

STUDY ON THE PATELLOFEMORAL JOINT USING MAGNETIC RESONANCE IMAGING: MORPHOLOGICAL VARIATION OF THE MEDIAL PATELLOFEMORAL LIGAMENT

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ABSTRACT

Objectives: To study the measurements and anatomical relationships of the patellofemoral joint using magnetic resonance imaging, and to evaluate the variation in the morphology of the medial patellofemoral ligament (MPFL) according to patients' heights and ages and the variation in measurements on other structures that are known to be involved in predisposition to patellar instability. **Method:** Twenty-three knees (18 patients) underwent magnetic resonance imaging and their interepicondylar distance, patellar height, trochlear depth, ventral trochlear prominence, trochlear groove angle, lateral facet tilt, lateral patellar tilt and size of the lateral and medial

facets and their ratio were measured. These measurements were compared with the length and thickness of the MPFL. **Results:** The average length of the MPFL was 46.4 mm, while the average thicknesses of its patellar insertion, middle third and femoral insertion were, respectively, 1.7 mm, 1.4 mm and 1.2 mm. The thickness of the MPFL correlated positively with the lateral condyle and interepicondylar distance measurements, and negatively with the patients' ages. **Conclusion:** The morphology of the MPFL varies with the interepicondylar distance and the lateral condyle distance, and with patients' ages.

Keywords – Patella; Patellar Ligament; Joint Instability; Knee

INTRODUCTION

Detailed study of the anatomy of the knee is fundamental for understanding the infirmities that affect it. Among the abnormalities that involve the knee joint, disorders of the extensor apparatus are one of the most frequently encountered problems in orthopedic practice⁽¹⁾.

Instability of the extensor apparatus, represented by recurrent dislocation and subluxation of the patella, consists of displacement of the patella, generally laterally, which occurs at some point of the flexion and extension movement of the knee^(1,2).

This instability may affect both athletes and non-athletic individuals, causing pain and incapacity. It in-

volves great biomechanical complexity and frequently necessitates surgical intervention to treat it⁽²⁾.

It occurs most frequently in individuals with one or more anatomical abnormalities that predispose towards dislocation or subluxation, such as trochlear or patellar dysplasia, high patella, rotational deviations of the lower limbs, muscle dysplasia (especially of the vastus medialis obliquus), retinacular dysplasia and generalized laxity of the ligaments⁽²⁻⁵⁾.

Patellofemoral stability is promoted by bone and soft-tissue structures. The soft tissues that restrict subluxation or lateral displacement of the patella include the medial patellofemoral ligament (MPFL), the medial patellomeniscal ligament, the medial patellotibial

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ligament, the medial retinaculum and even the lateral retinaculum^(1,2,6-8).

Among these structures, it has been accepted that the MPFL is the primary restrictor against lateral patellar displacement^(1,6,7-9). It is recognized as the most important structure in restricting against lateral displacement or subluxation of the patella, and tearing of the MPFL is frequently cited as the essential lesion in lateral displacement of the patella. This theory is increasingly accepted, based both on biomechanical and on clinical factors^(2,7-9).

Studies have demonstrated that the MPFL is responsible for 50 to 60% of the restriction of lateral displacement of the patella promoted by soft tissues, when the knee is in a position of 0 to 20 degrees of flexion^(1,2,7,10).

The MPFL is a very variable structure that is located in a layer below the vastus medialis obliquus muscle. It has insertions at variable levels of the medial femoral epicondyle and medial edge of the patella^(6,9,11).

There is insufficient information about how the MPFL relates to other anatomical structures to determine whether it would be possible to correlate its morphological alterations with variations in the structures of the knee, such as the shape of the sulcus of the trochlea and whether there is any association between the presence of dysplastic abnormalities (in bones or other ligaments) and the presence of abnormalities of ligament morphology^(6,12).

OBJECTIVE

To study the measurements and anatomical relationships of the patellofemoral joint in magnetic resonance examinations, and to assess whether the variations in MPFL morphology have any association with patients' height and age, and with variations in the measurements of other structures in the knee.

