, respectively). Furthermore, there were insignificant higher values between the right MMi versus the right LMi regarding volume ($P = 0.476$) and SA ($P = 0.728$).

Comparisons between left MMi and LMi showed that APD, OCL, and ICL were significantly higher in left MMi compared to left LMi ($P < 0.0001$, $P = 0.043$ and $P = 0.002$, respectively). While BP was significantly lower in left MMi compared to left LMi ($P = 0.018$). There were insignificant changes between left MMi compared to left LMi regarding BA and BM ($P = 0.119$, $P = 0.856$, $P = 0.741$, respectively). Regarding TA, TM, and TP, they were insignificantly higher in left MMi as compared to left LMi ($P = 0.949$, $P = 0.077$, $P = 0.125$). Also, there were insignificant higher values between the right MMi versus the right LMi regarding volume ($P = 1.00$) and SA ($P = 0.204$).

Comparisons between right and left MMi: In females, APD, OCL, and BA were significantly lower in the right MMi compared to left MMi ($P = 0.024$, $P = 0.041$, $P = 0.006$, respectively). Furthermore, there were insignificant lower values between the right MMi versus the left MMi regarding volume ($P = 0.647$) and SA ($P = 0.902$).

Comparisons between right and left LMi showed that there were insignificant changes in right LMi versus left LMi of all measured parameters APD, OCL, ICL, BA, BM, BP, TA, TM, and TP ($P = 0.024$, $P = 0.041$, $P = 0.798$, $P = 0.006$, $P = 0.324$, $P = 0.065$, $P = 0.325$, $P = 0.783$, $P = 0.125$, respectively). Furthermore, there was an insignificant change between right versus left MMi regarding volume ($P = 1.00$). Meanwhile, the SA was insignificantly higher in the right versus the left MMi ($P = 0.204$).

Comparisons between right and left medial menisci and lateral menisci in males and females

Figure 3 shows comparisons of all measured parameters of right MMI in males and females. In males, right MMi APD, OCL, BA, BM, TM, and TP were significantly higher than females ($P = 0.003$, $P < 0.0001$, $P = 0.003$, $P = 0.014$, $P = 0.003$, respectively). Meanwhile, ICL, BP, TA in males were insignificantly higher than in females ($P = 0.835$, $P = 0.303$, $P = 0.073$, respectively). Furthermore, both meniscal volume and SA were significantly higher in males versus females ($P < 0.0001$).

Table 4: Comparison of all measured parameters between right and left medial (lateral menisci) and lateral (lateral menisci) menisci in females

Meniscal parameters	Right MMi	Right LMi	Left MMi	Left LMi
Distance between APD (cm)	3.41±0.24	2.44±0.24	3.80±0.44	2.64±0.29
Significance (*P*)		<0.0001[a]	0.013[c]	<0.0001[b]; 0.0242[d]
OCL (cm)	6.59±0.88	7.18±0.95	7.42±0.81	6.58±0.92
Significance (*P*)		0.1668[a]	0.025[c]	0.0439[b]; 0.0416[d]
ICL (cm)	4.50±0.81	3.73±1.15	4.59±0.74	3.37±0.79
Significance (*P*)		0.1005[a]	0.776[c]	0.0022[b]; 0.7983[d]
BA (cm)	0.35±0.16	0.79±0.26	0.61±0.21	0.83±0.37
Significance (*P*)		<0.0002[a]	<0.0001[c]	0.1194[b]; 0.006[d]
BM (cm)	0.58±0.19	0.63±0.21	0.73±0.15	0.75±0.31
Significance (*P*)		0.5835[a]	0.054[c]	0.8563[b]; 0.0657[d]
BP (cm)	0.83±0.28	1.14±0.32	0.95±0.25	1.24±0.25
Significance (*P*)		0.033[a]	0.294[c]	0.0183[b]; 0.3254[d]
TA (mm)	2.92±0.44	3.02±0.41	2.86±0.52	2.84±0.84
Significance (*P*)		0.6054[a]	0.062[c]	0.9497[b]; 0.7838[d]
TM (mm)	4.52±0.27	3.96±0.84	4.66±0.72	4.04±0.76
Significance (*P*)		0.0600[a]	0.792[c]	0.0774[b]; 5719[d]
TP (mm)	4.56±0.98	3.32±0.73	4.46±0.62	3.88±0.96
Significance (*P*)		0.0049[a]	0.011[c]	0.1259[b]; 0.7882[d]
Volume (mm^3)	2.49±0.22	2.43±0.14	2.53±0.16	2.45±0.11
Significance (*P*)		0.4762[1]	0.6475[c]	0.2090[b]; 1.000[d]
SA (mm^2)	3.86±0.92	3.74±0.56	3.91±0.87	3.33±0.81
Significance (*P*)		7287[a]	0.9020[c]	0.1402[b]; 0.2045[d]

