Eur Radiol (2002) 12:824–829
DOI 10.1007/s003300101083

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MR imaging of the anterior intermeniscal ligament: classification according to insertion sites

Received: 27 March 2001
Revised: 31 May 2001
Accepted: 9 July 2001
Published online: 5 September 2001

This study was presented as a scientific exhibit (C-0553) (and included in the Poster Walking Tour) in ECR 2001 in Vienna, Austria (2–6 March 2001).

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Abstract Our objective was to study the frequency of anterior intermeniscal ligament on MR imaging and to make a classification according to its insertion sites on MR images. Sagittal T1-weighted and thin-section transverse T2*-weighted MR images of the knee were prospectively evaluated in 229 subjects without significant synovial effusion or total rupture of the anterior cruciate ligament. By using thin-section transverse images, the ligament was classified into three types according to its insertion sites (type A: between anterior horns of medial and lateral menisci; type B: between anterior horn of medial meniscus and anterior margin of lateral meniscus; type C: between anterior margins of medial and lateral menisci). On sagittal images location of the ligament was determined with respect to a line drawn between anterior of the tibial epiphysis and posterior of the intercondylar notch to look for a relation between its type on transverse images and location on sagittal images. Separately, arthroscopy was made in 36 patients to verify the MR assessment of the presence of the ligament. Anterior intermeniscal ligament was found in 53 % of the subjects. Type B was the most common group (58 %). Magnetic resonance imaging has a sensitivity and a specificity of 67 and 100 %, respectively, in the detection of the ligament. Types A and C had a statistically significant location posterior and anterior, respectively, to the master line on sagittal images. In arthroscopy, the ligament was either cord-like (67 %) or flat (33 %) in appearance. Routine sagittal MR images can help identify anterior intermeniscal ligament.

Keywords Anterior intermeniscal ligament · Insertion sites · MR imaging

Introduction

The anterior intermeniscal ligament (AIL) of the knee, also known as the transverse geniculate ligament, lies between the anterior horns of the menisci and is not a constant feature in all individuals. Although the roles of the cruciate and collateral ligaments in knee stability have been thoroughly addressed, the biomechanical function of the AIL and its part in the joint congruity and meniscal motion have been the subject of relatively few studies [1, 2, 3]. A recent study showed that the AIL had a restricting effect on anterior–posterior excursion of the anterior horn of the medial meniscus at lower degrees of knee flexion [3].

Several cadaveric and imaging studies of this ligament have been made and it has been shown to be of variable thickness when present [4, 5, 6, 7, 8, 9]. In a recent cadaveric study, three distinct types of AIL were described with regard to its insertion on or near the anterior horns of the menisci [4]. According to the study by Nelson and LaPrade [4], type I AIL has attachments to the anterior horn of the medial meniscus and anterior margin of the lateral meniscus, type II AIL has medial attachment to the anterior margin of the medial meniscus and lateral attachment to the joint capsule anterior to lateral meniscus, and type III AIL has medial and lateral capsular anterior attachments only, with no direct attachments to the anterior horn of the medial meniscus or to the lateral meniscus (Fig. 1) [4].

The AIL can sometimes be depicted in a lateral knee radiograph when there is enough surrounding fat to create adequate contrast around it [7, 8]; however, it is with MR imaging that the AIL can best be visualized non-invasively. When present, this ligament is usually seen easily in the anterior part of the knee joint as a low-intensity band in MR imaging examinations of the knee [8, 9]. There is a single MR imaging study reporting the frequency of AIL in 50 patients [8]; however, no MR imaging investigation to classify this structure with regard to its insertion sites has been reported. Moreover, arthroscopic verification of MR imaging findings regarding the AIL has not been previously reported. We aimed in this study to determine the frequency of AIL on MR imaging in a large group of subjects, to test the accuracy of MR imaging in the detection of AIL by performing arthroscopy in a smaller group of patients, and to make an MR imaging classification according to its insertion sites.

Materials and methods

Study groups

Group I

In the first group of subjects, frequency of the AIL on MR imaging was investigated in 229 patients. This group consisted of patients who presented with knee problems, patients who were referred for an MR examination of another body part and who volunteered for an MR examination of the knee, and volunteers without any knee problems. Persons who had undergone arthroscopy or surgery to the knee previously were not included in this group; moreover, persons detected to have rupture of the anterior cruciate ligament (ACL) in their MR imaging examinations were excluded from the study group since the incident causing the rupture of their ACL might have caused rupture of a pre-existing AIL as well. For all subjects MR imaging of the knee was made for one side only.