METHODS

Twenty-three magnetic resonance imaging (MRI) examinations on knees were assessed. These consisted of 12 left knees and 11 right knees, of 18 outpatients registered at the Department of Orthopedics and Traumatology, Santa Casa de Misericórdia de São Paulo. The patients were 11 women and seven men, with a mean age of 45 years (range: 14 to 70 years), who had undergone the examination because of a variety of

symptoms and clinical conditions between November 2010 and January 2011.

Patients who had undergone any previous surgical intervention in the knee under examination, and patients with a history of patellar instability, were excluded from the study.

The images were obtained from the Department of Imaging Diagnostics, Santa Casa de Misericórdia de São Paulo, using a 1.5 T magnetic resonance machine (Intera, Philips), a specific eight-channel coil and proton density-weighted sequences in three planes (sagittal, coronal e axial), with and without fat saturation, using the following parameters: TE 1642; TE 30; matrix 512×256; FOV, 16×16; and slice thickness 3.5 mm, with intervals of 0.3 mm). The image analyses and all the measurements and correlations necessary were done on workstations with the Agfa PACS/RIS system, by two radiologists who were specialists in radiology of the musculoskeletal system, who analyzed the images together and simultaneously.

The following measurements were obtained from the MRI: anteroposterior distances along the lateral and medial femoral condyles, measured on their greatest anteroposterior axes (Figure 1); interepicondylar distance, measured on axial and coronal slices (Figures 2 and 3), at the level of the confluence of the insertions of the medial collateral ligament, adductor magnus and MPFL; height of the patella, measured on the joint surface on a sagittal slice (Caton-Deschamps method); depth of the trochlea, measured on an axial slice, 3 cm above the joint surface; ventral trochlear prominence, measured on a sagittal slice; angle of lateral inclination of the patella (angle between the lateral facets of the patella and trochlea), measured on the axial slice, 3 cm above the joint surface; angle of the sulcus of the trochlea, measured on the axial slice, 3 cm above the joint surface; inclination of the lateral facet (angle of inclination of the lateral facet in relation to the coronal plane tangential to the posterior region of the femoral condyles); measurement of the size of the patellar facets on the axial slice; ratio between the trochlear facets (lateral over medial), measured on the axial slice, 3 cm above the joint surface; Wiberg classification of the patella; and measurements on the MPFL regarding its total length, thickness in the middle third, thickness at the patellar insertion and thickness at the femoral insertion (Figure 4).

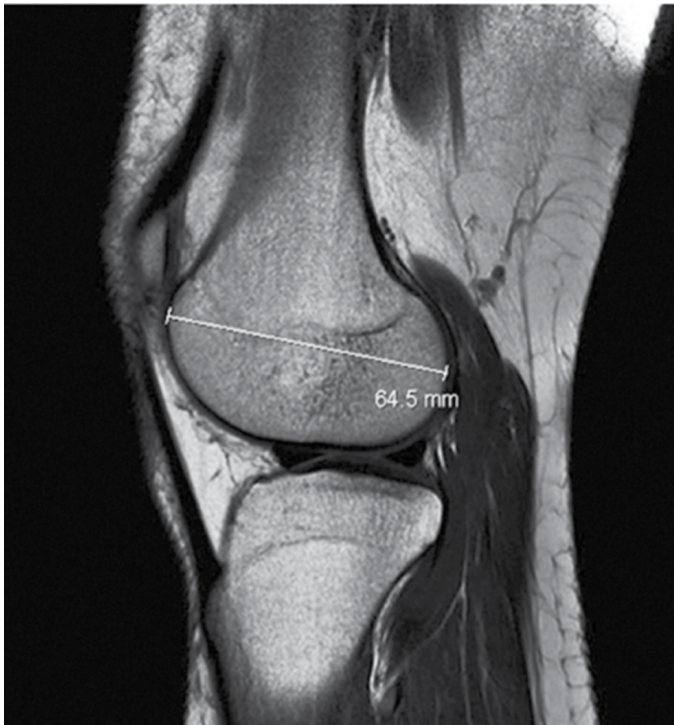


Figure 1 – Measurement of the anteroposterior distance of the lateral condyle.