[a]*P*: Significance right MMi versus LMi, [b]*P*: Significance left MMi versus LMi, [c]*P*: Significance right and left MMi, [d]*P*: Significance right and left LMi, Data were expressed as mean±SD, difference between groups was made using unpaired Student's *t*-test. LMi: Lateral menisci, MMi: Medial menisci, SD: Standard deviation, OCL: Outer circumferential length, ICL: Inner circumferential length, BA: Breadth anterior one-third, BM: Breadth middle one-third, BP: Breadth posterior one-third, TM: Thickness middle one-third, TP: Thickness posterior one-third, TA: Thickness Anterior one-third, SA: Surface area, APD: Anterior and posterior ends

Figure 4 shows comparisons of all measured parameters of left MMI in males and females. In males, APD, BM, TA, and TP of left MMi were significantly higher than females ($P = 0.029$, $P = 0.045$, $P = 0.0008$, $P = 0.005$, respectively). Meanwhile, there were insignificant changes between males and females regarding OCL, ICL, BA, BP, TM of left MMi ($P = 0.979$, $P = 0.368$, $P = 0.481$, $P = 0.156$, $P = 0.184$, respectively). Furthermore, the left MMi volume and SA were significantly higher in males versus females ($P < 0.0001$).

Figure 5 shows comparisons of measured parameters of right LMi in males and females. In males, APD, BA, BM, BP, TM, TP of right lateral menisci were significantly higher than females ($P < 0.0001$, $P = 0.0002$, $P = 0.010$, $P = 0.024$, $P = 0.028$, $P = 0.005$, respectively). Meanwhile, there were insignificant changes between males and females regarding OCL, ICL, BM, and TA ($P = 0.650$, $P = 0.093$, $P = 0.010$, $P = 0.8318$, respectively). Furthermore, the right LMi volume and SA were significantly higher in males versus females ($P < 0.0001$).

Figure 6 shows comparisons of measured parameters of left LMi in males and females. In males, APD, OCL, TM was higher than female ($P < 0.0001$, $P = 0.050$, $P = 0.035$, respectively). Meanwhile, there were insignificant changes regarding ICL, BA, BM, BP, TA and TP ($P = 0.592$, $P = 0.384$, $P = 0.854$, $P = 0.669$, $P = 0.138$, $P = 0.3161$, respectively). Furthermore, the left LMi volume and SA were significantly higher in males versus females ($P < 0.0001$).

Discussion

This study described the different morphological and morphometric parameters of both MM and LM in aged male and female cadavers. The impetus for this work was that it had been documented that the knee meniscus changes gradually with age, both at the macroscopic, cellular, and tissue levels. However, little is known about these aged meniscal alterations in terms of morphological appearance and morphometric data.[11,15,26] The importance of this work was that the elderly people are frequently affected by degenerative meniscal pathologies; the matter that disturbs their daily activities and raises their social and economic burdens especially is that in the last few decades, the rise of life longevity is so remarkable.[27] Therefore, the data of meniscal dimensions may help the orthopedics and radiologists in developing better diagnostic and therapeutic strategies that facilitate the meniscal substitution.[26,28-32]

In this study, most of the menisci, either in males or in females, appeared more opaque, with a dark yellowish color. In accord, it was reported by[10] that menisci from patients of advanced age appeared darker with surface roughening as compared to the healthy young meniscus, which has a translucent, smooth, and glistening surface. This could happen as a result of fibronectin loss over time. In addition, it was reported that the knee menisci became harder and lost their elasticity.[1,33] According to the literature,[34] it had been highlighted that there had been a link between meniscus damage and subsequent osteoarthritis and increasing age.

