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Morphological structure and variations of fetal lateral meniscus: the significance in convenient diagnosis and treatment

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Abstract

Purpose The aim of this study is to evaluate of morphometry of the lateral meniscus (LM) and determine incidence of the LM shapes.

Methods This study was performed on fetal cadaver collection of Anatomy Department of Necmettin Erbakan University. Fifty human fetal cadavers (25 female, 25 male human fetal cadavers) were used in this study. Microdissection was performed. Morphometric measurements were performed. LM were classified into four types and five subtypes.

Results In this study, it was identified that all parameters which were measured were found to be increased with gestational ages. Four morphological types and five morphological subtypes were determined. It was found that 12% of the LM were crescent-shaped, 66% of the LM were C-shaped, 14% of the LM were incomplete-disc-shaped, 2% of the LM were disc-shaped, 6% of the LM were variant C-shaped.

Conclusions A few studies on fetal meniscal anatomy and its development were performed. Each new study is important for having detailed anatomy and development of the fetal menisci which will have both clinical and anatomical impacts during childhood and adulthood for orthopedic surgeons and anatomists, respectively. The most important results of this study were the detailed objective analysis of the macroscopic fetal growth of LM. It was significantly observed that four morphological types and five morphological subtypes of LM. The results of the present study related with both the observation of morphological development of the fetal meniscal anatomy, and its morphological variants, are important in terms of improving our knowledge, and clinical approach on the description, and the management of the symptomatic lateral discoid meniscus tears in children, adolescents, and adults. The clinical relevance of this study was that this classification of fetal menisci could ameliorate our current understanding of the morphology of lateral meniscus in adult, further.

Keywords Lateral meniscus · Fetal cadavers · Morphometry

Introduction

The knee joint contains two important structures called the medial meniscus (MM) and the lateral meniscus (LM). Those intra-articular fibrocartilage structures are localized between the femoral condyles and the tibial plateau, and attach to the tibial condyles via their peripheral structures, thereby increasing the tibial articular surface [19, 38]. The menisci are formed in the knee joint between the 8th and 10th weeks of embryonic life. The MM and LM have different shapes and sizes in humans. Despite that both menisci are wedge-crescenteric shaped, the LM is larger than the MM and exhibits mobility in terms of shape and thickness. The LM has anterior and posterior horns that are in close proximity, and a body. Collectively, the LM covers 75–93% of the tibial plateau [4, 20, 21, 39]. Additionally, the LM has more mobility on the tibia than the MM, and for this reason, may carry higher loads than the MM. The load-carrying capacity of the menisci depends on their shape and performance qualities [7, 28, 39].

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The menisci have a crucial role in the functions of the knee joint. Consequently, meniscus injuries may deteriorate joint stability and negatively affect the quality of life of the patient [2]. Knee joints that are damaged as a result of sports activities are frequently detailed in the literature, and recent research has shown that traumatic meniscal injuries are being seen with increased frequencies in children and adolescents [13, 16, 25, 28]. Since new imaging techniques such as arthroscopy, computed tomography, and magnetic resonance imaging are being used more frequently in some clinical branches for diagnosis and surgical operations, the morphological properties of intra-articular structures in the knee are becoming more considerable [25].

In young children, some knee joint abnormalities such as discoid menisci are diagnosed by their characteristic morphologies. Thus, it is necessary to identify the development of knee morphology during the early periods of fetal life. Although there are multiple studies on adult menisci, studies detailing fetal or newborn menisci are limited [1, 3, 4, 6, 7, 9, 13, 20, 22, 23, 26–28, 30, 31, 33, 39]. The aim of the current study was to evaluate the LM morphometry and determine the incidence of LM shapes in human fetal cadavers, and to detect whether there was a decrease in the incidence of complete or incomplete discoid menisci in the later stages of fetal development.

Materials and methods

This study was performed on 50 human fetal cadavers (25 female, 25 male). Fetal cadavers without any morphological malformations (no musculoskeletal anomalies) were included in the study, while those with dismorphic features were removed. First, 50 fetal cadavers ranging from 13 to 37 gestational weeks were classified according to the age determination method of Polin and Fox [10]. According to such parameters, microdissection was performed using a microdissection microscope. To reduce errors related to the measurement technique, measurements were obtained in duplicate by the same analyst. Microdissection was performed by dissecting the skin and muscles, making a vertical incision on the joint capsule, removing the collateral ligaments, and cutting the joint capsule and intra-articular ligaments. Morphometric measurements in dissected fetal cadavers were obtained using electronic calipers (mm). The width of the anterior (WAH) and posterior horns (WPH) was measured in the antero-posterior direction (Fig. 1). The width of the lateral horn (WLH) was measured in the transverse direction (Fig. 1). The thicknesses of the anterior (TAH), posterior (TPH) and lateral horns (TLH) were measured in the supero-inferior direction (Fig. 1). The distance between the tip of the anterior and posterior horns (AH–PH) was measured in the antero-posterior direction (Fig. 2).