Figure 2 – Measurement of the interepicondylar distance (axial).

The MPFL was characterized as a band of greater focal and continuous thickness in relation to the other portions of the medial patellar retinaculum. It presented a low signal in the proton density sequences, and extended from the medial margin of the upper half of the patella to the posterior portion of the medial epicondyle of the femur. The course and femoral and patellar insertions of the MPFL were better assessed in axial sequences. The course and insertion of the MPFL were better observed in coronal sequences than in sagittal sequences.



Figure 3 – Measurement of the interepicondylar distance (coronal).

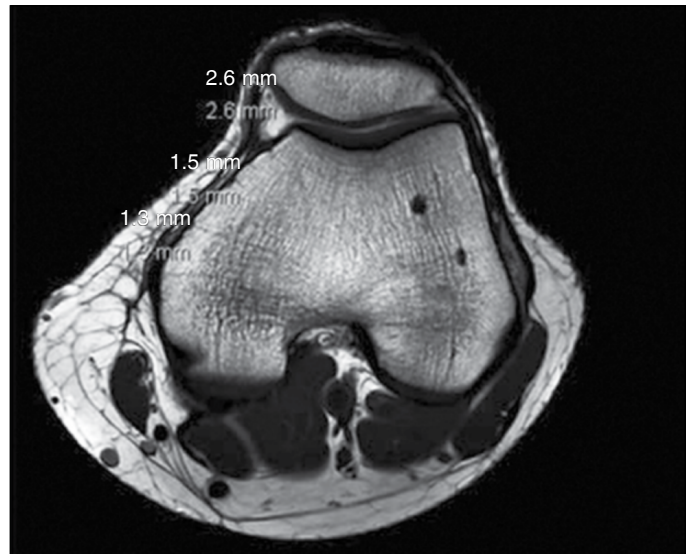


Figure 4 – Measurement of the thickness of the MPFL in its three thirds. The MPFL was characterized as a band of greater focal and continuous thickness in relation to the other portions of the medial patellar retinaculum, presenting a low signal in proton density sequences, extending from the medial edge of the upper half of the patella to the posterior portion of the medial epicondyle of the femur.

The results were organized by means of tables and graphs, and were then subjected to statistical tests to analyze and validate the results from this study.

To perform the general descriptive analysis, the mean, standard deviation, minimum value, median and maximum value of each of the measurements made were calculated.

To compare the length and thickness measurements

in the middle third of the MPFL with the other measurements made in this study, Pearson's correlation coefficient was used, except for comparisons with the angle of lateral inclination of the patella, for which Spearman's comparison coefficient was used.

The significance level used was 5% ($p\text{-value} \leq 0.05$).

RESULTS

The results revealed that the mean length and thickness of the middle third of the MPFL among the patients studied were, respectively, 46.4 mm and 1.4 mm, while the thickness of the MPFL at its femoral and patellar insertions presented dimensions of 1.2 mm and 1.7 mm, in this order (Table 1).

In relation to the Wiberg classification, 11 patients (48%) fitted into the morphology of type I, while 12 patients (52%) were placed in the type II morphological category (Table 2).

No statistically significant relationship was observed between the length of the MPFL and any of the other measurements (Table 3).

It was observed that the thickness of the MPFL in its middle third had positive relationships with the interepicondylar distance in the axial and coronal planes and with the measurement of the anteroposterior size of the lateral condyle; and a negative relationship with the patient's age (Table 4).

DISCUSSION

The presence of the MPFL was observed in the MRI examinations of the knees of all the patients included in our study, as suggested by the majority of published papers in the literature^(7,8,13-15). However, some studies that involved dissection of a cadaver failed to find this ligament in all specimens because of its small dimensions and the difficulty of dissection. Thus, from these studies, it was suggested that the MPFL did not exist in some knees^(9,16).

