

An Overview of Anatomy and Imaging of the Anterolateral Structures of the Knee

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Summary: Despite several previous articles in the literature, never before have so many studies with regard to anterolateral knee structures been performed. The anterolateral knee complex consists briefly of the iliotibial band, with its proximal and distal attachments, the joint capsule, and the anterolateral ligament (ALL). The recently introduced ALL has several different descriptions, making it difficult to build a consensus with regard to its anatomy. An extensive description of these structures, particularly the iliotibial band and the ALL, with regard to anatomy and imaging, will be provided in this article.

Key Words: anterolateral complex—iliotibial band—anterolateral ligament—anatomy—imaging.

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Even though Paul Segond first described a fibrous and resistant fibrous band inserting into the anterolateral avulsion fracture of the tibia in the 19th century, never before have so many studies with regard to the anterolateral knee structures been performed.^{1–5} Interest in this theme arises from the possibility of an extra-articular reinforcement improving functional results and decreasing the rupture rate of patients submitted to reconstructions of the anterior cruciate ligament, especially in populations at risk of failure.^{6,7}

The anterolateral knee complex consists of all layers of the iliotibial tract, including the Kaplan fibers, the joint capsule, and the recently studied anterolateral ligament (ALL). These structures act synergistically with the ACL, mainly in the control of the anterolateral rotational stability.^{8,9}

Hughston et al¹⁰ in 1976 described the middle third lateral capsular ligament, a structure within the anterolateral joint capsule, which when injured would cause anterolateral rotational instability. Muller,¹¹ in 1982, also described the anterolateral femorotibial ligament, a structure that would be responsible for the control of rotational instability. Terry et al¹² described the capsulous-osseous layer of the iliotibial tract, which would also function, according to these authors, as a true anterolateral knee ligament. This variability of nomenclature made standardization difficult in the study of the anterolateral knee complex, so that many times the same structure is named

differently, which contributes to some of the controversies present in the literature.

ANATOMY

Iliotibial Band (ITB)

The ITB can be divided into layers, but functions as a single unit. Proximally, in a simplified way, it presents several points of femoral insertion. Its more superficial layer inserts in the linea aspera via the lateral intermuscular septum, and its deep layer inserts in the femur by the Kaplan fibers.¹³ A recent study by Godin et al⁹ showed in detail that there are 2 bony ridges that represent the insertion points of the proximal and distal Kaplan fibers, located on the proximal ridge of the distal femoral diaphysis and on the supracondylar flare of the distal femur. Deep to the distal layer, a fascial portion of the ITB (capsulous-osseous layer) inserts immediately proximal to the lateral gastrocnemius tubercle. All these structures are inserted together in Gerdy's tubercle, so that their distal isolation is more difficult to perform and often unnecessary.

Possibly because of the complex anatomy of this region, new studies are still being published with new information with regard to these structures, and yet the results are often conflicting, mainly with regard to the presence or absence of a true ligamentous structure within the anterolateral capsule, and the anatomic parameters of the capsulous-osseous layer.^{9,14} The studies of Herbst et al¹⁴ and Godin et al⁹ are examples of meticulous well-performed dissections that present innumerable similarities but some points of difference. Godin et al,⁹ for example, described the capsulous-osseous layer as "attached just proximal to the lateral gastrocnemius tubercle on the distal ridge 19.1 mm proximal to the lateral epicondyle, with an attachment area of 48.9 mm²," and Herbst et al described it as a layer contiguous with the fascia of the lateral gastrocnemius and plantaris muscles, with only flimsy fibers variably inserted in the area of the lateral femoral epicondyle.¹⁴

In relation to several studies in the literature, we believe that much of the controversy can be explained by different dissection protocols, mainly the way the ITB is reflected and the dissection path (proximal to distal or distal to proximal), and by the use of embalmed rather than fresh specimens that hinder the complete isolation of tissues.

