Morphologic Characteristics of Meniscofemoral Ligaments

Meniskofemoral Ligamentlerin Morfolojik Özellikleri

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ABSTRACT Objective: The aim of this study was to describe the presence, lengths, widths, attachment sites, course of the fibers, histological properties and the sizes of the attachment sites of the meniscofemoral ligaments to the lateral meniscus. **Material and Methods:** Forty fresh frozen knees obtained from 22 human cadavers were examined. The knee was dissected by posterior approach and the anterior and posterior meniscofemoral and posterior cruciate ligaments were measured after exposing them. The sections of ligaments were stained with the Mason trichrome stain and under light microscope. **Results:** At least one of the meniscofemoral ligaments was present in 37 (92.5%) cases. Twenty (50%) were anterior meniscofemoral ligaments and 24 (60%) were posterior. In seven cases (17.5%) both anterior and posterior meniscofemoral ligaments were present. The oblique fibers of the posterior cruciate ligament were observed in 11 (27.5%) cases. A separating membrane between the meniscofemoral ligaments and the posterior cruciate ligament was observed. The mean lengths of the posterior and anterior meniscofemoral ligaments were 23.82 ± 1.51 mm and 21.55 ± 0.97 mm, respectively. The mean widths of the anterior and posterior meniscofemoral ligaments were 3.43 ± 0.57 mm and 4.09 ± 0.77 mm, respectively. The mean lengths of the attachment sites of posterior and anterior meniscofemoral ligaments to lateral meniscus were 11.30 ± 1.85 mm and 6.19 ± 1.23 mm respectively and the mean widths were 3.39 ± 0.92 mm and 4.88 ± 0.96 mm, respectively. **Conclusion:** Details concerning the dimensions and histological properties of the meniscofemoral ligaments, their relation to the posterior cruciate ligament and lateral meniscus will contribute to a clear understanding of the biomechanics of the knee as well as the radiologic diagnosis and the treatment of knee problems.

Key Words: Knee joint; menisci, tibial; posterior cruciate ligament

ÖZET Amaç: Bu çalışmada, anterior ve posterior meniskofemoral ligamentlerin görülme sıklığı, uzunluğu, genişliği, yapışma yerleri, liflerinin yönü, histolojik özellikleri ve lateral menisküsteki yapışma yerlerinin boyutlarının incelenmesi amaçlandı. **Gereç ve Yöntemler:** Taze dondurulmuş 22 adet insan kadavrasından elde edilen kırk adet diz incelendi. Dizler posterior yaklaşımla disseke edildi ve görünür hale getirilen anterior ve posterior meniskofemoral ligamentler ile posterior çapraz bağların ölçümleri yapıldı. Ek olarak, ligamentlerden alınan kesitler, Mason trichrome ile boyanıp ışık mikroskobu altında değerlendirildi. **Bulgular:** Kırk olgudan 37'sinde (%92.5) en az bir tane meniskofemoral ligament vardı. Bunların, 20'si (%50) anterior ve 24'ü (%60) posterior meniskofemoral ligamentti. Yedi (%17.5) olguda hem anterior hem de posterior meniskofemoral ligament görüldü. Arka çapraz bağın oblik lifleri 11 (%27.5) olguda gözlendi. Meniskofemoral ligamentler ile arka çapraz bağ arasında ayırıcı bir membran olduğu tespit edildi. Posterior ve anterior meniskofemoral ligamentlerin ortalama uzunlukları sırasıyla 23.82 ± 1.51 mm ve 21.55 ± 0.97 mm olarak bulundu. Posterior ve anterior meniskofemoral ligamentlerin ortalama genişlikleri ise sırasıyla 3.43 ± 0.57 mm ve 4.09 ± 0.77 mm ölçüldü. Posterior ve anterior meniskofemoral ligamentlerin lateral menisküse yapışma yerlerinin ortalama uzunlukları sırasıyla 11.30 ± 1.85 mm ile 6.19 ± 1.23 mm, genişlikleri ise 3.39 ± 0.92 mm ile 4.88 ± 0.96 mm olarak bulundu. **Sonuç:** Meniskofemoral ligamentlerin boyutlarının ve histolojik özelliklerinin detayları, arka çapraz bağ ve dış menisküsle olan ilişkisi, diz ekleminin biyomekaniğinin daha iyi anlaşılmasına, hem de diz ile ilgili sorunların radyolojik tanısı ve tedavisine katkı sağlayacaktır.