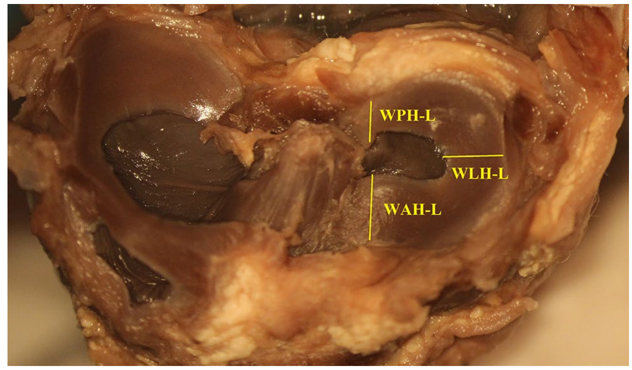

Fig. 1 On the left knee region, width measurements of anterior horn, posterior horn and lateral horn of LM in male fetal cadaver belonging to third trimester

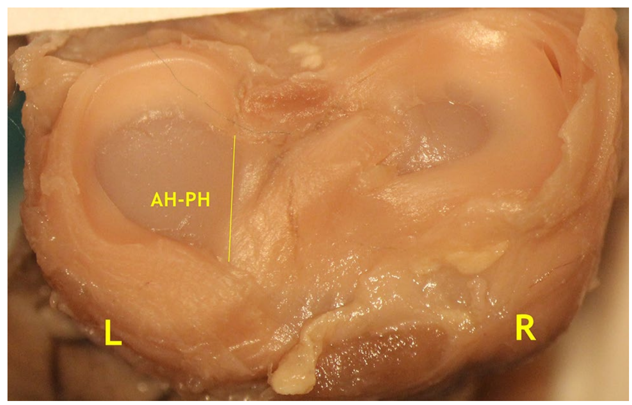

Fig. 2 On the left knee region, the distance tip of the anterior and posterior horn of LM in female fetal cadaver belonging to second trimester

LM shapes were photographed and classified into four morphological types and five morphological subtypes (variant C-shaped). The morphological types included Type 1 (*Crescenteric type*, the AH and PH of the LM were thin and contained sharp tips. The body of the LM was thin), Type 2 (*C-shaped*, the AH and PH of the LM were thick and contained blunt tips. The body of the LM was thicker than that of Type 1), Type 3 (*Incomplete discoid*, the LM appeared outside the classic form. The tips of the AH and PH were close, but not unconjugated. The tibial plateau was incompletely covered by the LM), and Type 4 (*Complete discoid*, the LM appeared outside the classic form. The AH and PH were conjugated. There was no free field in the middle of the LM) (Figs. 3, 4). The morphological subtypes of the LM originated from various combinations of crescenteric and c-shaped types (Figs. 5, 6). Subtypes were classified into Type A (a crescenteric-c-shaped appearance. Both the AH and PH were of the same width. The AH contained a sharp tip, while the PH had a blunt tip); (Fig. 5), Type B (a crescenteric-c-shaped appearance. The AH contained a