ALL

Descriptions of the ALL have existed since the classic work of Paul Segond in 1879,¹ but a better understanding of this structure has only recently been gained. Although there is not yet a standardization of nomenclature of lateral structures, during the 20th century, the ligament structure connecting the epicondylar region of the femur to the proximal anterolateral tibia had several denominations, such as the short lateral ligament proposed by Last in 1948¹⁵ or the anterior oblique band proposed by Irvine et al in 1987.¹⁶ Only in 2007, in a study focused on the ITB anatomy, Cruells Vieira et al¹³ introduced the term ALL.

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The authors declare that they have nothing to disclose.

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The first study that described the ALL with more detail was published by Vincent et al¹⁷ in 2012. In this study, the authors described the findings in anatomic dissections and visualization of this structure during knee arthroplasties. The origin was described as being close to the popliteus tendon, and the insertion between Gerdy's tubercle and the fibular head. During the following years, after the study by Claes et al,² the ALL gained interest even from the lay media, but, until today, some authors are referring to the ALL as an extracapsular structure, whereas others are referring to it as a structure in layer 3 of the knee.^{14,18}

Much controversy existed with regard to the femoral origin of the ALL, with studies showing it was anterior and distal to the origin of the lateral epicondyle, or in the center of the epicondyle and also posterior and proximal to it.^{2-5,18} One study by Helito et al¹⁹ also identified 2 possible layers of the ALL with different femoral attachments. With a better understanding of this structure and a more accurate dissection technique, there seems to be a trend with regard to the origin of this structure in a region that goes from the center to the posterior and proximal region of the lateral epicondyle¹⁸ (Fig. 1).

After the femoral origin, the ALL presents an anterodistal path toward the tibia, passing superficially to the lateral collateral ligament (Fig. 2). At around 50% of its length, it presents a portion that goes toward the lateral meniscus, inserting itself in the transition between the body and the anterior horn of the meniscus.²⁰ Helito et al²⁰ described this meniscal insertion in detail, showing that there is a spreading of the ALL fibers immediately before contact with the external meniscal surface.

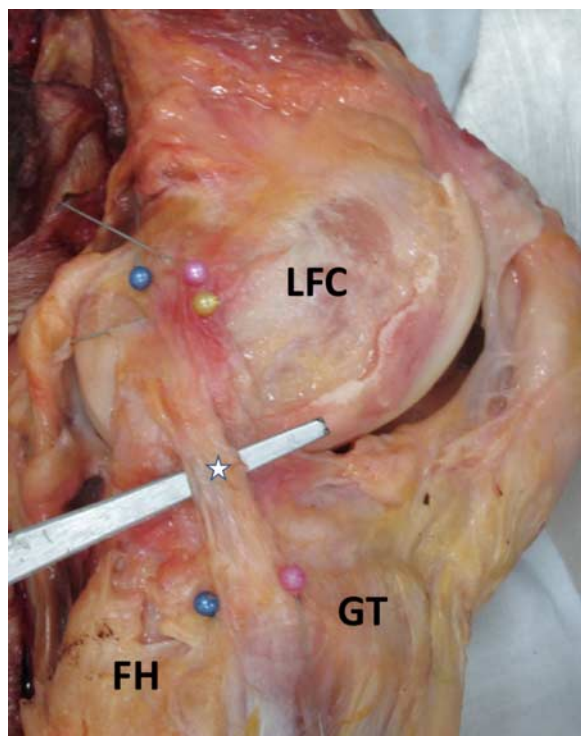


FIGURE 1. Anterolateral image of a right knee showing the ALL (asterisk) with origin posterior and proximal to the lateral epicondyle (yellow dot) and insertion between GT and the FH. The pink and blue dots represent the anterior and posterior extents of the ALL's proximal and distal attachments. ALL indicates anterolateral ligament; FH, fibular head; GT, Gerdy's tubercle; LFC, lateral femoral condyle. [full color online](#)