The studies evaluating of the anatomy of the MPFL are diverse, but almost all of them use dissection of specimens and manual measurements as the study method. Among these, Tuxøe et al⁽¹⁵⁾ observed that the mean length of the MPFL was 53 mm; Aragão et al⁽⁹⁾ found a mean length of 55.6 mm; Philippot et al⁽⁸⁾ found a mean length of 57.7 mm; and Nomura et al⁽⁷⁾ dissected 20 knees and found a mean MPFL length of 58.8 mm, which was the same as found by LeGrand

Table 1 – Descriptive analysis on the numerical variables.

Variables	Mean	Standard deviation	Minimum	Median	Maximum
Patient's age ¹	44.6	16	14	44	70
Patient's height ²	170	10	150	170	190
Size of lateral condyle (anteroposterior) ³	62.6	4.8	51.5	62.1	70.7
Size of medial condyle (anteroposterior) ³	56.5	3.8	50.9	56.4	62.4
Interepicondylar distance (axial) ³	77.7	6.1	67.6	77	88.5
Interepicondylar distance (coronal) ³	77.1	5.7	65.3	77.6	86.8
Height of patella	1.1	0.2	0.9	1.1	1.6
Depth of trochlea ³	4.2	1.6	0	4.5	7.3
Prominence of ventral trochlear ³	4.9	1.7	2	4.9	8.7
Angle of lateral inclination of the patella	5.6°	4.3°	0.6°	4.0°	15.4°
Angle of the trochlear sulcus	146.1°	9.5°	133.0°	146.0°	171.0°
Inclination of the lateral facet	23.1°	6.7°	4.8°	23.0°	37.0°
Ratio between the trochlear facets	1.3	0.2	1	1.3	1.7
Size of the lateral facet ³	23.8	2.9	17.6	23.8	28.5
Size of the medial facet ³	18.8	3.8	13.2	19.2	28.4
Length of the MPFL ³	46.4	5.2	38.8	45.7	57.9
Thickness of the MPFL in the middle third ³	1.4	0.4	0.7	1.5	2.4
Thickness of the MPFL at the patellar insertion ³	1.7	0.6	0.9	1.5	2.7
Thickness of the MPFL at the femoral insertion ³	1.2	0.5	0.4	1.3	2.7

¹Measured in years

²Measured in meters

³Measured in millimeters

Table 2 – General descriptive analysis for the categorical variable "Wiberg".

Wiberg	Total	(%)
I	11	48.00%
II	12	52.00%

Table 3 – Relationship between length of the MPFL and each of the variables.

Comparisons	Correlation coefficient	p-value
MPFL length vs. age	-0.012 ¹	0.955
MPFL length vs. height	0.373 ¹	0.08
MPFL length vs. interepicondylar distance (axial)	0.267 ¹	0.218
MPFL length vs. interepicondylar distance (coronal)	0.259 ¹	0.232
MPFL length vs. height of the patella	0.293 ¹	0.174
MPFL length vs. depth of the trochlea	0.014 ¹	0.948
MPFL length vs. prominence of the ventral trochlea	0.400 ¹	0.059
MPFL length vs. angle of the trochlear sulcus	-0.150 ¹	0.494
MPFL length vs. inclination of the lateral facet	-0.055 ¹	0.803
MPFL length vs. ratio between the trochlear facets	0.181 ¹	0.409
MPFL length vs. size of the lateral facet	0.060 ¹	0.785
MPFL length vs. size of the medial facet	-0.101 ¹	0.648
MPFL length vs. angle of lateral inclination of the patella	0.171 ²	0.435

Table 4 – Relationship between MPFL thickness in the middle third and each of the variables.