Anahtar Kelimeler: Diz eklemi; tibial menisküsler; ligamentum cruciatum posterius

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The anterior and posterior meniscofemoral ligaments (aMFL and pMFL) in relation with the lateral meniscus. They connect the lateral meniscus to the lateral wall of the medial condyle of the femur. The pMFL (of Wrisberg) extends posteriorly to the posterior cruciate ligament (PCL) whereas aMFL (of Humphry) extends anteriorly to the PCL. The aMFL attaches to the femur, distal to the PCL, while the pMFL attaches proximal to the PCL. They both attach distally to the posterior horn of the lateral meniscus (LM).[1] The function of the MFLs has been related to the stability and congruency of posterior horn of the LM.[2]

Clinical problems caused by the MFL have resulted in extensive studies of this ligament.[3-7] MFLs can be observed in the majority of knees on magnetic resonance imaging (MRI).[4] The MFL can be misdiagnosed as an intraarticular loose body on MRI.[8] The MFLs commonly cause a pseudotear of the posterior horn of the LM on MR images.[9] A better understanding of the MFLs may have an effect on clinical approaches to certain knee disorders like lateral meniscotomy, PCL reconstruction and meniscal transplantation.[3]

In this study, we aimed to describe the presence, length, width, attachment sites, and the course of fibers of the MFL and the relation of the MFL to the oblique fibers of the PCL, as well as the histological properties of the attachment site of the MLFs to the LM.

MATERIAL AND METHODS

Forty fresh frozen knees from 22 human cadavers (three females and 19 male) were examined. Approval of the use of human material was in accordance with the Laws of the Republic of Turkey. The cadavers were obtained from the Istanbul Council of Forensic Medicine according to Turkish legislation. The mean age was 47 years (range 25 to 65 years). Four knees were excluded from the study due to a previous knee operation, amputation or knee injury.

ANATOMICAL DISSECTIONS

The dissections were made by a posterior approach. The knee was extended and a vertical incision was made at the midpoint of the knee. The semitendinosus, semimembranosus, biceps femoris, gastrocnemius and soleus muscles were dissected to expose the knee joint. The popliteal artery and vein were ligated and cut proximal and distal to the knee joint to prevent any bleeding into the area of the dissection. An incision was made from the posterior femoral condyles to the tibial condyles along the midline. The joint capsule was dissected as a U-shaped flap. The presence of a pMFL was determined. Then the PCL was exposed and inspected carefully, and the aMFL was inspected, if present. The measurements were made with a digital compass.

MEASUREMENTS

The distance between the points where the pMFL attaches the condyle of the femur and LM was accepted as the length of pMFL (Figure 1). The width and the length of the pMFL and the attachment site of pMFL to the LM were measured. The width of the pMFL was measured at the midline of intercondylar area. The width of the attachment site of MFL to the LM was measured at the initial attachment site of the MFL to the meniscus. The distan-

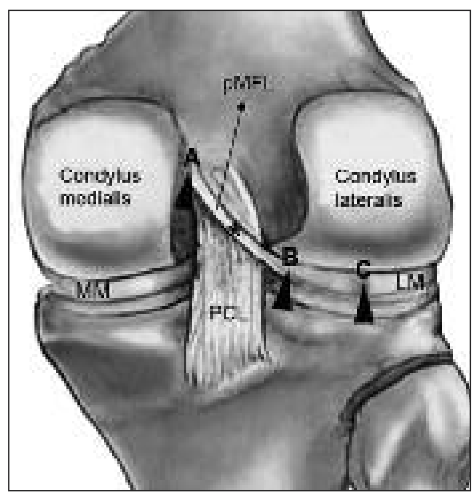


FIGURE 1: The points where the measurements were performed. The same criteria were used for the measurements of aMFL.
A-C: The length of the ligament
B-C: The length of the attachment of meniscofemoral ligament to lateral meniscus
*: The midpoint where the width of the ligament was measured.
B (the initial attachment site of the MFL to the LM) is the point where the width of the attachment site of MFL was measured.
LM= lateral meniscus, MM= medial meniscus, PCL= posterior cruciate ligament, pMFL= posterior meniscofemoral ligament.

ce between the pMFL and the PCL was measured at the midline of intercondylar area.

