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Research article

Imaging appearance and prevalence of the anteromedial meniscofemoral ligament: A potential pitfall to anterior cruciate ligament analysis on MRI

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ABSTRACT

Purpose: To describe the aspect of the anteromedial meniscofemoral ligament on MRI and to assess its prevalence.

Method: One thousand five hundred sixty knee MRI studies were retrospectively evaluated for the presence of an anteromedial meniscofemoral ligament. In addition to these studies, nine full MRI studies from our department's image archive were also analysed. The anteromedial meniscofemoral ligament length, thickness, and angle with respect to the tibial plateau were evaluated independently by two radiologists. For comparison purposes, the anterior cruciate ligament was assessed in the same manner.

Results: There was a 0.77% prevalence of the anteromedial meniscofemoral ligament in the study population. Compared to the anterior cruciate ligament, the anteromedial meniscofemoral ligament was 80.6%–83.8% thinner according to both observers ($P = 0.0002$), with a mean thickness of 1.53 ± 0.47 mm and 1.80 ± 0.66 mm determined by observers 1 and 2, respectively. The anteromedial meniscofemoral ligament angles were 15%–17.7% lower than the anterior cruciate ligament angles ($P < 0.003$). Interobserver reproducibility was considered excellent for the length and angle measurements (ICCs varying from 0.85–0.97) and good for the thickness measurements (ICCs 0.66–0.77).

Conclusions: The anteromedial meniscofemoral ligament is a rare structure that can be differentiated from the anterior cruciate ligament based on morphologic criteria.

1. Introduction

The anteromedial meniscofemoral ligament (AMMFL) described by Mc Cormack et al. is a relatively unknown anatomic structure with a wide variation in prevalence reported in previous literature (1.2% to 15%) [1–5]. This accessory ligament classically expands from the anterior horn of the medial meniscus to the medial aspect of the lateral femoral condyle (Fig. 1). The AMMFL is considered a distinct anatomic structure from the infrapatellar plica, which is a synovial fold that passes through Hoffa's fat pad and connects the lower edge of the patella to the anterior portion of the inter-condylar notch [6]. Although the role of the AMMFL in knee stabilization and in causing patient symptoms when injured is likely minimal, due to its anatomic position, it could be misinterpreted as fibres of the anterior cruciate ligament (ACL) [1,5,7].

The purpose of the study is to describe the appearance of the AMMFL on MRI and to assess its prevalence. This information could increase radiologists' awareness of this ligament and improve its identification, thus avoiding potential interpretation errors in MRI studies of patients with ACL tears.

2. Materials and methods

2.1. Patients

One thousand five hundred and sixty MRIs of knees taken from November 2016 to April 2017 were retrospectively evaluated. In addition, nine full knee MRI studies that demonstrated an AMMFL upon retrieval from our institution's image archive (studies performed between 2009 and 2017) were also evaluated.

Abbreviations: AMMFL, anteromedial meniscofemoral ligament; ACL, anterior cruciate ligament; MRI, magnetic resonance imaging; PACS, picture archiving and communication system; ICC, intraclass correlation coefficient

