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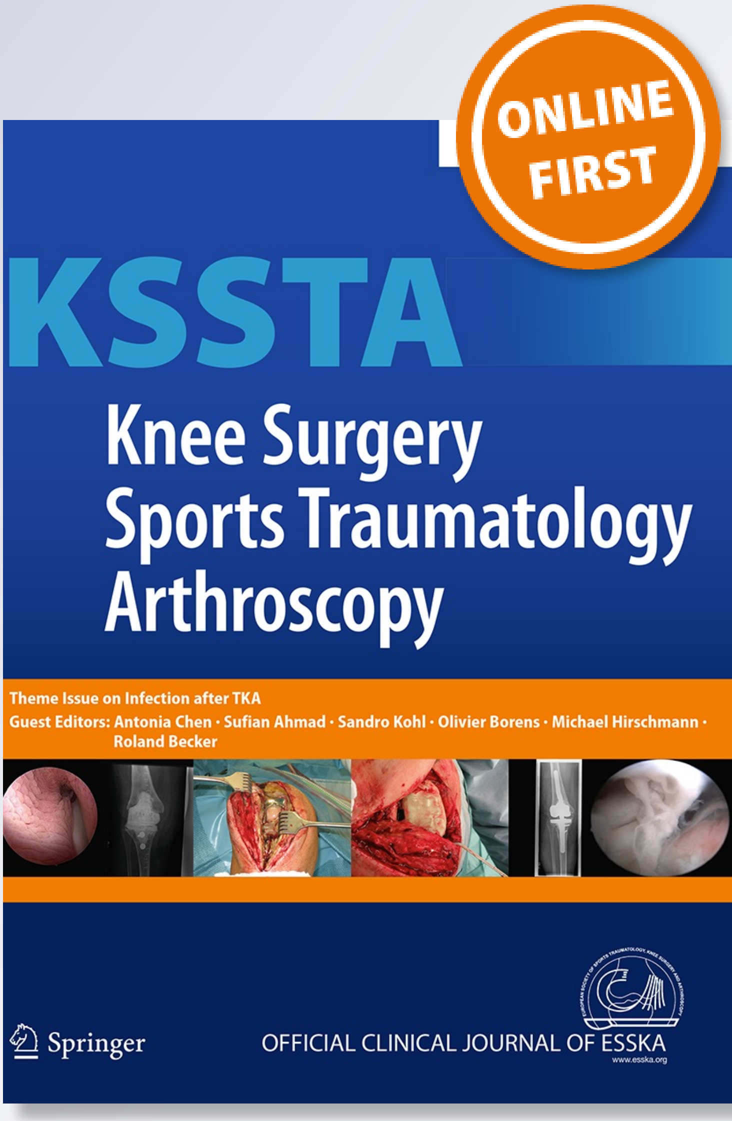

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Cadaveric study of the secondary medial patellar restraints: patellotibial and patellomeniscal ligaments

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Abstract
Purpose To detail the anatomy of the medial patella stabilizers, medial patellotibial (MPTL), and medial patellomeniscal ligaments (MPML), focusing on the points of origin and insertion, length, thickness, width, and fibres orientation to study the frequency of anatomical variations and the anatomy of these ligaments, thereby improving surgical techniques.
Methods Thirty dissected knees were analysed. A digital caliper was used to measure the length, thickness, and width, as well as the mid-point of the ligaments insertion and the distance from the MPTL insertion to the articular surface of the tibia. The angle of inclination of the ligaments was calculated in the coronal plane. The collected data were tabulated and statistically analysed.
Results MPTL was present in 90 % as a visible thickening of the deep medial retinaculum and exhibiting only one anatomical variation. The MPML was absent in one of the dissected knees, and one anatomical variation was found. The tilt angle of the ligaments was very similar, with an average of 22.2° ± 7.6° for the MPTL and 24.2° ± 6.6° for the MPML.
Conclusion The MPTL is a long visible structure of the deep layer of the medial retinaculum, but with a distinct origin and insertion. The MPML is thicker with an angular direction similar to MPTL. The presence of these ligaments in most of the specimens studied suggests that the real anatomical and biomechanical importance of these ligaments should be further investigated because they play a role in the patellar stability.