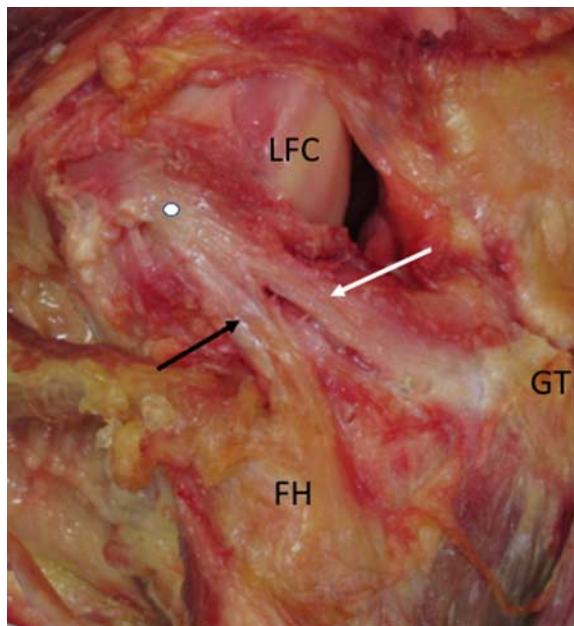


FIGURE 2. Anterolateral image of a right knee showing the relationship between the ALL (white arrow) and the LCL (black arrow). Note that the ALL passes above the LCL origin on its way from the femur to the tibia. The white dot represents the lateral epicondyle. ALL indicates anterolateral ligament; FH, fibular head; GT, Gerdy's tubercle; LCL, lateral collateral ligament; LFC, lateral femoral condyle. [full color online](#)

The other ALL insertion occurs in the proximal anterolateral region of the tibia. In this region, the bone landmark for insertion is located between Gerdy's tubercle and the fibular head, about 5 to 10 mm below the lateral tibial plateau.²⁻⁶ An imaging study performed by Claes et al²¹ suggested that this region corresponds to the Second fracture site, although some controversy still exists with regard to which would be the main structure responsible for this fracture avulsion.²² It is important to note that the thickness of the ALL varies from 1 to 3 mm, being a delicate structure for dissection. The thickness of the ALL in men is about double the thickness in women according to a comparative study conducted by Daggett et al.²³ This may represent one more risk factor for women to tear the ACL more than men.

In a view from inside the joint, the ALL forms a triangle with the popliteus tendon in the lateral region of the knee, the base being the tibial plateau and the apex the lateral epicondyle region⁴ (Fig. 3). This association suggests that the ALL might be a restrictor of internal rotation of the tibia, an opposite function of the popliteus tendon, which is an external rotation stabilizer.

Anatomic studies in pediatric specimens were able to isolate the ALL in the minority of the specimens; hence, it was suggested that the ALL might not be present at the beginning of development, appearing in the capsular region because of in situ mechanical forces.^{24,25} After this assumption, studies on fetal specimens were performed by Helito et al²⁶ and Toro-Ibarguen et al,²⁷ and clearly found the ALL in 100% of cases, despite some controversy caused by the study of Sabzevari et al²⁸ that failed to identify this structure.

Despite all the anatomic parameters presented, what defines the ALL as a ligament are its histologic features. Dense and well-organized connective tissue, compatible with ligamentous tissue was found within the structure.^{3,4,26} Histologic analysis in fetus specimens also found a similar ligament

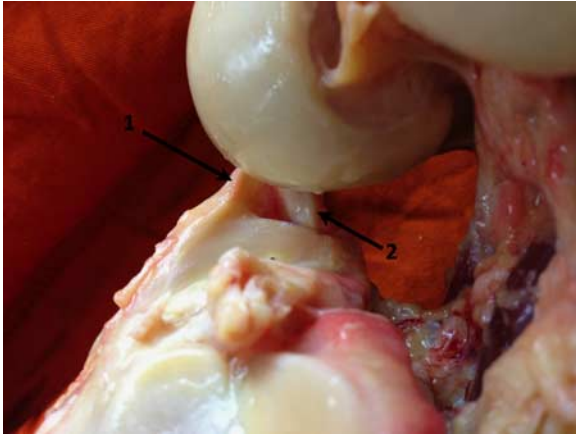


FIGURE 3. Inside view of the lateral section of the right knee showing a triangular image with a distal base formed by the tibia, popliteus tendon, (2) and the meniscal portion of the anterolateral ligament (1). This figure is reprinted with permission from Helito et al.⁴ Copyright 2013 [SAGE Publications Inc.], Thousand Oaks, CA. All permission requests for this image should be made to the copyright holder. [full color online](#)

structure compared with the adult specimens, with the exception of a larger number of fibroblasts, attributable to its developing nature.²⁶

