Relationship of the Cruciate and Meniscofemoral Ligaments with the Knee Osteology. An Anatomical Study*

Relação dos ligamentos cruzados e meniscofemorais com a osteologia do joelho: Um estudo anatômico

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Abstract

Objective To analyze the dimensions of the posterior cruciate ligament (PCL), anterior cruciate ligament (ACL), the presence of meniscus-femoral ligaments MFLs in human knees, and the correlation with the dimensions of the knee skeleton.

Methods Anatomical study on 29 specimens of human knees in which we measured the length and width of the cruciate and meniscus-femoral ligaments and the dimensions of femoral and tibia condyles and the femoral notch. The ACL length was calculated with different degrees of knee flexion. The relationship between the ligaments and bone dimensions were analyzed.

Results The length of the ACL and the PCL were similar. Posterior MFL was more frequent and longer than the anterior MFL. We found the posterior MFL in the 72.41% of the knees and anterior MFL in 20.69%. The ACL presented 30% of its maximum length up to 60°, approximately half of its length between 90° and 120°, reaching its maximum length at 170°. We found a strong correlation between the length of the ACL and that of the PCL ($p = 0.001$). However, the lengths of the ACL and PCL were not related with the bone dimensions.

Conclusion We have found no correlations between the cruciate and MFLs and the anatomical dimensions of the intercondylar notch and the proximal tibia and distal femur. The presence of the posterior MFL was more frequent and longer than that of the anterior ligament.

Keywords
- knee
- anterior cruciate ligament
- posterior cruciate ligament
- meniscus

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Resumo

Objetivo Analisar as dimensões do ligamento cruzado posterior (LCP), do ligamento cruzado anterior (LCA), a presença de ligamentos meniscofemorais (LMFs) em joelhos humanos e a correlação com as dimensões do esqueleto do joelho.

Métodos Estudo anatômico em 29 espécimes de joelhos humanos nos quais medimos o comprimento e a largura dos ligamentos cruzado e meniscofemoral e as dimensões dos côndilos femorais e tibiais e do entalhe femoral. O comprimento do LCA foi calculado com diferentes graus de flexão do joelho. Analisou-se a relação entre os ligamentos e as dimensões ósseas.

Resultados O comprimento do LCA e do LCP foram semelhantes, LMF posterior foi mais frequente e mais longo do que o LMF anterior. Foram encontradas LMF posterior em 72,41% dos joelhos e LMF anterior em 20,69%. O LCA apresentou 30% de seu comprimento máximo até 60°, aproximadamente metade de seu comprimento entre 90° e 120°, atingindo seu comprimento máximo com flexão de 170°. Encontramos uma forte correlação entre o comprimento do LCA e do LCP ($p = 0{,}001$). No entanto, os comprimentos do LCA e do LCP não estavam relacionados com as dimensões ósseas.

Conclusão Não encontramos correlações entre os ligamentos cruzado e meniscofemoral e as dimensões anatômicas do entalhe intercondilar e da tíbia proximal e do fêmur distal. A presença do LMF posterior foi mais frequente e maior que a do ligamento anterior.

Palavras-chave
- ► joelho
- ► ligamento cruzado anterior
- ► ligamento cruzado posterior
- ► menisco

Introduction

The posterior cruciate ligament (PCL) is intra-articular, although extra synovial and wide, and it varies according to each individual. It follows an oblique course upward, forward, and inward, in a curved configuration to span the posterior border of the proximal tibia. It is flatter and thinner than the anterior cruciate ligament (ACL) and its wider attachments. The tibial insertion, unlike the ACL, is located in its posterior cortex and reaches 1 cm distal and slightly lateral to the articular interline besides being smaller than the femoral one. At the tibial insertion, it is 50% wider than the ACL at its femoral insertion and 20% wider at its tibial insertion[1–3] (►**Fig. 1**). Like the ACL, the PCL is made up of a set of fibers that constitute two fascicles, the antero-lateral (AL) and the postero-medial (PM)[4,5] (►**Fig. 2**).