Keywords Knee · Patella · Patellar dislocation · Patellofemoral Joint · Ligament

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Introduction

The joint between the patella and the femur is a complex anatomical and functional entity. Static and dynamic restraints and bony structures are important to ensure the stability of the patellofemoral joint [12, 13, 17]. The dynamic alignment of the patella is determined by the geometry of the trochlea and by active and passive stabilizers. The consensus in the literature on the importance of the medial patellofemoral ligament (MPFL) is that it is the main primary restraint of patellar lateralization, contributing 50–60 % of the medial stabilization force, and it is injured in 98.6 % of acute patellar dislocations [1, 4, 5, 11–13, 18]. Although the MPFL is defined as the primary stabilizer against lateral patellar dislocation between 0°

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and 30° of knee flexion, the medial patellotibial ligaments (MPTLs) and medial patellomeniscal ligaments (MPMLs) are also part of the medial ligament complex; moreover, despite the fact that they are secondary restraints for lateral displacement, they aid in patellar rotation and tilt when the knee is flexed beyond 45° [4, 17, 20].

After gaining an anatomical and biomechanical understanding of these medial stabilizers, the recommendations for treating lateral patellar dislocations include surgery to reconstruct the MPFL when the morphology of the joint is normal, achieving high rates of success and minimal rates of recurrence [15, 23, 24]. However, there is not yet a consensus on the most appropriate technique or on which determinants are necessary for achieving the best results [15, 23]. Thus, reconstruction of the MPFL associated with the MPTL is an option that has been recently described and may be a solution for improving patellar stability to near full extension [6, 14, 19, 23, 24]. However, the biomechanical importance of this ligament is minimal, whereas the MPML contributes 13–22 % of the medial restraining force [4, 5]. Although the MPML and MPFL contribute more than 75 % of the medial restraining force, no surgical technique has been proposed for reconstructing both of these ligaments, although a repair for the MPML has recently been proposed [14]. Improving our knowledge of the anatomy and biomechanics of the medial restraints will lead to a better understanding of injuries that cause patellar instability and will improve the current surgical repair and reconstruction techniques [2–4, 6, 8].

The aim of the present study is to detail the anatomy of the secondary medial stabilizers of the knee, specifically the MPTL and MPML, focusing on their points of origin and insertion, length, thickness, width, and the angular orientation of the fibres. Furthermore, the frequency of anatomical variations is studied in order to better describe the anatomy of these ligaments. The main hypothesis of the study is that the MPTL and the MPML are two different structures present in most knees, with different origins and insertions sites.

Materials and methods

Thirty knees from transfemoral amputations performed by the vascular surgery team were consecutively dissected after being stored in a 10 % formaldehyde solution and refrigerated at 5.3 °C. The specimens were obtained from exclusively vascular amputations, and specimens with signs of trauma, scars, or previous surgeries were excluded. The specimens were identified according to the side, age, gender, date of amputation, and dissection. Dissections were performed in the institution's morgue an average of 16.4 days following the amputation. The specimens were from 30 patients who were considered an adequate sample based on the sample size calculation due to the low levels of anatomical variability.

For the dissection of the anatomical planes, a longitudinal incision was made and the subcutaneous cellular tissue was dissected, exposing and releasing the lateral retinaculum, and the patella was pushed to the medial side, allowing access to the joint. The distal insertion of the vastus medialis oblique muscle was exposed and sectioned along with the medial patellofemoral ligament to facilitate patella mobilization.

For the purpose of the dissection and its report, the findings of Warren and Marshal were followed [22]. After removing the layer 1 of the inferomedial patellar region, we identified the MPTL as a visible thickening of the intermediate layer of the medial retinaculum. The MPTL was isolated by careful dissection, defined by its origin at the medial region of the lower patellar pole and its insertion at the anteromedial tibial region. After isolating the MPTL, the patella was then pushed to the anterior portion, subsequent to carefully removing the infrapatellar fat pad and visualizing the medial meniscus, to identify the insertion of the MPML and to isolate this ligament.