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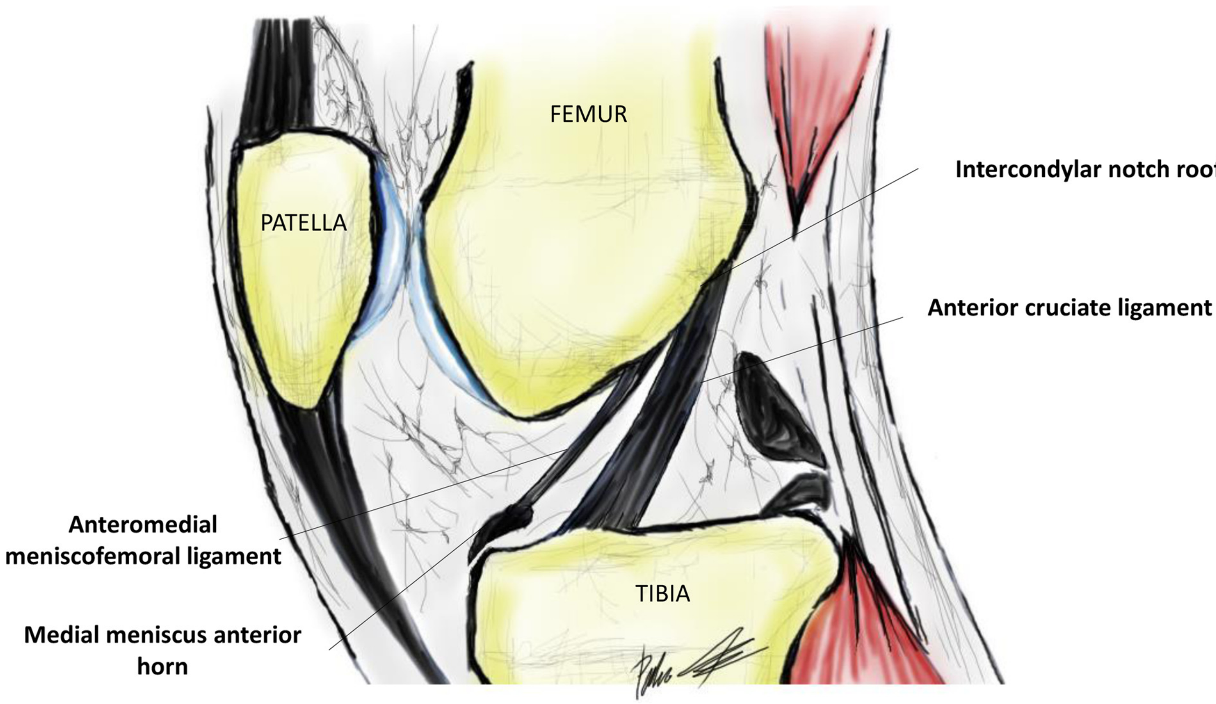

Fig. 1. Schematic drawing demonstrating the anatomy of the anteromedial meniscofemoral ligament and its position compared to the anterior cruciate ligament.

All included patients had been imaged due to knee pain of various aetiologies (inflammatory joint disease, post-traumatic and micro-traumatic injuries, and tumours around the knee).

In our institution, non-interventional retrospective studies on fully anonymized images acquired with conventional imaging protocols do not require ethics committee approval (IRB waved).

2.2. Image acquisition

Images were acquired with three MRI scanners with dedicated knee coils: 1.5 T MRI Signa HDxt, 1.5 T Brivo MR355, and 3 T MRI Discovery MR750W (GE Healthcare, Milwaukee, WI, USA). All patients were put in a supine position with the knee extended and with neutral rotation of the lower limb. Images were acquired with conventional clinical protocols that included T2-weighted or proton-density-weighted fat-saturated fast spin-echo sequences in the three orthogonal planes as well as an axial T1-weighted fast spin-echo sequence. The acquisition parameters of these sequences in each of the MRI scanners used are presented in Table 1.

AMMFL evaluation was performed mainly on oblique sagittal sequences. This ligament could also be seen in its short axis on axial and coronal sequences.

The oblique sagittal plane was defined parallel to the external surface of the lateral femoral condyle [8].

Table 1
Oblique sagittal T2/DP-weighted fat-saturated acquisition parameters.

MR Scanner model	Signa HDxt	Discovery MR750W	Brivo MR355
Field strength (T)	1.5	3	1.5
FOV (mm)	16	16	15.5
Matrix	320 × 288	416 × 352	352 × 256
TE (ms)	45	73.2	30
TR (ms)	2608	5265	4766
ETL	10	22	15
Bandwidth (Hz)	31.25	40.87	41.67
NEX	2	3	3
Acceleration factor	2	2	2
Slice thickness (mm)	3.5	2	3.5
Gap (mm)	0.5	1	0.5

2.3. Image analysis

Images were displayed on a PACS workstation (Fujifilm Synapse v4.1.600, Fujifilm, USA) and were evaluated independently by two radiologists with three and seven years of clinical experience (observers 1 and 2, respectively). Two multiplanar reformatted images demonstrating the full length of the AMMFL and the ACL were created from the oblique sagittal images of each study by observer 1. Image quality degradation in these reformatted images was acceptable because the reformatted images were in a plane that was only a few degrees different than the original oblique sagittal plane used (Fig. 2). These images were created to allow measurements of the full ligament length.