For their part, the meniscus-femoral ligaments (MFLs) originate in the posterior horn of the external meniscus and insert into the medial femoral condyle anterior (Humphrey ligament) and posterior (Wrisberg ligament) to the PCL. Its dimensions are variable and so is its presence (►**Figs. 3**, **4**, and **5**). The tangential insertion of the MFLs in the posterior horn of the meniscus increases and redirects the shear stresses that are transmitted to the external meniscus, and its function is to prevent excessive extrusion of the meniscus under axial stresses in the case of ruptures of the posterior horn of the external meniscus.[6–8]

The PCL is a constant anatomical structure, being the MFLs extensions of the posterior horn of the external meniscus, accessory structures that stabilize its anchorage. In the present work, we will analyze the dimensions of the PCL, ACL, the presence of the MFLs in human knees, and the correlation with the dimensions of the knee skeleton.

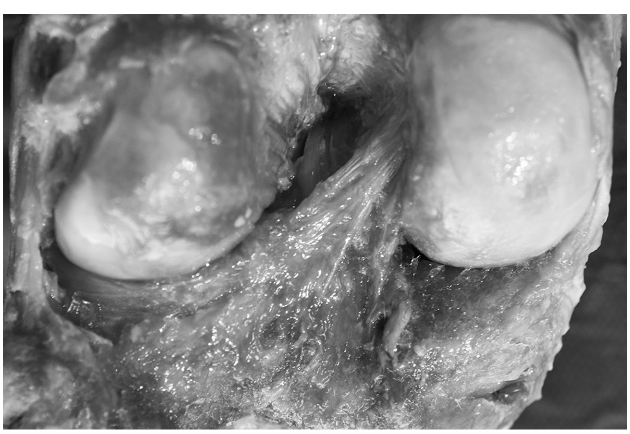

Fig. 1 Insertion of the posterior cruciate ligament from the posterior tibial fossa.

Fig. 2 Anterior aspect of a flexed knee, showing the insertion of the posterior and anterior cruciate ligament.

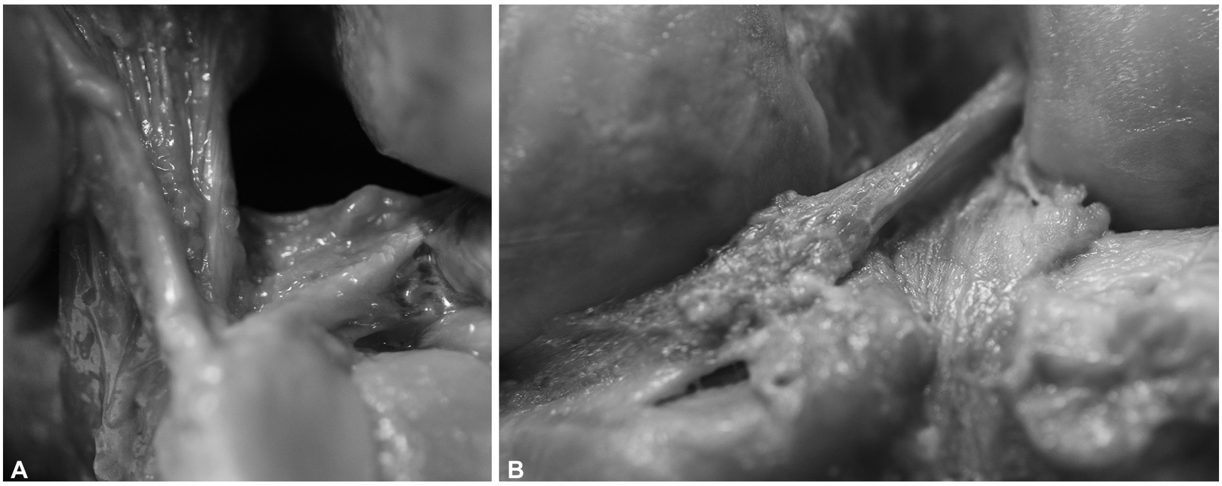

Fig. 3 (A, B) Anterior meniscofemoral ligament after removal of the posterior cruciate.