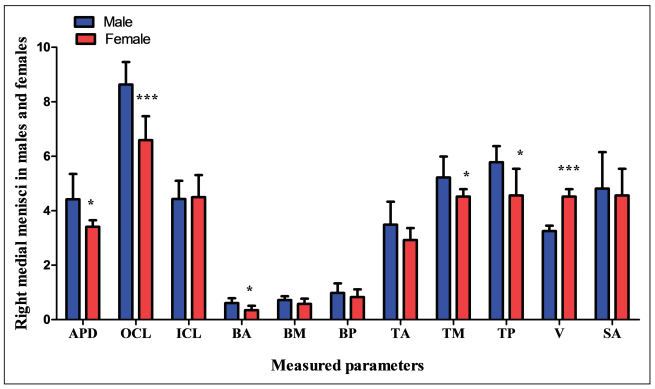

Figure 3: Comparison of all measured parameters of right medial menisci (MMi) between males and females. Data were expressed as mean ± standard deviation. Difference between groups was made using unpaired Student's *t*-test. *Significance right male MMi versus right female MMi. *$P < 0.050$; **$P < 0.010$; ***$P < 0.001$

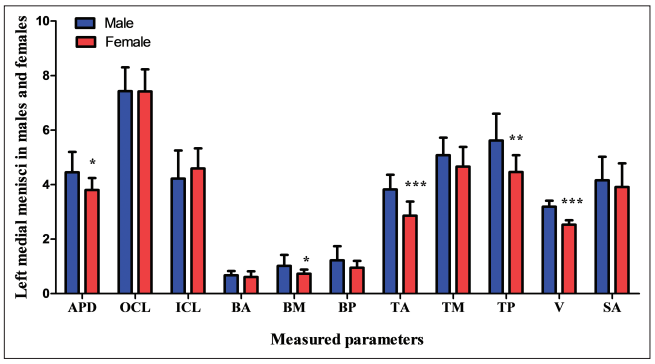

Figure 4: Comparison of all measured parameters of left medial menisci (MMi) between males and females. Data were expressed as mean ± standard deviation. Difference between groups was made using unpaired Student's *t*-test. *Significance left male MMi versus left female MMi. *$P < 0.050$; **$P < 0.010$; ***$P < 0.001$

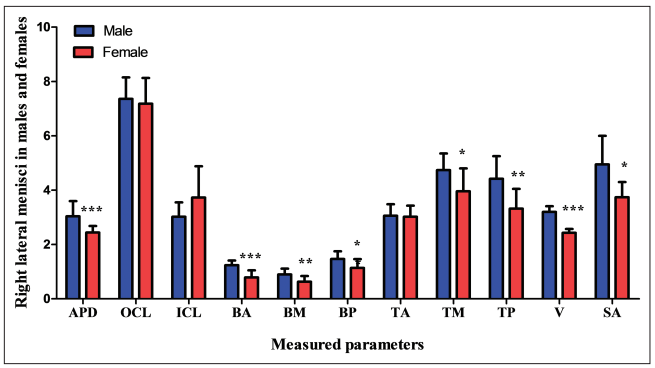

Figure 5: Comparison of all measured parameters of right lateral menisci (LMi) between males and females. Data were expressed as mean ± standard deviation. Difference between groups was made using unpaired Student's *t*-test. *Significance right male LMi versus right female LMi; **$P < 0.010$; ***$P < 0.001$

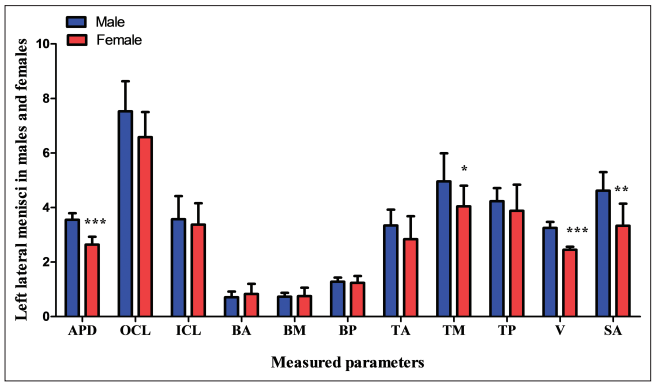

Figure 6: Comparison of all measured parameters of left lateral menisci (LMi) between males and females. Data were expressed as mean ± standard deviation. Difference between groups was made using unpaired Student's *t*-test. *Significance left male LMi versus left female LMi. *$P < 0.050$; **$P < 0.010$; ***$P < 0.001$

The various shapes of MMi and LMi in males and females were described in this study. Regarding MMi, the most common shape in males and females was the crescent-shaped (45. 8% and 50%, respectively), followed by Sickle-shaped (20.8% and 25%, respectively), C-shaped (16.6% and 12.5%, respectively), Sided U-shaped (8.3% and 4.2%, respectively) and Sided V-shaped (8.3% and 8.3%, respectively). However, variable percentages were recorded by several investigators who studied the different shapes of MMi. Other studies[35] conducted a morphological study of 108 menisci of 54 adult cadaveric knee joints and found that 50% of the MMi were crescent-shaped, 38.9% were V-shaped, and 11.1% were sided U-shaped. In addition, 120 menisci from 60 adult cadaveric knee joints in the Indian population have reported that 96.66% of MMi were crescentic-shaped.