In summary, the anatomy of the anterolateral region of the knee today seems to be better defined (Table 1). In spite of some of the controversies mentioned, a recent meta-analysis showed characterization of this structure in 96% of the dissected specimens, which confirms its presence.⁷ Despite this, its

TABLE 1. Anatomic and Histologic Features of the Anterolateral Ligament

Femoral attachment	From the center to posterior and proximal of the lateral epicondyle
Meniscal attachment	Between anterior horn and body of the lateral meniscus
Tibial attachment	Between Gerdy’s tubercle and fibular head, around 5 to 10 mm below the lateral plateau
Histologic features	Dense and well-organized connective tissue

function and need for reconstruction still deserve to be discussed for a better understanding.

IMAGING EVALUATION

In anterolateral knee injuries, imaging evaluation is mainly performed by magnetic resonance imaging (MRI). MRI has excellent soft tissue resolution in multiple planes and is well established as the main method for evaluating internal derangement of the knee²⁹; however, some studies have demonstrated that high frequency sonography may be used as an alternative.^{22,30} Adequate evaluation of anterolateral capsule structures is best achieved in high-field magnets (≥ 1.5 T) with dedicated knee coils and adequate protocols.

The basis for the ALL MRI assessment consists in studies performed in cadavers by Helito et al³¹ and Catherine et al,³ which demonstrated that, with specific protocols (no spacing, slice thickness around 1 to 2 mm), the ALL could be visualized as a distinct structure with good anatomic correlation. Helito et al³¹ demonstrated excellent objective correlation with anatomy in the

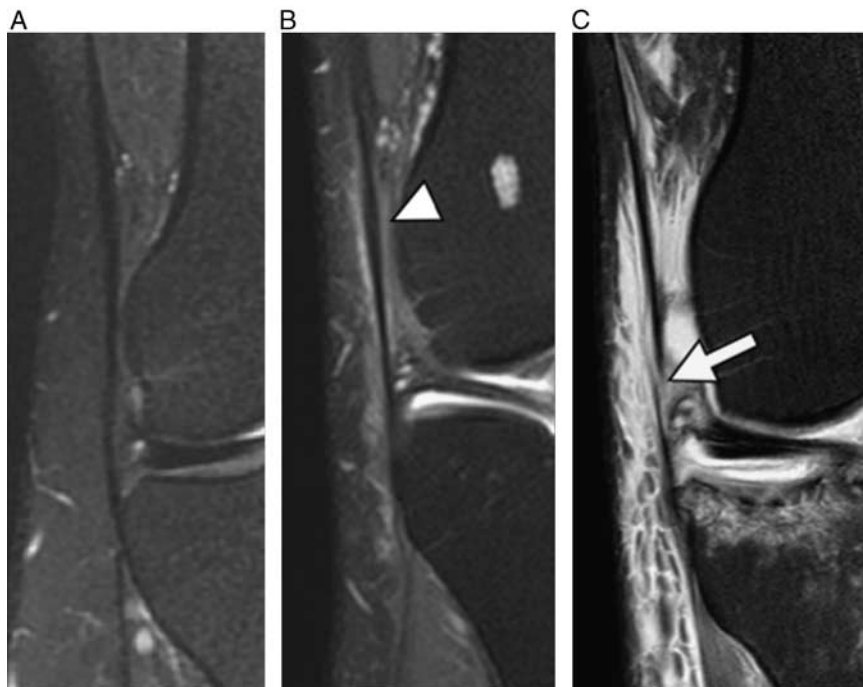


FIGURE 4. Iliotibial band tears. Coronal T2W MRI images demonstrating normal iliotibial band (A) and iliotibial band tears (B, C). The normal iliotibial band (A) has homogeneous hyposignal and no adjacent edema. An iliotibial band strain is represented in B, the arrow head points a focal thickening with peripheral edema. The arrow in C demonstrates an iliotibial band tear, with a focal discontinuity of its fibers. MRI indicates magnetic resonance imaging; T2W, T2-weighted.

majority of the parameters (ALL measurements and distance to known anatomic landmarks) and good interobserver agreement.