Comparisons	Correlation coefficient	p-value
MPFL thickness vs. age	-0.452 ¹	0.031
MPFL thickness vs. height	0.195 ¹	0.373
MPFL thickness vs. lateral condylar size (anteroposterior)	0.471 ¹	0.023
MPFL thickness vs. medial condylar size (anteroposterior)	0.412 ¹	0.051
MPFL thickness vs. interepicondylar distance (axial)	0.451 ¹	0.031
MPFL thickness vs. interepicondylar distance (coronal)	0.439 ¹	0.036
MPFL thickness vs. height of the patella	0.406 ¹	0.055
MPFL thickness vs. depth of the trochlea	0.253 ¹	0.243
MPFL thickness vs. prominence of the ventral trochlea	0.261 ¹	0.229
MPFL thickness vs. angle of the trochlear sulcus	-0.183 ¹	0.403
MPFL thickness vs. inclination of the lateral facet	-0.297 ¹	0.169
MPFL thickness vs. ratio between the trochlear facets	-0.290 ¹	0.179
MPFL thickness vs. size of the lateral facet	0.082 ¹	0.71
MPFL thickness vs. size of the medial facet	0.227 ¹	0.297
MPFL thickness vs. angle of lateral inclination of the patella	-0.045 ²	0.838

et al⁽²⁾. Higuchi et al⁽¹⁴⁾ analyzed the MPFL by means of MRI examination and found a mean MPFL length of 52 mm, while the mean length of this ligament found in the present study was 46.4 mm (range: 38.8-57.9 mm). This suggests that manual measurements on cadavers (which are less precise) find higher values. This may be due to difficulty in separating out the ligament during the dissection in order to make the measurement.

This suspicion becomes even more sustainable through our assessment of the ligament thickness measurements in the middle third, which would be difficult to achieve with extreme precision with unaided eyes. Both Nomura et al⁽⁷⁾ and LeGrand et al⁽²⁾ found a mean thickness of 0.44 mm for the ligament in their studies on cadavers, while the mean thickness of the MPFL in its middle third in the present study was 1.4 mm (range: 0.7-2.4 mm), which suggests that dissection of the ligament in specimens excludes from the measurement a good part of the structure that works towards medially stabilizing the patella. Unfortunately, Higuchi et al⁽¹⁴⁾ did not make thickness measurements in their study: such measurements would have provided a better basis for our reasoning. We also made thickness measurements on the MPFL at its femoral and patellar insertions, with values of 1.2 mm (range: 0.4-2.7 mm) and 1.7 mm (range: 0.9-2.7 mm), respectively. These measurements were not made on specimens because of the difficulty in performing dissections to measure the ligament at its insertion sites.

One limitation of our study was the impossibility of evaluating the width of the MPFL using MRI, which has been done in several studies on anatomical dissection of cadavers^(7,9). Because of the oblique layout and small dimensions, this measurement was impaired on conventional MRI slices. We chose not to produce special slices during the examination so that we would not modify the study protocol, which would have diminished the reproducibility and applicability of this study.

In 1941, Wiberg⁽¹⁷⁾ showed that the shape of the patella is also important in containing it within the trochlear sulcus. Like in the study by Higuchi et al⁽¹⁴⁾, who analyzed the MPFL by means of MRI examinations on healthy individuals and found that the patella was Wiberg type I or II in all cases⁽¹⁷⁾, the patellae of all the patients in the present study were classified as presenting

type I or II morphology. This was already expected, since none of the patients had complaints of instability.

A positive association was found between the thickness of the MPFL in its middle third and the interepicondylar distance (in the axial and coronal planes) and between MPFL thickness and measurement of the anteroposterior size of the lateral condyle. No studies evaluating these relationships were found in the literature, but it is plausible and to be expected that in knees of larger diameter, all the anatomical structures would have larger dimensions, and not just the MPFL.

No relationship was observed between the length or thickness of the MPFL and the patients' height. However, a negative association between MPFL thickness in the middle third and age was observed. No studies evaluating these relationships were found in

the literature, but this finding was interpreted as a consequence of the effects of the natural process of aging, reflected in the fibers of the MPFL.

CONCLUSION

The mean length of the MPFL was 46.4 mm, while the mean thickness of the ligament in its middle third was 1.4 mm.