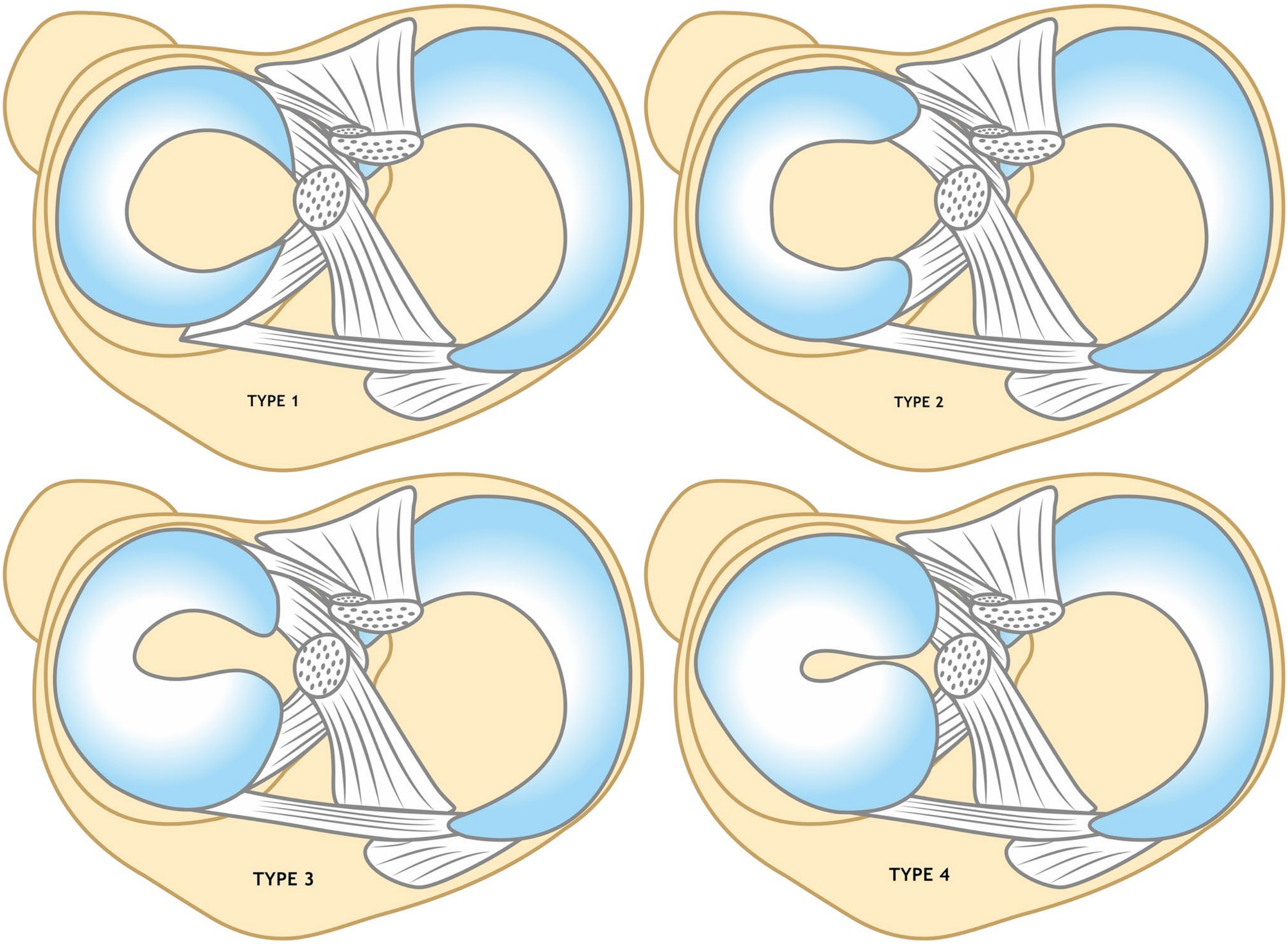

Fig. 3 Morphological types of LM in fetal cadavers belonging to second and third trimester

blunt tip, while the PH had a sharp tip); (Figs. 5, 6), Type C (a crescenteric-c-shaped appearance. The AH was thicker than the PH. The AH contained a blunt tip, while the PH had a sharp tip); (Figs. 5, 6), Type D (a crescenteric-c-shaped appearance. The PH was thicker than the AH. The PH contained a blunt tip, while the AH had a sharp tip); (Figs. 5, 6), and Type E (a crescenteric-c-shaped appearance. The AH and PH had blunt tips. The PH was thinner than the AH); (Figs. 5, 6).

Approval for this study was obtained from Necmettin Erbakan University's Meram Faculty of Medicine's Non-Interventional Clinical Research Ethics Committee (decision number: 2017/58).

Statistical analysis

Sample size was calculated as below:

$$n = (tl - \alpha)^2 (p - q)^2 / S^2,$$

where, $tl-\alpha$: 95% confidence intervals, t value: 1.96. p is incidence of investigated event in the universe (incidence of crescenteric shape of LM was determined as 19% in study of Koyuncu et al. [18]), q: $1-p$, S standard error 0.05 for 95% confidence intervals, n is sample number, $n=(1.96)^2 (0.19.0.81)^2/(0.05)^2$: 36.4 (minimum number of individuals).

All data were evaluated using SPSS 21.0 (Statistical Package for Social Science; IBM, Chicago, IL, USA). The mean values, standard deviations, maximum and minimum values, and percentages were determined. The differences between the morphometric values of the LMs of male and female fetal cadavers were compared using an independent sample t test. Data from morphometric measurements from right and left sides of the fetal cadavers were compared using a paired sample t test. The 95% confidence intervals were calculated and a $p<0.05$ was considered statistically significant.