As regards the ALL evaluation *in vivo*, several studies have proved that MRI can access the normal ALL in routine protocols with coronal T2-weighted with fat saturation sequences.^{30–35} Although a study by Helito et al³⁴ has demonstrated that proton density-weighted without fat saturation coronal sequences had slightly better performance to depict the femoral portion of the normal ligament, the majority of the ALL abnormalities are described in the literature in T2-weighted with fat saturation sequences.^{33,36–38}

As for the ITB, MRI has great performance, especially in high-grade injuries, with accuracy values of up to 95% to 100%.³⁹

ITB

ITB traumatic injuries are common, occurring mainly in association with anterior cruciate ligament injuries and transient patellar dislocation.⁴⁰ According to Mansour et al,⁴⁰ in patients with knee trauma, the ITB was injured in 57.5%, the majority of cases being sprains in 95% and only 5% had actual tears. Helito et al identified a 60% prevalence of ITB injuries in patients with ACL tear.³⁷ ITB injury is also more common in its midsubstance⁴¹ (Fig. 4).

The normal ITB appears in MRI examinations as a band-like structure in coronal plane with hyposignal in all sequences and regular margins, measuring from 1 to 3 mm at the level of

the lateral femoral condyle.⁴² Mansour et al⁴⁰ classified ITB traumatic injuries as minor sprain, severe strain and torn, similar to other ligament and tendon injury classifications.^{43,44} Minor sprains were defined as adjacent superficial and deep edema, with intact fibers and normal thickness. Severe sprains were depicted as ITB abnormal signal and focal or diffuse thickening, associated with adjacent soft tissue edema. The torn ITB was either a discontinuity in its fibers or a bone avulsion at the Gerdy tubercle.

The iliotibial band syndrome is the most common non-traumatic ITB injury, frequently associated with sports like cycling and running, with an incidence of 1.6% to 12% in runners.⁴⁵ Although this syndrome was initially attributed to friction between the ITB and the lateral femoral condyle during knee flexion-extension movements, this idea is currently less accepted. Fairclough et al⁴⁶ conducted an anatomic and functional study demonstrating that the ITB does not “roll over” the lateral femoral condyle and attributed the overuse injuries to compression rather than friction. There is also discussion with regard to the presence of a real bursa between the ITB and the femur, with some authors defending the resection of this bursa as a treatment option.⁴⁷

Regardless of the etiology, the iliotibial band syndrome has a typical MRI appearance (Fig. 5). It is depicted as increased signal in the fat deep to the ITB in fluid-sensitive sequences.^{43,45,48,49} ITB local thickening and abnormal signal may also be identified. It is important to note that in some cases, especially in older

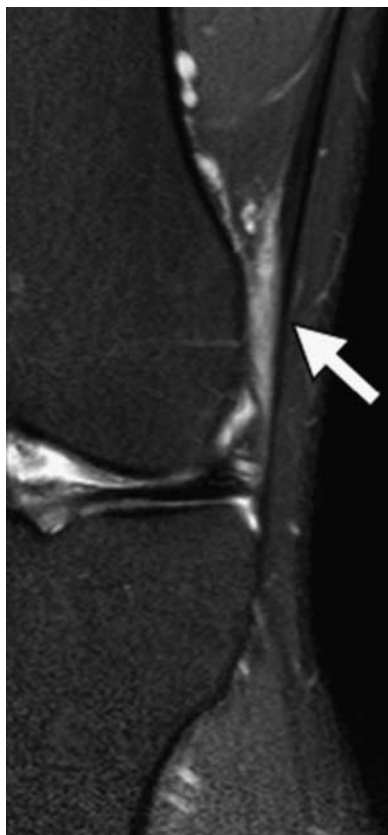


FIGURE 5. Iliotibial band syndrome. Patient had a lateral knee pain with no history of trauma. The arrow indicates edema of the fat interposed between the iliotibial band and the lateral femoral condyle.