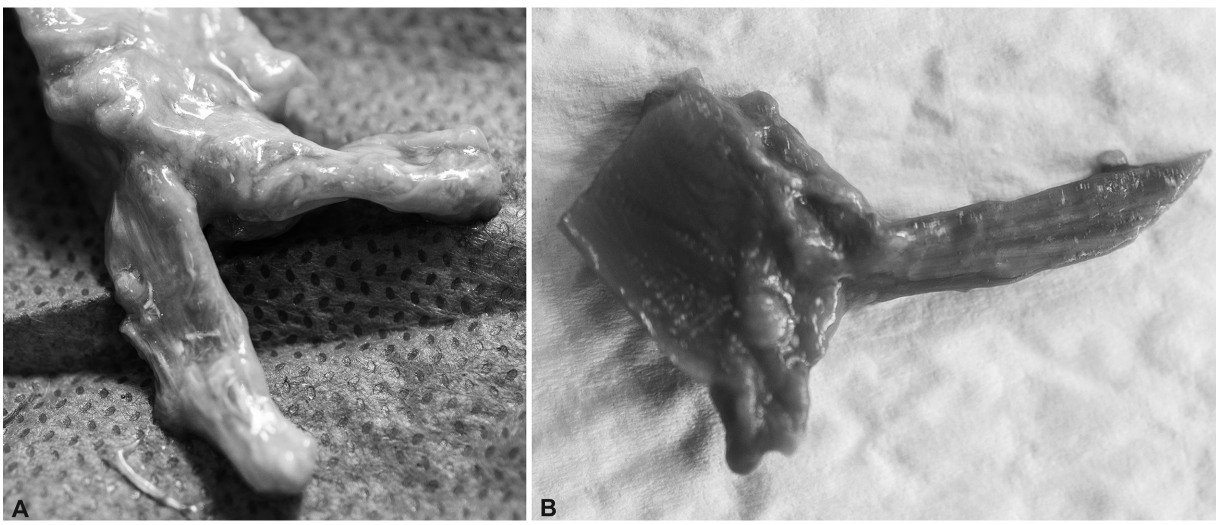

Fig. 4 (A, B) Macroscopic image of the posterior horn of the external meniscus with the meniscofemoral ligaments.

Material and Methodology

Anatomical study on 30 specimens of human knees, dissected following the same protocol: dissection of the skin and subcutaneous cellular tissue. The capsule was opened with a parapatellar incision to observe the existence and visualize the ACL. One knee had a stump as an ACL, so we discarded the piece; 16 were from the right side and 13 were from the left.

Once the presence of the ACL was confirmed, the posterior face was dissected, dissecting and visualizing the PCL, cleaning its origin, trajectory and insertion, and also dissecting, when they were present, the MFLs and the posterior horn of the meniscus external.

We measured with a caliper the length and width of the cruciate ligaments, anterior at 90°, and posterior in full extension. We obtained the maximum anteroposterior

Fig. 5 (A-C) Insertion of the posterior meniscofemoral ligament and its relationship with the posterior cruciate.

diameter of the femoral condyles and the proximal extremity of the tibia; maximum transverse diameter of the femoral condyles and of the proximal end of the tibia, as well as the dimensions of the femoral notch, height, width, and depth. In addition, we measured and analyzed the presence of the MFLs.

The length of the ACL was calculated with different degrees of knee flexion measured with a goniometer.

Each length measurement was made three times, and the mean of the three measurements was recorded. The width was measured, in each of the ligaments, three times in the proximal area and three times in the distal area, recording the average of the three measurements.

Once the ACL and PCL were measured, they were sectioned in their most proximal portion, after which we extracted the posterior horn of the external meniscus and the two MFLs, measuring their length, as well as noting their shape and presence.

Statistical Study

A descriptive statistical study was made of all the variables (mean, standard deviation, and range) and the relationship in the anatomical samples between the length and width of the ligaments with the dimensions of the variables obtained in the tibia and in the femur was analyzed. To study the correlations, we performed the Pearson correlation coefficient.