All specimens were photographed using a 12-megapixel digital camera and measured using a digital caliper accurate to 0.01 mm (Mitutoyo™, Japan). Mid-points of the origin and insertion of the MPTL and MPML were defined at the osteoligamentous transition, as well as the mid-point of the ligament extension to measure its thickness and width. All measurements were taken with the knee positioned at 30° flexion by three evaluators, including one knee surgery specialist and two senior residents in Orthopedics and Traumatology.

The length, width at three different points (the origin, mid-point, and insertion), and the ligament thickness at the mid-point were measured for both the MPTL and MPML. Fixed bony landmarks were considered the best parameters for evaluating the measurements. The distance from the superior patellar pole to the origin of each ligament was measured; to precisely determine the MPTL insertion site, the distances from the ligament insertion to the tibial articular surface and to the anterior tibial tuberosity (ATT), as well as the longitudinal distance from the axis formed between the ATT and the centre of the patella, were measured (Fig. 1). The insertion site of the MPML at the medial meniscus was visualized, but no specific measurements were taken. Using a conventional goniometer, we determined the angle formed between the axis of the line from the ATT to the centre of the patella and the axis of the respective knee ligaments that were studied.

This study had been previously approved by the IRB of the Santa Casa School of Medicine and Hospitals of São Paulo, Brazil (ID approval number: 08884712.8.0000.5479).

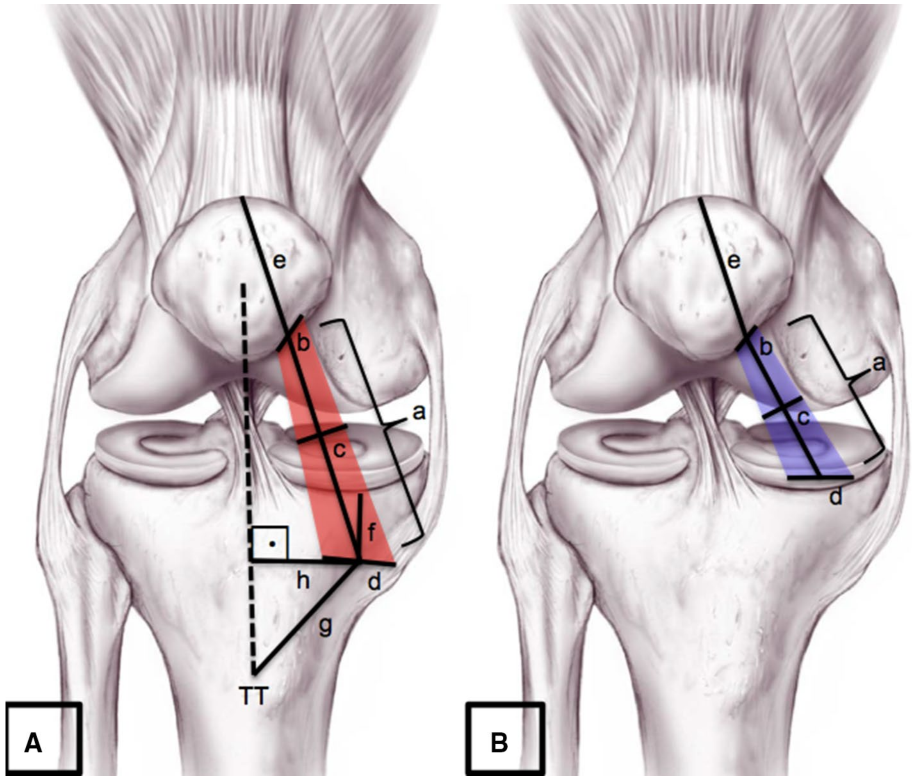

Fig. 1 Schematic illustration of the measurements performed on the knee. **A** Medial patellotibial ligament; **B** medial patellomeniscal ligament. *a* Ligament extension; *b* width at the origin; *c* width at the mid-point; *d* width at the insertion; *e* distance from the superior patellar pole to the origin; *f* distance from the articular surface to the insertion; *g* distance from the TT to the insertion; *h* distance from the TT-patella centre axis to the insertion

Statistical analysis

The data for the ligaments from the 30 dissected specimens were collected and tabulated separately, and cases of anatomical variation were studied individually (two variations, one for each of the ligaments) and were excluded from the overall statistical analysis. If one of the ligaments was absent, it was not included in the analysis, and thus, the analysis included 26 MPTLs (three absent) and 28 MPMLs (one absent).