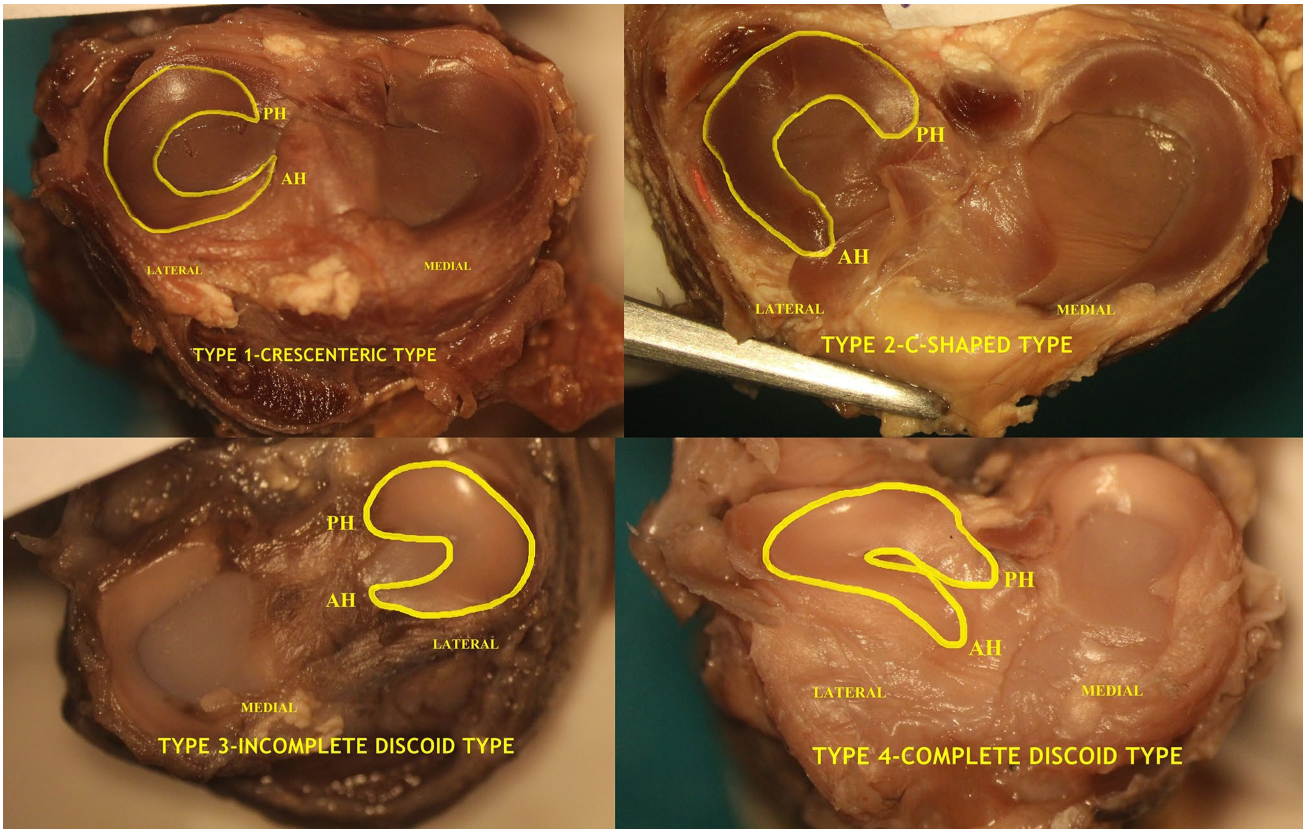

Fig. 4 Morphological subtypes of LM in fetal cadavers belonging to second and third trimester

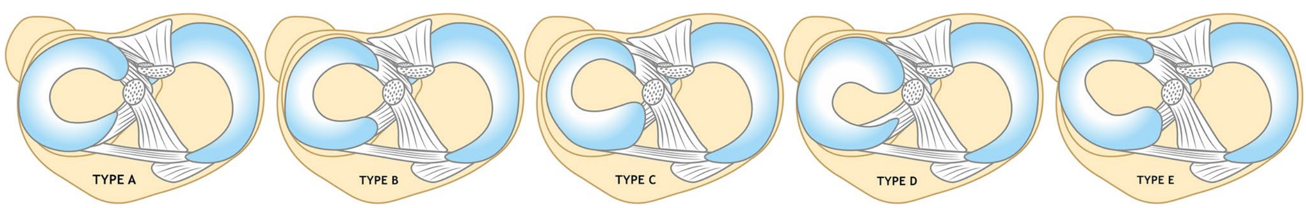

Fig. 5 Schematic views of morphological subtypes of LM

Results

This study was conducted on 50 fetal cadavers belonging to the second and third trimesters. Table 1 shows the distributions of fetal cadavers according to sex and trimesters. The mean values and standard deviations of the parameters are shown in Tables 2 and 3. All parameters increased with gestational age and there was a significant difference between the second and third trimesters in all parameters except TAH-R, TPH-R, and TLH-R ($p < 0.005$) (Table 4). No differences in parameters were observed between males and females (Table 5).

In the left knee region, the mean widths of the anterior horn, posterior horn, and lateral horn were 1.9 ± 0.7 mm, 2.2 ± 0.7 mm, and 2 ± 0.7 mm, respectively. Those values were 1.9 ± 0.8 mm, 2 ± 0.7 mm, and 1.9 ± 0.6 mm, respectively, for the right knee. Similarly, we determined that the mean thicknesses of the anterior horn, posterior horn, and lateral horn were 1.2 ± 0.4 mm, 1.2 ± 0.4 mm, and 1.2 ± 0.4 mm, respectively, in the left knee. The thicknesses for the right knee were 1.3 ± 0.5 mm, 1.3 ± 0.4 mm and 1.7 ± 0.5 mm for the anterior, posterior, and lateral horns, respectively (Table 3).