In the present study, the common shapes of LMi in males and females were sided U-shaped (29.1% and 33.3%, respectively), crescent-shaped (25% and 25%, respectively), C-shaped (20.8% and 12.5%, respectively), sickle-shaped (16.6% and 12.5%, respectively) and sided V-shaped (8.3% and 16.6%, respectively). Again, different percentages were recorded by several authors who studied the different shapes of LMi, 13.63% of LMi were crescent-shaped, 9.09% were C-shaped, and 77.27% were discoid-shaped. Furthermore, the author in[36] mentioned that the percentage of the different types of LMi were C-shaped (61.1%), crescent-shaped (38.9%). However, the most common shape of LMi was the C-shape (88.33%).

Different measurements of the MMi and LMi in males and females were determined in this study, including the distance between anterior and posterior horns, outer and inner circumferences, width (breadth) and thickness, SA, and volume. When comparing MMI and LMi in male and female cadavers, the morphometric analysis indicated statistically significant positive relationships between the different indices.

Regarding the distance between anterior and posterior horns (length), the values in the MM showed higher values compared with those of the LM, which was statistically highly significant either in males or females for both right and left MMI and LMi. These results agreed with other studies,[6,22] who also mentioned that the greater proximity of the horns of the LMi might explain why they are less prone to injury than MMi.

In the current study, the outer and inner circumferences showed that they were significantly more in MMi than that of the LMi both in males and females. These findings closely matched with the results of some authors[9,22,24] in contrast to other earlier studies, which showed some variations[6,34] that were reported to be because of racial variations or due to different used methods.[37] Moreover, the comparison of these lengths between males and females for both MMi and LMi revealed significantly higher values in males when compared to the females. Such correlation has not been addressed in any previous study. Also, our results showed less significant differences in these circumferences between right and left sides. In accord to other authors[3,37] who found no significant differences in these lengths between right and left sides regarding both MMi and LMi.

The width (breadth) of the MMi and LMi was measured and studied in the current study at the anterior, middle, and posterior thirds. Our findings revealed that the mean width of the LMi was significantly greater than that of the MMi at each of the three parts; also, the posterior one-third was the broadest area in both the MMi and the LMi. In contrast,[8] showed that the widths of LMi were more uniform, with the width of the middle third of LMi being more significant than the width of the posterior third.

Furthermore, the individual analysis of MMi on the right and left sides both in males and females showed that the posterior one-third was the widest, followed by middle one-third then the anterior one-third with statistically significant differences. While the individual analysis of LMi on the right and left sides both in males and females showed that the posterior one-third was the widest, followed by anterior one-third then the middle one-third with statistically significant differences. These results were in agreement with the literature,[34] who stated that the measurements of the width of anterior and middle one-third of LMi were much higher than those of MMi, which is statistically significant. However, they mentioned that the posterior one-third of MMi was wider than LMi, which was not like our results that showed that the posterior one-third of MMi was less than LMi. Furthermore, our results were in accordance with previous studies, which reported that the posterior horn of MMi and LMi was the widest part of the meniscus and the anterior horn is the narrowest.[8,9,22,25] Moreover, some results[9] suggested that the narrow meniscus is less prone to rupture than the wide one, where the greater of meniscal width, the more the exposure to friction and compression. Furthermore, the mean values of the width of the anterior, middle, and posterior thirds of MMi and LMi in this study were higher than those reported.[25]