The data for all statistical analyses were analysed using a descriptive method performed by the statistical program SPSS, version 15.0, for Windows. The mean, standard deviation, and the frequency based on the 25th, 50th, and 75th percentiles were calculated.

Results

Thirty knees (21 right knees and 9 left knees) were dissected, including specimens from 18 female and 12 male individuals whose median age was 68 years (ranging from 28 to 94 years).

The MPTL was present in 27 (90 %) of the knees dissected as a visible oblique thickening of the layer two but was not identified in three of the knees [22]. The origin was located at the inferomedial patellar border near the articular surface, and the insertion was at the anteromedial tibial region (Fig. 2). An anatomical variation was only observed in one knee, in which the MPTL was Y-shaped with two origins (Fig. 3). The MPML was identified in 29 (96.7 %) knees dissected, located deep to the MPTL as a palpable fibrous band along its entire length, with an intimate relationship with Hoffa's fat pad. The origin of the MPML was identified at the lower patellar pole, distal to the origin of the MPTL, and the insertion was always identified at the anterior horn of the medial meniscus, even in the case of anatomical variation in which the origin and insertion occurred at two separate points, featuring two parallel and distinct medial patellomeniscal ligaments (Fig. 4).

For the MPTL measurements, data were collected from 27 specimens in which the ligament was present. The one case of anatomical variation was excluded from the analysis. Therefore, based on the 26 cases analysed, the length has a high level of variation. When considering the 75th percentile, the value for the length was 52.6 mm. The width was larger in the origin and insertion than in the body (Table 1).

The identification of the MPML was facilitated after pushing the patella to the anterior side, which helped better visualize the patellar insertion at the anterior horn of the medial meniscus at the third layer. This ligament was absent in one case, and the only anatomical variation found was excluded from the statistical analysis for 28 specimens in total. The entire length could be palpated, facilitating its dissection near Hoffa's fat pad. Despite its tendon-like