Results

The length of the ACL and the PCL were very similar. The width was more difficult to compare because of the conical shape of the ACL. The width at the femur of the PCL was 13.9 mm (standard deviation [SD]: 2.2; range: 10.5–19.6) (►**Table 1**).

We found the posterior meniscus-femoral ligament (pMFL) in 21 (72.41%) knees and the anterior meniscus-femoral ligament (aMFL) in 6 (20.69%). The pMFL was not only more frequent, but it was also longer, 31.4 (SD: 4.8; range: 22.5–42.6) mm and 20.6 mm (SD: 3.8, range: 16.3–25.6) the aMFL.

We did not find a correlation between the length of the pMFL with the length of the ACL ($p = 0.471$) or with the length of the PCL ($p = 0.742$).

The dimensions of the femur and the tibia are presented in ►**Table 2**.

The ACL presented 30% of its maximum length up to 60°, approximately half of its length between 90° and 120°,

Table 1 Dimensions of the cruciate ligaments (length-width) and meniscofemoral ligaments (length)

	pMFL		aMFL		ACL		PCL
	N	X (DE) rank	N	X (DE) rank	N	X (DE) rank	X (DE) rank
Length (mm)	21	31,4 (4,8) 22,5–42,6	6	20,6 (3,8) 16,3 - 25,6	29	37,8 (5,4) 30,0–47,1	36,6 (3,7) 29,0–44,5
					Femur	Tibia	Femur
Width (mm)					14,9 (2,5) 11,3–20,8	12,7 (1,7) 10,6–18,2	13,9 (2,2) 10,5–19,6

Abbreviations: ACL, anterior cruciate ligament; aMFL, anterior meniscofemoral ligament; PCL, posterior cruciate ligament; pMFL, posterior meniscofemoral ligament.

Table 2 Skeletal measurements of the femur and tibia

	X (cm)	DE	Rank (cm)
Femur			
Maximum femur width	8,54	0,48	7,7–9,7
Diameter AP			
internal condyle	6,16	0,58	4,7–7,35
external condyle	6,16	0,78	4,16–7,53
Tibia			
Maximum warm width	7,22	0,79	5,56–8,16
Maximum tibial AP diameter	6,09	0,99	5,03–8,8
Intercondylar notch			
Depth	3,32	0,36	2,84–4,1
Width	2,06	0,25	1,46–2,4
Length	2,59	0,34	1,74–3,23

Abbreviation: AP, anteroposterior.

Table 3 Anterior cruciate ligament's length (cm) at different degrees of flexion (mean value, SD, the percentage of the maximal length and the rank)

	X	SD	% total	Rank
30°	1,16	0,21	30,69	0,7–1,46
60°	1,35	0,22	35,71	1–1,85
90°	1,76	0,32	46,56	1,18–2,6
120°	2,09	0,36	55,29	1,53–2,9
170°	3,78	0,54	100	3–4,71

Abbreviation: SD, standard deviation.

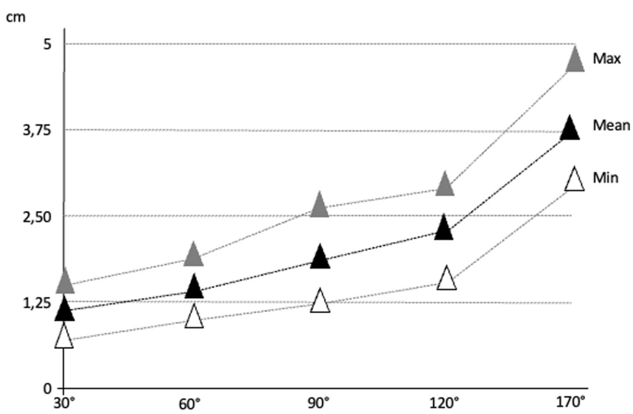

Fig. 6 Anterior cruciate ligament's length (cm) at different degrees of flexion (mean value and the rank with maximum and minimum values).

reaching its maximum length with non-physiological flexion of 170° (►**Table 3** and ►**Fig. 6**).