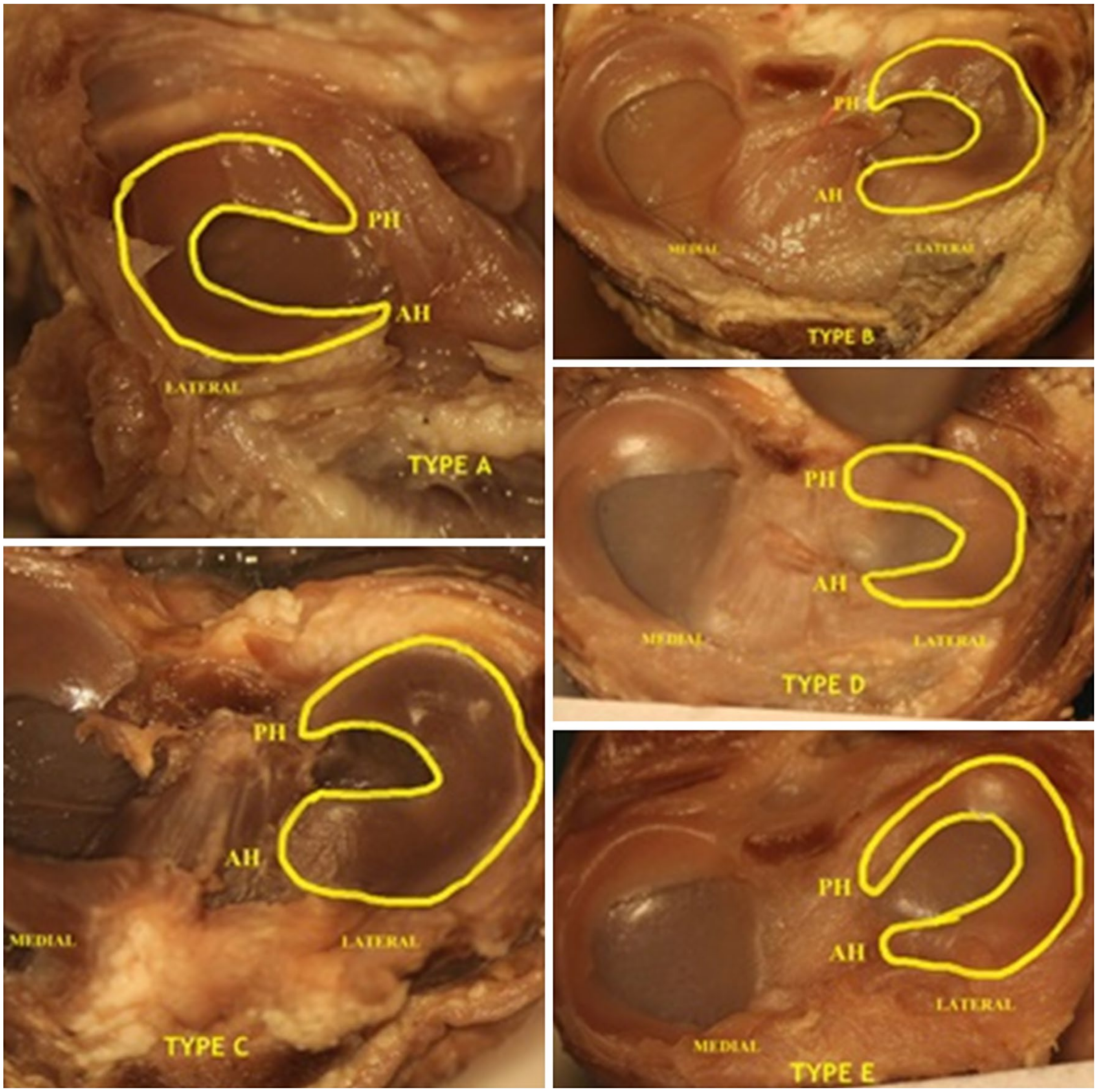

Fig. 6 Morphological subtypes of lateral meniscus in fetal cadavers belonging to second and third trimester. *AH* anterior horn, *PH* posterior horn

Table 1 Number of fetal cadavers according to trimesters

Sex	Total fetal cadavers		Second trimester		Third trimester	
	Sample (*n*)	Frequency (%)	Sample (*n*)	Frequency (%)	Sample (*n*)	Frequency (%)
Male	25	50	19	52.8	6	42.9
Female	25	50	17	47.2	8	57.1
Total	50	100	36 (72%)	100 (100%)	14 (28%)	100 (100%)

Four morphological types and five morphological subtypes for LM shapes were identified. It was found that 12% of the LMs were crescent-shaped, 66% were C-shaped, 14% were incomplete discoid-shaped, 2% were complete discoid-shaped, and 6% were variant C-shaped (Table 6; Figs. 4, 6). The most remarkable finding of the study was that the incidence of incomplete discoid types decreased with gestational age (Table 6).

Table 2 Minimum, maximum, and mean values and standard deviations of parameters

	n	Min	Max	Mean ± SD
WAH	100	0.7	5.2	1.9 ± 0.8
WLH	100	0.8	4.3	2.1 ± 0.7
WPH	100	0.9	4.2	1.9 ± 0.7
TAH	100	0.4	2.7	1.3 ± 0.5
TLH	100	0.5	2.8	1.3 ± 0.4
TPH	100	0.4	3.4	1.2 ± 0.5
AH–PH	100	0.0	4.0	1.8 ± 0.8

WAH, WLH, and *WPH* the width of anterior, lateral, and posterior horn, *TAH, TLH* and, *TPH* the thickness of anterior, lateral, and posterior horn, *AH–PH* the distance between anterior and posterior horn)

Table 3 Minimum, maximum, and mean values and standard deviations of left and right parameters