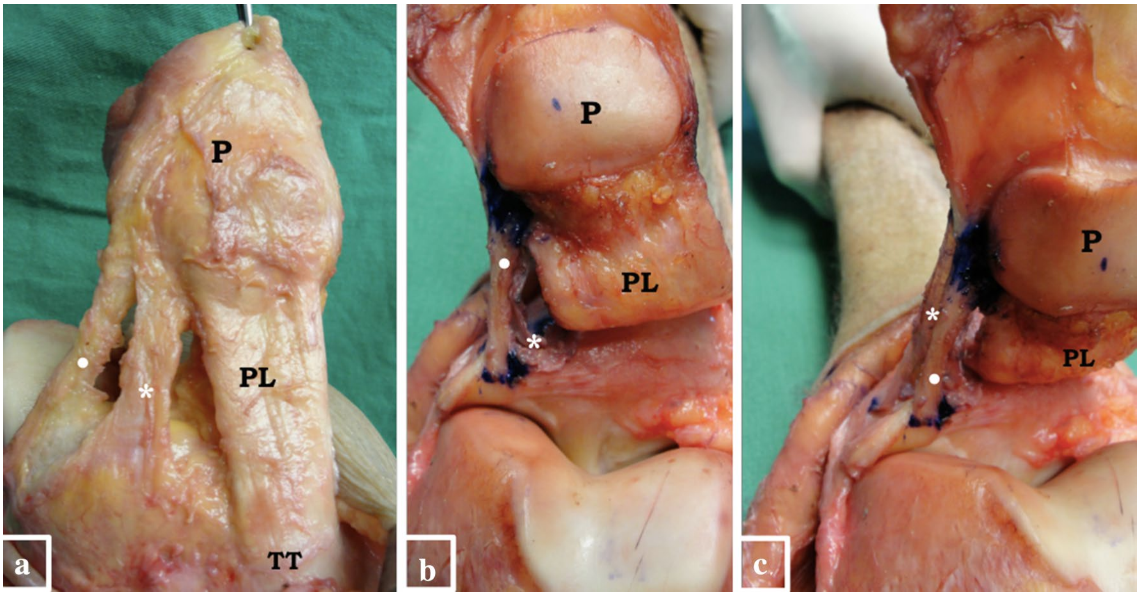

Fig. 2 Image of knee dissections demonstrating the anatomical relationship between the MPTL and MPML. **a** Anterior view of the left knee showing the dissected ligaments; **b**, **c** posterior view of the right knee at different angles. *P* patella, *PL* patellar ligament, *TT* tibial tuberosity; *asterisk* medial patellotibial ligament; *black dots* medial patellomeniscal ligament

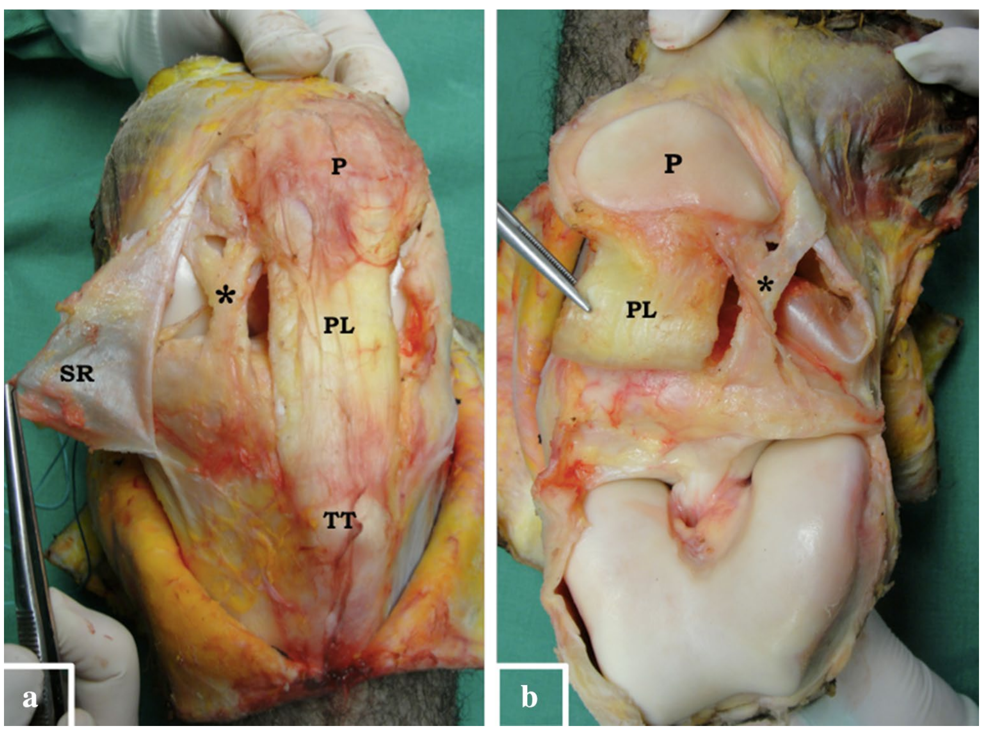

Fig. 3 Image of the left knee showing the anatomical variation of the medial patellotibial ligament. **a** Anterior view; **b** posterior view. *P* patella, *PL* patellar ligament, *TT* anterior tibial tuberosity, *SR* superficial medial retinaculum; *asterisk* Y-shaped bifurcation

aspects, the width of the ligament varied between its origin, body, and insertion. Its origin is also in the inferior pole of the patella, and although it was close to the MPTL, the MPML origin was more posterior and juxta-articular to the medial facet of the patella. The results are reported in Table 1.