The AMMFL was considered present when a homogeneous low signal band anterior to the ACL was visualized connecting the medial portion of the anterior horn of the medial meniscus (anterior root ligament) to the posterolateral intercondylar notch. The length and thickness of the AMMFL and ACL were measured on two reformatted images showing the long axis of these two ligaments (Fig. 3A). AMMFL and ACL orientations were also assessed by measuring the angle formed between two lines. The first line was drawn perpendicular to the long axis of the tibia (defined by the orientation of the posterior cortex of the tibial diaphysis in the sagittal plane) passing through the most anterior fibres of the distal insertion of the AMMFL and ACL. The second line was drawn intersecting the most anterior fibres of the origin and distal insertions of the ACL and AMMFL (Fig. 3B). The posterior tibial cortex was used to determine the tibial long axis because it has fewer contour variations, followed by determining the anterior counterpart since the tibial tuberosity causes anterior cortical contour abnormalities [8].

The integrity of the ACL was evaluated in consensus by both observers using classic diagnostic criteria [9]. The ACL was considered to be torn if a clear loss of ligament fibre continuity was observed in association with a change in the ligament orientation compared to Blumensaat's line. ACL measurements were not performed in patients with ACL tears.

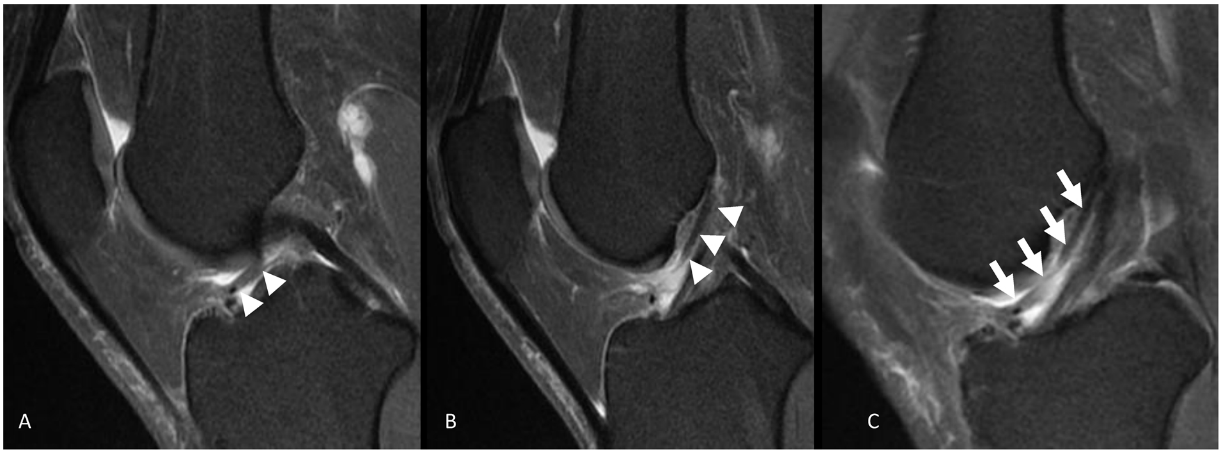

Fig. 2. 46-year-old female with left knee pain and clinical suspicion of a meniscal tear. A–B) Consecutive oblique sagittal T2-weighted fat-saturated images demonstrating an AMMFL (arrowheads). C) Sagittal T2-weighted fat-saturated oblique sagittal reformation of the same data set demonstrating an AMMFL in a single slice (arrows). Note that the image quality of the reformatted image C) remains similar to the quality of the original (A and B).

2.4. Statistical analysis

Measurements are presented as the mean ± standard deviation. The coefficient of variation (standard deviation/mean * 100) was calculated for all measurements. Intra-class correlation values (ICCs) were calculated to assess the interobserver agreement of the measurements performed. ICC values of 0–0.20 were considered to represent slight agreement; 0.21–0.4 fair agreement; 0.41–0.60 moderate agreement; 0.61–0.80 good agreement; and 0.81–1 excellent agreement. A paired Wilcoxon test was used to evaluate the difference between the AMMFL and ACL measurements. A *P* value of 0.05 was considered the threshold of statistical significance.