We found a strong correlation between the length of the ACL and the PCL ($p = 0.001$). However, the length of the ACL was not related to the maximum width of the distal end of the femur ($p = 0.080$), nor to the anterior-posterior diameter of the medial condyle ($p = 0.731$), nor to the anterior-posterior diameter of the external condyle ($p = 0.789$), nor with the maximum width of the proximal extremity of the tibia ($p = 0.873$), nor with the maximum anterior-posterior diameter of the proximal extremity of the tibia ($p = 0.216$). The length of the ACL was not related to the parameters of the intercondylar notch, neither with its depth ($p = 0.876$), nor with the width ($p = 0.587$), nor with the length of the notch ($p = 0.125$). Similarly, the length of the PCL was not related to the maximum width of the distal end of the femur ($p = 0.059$), nor to the anterior-posterior diameter of the medial condyle ($p = 0.111$), nor to the anterior-posterior diameter posterior lateral condyle ($p = 0.122$), nor with the maximum width of the proximal extremity of the tibia ($p = 0.241$), nor with the maximum anterior-posterior diameter of the proximal extremity of the tibia ($p = 0.569$). The length of the PCL was not related to the parameters of the intercondylar notch, neither with its depth ($p = 0.456$), nor with the width ($p = 0.565$), nor with the length of the notch ($p = 0.214$).

Discussion

Different methods have been used to determine the location and extent of the insertions, femoral and tibial, of the PCL. Both in X-rays and on the cadaver. For anatomical studies, it has been recommended to remove the external femoral condyle and disinsert the fibers from the fascicles at their origin before marking with a radiopaque dye or contrast to perform a microsurgical dissection technique for more reliable measurements.[9] We have performed our results directly on the bone using a caliper.

The femoral insertion of the PCL is variable in size and shape, but has been described "crescent," with a curved distal edge next to the articular cartilage and another proximal anterior-posterior edge. In the tibia, it is inserted into the posterior cortex, 1 cm distal and slightly lateral to the joint line.[1–3] The tibal insertion of the PCL occupies ~ 50% posteriorly of the area of the PCL fossa with the posterior cortex.[10,11]

The distal insertion shows many variations in the literature as the most posterior fibers intermingle with the periosteum and run down the posterior aspect of the tibial surface 2 or more cm.[12–14] Moorman et al.[11] consider that the most posterior fibers insert more than 20 mm below the posterior cortex of the tibia, posterior and inferior to the posterior intercondylar fossa, with a thickness of 0.5 mm.

The PCL is not an isometric ligament.[15,16] Most PCL fibers change their length during flexion-extension and only 5 to 15% of the femoral footprint is truly isometric.[17] Covey et al.[17] showed that the PCL fibers act differently depending on the flexion angle and the load to which the knee is subjected, and they did not see the opposite effect, that is, the thickening of the PCL fiber fibers, when it is reached full extension of the knee.

Markolf et al.[18] indicate that the greatest posterior translation is 1.06 mm at 0° with no appreciable increase at 90° of flexion. Posterior instability of the tibia with the knee in extension after sectioning the PCL is between 1 and 3 mm; applying a posterior force of 100 N, the displacement is 6.5 to 7.1 mm at 30° and between 11.4 and 15.3 mm at 90°.[19,20]

The length of the PCL is estimated between 120 and 150% longer than the ACL. In our study, the two cruciate ligaments had similar lengths, the PCL was 96% of the length of the ACL, and, in addition, we found a strong correlation between ACL and PCL lengths ($p = 0.001$). The width was more difficult to compare due to the conical shape of the ACL.

The anatomical dimensions of the proximal tibia or distal end of the femur are not related to the length of the cruciate ligaments, nor to the measured dimensions of the MFLs. We found interesting the lack of correlation of the dimensions of the cruciate ligaments with the dimensions of the intercondylar notch.