Parameters	*n*	Min	Max	Mean ± SD
WAH-L	50	0.7	3.7	1.9 ± 0.7
WPH-L	50	1.1	4.3	2.2 ± 0.7
WLH-L	50	0.9	4.2	2 ± 0.7
TAH-L	50	0.4	2.7	1.2 ± 0.4
TPH-L	50	0.5	2.3	1.2 ± 0.4
TLH-L	50	0.4	2.7	1.2 ± 0.4
AH–PH-L	50	0.2	3.6	1.8 ± 0.8
WAH-R	50	0.9	5.2	1.9 ± 0.8
WPH-R	50	0.8	4.2	2 ± 0.7
WLH-R	50	0.9	3.8	1.9 ± 0.6
TAH-R	50	0.5	2.6	1.3 ± 0.5
TPH-R	50	0.6	2.6	1.3 ± 0.4
TLH-R	50	0.5	3.4	1.7 ± 0.5
AH–PH-R	50	0.0	3.9	1.7 ± 0.8

WAH, WLH, and *WPH* the width of anterior, lateral, and posterior horn, *TAH, TLH*, and *TPH* the thickness of anterior, lateral, and posterior horn, *AH–PH* the distance between anterior and posterior horn, *L* left, *R* right

Discussion

The most important finding of the present study was related to the observations of morphological development of the fetal meniscal anatomy, and its morphological variants. Such morphological variants may be considerable factors in understanding the function of menisci, meniscal tear patterns, and for the appropriate diagnosis and treatment of children, adolescents, and adults.

Variations in LM size, shape, and attachment were reported in multiple studies. Many of those studies were performed on adult human knees [3, 5, 6, 11, 27, 30–33, 36, 39], where variations may be related to congenity or development [4, 7, 9, 13, 19, 24–27, 33].

Congenital anomalies of the menisci are rare and such anomalies were frequently observed in the LM. Discoid menisci were more common than other anomalies, including ring-shaped LMs, double-layered LMs, and partially duplicated LMs [1, 6, 12, 15, 35, 38]. Having fundamental embryological knowledge about menisci is critical for the diagnosis and treatment of cases containing various meniscal pathologies [16, 18, 33]. In the early stages of fetal life, both menisci develop into their typical shapes. The menisci develop from the differentiation of mesenchymal tissue. They become prominent during the 8th week of fetal life. O'Rahilly investigated the development of the knee joint and composed a morphogenetic time table under multiple phases. It was determined that chondrification forms eccentric bands in the mesenchymal tissues during phase 18 and the appearance of the knee joint cavity occurs during phase 22. To form articular cartilage, the perichondrial connective tissue differentiates into a dense band during phase 22 as well. During phase 23 (approximately the 10th and 11th week of fetal life), the LM and MM become easily distinguishable [17].

Notwithstanding, the number of studies based on the developmental characteristics of the knee joint is very limited [4, 7, 8, 13, 23, 25, 26, 37]. However, such studies identified that minimal differences existed between the parameters of adult and fetus knees. Additionally, those studies detected that the LM was larger than the MM in earlier gestational stages [36].

Kale et al. [13] examined 22 knee joints from 11 neonatal cadavers (7 female and 4 male) and determined that the LM was the same shape on each side in 73% (8 cadavers) of individuals. The authors classified the LM as discoid or un-discoid menisci and divided each group into two subgroups (complete–incomplete for the discoid lateral menisci, crescentic (semilunar) and C-shaped for the un-discoid lateral menisci). The total percentages of discoid and un-discoid lateral menisci were 77.27% and 22.72%, respectively. Additionally, 22.72% of LMs were complete discoid, while 54.54% were incomplete discoid. Among the un-discoid menisci, 13.63% were crescent-shaped and 9.09% were C-shaped [13]. The percentages of the same parameters were 17.9%, 82.1%, 3.8%, 14.1%, 19.8%, and 62.3%, respectively, in the study of Murlimanju et al. [25].

Koyuncu et al. [18] classified the LM as C shape, crescenteric shape, incomplete, or complete in 105 human fetuses. The percentages of such shapes were 61%, 19.0%, 18.6%, and 14%, respectively. Thus, the results of the current study are similar to those of Murlimanju et al. [25] and Koyuncu et al. [18] (Table 7).

A variety of speculations by multiple authors have been made regarding the development of discoid LMs (DLM) [4, 14, 16, 19, 34, 37]. Thus, studies should be performed to clarify the morphological development of the LM. In

Table 4 Mean values, standard deviations, maximum, and minimum values of parameters according to trimester