3. Results

Among the 1560 MRI studies evaluated, an AMMFL was identified in 12 patients (0.77% prevalence). The nine patients recovered from the image archive were not considered in the calculation of the AMMFL prevalence. When all patients available were added, a total of 21 patients with an identifiable AMMFL were available. Among the patients with an AMMFL, the mean age was 46.5 ± 14.4 years; there were 17 males and four females. In three patients, an AMMFL was observed in association with an ACL tear (14%) (Fig. 4). Interobserver agreement was considered excellent for the length and angle measurements (ICCs varying from 0.85–0.97) and good for the thickness measurements (ICCs varying from 0.66–0.77). The mean values of the measurements performed as well as the respective ICC values are presented in Table 2.

An AMMFL was observed in all our patients on oblique sagittal

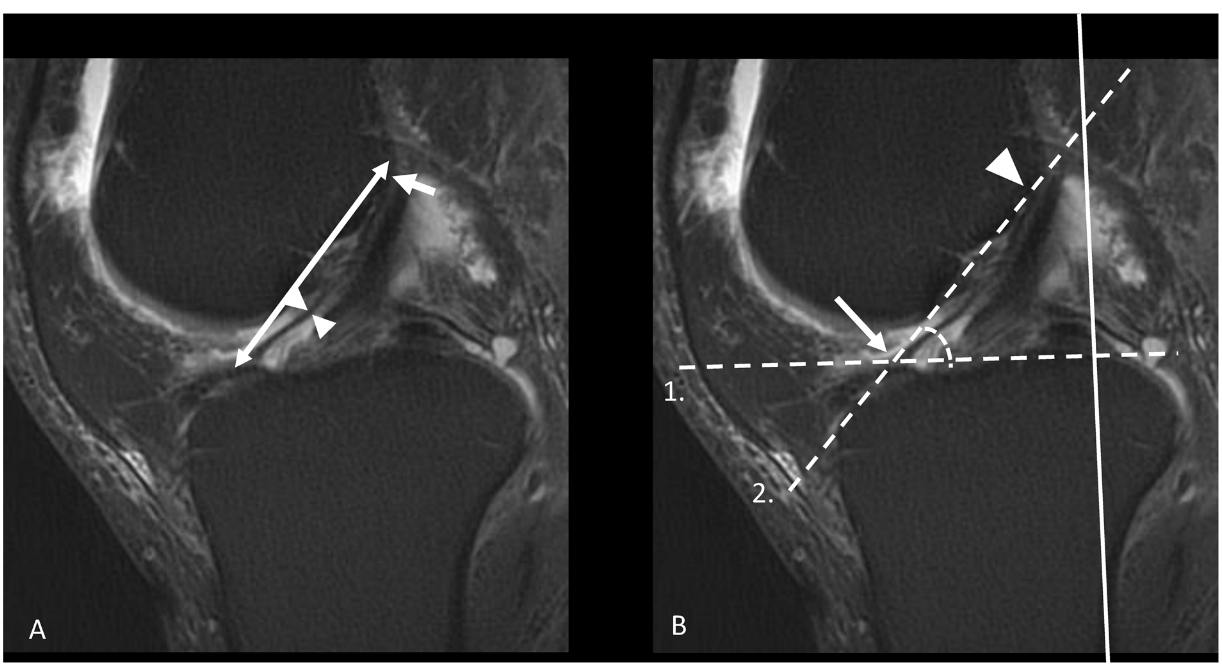

Fig. 3. 65-year-old male with right knee pain after trauma. A) Oblique sagittal T2-weighted fat-saturated reformatted image demonstrating the measurement procedure for the AMMFL length (double-headed arrow) and thickness (between arrowheads). B) Oblique sagittal T2-weighted fat-saturated reformatted image demonstrating the AMMFL angle measurement procedure. The white line corresponds to the orientation of the posterior tibial cortex (tibial long axis). Dashed line 1 is perpendicular to the tibial long axis and passes through the distal insertion of the AMMFL (arrow), while dashed line 2 connects the proximal (arrowhead) and distal (arrow) insertion of the AMMFL. The angle between lines 1 and 2 represents the AMMFL angle. A similar procedure was used to measure the ACL.