Several authors find one of the MFLs in between 93 and 100% of the dissections.[1,21–24] The two MFLs are present 50% of the time.[21,23,24] The MFLs are stabilizing and protective structures of the meniscus-condylar posterior-lateral compartment of the knee and a secondary limiter of posterior tibial-posterior translation.[21,25]

The posterior horn of the external meniscus has a double insertion: the anterior portion is inserted into the tibial intercondylar eminence, while, in most cases, the posterior portion is inserted into the femur by means of the MFLs, mainly the aMFL, pulling the posterior horn of the lateral meniscus medially and slightly forward, improving femoro-meniscus-tibial congruence.[21,26,27] The two MFLs connect the posterior horn of the lateral meniscus to the internal aspect of the medial condyle of the femur as independent structures with different meniscal and femoral attachments.[21,27] The oblique fibers of the PCL are called "false posterior MFL," since some studies confuse them with a MFL.[28] These fibers are also frequently confused on magnetic resonance imaging (MRI) or are considered an anatomical variation of the PCL[29] and are present in 20% of cases; also in dissection, with the pMFL[1,21,23,27,28]; moreover, Hassine et al.[29] describe the fusion of these two structures.

For Kaplan,[30] the aMFL originates from the pMFL, as if it were its previous branch; Gupte et al.[21] consider them independent structures that coexist in 50% of the knees, with individualized origins and insertions. Lahlaidi and Vaclavek[31] propose an embryological explanation to explain the observed anatomical variations, suggesting that the site of the PCL during embryological development determines the presence and position of the MFLs.

The pMFL has been found in quadrupeds and humans, while the anterior has never been seen in quadrupeds.[21] Le-Minor[32] point out that while the pMFL is present in all animals, such as sheep, dog, and horse, it is absent, on occasions, in man. For this reason, they point out that the pMFL in man is a recessive and vestigial structure while the aMFL is progressive, but to reach this conclusion, a more serious study with a larger number of samples is necessary.

The MFLs work in a reciprocal manner during flexion and during extension: the aMFL develops tension during flexion and the pMFL does so during extension. In case of PCL rupture, the posterior drawer is reduced in those PCL tears in which the pMFL is present and intact.[22] The MFLs contribute 30% of the posterior drawer strength and can reach 70% when there is an LCP tear. In these conditions, MFLs help stabilize the knee with poor PCL and can be useful when undergoing treatment. Firm attachment of the MFLs to the lateral meniscus may increase the risk of injury to the PCL when removing or repairing the posterior horn.[21,27,28]

Gupte et al.[27] suspected that there were large differences in the frequency of racial MFLs. Meniscofemoral ligaments are more frequent in Western countries than in Asia.[21–24,29] In western anatomical specimens, all pieces have been found to have at least one MFL,[22,24] while few aMFL (0–3.8%) have been found in Asian specimens. In general, pMFL is slightly more common in Asians than in Westerners, although due to lack of data, it is difficult to determine the differences between pMFL in contrast to aMFL.[33] The Korean and Japanese population seem to show the opposite trend to the western population.[33]

The pMFL has very different shapes and sizes.[29] Anterior and posterior MFLs are more frequently found in young patients, which may indicate that they are structures that suffer injuries during life that detach them from the femoral condyle and lead to degeneration and atrophy.[21,27]

Gupte et al.[21] found, in 28 cadaver knees, a high modulus of tension of the MFLs indicates that they act together with the rest of the structures of the knee. The length of the aMFL, measured in 62 knees, was 20.7 ± 3.9 mm, and the length of the pMFL, measured in 58 knees, was 23.0 ± 4.3 mm. In our study, the pMFL was more frequent and longer than the aMFL. In the anatomical dissection, we found the pMFL in almost ¾ of the pieces (72.41%), while the aMFL was found only in ⅕ (20.88%). Only in 4 cases (13.8%) were the 2 MFLs observed.