Parameters	Second trimester				Third trimester				*p* value
	n	Min	Max	Mean ± SD	*n*	Min	Max	Mean ± SD	
WAH-L	36	0.7	2.7	1.6 ± 0.4	14	1.3	3.7	2.6 ± 0.7	0.000
WPH-L	36	1.1	3.6	1.9 ± 0.5	14	2.1	4.3	2.9 ± 0.07	0.000
WLH-L	36	0.9	3.0	1.7 ± 0.5	14	2.0	4.2	2.7 ± 0.6	0.000
TAH-L	36	0.4	1.7	1.1 ± 0.7	14	0.8	2.7	1.5 ± 0.5	0.009
TPH-L	36	0.5	1.9	1.1 ± 0.4	14	0.6	2.3	1.5 ± 0.5	0.015
TLH-L	36	0.5	2.1	1.1 ± 0.4	14	0.4	2.7	1.4 ± 0.5	0.046
AH–PH-L	36	0.2	3.6	1.5 ± 0.7	14	1.5	3.6	2.5 ± 0.6	0.000
WAH-R	36	0.9	2.6	1.6 ± 0.5	14	1.6	5.2	2.6 ± 1.1	0.004
WPH-R	36	0.8	2.9	1.7 ± 0.5	14	2.1	4.2	2.7 ± 0.6	0.000
WLH-R	36	0.9	2.7	1.7 ± 0.4	14	1.9	3.8	2.6 ± 0.5	0.000
TAH-R	36	0.6	2.6	1.3 ± 0.5	14	0.5	2.6	1.4 ± 0.6	n.s
TPH-R	36	0.6	2.1	1.3 ± 0.4	14	1.0	2.6	1.5 ± 0.5	n.s
TLH-R	36	0.5	2.0	1.2 ± 0.4	14	0.7	3.4	1.5 ± 0.6	n.s
AH–PH-R	36	0.3	3.5	1.5 ± 0.6	14	0.0	34.0	2.2 ± 0.9	0.031

p values for second and third trimester (*ns* non-significant)

WAH, WLH and, *WPH* the width of anterior, lateral, and posterior horn, *TAH, TLH*, and *TPH* the thickness of anterior, lateral and posterior horn, *AH–PH* the distance between anterior and posterior horn, *L* left, *R* right

Table 5 Mean values, standard deviations, maximum, and minimum values of parameters according to sex

Parameters	Male				Female				*p* value
	n	Min	Max	Mean ± SD	*n*	Min	Max	Mean ± SD	
WAH-L	25	0.7	3.3	1.8 ± 0.7	25	1.10	3.7	2.0 ± 0.7	n.s
WPH-L	25	1.1	3.7	2.1 ± 0.6	25	1.26	4,3	2.3 ± 0.8	n.s
WLH-L	25	0.9	3.3	1.9 ± 0.6	25	1.15	4,2	2.1 ± 0.8	n.s
TAH-L	25	0.4	1.8	1.2 ± 0.3	25	0.67	2.7	1.2 ± 0.4	n.s
TPH-L	25	0.5	2.0	1.2 ± 0.4	25	0.51	2.3	1.3 ± 0.4	n.s
TLH-L	25	0.4	2.7	1.2 ± 0.5	25	0.74	2.0	1.2 ± 0.3	n.s
AH–PH-L	25	0.2	3.6	1.7 ± 0.9	25	0.98	3.6	1.9 ± 0.7	n.s
WAH-R	25	1.1	5.2	1.9 ± 1.1	25	0.90	2.6	1.9 ± 0.4	n.s
WPH-R	25	0.8	4.2	2.0 ± 0.8	25	0.92	3.3	2.0 ± 0.6	n.s
WLH-R	25	0.9	3.8	1.9 ± 0.7	25	1.03	3.00	1.9 ± 0.6	n.s
TAH-R	25	0.5	2.6	1.3 ± 0.6	25	0.77	2.6	1.4 ± 0.4	n.s
TPH-R	25	0.6	2.6	1.3 ± 0.5	25	0.78	2.00	1.4 ± 0.4	n.s
TLH-R	25	0.5	3.4	1.3 ± 0.6	25	0.70	2.00	1.3 ± 0.4	n.s
AH–PH-R	25	0.0	3.5	1.7 ± 0.8	25	0.25	4.0	1.8 ± 0.7	n.s

p values for sex

WAH, WLH, and *WPH* the width of anterior, lateral, and posterior horn, *TAH, TLH*, and *TPH* the thickness of anterior, lateral, and posterior horn, *AH–PH* the distance between anterior and posterior horn, *L* left, *R* right

this study, the percentage of the DLMs was 16% (Tables 6, 7—Type 3 + Type 4), which was consistent with the results of Murlimanju et al. [25]. DLM was also observed in the left knee joint of a female fetus by Murlimanju et al. [26] during a routine dissection. Such results lead to the hypothesis that DLM is a morphological variant.

Tena-Arregui et al. [37] only observed a variation in a fetus belonging to an earlier gestational age. They found that the LM was larger than the MM. Another discoid shape was also observed on the left side of the knee in a fetus at 14 weeks gestation [25]. Fukazawa et al. [7] investigated the knee joints of 41 human fetuses and 14

Table 6 Types of lateral meniscus in all fetal cadavers

Type	Total fetal cadavers		Male		Female		Second trimester		Third trimester	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Type 1	12	12	7	14	5	10	9	12.5	3	10.7
Type 2	66	66	29	58	37	47	51	70.8	15	53.5
Type 3	14	14	9	18	5	10	10	13.9	4	14.3
Type 4	2	2	1	2	1	2	1	1.4	1	3.6
Type A	1	1	1	2	–	–	–	–	1	3.6
Type B	1	1	1	2	–	–	–	–	1	3.6
Type C	2	2	2	4	–	–	–	–	2	7.1
Type D	1	1	–	–	1	2	–	–	1	3.6
Type E	1	1	–	–	1	2	1	1.4	–	–
Total	100	100%	50	100%	50	100%	72	100%	28	100%