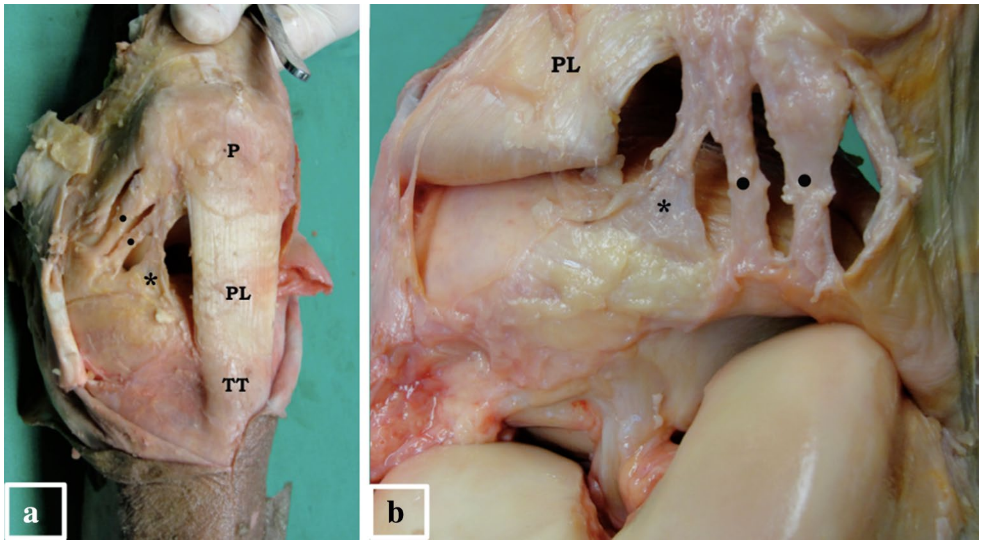

Fig. 4 Image of the left knee showing the anatomical variation of the medial patellomeniscal ligament. **a** Anterior view; **b** posterior view. *P* patella, PL patellar ligament, *TT* tibial tuberosity; *asterisk* medial patellotibial ligament; *black dots* distinct origin and insertion

Table 1 Results of the anatomical measurements analysis

	Mean	SD	Minimum	Maximum	Percentile		
					25	50	75
Medial patellotibial ligament ($N = 26$)							
Length (mm)	46.3	8.8	26.5	64.6	42.7	47.7	52.6
Width (mm)							
Origin	12.1	3.4	6.8	18.8	8.9	12.6	14.6
Body	9.2	2.7	4.1	14.8	7.5	9.2	10.8
Insertion	17.5	3.4	11.7	26.2	15.0	16.7	19.2
Thickness (mm)	0.9	0.3	0.3	2.0	0.7	0.9	1.0
Distance (mm)							
Origin—superior patellar pole	35.1	3.9	25.5	42.6	33.3	35.0	37.8
Insertion—ATT	43.0	7.9	30.4	63.4	36.5	42.4	46.3
Insertion—articular surface	13.4	2.5	8.7	18.6	11.4	12.9	15.4
Inclination angle (°)	22.2	7.6	9	38	18	22	27.5
Medial patellomeniscal ligament ($N = 28$)							
Length (mm)	37.4	7.3	22.8	50.2	32.1	37.8	43.0
Width (mm)							
Origin	8.5	2.6	3.0	14.1	6.7	7.9	10.7
Body	4.3	1.5	1.3	7.4	2.8	4.3	5.6
Insertion	6.7	1.9	3.4	10.4	5.2	7.0	7.9
Thickness (mm)	1.4	0.4	0.8	2.6	1.1	1.3	1.6
Distance (mm)							
Origin—superior patellar pole	36.0	2.8	29.3	43.8	34.5	36.1	37.4
Inclination angle (°)	24.2	6.6	10	38	20.2	24	28

Results of the descriptive method analysis

SD standard deviation, *ATT* anterior tibial tuberosity

Discussion

The most important finding of the present study was the finding of the MPTL and MPML in most of the dissected knees. The presence of the medial secondary stabilizers could help in better understanding of the anatomical presentation of the MPTL as a visible thickening of the deep layer of the medial retinaculum and the MPML as a thicker ligament with an angular direction similar to MPTL. These findings can elucidate and improve surgical techniques for the secondary medial restraints reconstructions.