In this study, the thickness of MMi and LMi were also recorded in the same three locations, anterior, middle, and posterior

thirds. Our results showed that the MMi was thicker when compared to the LMi in both the right and left sides, both in males and females. In male MMi, the mean values of thickness in anterior, middle, and posterior thirds were 3.49, 5.22, and 5.78 mm, respectively, on the right side and 3.82, 5.08, and 5.62 mm, respectively, on the left side, which showed that the posterior one-third was the thickest and the anterior one-third was the thinnest part. While in male LMi, the mean values of thickness in anterior, middle, and posterior thirds were 3.06, 4.74, and 4.42 mm, respectively, on the right side and 3.34, 4.96, and 4.23 mm, respectively, on the left side, which showed that the middle one-third was the thickest followed by posterior one-third and then the anterior one-third, which was the thinnest part. A comparison between male and female thickness measurements for both MMi and LMI showed similar results between them regarding the thickness of different meniscal parts; however, in general, the measurements in female MMi showed less value than in males, which were statically significant. According to our measurements, other reporting[38] more or less similar results regarding the thickness of anterior, middle, and posterior thirds of both MMi and LMi. Also,[25] who studied six pairs of menisci of human knee male cadavers in the Canadian population, have reported identical results. Similarly, a study[39] included 100 LMi of adult human male cadavers in the Indian population and found that the thickest part of LMi was the middle one-third. Moreover, it was mentioned[24] that in comparing MMi with LMi, the anterior and posterior thirds of MMi were thicker than LMi. Furthermore, they added that the individual analysis of each meniscus showed that not much difference was observed among anterior, middle, and posterior thirds of MMi, while in LMi, the anterior third was the thinnest part.

In contrast to our results, a study[8] conducted a morphometric study of 44 menisci of 22 knees, have stated that the middle one-third of MMi was the smallest, followed by the anterior and posterior thirds and also, to a study[6] which conducted a morphometric study of 40 menisci of 20 knees and found that the thickness of MMi in the anterior, middle and posterior thirds was 6.17, 6.31 and 5.18 mm respectively and for LMi were 4.40, 6.52 and 5.46 mm. Also to reporting[4] that the thickness of MMi was least in the middle one-third whereas in LMi was thickest in the middle one-third.

In this study, the meniscal volume was determined using a simple method of water replacement. Our findings revealed that the mean volume of MMi and LMi were more or less similar on both sides and these values were significantly higher in males than in females [Tables 3 and 4]. These data conformed to the results of width and thickness dimensions in this study and other studies[24,40] which entailed the bigger values in males than in females. Clinically, two studies[41,42] have validated quantitative MRI to evaluate meniscal volume *in vivo* and volume changes after partial meniscectomy. They concluded that it was possible that a loss of meniscal volume at the time of injury may affect the preoperative meniscal volumes.

In the current study, the meniscal SA was measured. Our findings showed nearly similar mean values between MMi and LMi in males and females on both right and left sides [Tables 3 and 4]. However, comparing these values between males and females revealed lower meniscal SAs in both female MMI and LMi than those in males, which was statistically significant. In agreement, other papers[43] reported that in adults, the meniscal area was not significantly different between the LMi (4.6 ± 0.98 mm^2) and MMi (4.4 ± 0.93 mm^2) sides. However, the area of the tibial plateau was significantly larger on the medial side (7.4 ± 1.6 mm^2) than on the lateral side (6.2 ± 1.1 mm^2).

It was reported that the menisci cover from 1/2 to 2/3 of the articular surface of the corresponding tibial plateau, with LM covering an area higher than MM due to its semicircular shape. Furthermore, in this regard, it was suggested that meniscal SA strongly scales with ipsilateral tibial plateau area and that tibial coverage by the meniscus was similar between men and women.[28,29]

Finally, it was reported that there is an important relationship between the morphometric data of menisci and the clinical findings, which showed that meniscal variations, particularly in thickness and width, could determine not only the possibility of an injury but also the location and the kind of injury. It can be said that the width and thickness were inversely related; the greater the width of one of the thirds, the smaller the thickness, while the opposite was also confirmed.[37] Moreover, meniscal replacement and grafting due to various pathologies have recently gained greater attention. Such procedures are dependent on the proper sizing, which is critical in restoring meniscal function. Incorrect sizing can lead to various problems, including incompatibility with the femoral and tibial condyles, excessive strain, and even extrusion, culminating in unsuccessful transplantation.[23,44,45]

Conclusion

The findings of this study were essential in providing new information on various morphological and morphometric parameters of the MMi and LMi in aged males and females, which are necessary to require more precise and comprehensive fundamental data that will be helpful for many specialists for better diagnostic and therapeutic approaches; aiming to restore normal joint conditions in senile people complaining of different meniscal pathologies.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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