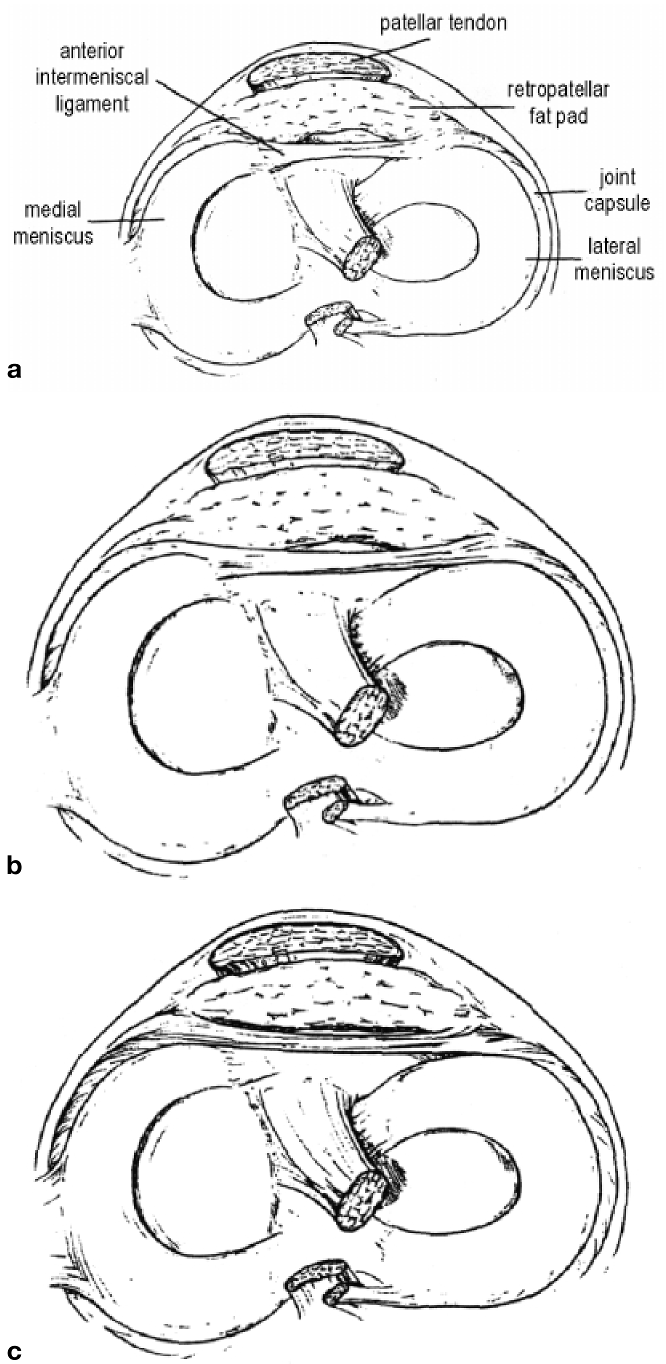


Fig. 1 a–c Three types of insertion patterns of the anterior intermeniscal ligament (AIL) as demonstrated in a cadaveric study by Nelson and LaPrade [4]. **a** Type I has attachments to the anterior horn of the medial meniscus and anterior margin of the lateral meniscus. **b** Type II has medial attachment to the anterior margin of the medial meniscus and lateral attachment to the joint capsule anterior to lateral meniscus. **c** Type III has medial and lateral capsular anterior attachments only, with no direct attachments to the anterior horn of the medial meniscus or to the lateral meniscus

There were 115 females and 114 males in this group, between the ages of 8 and 86 years (range 8–82 and 11–86 years of age for females and males, respectively), and mean age was 39 years (both for females and males). The MR imaging examination was performed on the right knee in 115 patients and on the left knee in 114 persons. The subjects were grouped as being under 20 or over 59 years of age or in decades of ages in between.

Group II

In the second group of subjects, knee arthroscopy was performed following MR imaging. Thirty-six patients who underwent arthroscopy of the knee after consideration of their clinical features and MR imaging examination findings were included in this group. For all subjects MR imaging of the knee was made for one side only. There were 21 males and 15 females, between the ages of 17 and 60 years (range 17–60 and 18–60 years of age for males and females, respectively), and mean age was 37 years (males 34 years, females 42 years). The MR imaging examination and later arthroscopy were performed on the right knee in 18 patients and on the left knee in 18 patients. Of the 36 patients in this second group, 30 were from group I; the remainder were patients who had MR imaging findings of rupture of the ACL – and therefore had been excluded from group I – and for whom arthroscopy was being planned and was actually performed later.