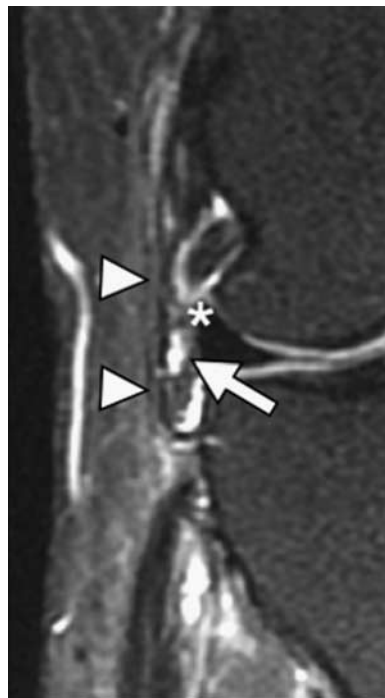


FIGURE 6. Normal ALL. T2W MRI image at the coronal plane. The arrowheads indicate the anterolateral ligament fibers, which are thin and regular and have homogeneous low signal. Note that there is a thin portion of the ligament that attaches to the lateral femoral condyle (asterisk). The arrow is pointing to the inferior lateral genicular artery and veins that pass just below the ALL bifurcation. ALL indicates anterolateral ligament; MRI, magnetic resonance imaging; T2W, T2-weighted.

patients, a mild hyperintensity may be identified in this region, and should be carefully correlated with symptoms.⁴⁸

ALL

For didactic purposes, in this article, the ALL portion proximal to the bifurcation will be referred to as femoral, and the portions distal to the bifurcation will be named tibial and meniscal, according to their insertions. The ALL is better depicted in the coronal plane and, because of its oblique path from posterosuperior to anteroinferior, it is rarely visualized in a single coronal slice. Therefore, care should be taken to seek the ALL in subsequent coronal slices. It is often not easy to distinguish the ALL fibers in the axial and sagittal sequences, but those sequences are of great use for cross reference and anatomic guidance. The normal MRI signal of the ALL is expected to be low in all sequences.

Although anatomic studies^{2,4,17,19,20,50–52} and MRI cadaveric studies^{3,31} were able to clearly identify a distinct femoral origin of the ALL, in vivo MRI is often unable to discriminate the ALL origin from the lateral collateral ligament origin.^{34,50,53,54} This difference can be explained by the small size of the ALL (1.5 ± 0.5 -mm thick and 5.2 ± 0.7 -mm wide) in MRI studies,^{31,35} making it susceptible to partial volume effects.

The ALL bifurcates 18 mm distal from its origin,³¹ just above the inferior lateral genicular vessels.³⁴ The identification of the inferior lateral genicular vessels is often very useful to access the ALL. The ALL then divides into the meniscal portion and the tibial portions. The meniscal portion is slightly deeper and inserts at the lateral meniscus, between its anterior

horn and body.²⁰ The tibial portion is slightly superficial and longer than the meniscal portion. The ALL tibial insertion is about 6 to 7 mm^{3,31,32,34,35,53} distal to the lateral tibial plateau cartilage and midway between the fibular head and the Gerdy's tubercle (Fig. 6).

ALL pathology is associated with traumatic and sports injuries. Although there are several studies with regard to ALL lesions using MRI, thus far, there is no imaging study with pathologic correlation. Therefore, criteria for injuries of similar ligamentous structures are used to define ALL tears, such as peripheral edema, irregularity of fibers, discontinuity, and bone avulsions.^{7,33,36–38,55–57} The bone avulsion occurs at its distal insertion and corresponds to Segond fractures according to some authors^{1,35,58,59} (Fig. 7).