After the measurements of the pMFL were completed, it was dissected. Then the PCL was dissected and the aMFL was exposed. The measurements of the aMFL were performed similar to the measurements of the pMFL. The distance to PCL was not measured because PCL was cut to expose aMFL.

HISTOLOGICAL PROCESSING

The pMFL, PCL and aMFL were dissected from their attachment sites after the measurements were completed. The LM was also dissected. All ligaments were stored in 10% formaldehyde. They were dehydrated in alcohol and embedded in paraffin blocks and 7μ-thick sections were cut. These sections were stained with the Mason trichrome stain to analyze the histological properties.

SSPS 15.0 was used for the statistical analysis. The correlation between groups was analyzed using the Spearman test. The level of significance was set as $p < 0.05$.

RESULTS

Forty knees from 22 individuals were evaluated. In 18 cases both knees and in four cases only one side were used in the study. There was no statistically significant difference between right and left sides of the knees by means of presence of MFLs and the dimensions of ligaments.

At least one of the MFLs was present in 37 (92.5%) cases. There were 20 (50%) aMFLs and 24 (60%) pMFLs (Figures 2 and 3). In seven (17.5%) cases both anterior and posterior MFLs were present. The oblique fibers of the PCL were observed in 11 (27.5%) cases (Figure 4) (Table 1).

The length and width of meniscofemoral ligaments (Table 2) and their attachment sites to the LM were measured. The results are presented in Table 3.

In 16 of 24 cases (66.6%) the pMFL had a direction from the LM to the femoral condyle by making a steep angle (Figure 5). In eight (33.3%) cases, the pMFL had a parallel course to the LM and then

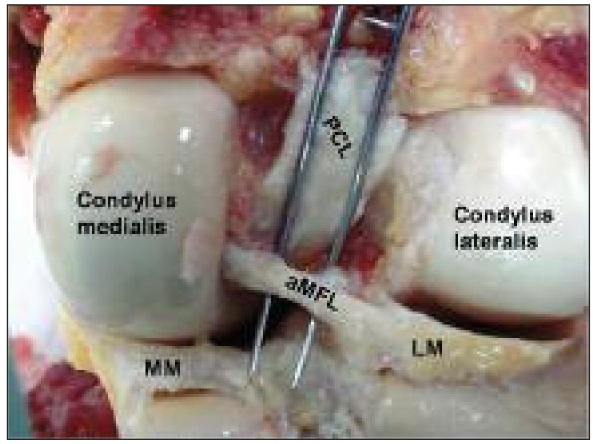


FIGURE 2: View of aMFL from the posterior aspect of the knee joint. The PCL was cut and reflected to expose the aMFL. The aMFL attaches to the condyle of the femur distal to the attachment site of the PCL.
LM= lateral meniscus, MM= medial meniscus, PCL= posterior cruciate ligament, aMFL= anterior meniscofemoral ligament.

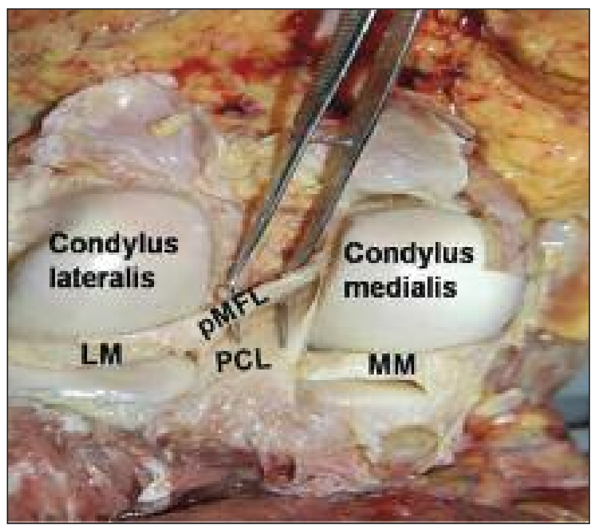


FIGURE 3: View of the pMFL from the posterior aspect of the knee joint. The pMFL was deflected. The PCL was located beneath the pMFL. The pMFL attaches to the condyle of the femur proximal to the attachment site of the PCL.
LM= lateral meniscus, MM= medial meniscus, PCL= posterior cruciate ligament, pMFL= posterior meniscofemoral ligament.

made a wide angle upwards at the midline of the interconylar area, and attached to the femoral condyle (Figure 6).