Informed consent was obtained after the nature of MR imaging examination and arthroscopy had been explained. The study was approved by our institutional review board.

MR imaging

The MR imaging was performed on all subjects with a 0.5-T unit (Gyroscan T5-NT, Philips Medical Systems, Best, The Netherlands) utilizing a receive-only surface coil. For patients presenting with a knee problem, our standard MR imaging examination of the knee consisted of obtaining three localizer images, acquired in the coronal, sagittal, and axial planes, followed by sagittal T1-weighted (TR/TE: 500/20 ms; 256 × 256 matrix; three signal averages; field of view 19 cm; 4-mm section thickness; 0.4- or 1-mm intersection spacing), proton-density and T2-weighted spin-echo sequences, transverse T2*-weighted gradient-echo recalled, and coronal spectral presaturation inversion recovery (SPIR) sequences. In patients referred for MR imaging of the knee, in addition to these basic MR imaging examination sequences for the knee, a transverse 3D T2*-weighted gradient-echo-recalled sequence was performed with the following parameters: TR/TE 37/27 ms; flip angle 25°; 256 × 256 matrix; eight signal averages; field of view 20 cm; 1-mm section thickness). In patients referred for MR imaging of another body part and who agreed to have an additional MR imaging examination of one of their knees, and in asymptomatic volunteers, the above-mentioned sagittal T1-weighted spin-echo and transverse 3D T2*-weighted gradient-echo-recalled sequences were performed after obtaining the three localizer images. Transverse 3D image set was appropriately – and slightly – angled to best visualize the AIL in its relation to the menisci when it was detected on sagittal images.

The MR images were interpreted by two radiologists (one a musculoskeletal radiologist). Consensus was reached in all cases. The AIL was considered to be present when it was seen in its entirety on consecutive MR images. Classification of the AIL was made according to its insertion sites, taking into consideration the cadaveric study of Nelson and LaPrade (Fig. 1) [4]. Three types of insertion of the AIL were noted according to their relation to the anterior horns of medial and lateral menisci on MR images (Fig. 2):

1. Type A: AIL merges inside the anterior horn of the medial meniscus medially and inside the anterior horn of the lateral meniscus laterally (Fig. 2a).
2. Type B: AIL merges inside the anterior horn of the medial meniscus medially and inserts to the anterior edge of the anterior horn of the lateral meniscus laterally (Fig. 2b).
3. Type C: AIL inserts to anterior edge of the anterior horn of the medial meniscus medially and to the anterior edge of the anterior horn of the lateral meniscus laterally (Fig. 2c).

Due to the limited spatial and contrast resolution of mid-field MR imaging when compared with a cadaveric study, our classification did not exactly match that of Nelson and LaPrade [4]. When compared with these authors' classification of the AIL according to its insertion sites based on their cadaveric study, type B in our study approximately corresponded to their type I and type C to their types II and III.

In order to investigate whether or not a relation existed between the three different types of AIL as determined on thin-section transverse MR images and the location of the ligament on sagittal T1-weighted MR images in all but two subjects in group I, a "master line" was drawn between the most posterior portion of the distal femur and the most anterior portion of the anterior cortex of the proximal tibia on the sagittal MR image displaying the intercondylar notch, when there was an AIL, and the distance of the center of the cross-sectional AIL to that line was measured (Fig. 3). Master line was not drawn in two cases (in group I) who had significant synovial fluid collection between the AIL and an intact ACL to displace and distend the AIL such that an erroneous determination of its type according to its insertion sites could have been made. The master line resembles, but is different from, Blumensaat's line, which marks the roof of the intercondylar fossa. Distance measurements were recorded as positive, negative, or zero, with regard to the location of the center of the cross-sectional AIL being anterior or posterior to the master line, or crossed by the master line, respectively.

Arthroscopy

Standard knee arthroscopy was performed in group II using a 4-mm 30° arthroscope (Storz GmbH, Tuttlingen, Germany) from the anterolateral portal. In order to look for the presence of an AIL, however, special care was taken and a 4-mm 70° arthroscope (Storz GmbH, Tuttlingen, Germany) was also utilized while examining the intercondylar notch region. The mean interval between MR imaging and arthroscopy was 13 days (range 0–104 days). During the procedure, AIL, when present, was seen as either a cord-like or a flat structure (Fig. 4).