Our study has limitations. First, we must mention the size of the sample;considering that it is an anatomical study, it was not easy to achieve a higher number of fresh knees. Measurements are not always easy to perform due to the divergence of the ligament fibers, it is especially difficult to measure the ACL at its distal insertion, due to its conical geometry. The PCL is shaped like a rectangular fibrous band, but its distal insertion is not easy to determine as it is intermixed with the fibers of the periosteum. In addition, the PCL forms a posterior convex curvature to conform to the shape of the proximal end of the tibia. We were also unable to measure the variations in the length of the PCL during joint mobility.

We have found no correlations between the cruciate and MFLs and the anatomical dimensions of the proximal extremity of the tibia and the distal extremity of the femur. The dimensions of the intercondylar notch are also unrelated to the dimensions of the cruciate ligaments. In our anatomical study, the presence of the pMFL was more frequent. In the anatomical samples, we found them in 72.41%, and the aMFL was found in 20.68% of the anatomical pieces. In our study, the pMFL was also longer than the aMFL.

Conflict of Interests
The authors declare that there is no conflict of interests.

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References

1 Amis AA, Gupte CM, Bull AM, Edwards A. Anatomy of the posterior cruciate ligament and the meniscofemoral ligaments. Knee Surg Sports Traumatol Arthrosc 2006;14(03):257–263
2 Greiner P, Magnussen RA, Lustig S, Demey G, Neyret P, Servien E. Computed tomography evaluation of the femoral and tibial attachments of the posterior cruciate ligament in vitro. Knee Surg Sports Traumatol Arthrosc 2011;19(11):1876–1883
3 Takahashi M, Matsubara T, Doi M, Suzuki D, Nagano A. Anatomical study of the femoral and tibial insertions of the anterolateral and posteromedial bundles of human posterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc 2006;14(11): 1055–1059
4 Ahmad CS, Cohen ZA, Levine WN, Gardner TR, Ateshian GA, Mow VC. Codominance of the individual posterior cruciate ligament bundles. An analysis of bundle lengths and orientation. Am J Sports Med 2003;31(02):221–225