The histological sections of the ligaments showed that the ligaments were formed by collagen fibers, a small amount of fat tissue and loose connective tissue (Figures 7a and 7b). Loose connective tissue was present around the MFLs. This

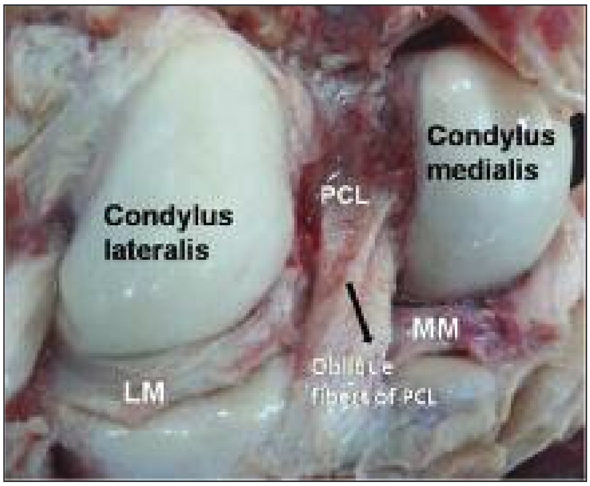


FIGURE 4: The oblique fibers of posterior cruciate ligament are demonstrated by the arrow. The distal fibers do not attach to the LM, instead they fuse with the fibers of the PCL.

LM= lateral meniscus, MM= medial meniscus, PCL= posterior cruciate ligament.

TABLE 1: Incidence of meniscofemoral ligaments.

Ligament	Incidence
At least one MFL	92.5%
Only pMFL	60%
Only aMFL	50%
Both coexisting	17.5%

aMFL= anterior meniscofemoral ligament
pMFL= posterior meniscofemoral ligament

TABLE 2: Dimensions (mm ± SD) of meniscofemoral ligaments.

	Number of occurence	Mean length (mm ± SD)	Mean width (mm ± SD)	Mean distance to PCL (mm ± SD)
aMFL	20	21.55 ± 0.97	4.09 ± 0.77	-
pMFL	16	23.82 ± 1.51	3.43 ± 0.57	4.19 ± 1.59

aMFL= anterior meniscofemoral ligament
pMFL= posterior meniscofemoral ligament
PCL= posterior cruciate ligament

TABLE 3: Dimensions (mm ± SD) of attachment sites of MFLs to LM.

	Mean length (mm ± SD)	Mean width (mm ± SD)
aMFL attachment	6.19 ± 1.23	4.88 ± 0.96
pMFL attachment	11.30 ± 1.85	3.39 ± 0.92

aMFL= anterior meniscofemoral ligament
pMFL= posterior meniscofemoral ligament

loose connective tissue acts a separating membrane among the MFLs and the menisci and PCL. It was observed that this membrane prevents fusion of the fibers of MFLs with LM and PCL.

The attachment sites of the MFLs were evaluated in detail. The attachment sites of the pMFLs were the superior edge of the LM in 18 cases and

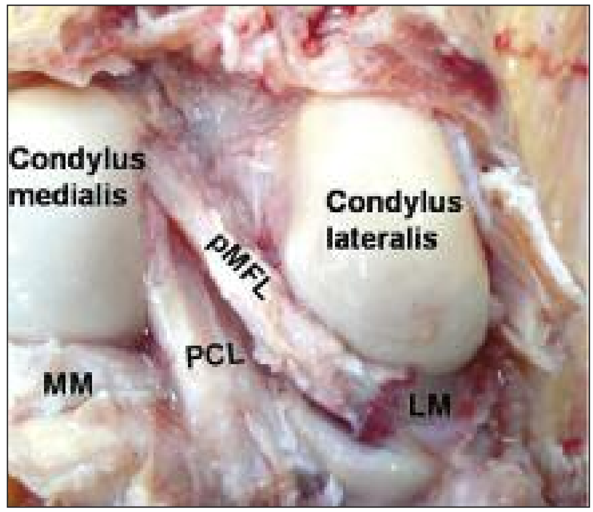


FIGURE 5: The pMFL makes a steep angle from lateral meniscus to the femoral condyle.

pMFL= posterior meniscofemoral ligament LM= lateral meniscus, MM= medial meniscus, PCL= posterior cruciate ligament.