Statistical analysis

The chi-square test was used in the statistical analysis of results.

Results

The AIL was detected on MR images in 122 subjects (53%) in group I. For males and females in this group, percentages of subjects with the AIL on MR images

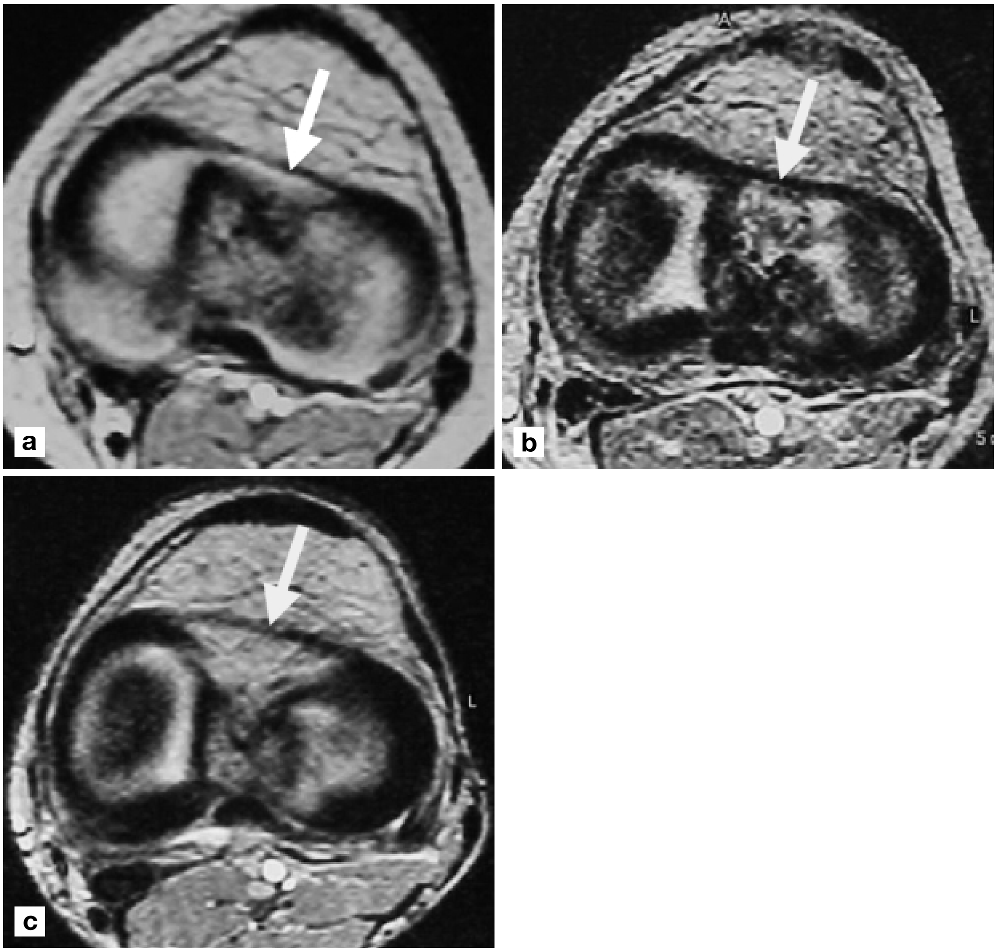


Fig. 2 a–c Transverse gradient-echo recalled MR images (TR/TE: 37/27 ms; flip angle 25°) showing the three types of insertion patterns of the AIL *(arrows)*. **a** Type A merges inside the anterior horn of the medial meniscus medially and inside the anterior horn of the lateral meniscus laterally. **b** Type B merges inside the anterior horn of the medial meniscus medially and inserts to the anterior edge of the anterior horn of the lateral meniscus laterally. **c** Type C inserts to anterior edge of the anterior horn of the medial meniscus medially and to the anterior edge of the anterior horn of the lateral meniscus laterally

were 47 and 59%, respectively. The MR images displayed an AIL in 54% on the right knees and in 53% on the left knees. For males the AIL was present in 45% of the right knees and 49% for the left knees, whereas for females these figures were 61 and 57%, respectively. There was no statistically significant difference between males and females, sides of the knee examined, or in different age groups regarding the presence of AIL ($p > 0.05$). Type B was the most common type of AIL (58%) in group I, whereas types A and C were encountered in 12 and 30% of subjects, respectively.