In addressing the frequency of these ligaments, Marcacci et al. [14] reported that the MPTL is observed in 90 % of knees as a thickening of the medial capsule with an origin at the inferomedial patellar face and an insertion at the medial aspect of the tibia, anterior to the medial collateral ligament, and near the articular surface. In this study, we isolated the MPTL and MPML in 85 and 96 % of the dissected knees, respectively, and found that the MPTL insertion point is 13.4 distally from the articular surface. Conlan et al. [4] cited the MPML as being a structure located in the third layer of the medial portion of the knee that is directed towards the inferomedial patellar pole, extended obliquely and distally within the medial part of Hoffa's fat pad, inserted at the medial meniscus anterior to the medial collateral ligament, and inserted at the tibia through the coronary ligament. In our study, we observed that the MPML lies posterior to the MPTL and that the insertion invariably occurs at the anterior horn of the medial meniscus even in knees with anatomical variations involving two insertions very close to the anterior horn. However, we did not perform a correlation with the tibial collateral ligament for any of the ligaments because we believe that fixed bony landmarks such as the tibial tuberosity, the patella, and the tibial articular surface are of greater use to the orthopaedic surgeon.

Many authors consider reconstruction of the medial patellofemoral ligament to be the procedure of choice for stabilizing recurrent patellar dislocation in patients without any changes in their bone morphology and with normal alignment of the lower limbs [6, 12, 18, 19]. Several biomechanical studies have demonstrated the importance of secondary stabilizers, including the MPTL and MPML, in preventing recurrent patellar dislocation [2, 20, 23, 24]. In 1922, Galeazzi was the first to describe a surgical technique for the isolated reconstruction of the MPTL using a semitendinosus graft in immature skeletons. However, there was a high rate of recurrence of patellar dislocation, effectively preventing surgeons from using the technique for a few years [7]. More recently, in 2008, Brown and Ahmad [2] published the description of a technique for combined MPFL and MPTL reconstruction (also in children) and reported results considered satisfactory with a low recurrence rate; their study encouraged other authors to publish their personal combined reconstruction techniques, even in skeletally mature patients [2, 9]. According to Marcacci et al. [14], there were no episodes of relapse after using a strip of the patellar ligament for isolated reconstruction of the MPTL in 18 patients with lateral patellar subluxation. However, in 2013, Sobhy et al. [20] proposed a combined reconstruction of the MPFL and MPML using a semitendinosus tendon in patients with recurrent patellar dislocation and reported a 96.4 % clinical and radiological improvement, without any episodes of recurrence after a mean follow-up of 32.2 months.

However, despite the surgical descriptions reported and the discrepancies between the techniques adopted, the anatomical studies reported in the literature are scarce despite their importance in developing the best anatomical parameters for reconstructions. Kaplan et al. [12] published the first anatomical study citing the patellomeniscal ligaments, although greater attention was given to the lateral compartment, describing the ligament as part of the deep fascial plane extending from the lower patellar pole to the anterior horn of each meniscus, respectively, and they are thus known as Kaplan's ligaments [12]. In 1979, Warren and Marshall [22] published a classic anatomical study of the medial region of the knee that divided the structures into three layers, briefly citing the medial patellar stabilizers, and considered the MPML to be part of the third layer and the more superficial MPTL to be part of the second layer. Following this study and as part of a study in 1987 to understand infrapatellar contracture syndrome, Paulos et al. [16] briefly described the MPML as an integral portion of the deep fascial plane extending from the lower patellar pole to the anterior horn of the medial meniscus [16].