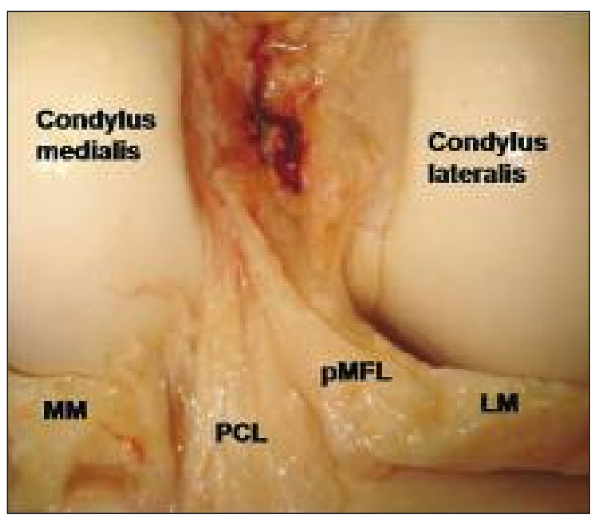
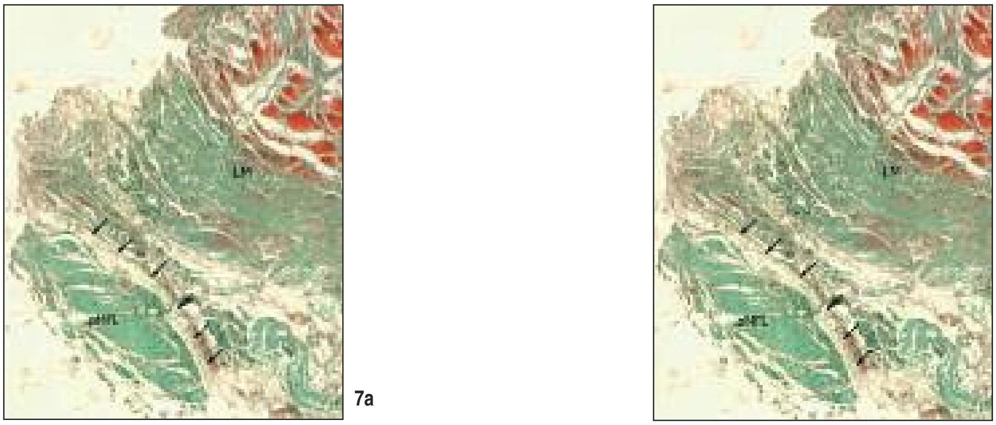


FIGURE 6: The pMFL has a parallel course to the meniscus and then makes a wide angle at the midline of the interconylar area to attach to the femoral condyle.

LM= lateral meniscus, MM= medial meniscus, PCL= posterior cruciate ligament, pMFL= posterior meniscofemoral ligament.



7a 7b

FIGURE 7a,b: The loose connective tissue around a) the posterior meniscofemoral ligament and b) the anterior meniscofemoral ligament are shown. Arrows indicate the loose connective tissue. 4X magnification

pMFL= posterior meniscofemoral ligament, aMFL= anterior meniscofemoral ligament, LM= lateral meniscus.

the inferior edge of the LM in two cases. In four cases with double attachment areas, one was attached to the superior and the other one was attached to the inferior edge of the LM.

In all of 20 cases, the aMFL was attached to the superior edge of the LM in a superioinferior direction. The attachment site was short. The fibers of the ligaments were not mixed with each other if both ligaments were present. The aMFL attached to the posterior horn of the LM and the pMFL was attached to the superior edge of the posterior horn.

It was observed that the fibers of the pMFL were not mixed with the PCL. The mean distance between the PCL and the pMFL at the midline of the intercondylar area was 4.19 ± 1.59 mm.

The pMFL had a course closer to the PCL and was attached to the femoral condyle proximal to the attachment site of the PCL. The aMFL generally had a course close to the PCL and the loose connective tissue around the aMFL separated the two structures. The aMFL was attached to the condyle of the femur distal to the attachment site of the PCL.

DISCUSSION

In this study, the presence, length, width, course and the attachment sites of MFLs have been studied. The dimensions of the attachment sites of the MFLs to the LM were also measured. Further, the ligaments were histologically assessed.