The analysis of distance measurements on sagittal MR images of group I subjects with an AIL (which was made in order to investigate the corresponding location of the three different types of the AIL as determined on thin-section transverse MR images) showed that there was a statistically significant relation for type C AILs to be on the "positive" side (anterior to the "master line" as described in Materials and methods; $p < 0.05$) and for type A AILs to be on the "negative" side (posterior to the "master line"; $p < 0.05$). No statistically significant relation existed for type B AILs with regard to their location with respect to the master line ($p > 0.05$).

In group II the AIL was detected in 16 patients (44%) on MR imaging and in 24 patients (67%) in arthroscopy. In no condition had MR imaging demonstrated an AIL, whereas arthroscopy did not disclose it; however, in 8 patients (22%) arthroscopy revealed an AIL undetected on MR imaging. In 20 patients AIL was not detected either on MR imaging or in arthroscopy. Considering arthroscopy as the gold standard in the detection of AIL in a live subject, positive and negative predictive values of MR imaging for the detection of AIL were 100 and 60%, respectively, whereas its sensitivity and specificity were 67 and 100%, respectively.

Of the 24 patients who were detected to have an AIL in arthroscopy, the ligament was of cord-like appearance in 16 (67%) and flat in 8 (33%). Twelve of 16 patients in group II who had AIL detected both on MR imaging and arthroscopy had cord-like AILs, whereas of the 8 patients in group II whose AILs were detected on arthroscopy, but not on MR imaging, four had flat AIL.

Fig. 3 Sagittal T1-weighted spin-echo MR image (TR/TE: 500/ 20 ms) showing the "master line" drawn, when there was an AIL, between the most posterior portion of the distal femur and the most anterior portion of the anterior cortex of the proximal tibia on the sagittal MR image displaying the intercondylar notch. The distance of the center of the AIL's cross section to that line was measured *(arrow)* and recorded as positive, zero, or negative according to its location being anterior to, crossed by, or posterior to the "master line", respectively

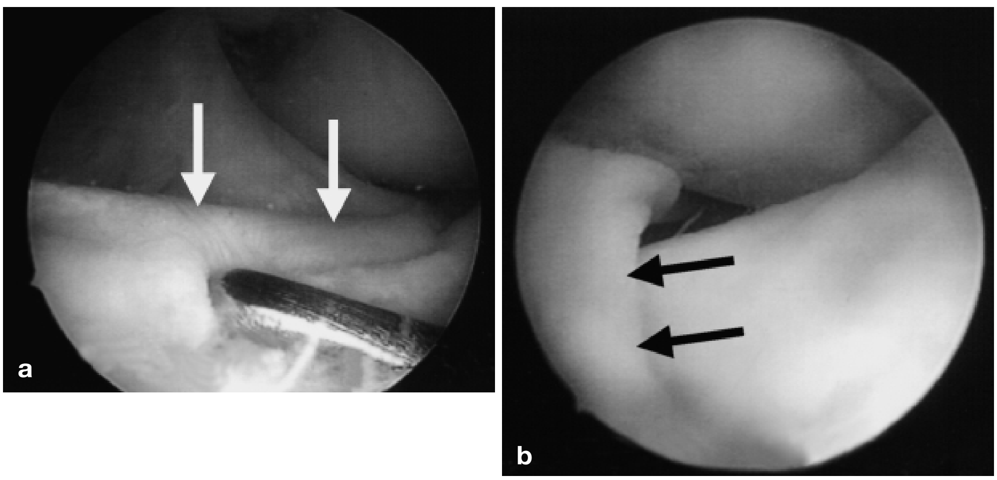
Of the 6 patients who had MR imaging findings of rupture of the ACL – and therefore had been excluded from group I – the AIL was detected in arthroscopy in four (three of these were detected on MR imaging prior to arthroscopy). Arthroscopy confirmed the rupture of ACL in all of these patients.