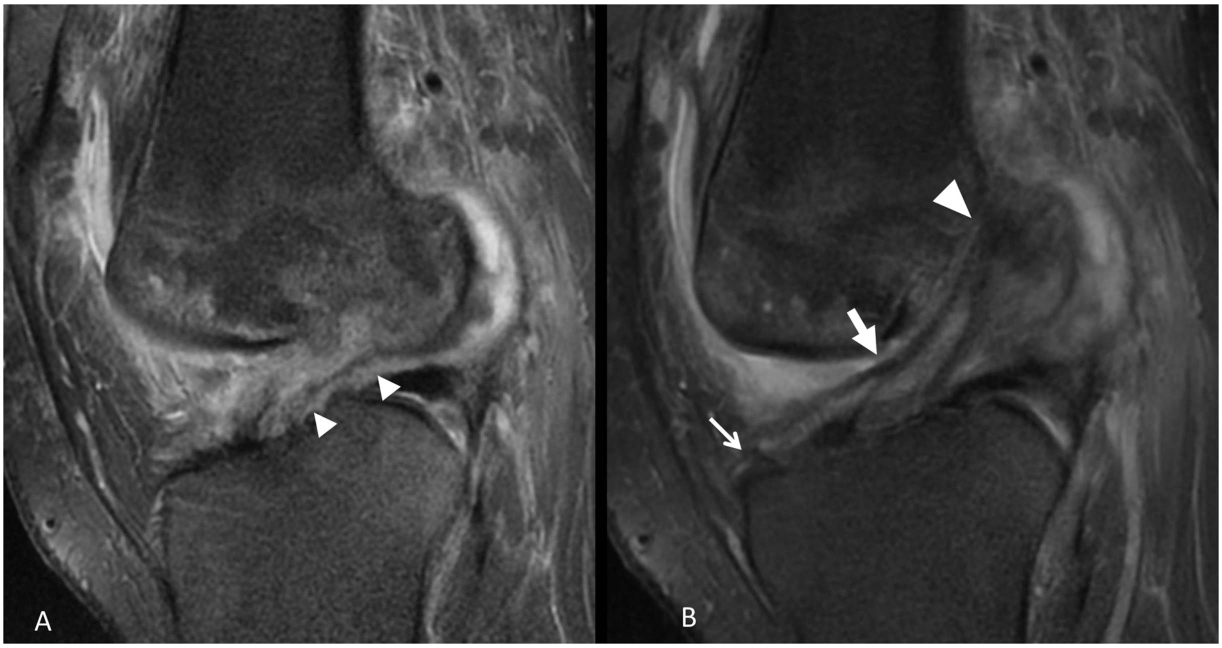

Fig. 4. 28-year-old male victim of a motor vehicle accident with knee trauma, multiple traumatic injuries and clinical knee instability. A) T2-weighted fat-saturated oblique sagittal reformatted image at the level of the ACL showing a loss of ligament fibre continuity and a horizontal position of the remaining fibres (arrowheads). B) Oblique sagittal reformation of the same patient showing the AMMFL (fat arrow) with the origin at the roof of the intercondylar notch (arrowhead) and the anterior horn of the medial meniscus (thin arrow). Note that this structure can be misinterpreted as intact ACL fibres.

Table 2
Mean values and interobserver variability of AMMFL and ACL measurements.

	Reader 1	Reader 2	ICC
AMMFL Length (mm)	37,4 ± 6,9	37,2 ± 6,4	0,96
ACL Length (mm)	42,7 ± 3,6	41,5 ± 4,2	0,85
AMMFL angle (°)	48,6 ± 8,3	47,7 ± 7,9	0,97
ACL angle (°)	57,2 ± 6,1	58 ± 6,3	0,91
AMMFL thickness (mm)	1,53 ± 0,47	1,80 ± 0,66	0,66
ACL thickness (mm)	9,5 ± 1,2	9,3 ± 1,6	0,72

images as a low-signal T2-weighted linear band: the AMMFL could be followed from its distal insertion on the anterior horn of the medial meniscus to its origin on the intercondylar notch. On axial and coronal sequences, this ligament appeared in its short axis as a round structure with low signal intensity anterior to the ACL (Fig. 5).