5 Papannagari R, DeFrate LE, Nha KW, et al. Function of posterior cruciate ligament bundles during in vivo knee flexion. Am J Sports Med 2007;35(09):1507–1512
6 Amadi HO, Gupte CM, Lie DT, McDermott ID, Amis AA, Bull AM. A biomechanical study of the meniscofemoral ligaments and their contribution to contact pressure reduction in the knee. Knee Surg Sports Traumatol Arthrosc 2008;16(11):1004–1008
7 Bao HR, Zhu D, Gong H, Gu GS. The effect of complete radial lateral meniscus posterior root tear on the knee contact mechanics: a finite element analysis. J Orthop Sci 2013;18(02):256–263
8 Pula DA, Femia RE, Marzo JM, Bisson LJ. Are root avulsions of the lateral meniscus associated with extrusion at the time of acute anterior cruciate ligament injury?: a case control study Am J Sports Med 2014;42(01):173–176
9 Osti M, Tschann P, Künzel KH, Benedetto KP. Anatomic characteristics and radiographic references of the anterolateral and posteromedial bundles of the posterior cruciate ligament. Am J Sports Med 2012;40(07):1558–1563
10 Racanelli JA, Drez D Jr. Posterior cruciate ligament tibial attachment anatomy and radiographic landmarks for tibial tunnel placement in PCL reconstruction. Arthroscopy 1994;10(05): 546–549
11 Moorman CT III, Murphy Zane MS, Bansai S, et al. Tibial insertion of the posterior cruciate ligament: a sagittal plane analysis using gross, histologic, and radiographic methods. Arthroscopy 2008; 24(03):269–275
12 Edwards A, Bull AM, Amis AA. The attachments of the anteromedial and posterolateral fibre bundles of the anterior cruciate ligament. Part 2: femoral attachment. Knee Surg Sports Traumatol Arthrosc 2008;16(01):29–36
13 Ramos LA, de Carvalho RT, Cohen M, Abdalla RJ. Anatomic relation between the posterior cruciate ligament and the joint capsule. Arthroscopy 2008;24(12):1367–1372
14 Makris CA, Georgoulis AD, Papageorgiou CD, Moebius UG, Soucacos PN. Posterior cruciate ligament architecture: evaluation under microsurgical dissection. Arthroscopy 2000;16(06):627–632
15 Race A, Amis AA. PCL reconstruction. In vitro biomechanical comparison of ‘isometric’ versus single and double-bundled ‘anatomic’ grafts. J Bone Joint Surg Br 1998;80(01):173–179
16 Pearsall AW IV, Hollis JM. The effect of posterior cruciate ligament injury and reconstruction on meniscal strain. Am J Sports Med 2004;32(07):1675–1680
17 Covey DC, Sapega AA, Marshall RC. The effects of varied joint motion and loading conditions on posterior cruciate ligament fiber length behavior. Am J Sports Med 2004;32(08):1866–1872
18 Markolf KL, Feeley BT, Jackson SR, McAllister DR. Biomechanical studies of double-bundle posterior cruciate ligament reconstructions. J Bone Joint Surg Am 2006;88(08):1788–1794
19 Bergfeld JA, McAllister DR, Parker RD, Valdevit AD, Kambic H. The effects of tibial rotation on posterior translation in knees in which the posterior cruciate ligament has been cut. J Bone Joint Surg Am 2001;83(09):1339–1343
20 Grood ES, Hefzy MS, Lindenfield TN. Factors affecting the region of most isometric femoral attachments. Part I: The posterior cruciate ligament. Am J Sports Med 1989;17(02):197–207
21 Gupte CM, Smith A, Jamieson N, Bull AM, Thomas RD, Amis AA. Meniscofemoral ligaments–structural and material properties. J Biomech 2002;35(12):1623–1629
22 Kusayama T, Harner CD, Carlin GJ, Xerogeanes JW, Smith BA. Anatomical and biomechanical characteristics of human meniscofemoral ligaments. Knee Surg Sports Traumatol Arthrosc 1994; 2(04):234–237
23 Poynton AR, Javadpour SM, Finegan PJ, O’Brien M. The meniscofemoral ligaments of the knee. J Bone Joint Surg Br 1997;79(02): 327–330
24 Yamamoto M, Hirohata K. Anatomical study on the meniscofemoral ligaments of the knee. Kobe J Med Sci 1991;37(4-5):209–226
25 Coulier B. Signification of the unusual delineation of the anterior meniscofemoral ligament of Humphrey during knee arthro-CT. Surg Radiol Anat 2009;31(02):121–128
26 Anderson CJ, Ziegler CG, Wijdicks CA, Engebretsen L, LaPrade RF. Arthroscopically pertinent anatomy of the anterolateral and posteromedial bundles of the posterior cruciate ligament. J Bone Joint Surg Am 2012;94(21):1936–1945
27 Gupte CM, Bull AM, Thomas RD, Amis AA. A review of the function and biomechanics of the meniscofemoral ligaments. Arthroscopy 2003;19(02):161–171
28 Amis AA, Bull AM, Gupte CM, Hijazi I, Race A, Robinson JR. Biomechanics of the PCL and related structures: posterolateral, posteromedial and meniscofemoral ligaments. Knee Surg Sports Traumatol Arthrosc 2003;11(05):271–281
29 Hassine D, Feron JM, Henry-Feugeas MC, Schouman-Claeys E, Guérin Surville H, Frija G. The meniscofemoral ligaments: magnetic resonance imaging and anatomic correlations. Surg Radiol Anat 1992;14(01):59–63
30 Kaplan EB. The lateral meniscofemoral ligament of the knee joint. Bull Hosp Jt Dis 1956;17(02):176–182
31 Lahlaidi A, Vaclavek J. [The posterior menisco-femoral ligaments and their significance in organogenesis]. Bull Assoc Anat (Nancy) 1975;59(164):177–183
32 Le Minor JM. Comparative morphology of the lateral meniscus of the knee in primates. J Anat 1990;170:161–171
33 Han SH, Kim DI, Choi SG, Lee JH, Kim YS. The posterior meniscofemoral ligament: morphologic study and anatomic classification. Clin Anat 2012;25(05):634–640