A positive association was found between the thickness of the MPFL in its middle third and the interepicondylar distance (both along the coronal axis and in the axial plane) and between MPFL thickness and the measurement of the anteroposterior size of the lateral condyle; and a negative association between MPFL thickness in the middle third and the patient's age.

REFERENCES

- Amis AA. Current concepts on anatomy and biomechanics of patellar stability. *Sports Med Arthrosc*. 2007;15(2):48-56.
- LeGrand AB, Greis PE, Dobbs RE, Burks RT. MPFL reconstruction. *Sports Med Arthrosc Rev*. 2007;15(2):72-7.
- Salzmann GM, Weber TS, Spang JT, Imhoff AB, Schöttle PB. Comparison of native axial radiographs with axial MR imaging for determination of the trochlear morphology in patients with trochlear dysplasia. *Arch Orthop Trauma Surg*. 2010;130(3):335-40.
- Pfirrmann CW, Zanetti M, Romero J, Hodler J. Femoral trochlear dysplasia: MR findings. *Radiology*. 2000;216(3):858-64.
- Biedert RM, Bachmann M. Anterior-posterior trochlear measurements of normal and dysplastic trochlea by axial magnetic resonance imaging. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(10):1225-30.
- Amis AA, Firer P, Mountney J, Senavongse W, Thomas NP. Anatomy and biomechanics of the medial patellofemoral ligament. *Knee*. 2003;10(3):215-20.
- Nomura E, Inoue M, Osada N. Anatomical analysis of the medial patellofemoral ligament of the knee, especially the femoral attachment. *Knee Surg Sports Traumatol Arthrosc*. 2005;13(7):510-5.
- Philippot R, Chouteau J, Wegrzyn J, Testa R, Fessy MH, Moyen B. Medial patellofemoral ligament anatomy: implications for its surgical reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(5):475-9.
- Aragão JA, Reis FP, de Vasconcelos DP, Feitosa VL, Nunes MA. Metric measurements and attachment levels of the medial patellofemoral ligament: an anatomical study in cadavers. *Clinics (Sao Paulo)*. 2008;63(4):541-4.
- Guerrero P, Li X, Patel K, Brown M, Busconi B. Medial patellofemoral ligament injury patterns and associated pathology in lateral patella dislocation: an MRI study. *Sports Med Arthrosc Rehabil Ther Technol*. 2009;1(1):17.
- Kaba R, Mashru S, Sooriakumaran P. Why do orthopaedic surgeons ignore the medial patellofemoral ligament? *Int J Surg*. 2004;2(2):101-3.
- Balcarek P, Ammon J, Frosch S, Walde TA, Schüttrumpf JP, Ferlemann KG, Lill H, Stürmer KM, Frosch KH. Magnetic resonance imaging characteristics of the medial patellofemoral ligament lesion in acute lateral patellar dislocations considering trochlear dysplasia, patella alta, and tibial tuberosity-trochlear groove distance. *Arthroscopy*. 2010;26(7):926-35.
- Camanho GL, Viegas AC. Estudo anatômico e artroscópico do ligamento femoropatellar medial. *Acta Ortop Bras*. 2003;11(3):145-9.
- Higuchi T, Arai Y, Takamiya H, Miyamoto T, Tokunaga D, Kubo T. An analysis of the medial patellofemoral ligament length change pattern using open-MRI. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(11):1470-5.
- Tuxøe JI, Teir M, Winge S, Nielsen PL. The medial patellofemoral ligament: a dissection study. *Knee Surg Sports Traumatol Arthrosc*. 2002;10(3):138-40.
- Reider B, Marshall JL, Koslin B, Ring B, Giris FG. The anterior aspect of the knee joint. *J Bone Joint Surg Am*. 1981;63(3):351-6.
- Wiberg G. Roentgenographic and anatomic studies on the femoropatellar joint, with special reference to chondromalacia patellae. *Acta Orthop Scand*. 1941;12:319-410.