The AMMFL was 80.6%–83.8% thinner than the ACL according to both observers ($P = 0.0002$ for both observers). The mean AMMFL thickness was 1.53 ± 0.47 [0.9–2.6] mm and 1.80 ± 0.66 [0.8–3] mm, while the mean ACL thickness was 9.5 ± 1.2 [7.2–11.5] mm and 9.3 ± 1.6 [7–11.5] mm according to observers 1 and 2, respectively. The AMMFL angles were 15%–17.7% lower than the ACL angles (mean 48.6 ± 8.3° [28–62] and 47.7 ± 7.9° [27–61] versus 57.2 ± 6.1° [47–69] and 58 ± 6.3° [48–71] for observers 1 and 2, respectively) ($P = 0.0031$ and 0.0008, respectively). In three patients according to observer 1 (17%) and two patients according to observer 2 (11%), the AMMFL angle was steeper than the ACL angle. The AMMFL length was 10.4%–12.4% shorter than the ACL length ($P = 0.0004$ and 0.0044 for observers 1 and 2, respectively). The mean AMMFL length was 37.4 ± 6.9 [19–48] mm and 37.2 ± 6.4 [21–46] mm, while the mean ACL length was 42.7 ± 3.6 [36–48] mm and 41.5 ± 4.2 [38–43] mm according to observers 1 and 2, respectively. In one patient according to reader 1 (6%) and two patients according to reader 2 (11%), the AMMFL was considered to be longer than the ACL.

4. Discussion

The AMMFL is an accessory anterior knee ligament that has been scarcely evaluated in the radiological literature [2,5,7,10]. The prevalence of AMMFL was 0.77% in our study population, which is comparable to the results of a recent arthroscopy study by Kim et al. (0.6% prevalence) [7]. The AMMFL has uniform low signal intensity on T1- and T2-weighted images and is best seen on oblique sagittal images anterior to the ACL. The anatomy of the distal insertion of the AMMFL may help differentiate between AMMFL and ACL fibres, as the latter insert at the anterior portion of the proximal tibia, whereas the AMMFL inserts onto the root ligament of the anterior medial meniscus [11]. The morphology and position of the AMMFL can also be used to differentiate it from the ACL. The AMMFL is significantly thinner (approximately 20% of ACL thickness) and more horizontally oriented (approximately 15°) than the ACL ($P < 0.003$). The AMMFL is also roughly five millimetres shorter than the ACL ($P < 0.004$). The AMMFL can also be mistaken for the infra-patellar plica (ligamentum mucosum). The latter structure, however, spans from the inferior edge of the patella to the intercondylar notch, usually with a descending rather than ascending trajectory, passing through Hoffa's fat pad [6]. Hypothetically, the AMMFL can be ruptured with an intact ACL. In this situation, the absence of secondary signs of ACL rupture (bone bruises, posterior cruciate ligament verticalization, anterior tibial translocation, *etc.*) and a reassuring physical examination can help confirm ACL integrity. This information may help identify this accessory ligament and facilitate its differentiation from ACL fibres.

Histopathological examination of this structure in different studies has confirmed its ligamentous nature with dense fibrous tissue and collagen interspersed with parallel rows of fibroblasts, thus evoking a ligamentous structure [1,2]. Conversely, Nakajima et al. [12] has suggested that this ligament contains the histological features of a meniscal structure. This difference could be related to variable biopsy sites, with a biopsy performed near the meniscal root ligament in the study of Nakajima et al. The AMMFL has had no biomechanical role demonstrated to date. Some authors have suggested that the AMMFL might play an anchor role for the anterior horn of the medial meniscus [1,7].