The prevalence of ALL abnormalities in patients with a ruptured ACL is variable in the literature, from as high as 78%²¹ to as low as 10%.⁵⁸ This is probably attributable to the heterogeneity in patient selection and injury criteria. In contrast, studies in patients with acute ACL injury showed an injury prevalence at around 40%.^{36–38,57} Controversy is also found with regard to the location of the ALL injury, although it is not clear whether this is clinically relevant. Although the majority of studies have found the tibial portion to be more frequently injured,^{21,38,55} 1 study identified more injuries in the femoral portion.³⁶ Segond fractures represent a minority of injuries in most studies.^{36–38}

Patients with ACL tears with lateral femoral and tibial bone contusion on MRI more frequently presented with ALL abnormalities.^{37,56,57} Bone contusions are related to higher grades of joint laxity, which may justify the association with

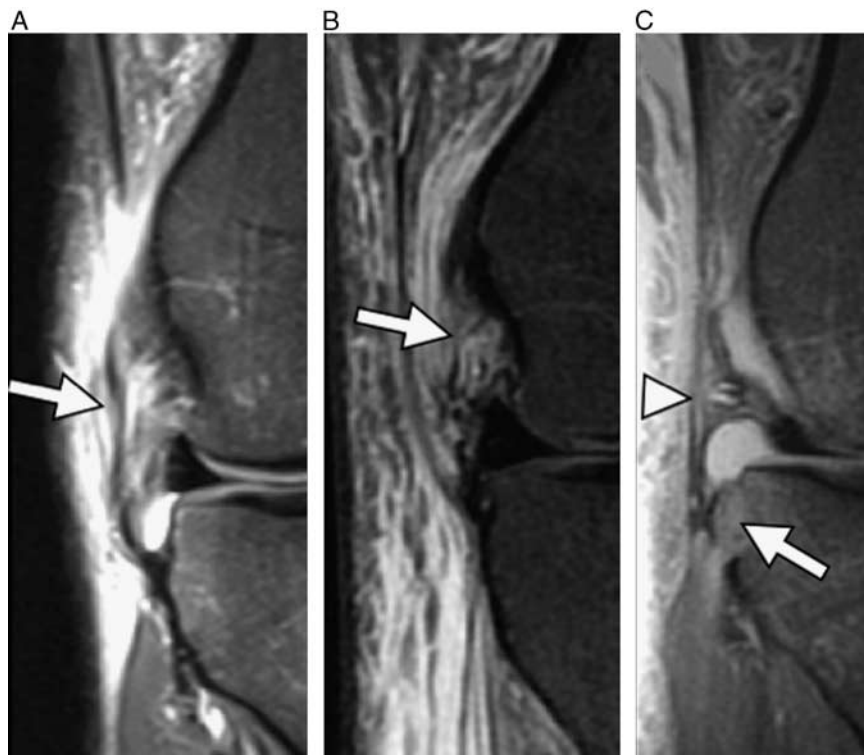


FIGURE 7. ALL tears. T2W MRI image at the coronal plane (A–C). The arrow in (A) indicates an ALL tear, with ligament thickening and high signal, as well as adjacent edema. B, Depicts a torn ALL at its proximal segment, with thinning and irregularity of its fibers (arrow) and adjacent edema. A Segond fracture is depicted in (C) with a bony avulsion of its tibial insertion (arrow) and also diffuse abnormal signal of its fibers (arrow head). ALL indicates anterolateral ligament; MRI, magnetic resonance imaging; T2W, T2-weighted.

ALL tears.³⁷ ALL abnormalities in ACL-injured knees were also associated with peripheral ligament injuries and ITB tears.³⁷ Some studies failed to identify the association between ALL MRI abnormalities and lateral meniscus tears in patients with a ruptured ACL, which makes this association still a matter of controversy.^{37,55} Although not statistically significant, Kosy et al⁵⁵ showed a tendency of higher incidence of lateral meniscus tears in association with ALL abnormalities, which may be caused by the rotational stress in ACL injuries.

As for a partially ruptured ACL, 1 study demonstrated that there was a negative association with ALL abnormalities.³⁷ The assumption that partial ACL tears would require lower energy trauma compared with complete ACL tears could justify this negative association.

CONCLUSIONS

In conclusion, great advances in the understanding of the anterolateral structures of the knee have been made in recent years. Although there is still some controversy with regard to the anatomy of the ALL, there is already an understanding of its presence and its parameters of origin and insertion. As regards imaging evaluations, although several studies have focused on the evaluation of the normal ALL, few studies have focused on lesions of this structure and there is still no correlation between the imaging findings and the surgical findings, which should be clarified in future studies.

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