The most important histologic feature defined is the loose connective tissue around the MFLs. Although it is a thin membrane, it is structurally important in preventing the fusion of the fibers of MFLs and LM and also the fibers of PCL and pMFL. This separating membrane has not been described previously in the literature. It can be important landmark for surgical procedures of the region.

In the present study, the incidence of at least one MFL was 92.5%. This ratio is one of the highest compared to the previous studies. The earlier studies indicated that the presence of at least one MFL varied between 71-100%. The incidence of the aMFL ranged between 0% and 83% and for the pMFL it was 35% to 93%. The presence of both ligaments was 0% to 64%.[2,5,7,10-13] The difference in ratios may be due to the different methods, different dissection techniques, the age of the subjects or mixing of fibers of pMFL and PCL.[2,5,7,12]

Dissection, arthroscopy and MRI have been the methods used to assess the MFLs previously.[4-6,13] The dissection technique is quite important to expose the structures of the region. The pMFL could not be recognized by the anterior approach to the knee because the pMFL is located behind the PCL.[5,12] Further, in the posterior approach, the aMFL can be cut while reflecting the PCL.[2,5,7,12] Therefore, a careful dissection should be done to prevent any damage to the ligaments.

Additionally, the oblique fibers of the PCL can be misinterpreted as the pMFL during dissection.[14] The distal attachment site of the oblique fibers of the PCL was same with the attachment site of the PCL. However, it was observed that the pMFL attached to the LM distally in the present study. Therefore, a careful dissection can help to distinguish the oblique fibers of PCL and pMLF. Gupte et al. found oblique fibers of the PCL in 19.04% of cases in a cadaver study whereas the oblique fibers of the PCL were present in 27.5% of the cases in this study.[5] The difference between two studies may be either due to the difference in the study population or due to a technical reason like misinterpretation of the oblique fibers of PCL.

Poynton et al. stated that the pMFL fused with the fibers of the PCL at the femoral attachment site, the aMFL also had a close relation with the PCL and fused with its fibers.[7] We observed that the fibers of the pMFL did not fuse with the PCL due to the separating membrane in between these two structures. The mean distance between these ligaments at the midline of the intercondylar area was 4.19 ± 1.59 mm. After the pMFL crosses the midline of the intercondylar area, it has a course closer to the PCL and attaches to the femoral condyle, posterior to the proximal end of the PCL attachment site. The aMFL has also a close attachment site to the PCL. The aMFL attaches to the femoral condyle, anterior to the distal end of the PCL attachment site. Although the attachment sites and the separating membranes between ligaments help one to differentiate these ligaments, it may still be possible to misinterpret these fibers with MRI or with a posterolateral surgical approach.

The results of this study cannot define any age-specific distribution for the presence of the ligaments. However, Gupte et al. showed a correlation between age and the presence of the ligaments, and suggested that the ligaments might have degenerated with age.[5] The limited number of subjects in the present study prevented to have more detailed information on this point.

Table 4 compares the measurements of the ligaments obtained from different studies.[2,4,7] The comparison of the results showed minor differences, however, the exact points of measurements were not stated in the earlier studies. It is known that the ligaments start from a large area on the meniscus and attach to a large area of the femoral condyle. Therefore, the exact points chosen for the measurements are necessary for comparison of the results. Gupte et al. stated that it was difficult to measure the ligaments correctly because of the soft consistency of the fresh cadaver tissue and the dissection technique.[5] The previous studies indicated a shorter aMFL compated to pMFL.[5,7] These results are in accordance with the present study. However, contrary to Poynton et al., the aMFL was found to be wider than pMFL in this study.[7]

The attachment sites of the MFLs onto the LM were the superior and inferior edges of the LM. Nagasaki et al. classified the attachment sites as proximal, central, distal, whole posterior surface, and femoral surface of the LM.[13] The dimensions of the

TABLE 4: Comparison of the results of different studies.