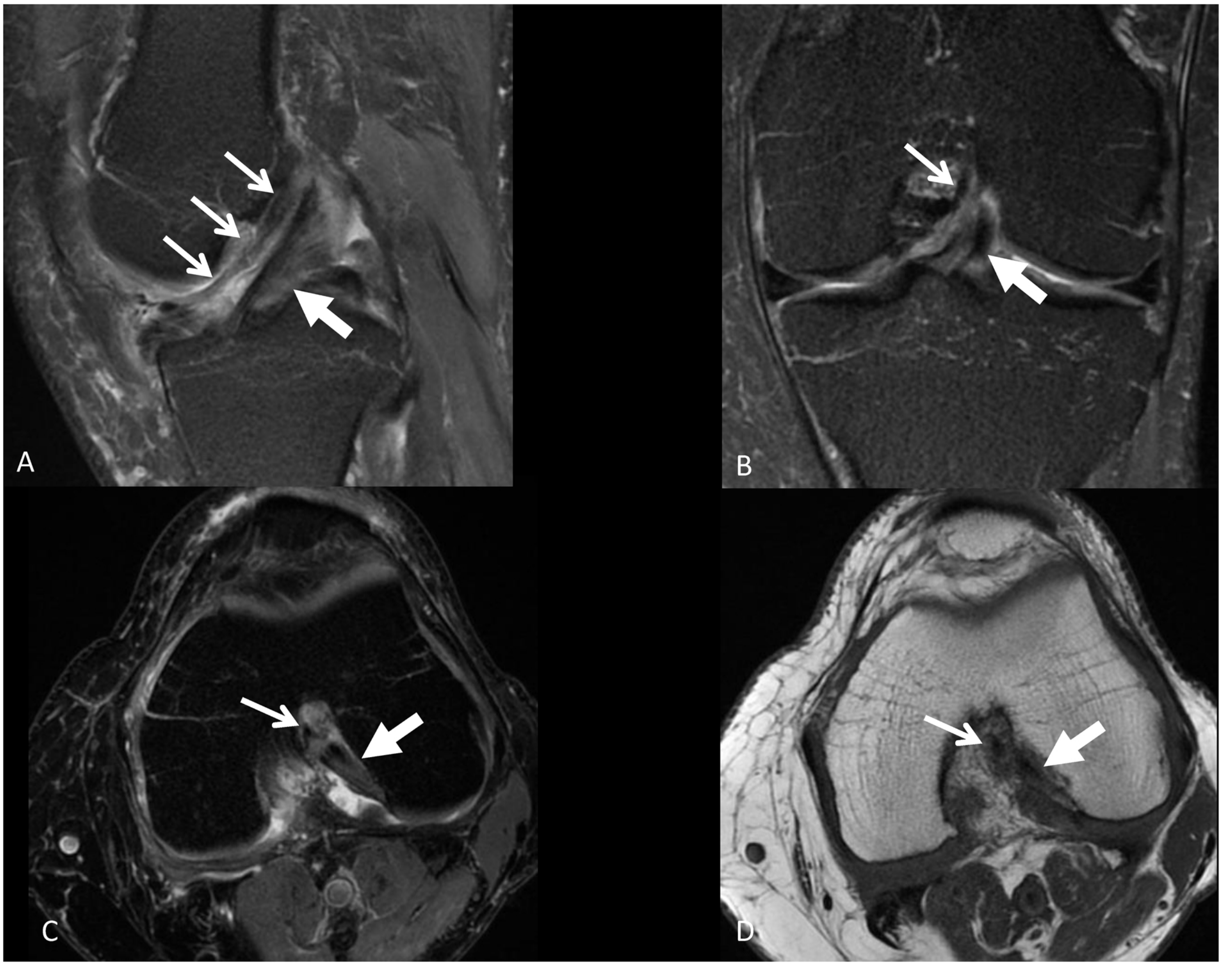

Fig. 5. 60-year-old male with a cracking sensation when moving from a crouched position to a standing position a month ago. Sagittal T2-weighted fat-saturated (A), coronal T2-weighted fat-saturated (B), axial T2-weighted fat-saturated (C) and T1-weighted (D) images showing the AMMFL (thin arrow) and the ACL (fat arrow) on the same slice. The AMMFL is seen in oblique sagittal images as a low-signal T2-weighted linear band from its distal insertion on the anterior horn of the medial meniscus to its origin on the intercondylar notch. On axial and coronal T2-weighted and axial T1-weighted sequences, the AMMFL appears as an oval structure anterior to the ACL with a low signal intensity in all pulse sequences.

In a report of three cases, Soejima et al. suggested that the AMMFL might be implicated in medial meniscus degeneration [5].

For most authors, the AMMFL is an insertion variant of the anterior horn of the medial meniscus. Ohkoshi et al. have described four types of variants of the anterior horn of the medial meniscus in which the anterior horn is not attached directly to the tibia: an ACL type, where the anterior horn is attached to the ACL; a transverse meniscal ligament type, where the anterior horn is attached to the transverse ligament; a coronary ligament type, where the anterior horn is attached to the coronary ligament; and a synovial infra-patellar type, where the anterior horn is attached to the synovial fold [13]. The AMMFL may correspond to a variant of the ACL-type anterior root insertion of the medial meniscus. Cha et al. have reported two origins of the AMMFL: the ACL or the intercondylar notch [10]. In our study, the origin of all evaluated AMMFLs was the posterolateral wall of the intercondylar notch.