Grouping fetal cadavers types according to sex and trimester

Table 7 Types of LM according to various researchers

	Samples	Crescenteric shape	C shape	Incomplete type	Complete type
Murlimanju et al. [25]	53 fetal cadavers	19.8	62.3	14.1	3.8
Kale et al. [13]	11 fetal cadavers	13.6	9.1	54.5	22.7
Koyuncu et al. [18]	105 fetal cadavers	19.0	61	18.6	1.4
Our study (2018)	50 fetal cadavers	12	66	14	2

adults. That study revealed that the lateral menisci covered most of the tibial plateau in fetuses. Those authors also emphasized that in all fetuses, the lateral menisci were round. This difference may be due to mesenchymal differentiation or variability in different races during early embryonic life [13].

Aside from the shapes of the LM, morphometric data related the LM, including thickness and width may affect the type of injury. Those data have been reported in adult cadavers by multiple researchers [3, 9, 22, 29, 30, 32, 36]. Using new imaging techniques, the menisci have become increasingly visible and it has become easier to obtain morphometric data [5, 11].

In a study by Murlimanju et al. [23] and a similar study [8] on fetuses, the LM was divided into three sections, including anterior, middle, and posterior. The thicknesses of the anterior, middle, and posterior third of the LMs was 1.57 ± 0.41 mm, 1.52 ± 0.39 mm, and 1.49 ± 0.34 mm, respectively, in the Murlimanju et al. study [23]. Gohiya and Pandey [8] reported thicknesses of 1.80 ± 0.42 mm, 2.00 ± 0.45 mm, and 1.76 ± 0.41 mm for the anterior, middle and posterior, respectively. Additionally, the widths for each of the three sections were 3.26 ± 0.60 mm, 3.53 ± 0.75 mm, and 3.44 ± 0.63 mm, respectively, in the Murlimanju et al. study [23], and 22 ± 0.50 mm, 3.49 ± 0.70 mm, and 3.63 ± 0.63 mm, respectively, in the Gohiya and Pandey study [8].

Kale et al. [13] reported that the mean width at the midpoint of the AH, PH, and the lateral side of the lateral menisci was 0.29, 0.34, and 0.37 cm, respectively. In this study, the thicknesses and widths of the anterior, lateral, and posterior horn were 1.3 ± 0.5 mm, 1.3 ± 0.4 mm and 1.2 ± 0.5 mm; and 1.9 ± 0.8 mm, 2.1 ± 0.7 mm, and 1.9 ± 0.7 mm, respectively (Tables 2, 8).

The distance between the AH and PH was 0.81 mm, 1.84 mm, 2.60 mm and 3.60 mm for first, second, third, and fourth trimesters, respectively, in the study by Koyuncu et al. [18]. Gohiya and Pandey [8] measured a distance of 3.07 ± 0.68 mm for the LM, while Murlimanju et al. found it to be 1.56 ± 0.61 mm [23]. In this study, we measured a distance of 1.8 ± 0.8 mm (Table 2).

The majority of limitations in this study are due to the limited number of fetal cadavers in the third trimester. In particular, the frequency of incomplete discoid menisci may vary according to gestational age, and it is therefore necessary to confirm alterations in additional fetal cadavers belonging to the third trimester in future studies.

Conclusion

This study revealed that morphological development of the LM during the fetal period was significant between the second and third trimesters. The C-shaped morphology was

Table 8 Thickness and width measurements according to various researchers

Researchers	Samples	Thickness			Width		
		Anterior third	Middle third	Posterior third	Anterior third	Middle third	Posterior third
Murlimanju et al. [25]	53 Fetal cadavers (CRL = ranging from 160 mm to 340 mm)	1.6 ± 0.4	1.5 ± 0.4	1.5 ± 0.3	3.3 ± 0.6	3.5 ± 0.8	3.4 ± 0.6
Gohiya and Pandey [8]	54 Fetal cadavers (Gestational age is ranging from 21 to 37 weeks)	1.8 ± 0.4	2.0 ± 0.5	1.8 ± 0.4	3.2 ± 0.5	3.5 ± 0.7	3.6 ± 0.6
Kale et al. [13]	11 Neonatal cadavers (Gestational age is ranging from 37 to 40 weeks)	–	–	–	2.9	3.4	3.7
Our study(2018)	50 Fetal cadavers	1.3 ± 0.5	1.3 ± 0.4	1.2 ± 0.5	1.9 ± 0.7	2.1 ± 0.7	1.9 ± 0.7

the most common type during the fetal period. The results of this study described the morphological development of the fetal meniscal anatomy. Such morphological variants are important for clinical diagnoses of such cases as snapping knee syndrome and the management of lateral discoid meniscus tears in children, adolescents, and adults.

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Compliance with ethical standards

Conflict of interest The research was not sponsored by an outside organization. We (all of the authors) have agreed to allow full access to the primary data and to allow the journal to review the data if requested. There is no conflict of interest between the authors and this manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

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