Discussion

The AIL usually draws attention with regard to its potential to simulate a tear adjacent to the anterior horns of menisci on MR imaging of the knee [9, 10, 11]. Considering the fact that there is only a single study reported in the literature about the frequency of AIL on MR imaging [8] and taking into account a recent cadaveric study which classified the AIL into three distinct types with regard to its insertion sites [4], we aimed in the present study to further investigate by MR imaging the frequency of this structure and make a morphological characterization of its insertion sites. The AIL was found in approximately 53 % of the subjects in our study, which had a large group of subjects in a wide range of ages. The single study in the literature regarding the MR imaging frequency of the AIL reported this ligament to be present in 58 % of a patient population of 50 (30 males and 20 females, with an age range of 12–78 years and a mean age of 35 years) [8]. This figure is close to the percentage of AIL observed on MR images in our study. The cadaveric study by Nelson and LaPrade [4], however, reports the frequency of AIL as 94 % in 50 unpaired knees. In two other cadaveric studies, one by Kohn and Moreno [5], who dissected 46 paired knees, and the other by Berlet and Fowler [6], who investigated medial meniscal insertion patterns in 34 specimens, the frequency of AIL was found to be 69 and 71 %, respectively.

Our study (which is the first in the literature to look for arthroscopic verification of MR imaging findings regarding the AIL in some patients), on the other hand, disclosed that MR imaging has a sensitivity of 67 % in the detection of AIL when arthroscopy was considered as the gold standard. Although larger groups of arthroscopic control would probably provide more accurate results, this probably explains the gap between the frequencies of AIL as detected by MR imaging examina-

Fig. 4 a, b Arthroscopic appearance of the anterior intermeniscal ligament. **a** Cord-like anterior intermeniscal ligament *(arrows)*. **b** Flat anterior intermeniscal ligament *(arrows)*



tions and anatomic studies. One reason MR imaging has a somewhat low sensitivity in displaying the AIL can be morphological differences of this structure causing it to be conspicuous in some persons and hard to identify in others. In arthroscopy in our study, the AIL was seen as either a cord-like or a flat structure. The most recent anatomic study of the AIL did not make a morphological classification of this ligament with regard to its cross-sectional shape; however, it reported that the average mid-substance width of this ligament was 3.3 mm with a range of 2–5 mm [4]. We did not make measurements of the mid-substance width of AIL in our study; however, given the range of the mid-substance width of AIL already established in the cadaveric study by Nelson and LaPrade [4], arthroscopically proven AILs which were undetected on MR imaging could have represented thinner AILs which were hard to identify on MR images. Our results suggest that arthroscopically proven AILs were more likely to have been diagnosed by MR imaging if they were cord-like; however, for the arthroscopically proven AILs which were not detected on MR imaging, appearance in arthroscopy was inconclusive to discredit a certain morphological type (i.e., cord-like or flat) as being likely to be missed on MR images.

Our classification of insertion types of the AIL is somewhat different from that proposed by Nelson and LaPrade in their anatomic study [4]. This is due to the fact that we could not reliably differentiate the joint capsule from the anterior edges of the menisci on MR images. This inability can be attributed to our use of a low-field MR imaging system. Further investigations with higher field strength (especially 3-T) MR imaging systems can help make the distinction between the joint capsule and the anterior margin of a meniscus.

Slight differences between Nelson and LaPrade's [4] classification of the AIL based upon their cadaveric study and that of ours notwithstanding, it is interesting to note that type B, which corresponds to type I (the most common type, 49 % of all AILs) in the cadaveric study, was the most commonly encountered (58 %) of all types of AIL in our study. The results of both the cadaveric study by Nelson and LaPrade [4] and the MR imaging study by our group suggest that the most common insertion type for the AIL is to the inside of the anterior horn of medial meniscus medially and to the anterior margin of the anterior horn of lateral meniscus laterally.

The statistically significant relation of type C AILs (lying between the edges of anterior horns of medial and lateral menisci) with being in a location on the "positive" side of (i.e., anterior to) the "master line" on sagittal MR images in our study can lead to a speculation that the insertion pattern of type C AILs renders them weaker than the other two types of this ligament (which have a merging pattern of insertion inside the meniscus in at least one of the two menisci). The determination of such an AIL on routine sagittal MR images can be of use in selected patients for whom arthroscopy or open surgery is warranted with clinical and MR findings such that the orthopedist can take extra caution to spare this ligament.

The AIL is invariably found within or overhung by the retropatellar fat pad [4, 6] and this can cause it to be overlooked during routine arthroscopic examinations of the knee or in surgical procedures such as debridement for tibial tunnel preparation during anterior cruciate ligament reconstruction; however, it can be important to preserve this ligament during arthroscopy or surgery.

Although the biomechanical significance of the AIL does not seem to be of paramount importance when compared with the basic ligaments of the knee, we believe that there is still not enough evidence to totally disregard this ligament in routine arthroscopic examinations and some surgical procedures. In such conditions, MR imaging can be of help to take into account the AIL when this ligament is displayed on sagittal images.

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