Various limitations of this study need to be acknowledged. There was no arthroscopic confirmation of the AMMFL visualized on MRI because the discovery of this ligament was fortuitous in all patients, most of whom had no indication for surgical treatment. Three of the patients presenting with an AMMFL underwent arthroscopy, but there was no mention of an AMMFL in the surgical reports because this structure is deemed to have no surgical importance. The number of AMMFLs studied was relatively small, with few cases associated with ACL tears. Despite this limitation, this study had a considerable number of cases compared to what has been reported in prior literature. Knee flexion may influence the angle measurements performed. To limit this potential bias, all MRI studies were performed with the knee in the neutral position (close to full extension). In studies performed with higher degrees of knee flexion, AMMFL and ACL angle measurements should be interpreted with caution.

In conclusion, an AMMFL was observed in approximately 0.77% of the population studied. The AMMFL can be differentiated from the ACL mainly from its distal insertion as well as, we believe, from certain morphologic MRI criteria, as this ligament is thinner, shorter and more horizontally oriented than the ACL. The distal insertion points of these two ligaments are also distinct, as the AMMFL inserts onto the anterior horn of the medial meniscus. This information may help avoid interpretation errors in cases of ACL tears in patients with an AMMFL.

Declaration of Competing Interest

None.

References

[1] A.F. Anderson, M.H. Awh, C.N. Anderson, The anterior meniscofemoral ligament of the medial meniscus: case series, Am. J. Sports Med. 32 (June 4) (2004) 1035–1040.
[2] B. Coulier, O. Himmer, Anteromedial meniscofemoral ligament of the knee: CT and MR features in 3 cases, JBRBTR 91 (November–December 6) (2008) 240–244.
[3] D. McCormack, J. McGrath, Antero-medial menisco-femoral ligament, Clin. Anat. 5

(6) (1992) 485–487.
[4] K.G. Shea, C. Westin, J. West, Anomalous insertion of the medial meniscus of the knee. A case report, J. Bone Joint Surg. Am. 77 (December 12) (1995) 1894–1896.
[5] T. Soejima, H. Murakami, N. Tanaka, K. Nagata, Anteromedial meniscofemoral ligament, Arthroscopy 19 (January 1) (2003) 90–95.
[6] R.L. Cothran, P.M. McGuire, C.A. Helms, N.M. Major, D.E. Attarian, MR imaging of infrapatellar plica injury, AJR Am. J. Roentgenol. 180 (May 5) (2003) 1443–1447.
[7] Y.M. Kim, Y.-B. Joo, Anteromedial meniscofemoral ligament of the anterior horn of the medial Meniscus: clinical, magnetic resonance imaging, and arthroscopic features, Arthrosc. J. Arthrosc. Relat. Surg. 34 (5) (2018) 1590–1600.
[8] G. Oldrini, P.G. Teixeira, A. Chanson, M.L. Erpelding, B. Osemont, M. Louis, et al., MRI appearance of the distal insertion of the anterior cruciate ligament of the knee: an additional criterion for ligament ruptures, Skeletal Radiol. 41 (September 9) (2012) 1111–1120.
[9] E.A. Brandser, M.A. Riley, K.S. Berbaum, G.Y. el-Khoury, D.L. Bennett, MR imaging of anterior cruciate ligament injury: independent value of primary and secondary signs, AJR Am. J. Roentgenol. 167 (July 1) (1996) 121–126.
[10] J.G. Cha, K.D. Min, J.K. Han, H.S. Hong, S.J. Park, J.S. Park, et al., Anomalous insertion of the medial meniscus into the anterior cruciate ligament: the MR appearance, Br. J. Radiol. 81 (January 961) (2008) 20–24.
[11] D. Araki, E. Thorhauer, S. Tashman, Three-dimensional isotropic magnetic resonance imaging can provide a reliable estimate of the native anterior cruciate ligament insertion site anatomy, Knee Surg. Sports Traumatol. Arthrosc. 26 (May 5) (2018) 1311–1318.
[12] T. Nakajima, Y. Nabeshima, H. Fujii, A. Ozaki, H. Muratsu, S. Yoshiya, Symptomatic anomalous insertion of the medial meniscus, Arthroscopy 21 (May 5) (2005) 629.
[13] Y. Ohkoshi, T. Takeuchi, C. Inoue, T. Hashimoto, K. Shigenobu, S. Yamane, Arthroscopic studies of variants of the anterior horn of the medical meniscus, Arthroscopy 13 (December 6) (1997) 725–730.