	aMFL-length (mm±SD)	aMFL-width (mm±SD)	pMFL-length (mm±SD)	pMFL-width (mm±SD)
Present study	21.55 ± 0.97	4.09 ± 0.77	23.82 ± 1.51	3.43 ± 0.57
Gupte et al.[5]	20.7 ± 3.9		23 ± 4.2	
DeAbreu et al.[4]		1.9 ± 0.61		1.8 ± 0.65
Poynton et al.[7]	27.1 ± 3.4 (M)	5.1 ± 1.4 (M)	31.1 ± 2.5 (M)	5.5 ± 2.1 (M)
	24.4 ± 3.4 (F)	2.9 ± 1.3 (F)	27.6 ± 3.7 (F)	4.7 ± 2.4 (F)

aMFL= anterior meniscofemoral ligament
pMFL= posterior meniscofemoral ligament
M= Male, F= Female.

attachment sites of MFLs to the LM were measured in the present study. In previous studies, we did not find any data indicating the dimensions of the attachment sites of MFLs to the LM. Besides, the properties of the attachment sites of MFLs and the directions of the pMFLs were studied. The fibers of the pMFLs showed two groups of angulations. In one group, the angulations were steeper compared to other group. The attachment sites, the attachment angles of the ligaments, and direction of the fibers may affect the strength and the functional role of the ligaments. The power of the ligament applied to the LM is closely related to its attachment. Therefore, knowledge of the dimensions of these sites may help a better understanding of the functions of the ligaments. Amadi et al. showed that the meniscofemoral ligaments play a role in reducing lateral tibiofemoral contact pressure in the human knee.[15] They found that loss of the MFL function led to approximately 10% increase in peak contact pressure on the articular cartilage. Gupte et al. proposed that the tangential attachments of the MFLs on the posterior horn of the lateral meniscus may decrease the contact pressures.[5]

The evolutionary aspect of the MFLs was also studied. Le Minor suggested that the homologue of the pMFL can be observed in all non-human primates whereas the aMFL was not found in any other primates.[16] Therefore, the aMFL was interpreted as a progressive structure and the pMFL as a regressive structure in man.[16] The incidence of the pMFL was higher than the aMFL in the present study, thus, the results of present study do not confirm the earlier hypothesis. The functional roles of these ligaments are also important to evaluate the evolutional changes. It was suggested that the evolution of these ligaments can be related to the human erect posture and bipedal locomotion.[16] The aMFL stabilizes the posterior horn of the LM in flexion and the pMFL stabilizes it in extension.[3] These ligaments have a reciprocal role in knee function. The aMFL tension increases especially with external tibial rotation however the pMFL tension is not significantly affected by rotation. The protective role of the MFLs on the LM has also been emphasized in the literature.[12] An evolutionary change can provide a benefit or can cause a handicap as a result of the erect posture. In the case of the MFLs, development of the aMFL is a beneficial result. On the other hand, it is hard to claim that the pMFL shows a regression because it is still functional and its function is reciprocal to a so-called progressive structure, the aMFL. Therefore, the pMFL most probably is not a regressing structure but the aMFL can be considered as a progressive structure.

It was reported that MFLs can cause diagnostic problems.[4,9,17,18] Silva and Sampaio presented a case report with absence of anterior cruciate ligament. It was suggested that aMFL compensated anterior cruciate ligament and the appearance of the aMFL might be misinterpreted as an intact native anterior cruciate ligament on MRI.[17] The MR images of the MFLs can be incorrectly evaluated as a pseudotear of the lateral menisci. Vahey et al. suggested that the insertion of the MFL may be interpreted as a meniscal tear in MR images of the knee.[9] A linear band of signal between the superior surface of the posterior horn of the LM and the MFL in a sagittal MR image of the knee can be confused with a meniscal tear.[9] These structures have two main courses. The majority of the ligaments have an oblique orientation extending from the superior articular surface posteriorly and inferiorly towards the base. The remainder have a more vertical orientation and run parallel to the base of the meniscus.[9] These descriptions are parallel to the courses of the pMFL described in this study.

CONCLUSION

Our study is in accordance with the literature for findings regarding the high incidence and the dimensions of the MFL. Further, the present study describes a separating membrane between the MFL and LM which was described for the first time in literature. The separating membrane helps to distinguish the fibers of the pMFL from the PCL. This anatomical structure can be an important landmark for surgical procedures of this region and also can provide more precise surgical approaches to the problems of PCL, MFLs and LM. The dimensions of the attachment sites of MFLs are important to understand biomechanics of the knee joint. The detailed knowledge of the MFL can improve the understanding the anatomy and the biomechanics of the knee joint. The role of MFLs in the biomechanics of the knee joint can also be important for the physical rehabilitation of the knee problems.

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