However, the most specific reference to the MPTL was made by Terry [21], who described it as an oblique condensation of the medial retinaculum, with an insertion located 15 mm from the joint line of the tibia in the anteromedial region [21]. Some biomechanical studies have also been performed and have included additional anatomical details. Desio et al. [5] described the MPTL as an oblique condensation of the fibres in the first layer as defined by Warren and Marshall [22], which coalesce with the MPFL fibres at the patella origin in the second layer. The same author cites data similar to those described by Terry et al. [21] and those observed in this study, in which the tibial insertion always occurs at least 0.9 cm from the articular surface.Regarding the patellomeniscal ligament, these findings also agree with the study by Desio et al. [5],whose identification of this ligament placed it at the medial edge of Hoffa's fat pad, easily palpated after sectioning the MPFL. In this study, its origin was in the lower two-thirds of the patella very near to the patellar ligament and its insertion at the anterior horn of the medial meniscus. Rare anatomical variations was identified, which in one case placed it as a continuation of the intermeniscal ligament [5].

This study adds relevant data to the recent literature, such as the angulation of these ligaments relative to the coronal plane along the axis from the patella centre to the ATT. The knowledge of the angle enables the orthopaedic surgeon to better position these structures (primarily the MPTL) when reconstruction is chosen and to select the technique that most resembles the ideal anatomy. Both angular values are very similar, with a mean of 22.2° for the MPTL and a mean of 24.2° for the MPML, which appear even closer still when considering that the ideal would be to use a 27.5° angle in the reconstruction of the MPTL and a 28° angle for MPML—values that would include the majority of the population. Panagiotopoulos et al. [15] described a very similar orientation of both ligaments in relation to patellar tendon (MPTL: 20°–25°; MPML: 15°–30°) [15]. Therefore, both ligaments have similar inclinations, and in the dissections, a parallelism and a very close anatomical relationship between them were noticed, given that individually identifying these ligaments was only possible with a careful dissection.

In addition, although the literature rarely addresses the individual importance of each of these ligaments, the fact that the thickness of the MPML was greater than the MPTL in all the analyses performed in this study allows to assume that reconstructing this ligament would lead to greater stability of the patellofemoral joint and to superior results. This impression has been confirmed in a biomechanical study performed by Desio et al. [5] in which the MPML contributed to 13 % of the restriction of patellar lateralization and the MPTL did not have any functional importance in preventing patellar translation. Conversely, the width of the MPTL along its path is much greater than the width of the MPML, especially at the insertion, respectively, averaging 17.5 and 6.7 mm. This difference may explain the importance of the reconstruction of this ligament. In 2012, another publication evaluated the biomechanical importance of the medial patellar stabilizers in knee flexion, differentiating only the medial patellofemoral ligament and considering the MPTL and MPML to be a ligament complex, and reported that the importance of this complex in restricting patellar lateralization gradually increases starting at 45° of knee flexion [17].

While there are a few previous studies related to the MPTL and MPML, the present study focuses only on the anatomy of these ligaments in order to find the most ideal place for reconstruction, specially the distal insertion from the joint line of the MPTL (13.4 mm) which has functional effects. Reconstruction as anatomically as possible should be the aim of the reconstruction of both structures when indicated. Some techniques describe the use of part of patellar ligament, and others prefer the semitendinous or gracilis to reconstruct the MPTL [23, 24]. It seems that the graft choice is surgeon dependent, but maintaining the hamstrings original attachment (41 ± 6.6 mm) is far from the anatomical landmarks of the MPTL insertion [10].

The main limitation of this study is related to the cadaveric specimens. We did not have access to previous medical history, so it was not accessed whether specimens had any type of knee joint pathology. Moreover, mean patient's age was 68.6 years; therefore, they had some degenerative changes in their knee anatomy. Another limitation is that the sample size was not calculated before the study. Despite the limitations, the anatomical findings can help the development and precision of the surgical techniques.

Conclusion

This study demonstrated that the MPTL is a visible thickening of the deep layer of the medial retinaculum present in 90 % of the dissected knees. It is a long structure with a firm and large insertion into the tibia. The MPML is a thicker ligament with an angular direction similar to MPTL. It was present in 96.7 % of the dissected knees.

Compliance with ethical standards

Conflict of interest The authors above declare that they have no conflict of interest.

Funding There is no funding source.

Ethical approval The study protocol for obtaining, use and disposal of human tissue specimens received approval in 12/05/2012, permit number CAAE 08884712.8.0000.5479.

Informed consent All patients provided written informed consent prior to participation.

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