KNEE

The anterolateral ligament

ANATOMY, LENGTH CHANGES AND ASSOCIATION WITH THE SEGOND FRACTURE

A. L. Dodds, C. Halewood, C. M. Gupte, A. Williams, A. A. Amis

From Imperial College London, London, United Kingdom

There have been differing descriptions of the anterolateral structures of the knee, and not all have been named or described clearly. The aim of this study was to provide a clear anatomical interpretation of these structures. We dissected 40 fresh-frozen cadaveric knees to view the relevant anatomy and identify a consistent structure in 33 knees (83%); we termed this the anterolateral ligament of the knee. This structure passes antero-distally from an attachment proximal and posterior to the lateral femoral epicondyle to the margin of the lateral tibial plateau, approximately midway between Gerdy’s tubercle and the head of the fibula. The ligament is superficial to the lateral (fibular) collateral ligament proximally, from which it is distinct, and separate from the capsule of the knee. In the eight knees in which it was measured, we observed that the ligament was isometric from 0° to 60° of flexion of the knee, then slackened when the knee flexed further to 90° and was lengthened by imposing tibial internal rotation.

Cite this article: Bone Joint J 2014;96-B:325–31.

The anatomy and function of the soft-tissue structures at the anterolateral aspect of the knee are poorly understood, despite clinical interest in injuries associated with instability. There are no standard anatomical names for the soft-tissue structures around the anterolateral aspect of the knee, nor any terms in widespread use in orthopaedic clinical practice. Functional studies of anatomical specimens can overcome this dearth of knowledge and provide a universally accepted, standardised, anatomical, clinical and operative nomenclature.

An ‘anterolateral ligament’ (ALL) has been described, which appears to be a structure within the capsule. Claes et al also described an ‘anterolateral ligament’, but despite having the same name, this appears to be a different structure. Several authors have described the importance of the ‘lateral capsular ligament’ or ‘mid-third lateral capsular ligament’ as a restraint against anterolateral rotational instability of the knee. Also the structure described in those earlier studies was claimed to be responsible for the Segond fracture, an avulsion of the lateral rim of the tibial plateau.

The pivot-shift phenomenon results from excess anterior tibial translation and internal rotational laxity following a tear of the anterior cruciate ligament (ACL). However, this instability may also be caused by damage to other structures on the lateral aspect of the knee. A Segond fracture is commonly associated with ACL injury and other soft-tissue structures in that area are also loaded during ACL injury.

The aim of this paper was to investigate the anatomy of the anterolateral soft-tissue structures of the knee in the hope that the differing anatomical descriptions of a capsular ALL by Vincent et al and an extracapsular ALL by Claes et al could be reconciled.

Materials and Methods

After obtaining ethical approval for the study, a total of 40 fresh-frozen cadaveric knees, each approximately 300 mm long, were thawed before dissection. The specimens were taken from 21 male and 19 female cadavers (18 left- and 22 right-sided), with a mean age at death of 75 years (58 to 90). The anterolateral structures were dissected with the surrounding tissue as intact as possible. Overlying skin and subcutaneous fat were removed. The interval between the biceps femoris and the iliotibial band was incised near the site of biceps femoris entering the deeper plane, with the two structures separated from proximal to distal. The iliotibial band was elevated from posterior to anterior and peeled off Gerdy’s tubercle so that the deeper structures could then be studied.

Photographs were taken during the dissection, with the addition of a ruler and coloured pins to aid identification of landmarks. A camera stand was used to take photographs as a
true lateral projection; the specimen was held with the tibia horizontal and with both the posterior condylar axis and the camera vertical. The images were analysed using a digital image analysis program (Image J; US National Institutes of Health, Bethesda, Maryland) to relate structures to anatomical landmarks.

After examining the anterolateral structures from the superficial aspect, the knee was opened from the medial side and disarticulated with only the anterolateral structures remaining intact. This facilitated examination of their deep aspect, with transillumination to display the capsular thickness above and below the lateral meniscus.

Changes in length of the ligaments were measured in eight of the 40 knees from 0° to 90° of flexion of the knee, using a technique which has previously been described.12,13 The femur was fixed in a testing rig via a cemented intramedullary rod, and tibial movement was unconstrained other than in flexion and extension. Structures to be studied were separated below the iliotibial band. The extensor mechanism was loaded with 100 N tension applied to the patella. The knee was flexed from 0° to 90° by lowering the femur from vertical to horizontal, with the tibia remaining vertical.14,15

The femoral and tibial attachments of the ligaments were identified, and small metal eyelets were screwed into the bone at their centres. The changes in the distance between the eyelets were measured using a monofilament suture (Ethilon 2/0; Ethicon Co., Somerville, New Jersey). One end was attached to the tibial eyelet, then the suture was passed along the structure to be studied, through the femoral eyelet and taken to a linear variable displacement transducer (LVDT; Solartron Metrology, Bognor Regis, United Kingdom). The LVDT was confirmed by micrometer to be accurate to ±0.01 mm. The suture slid and measured the changes in length between the femoral and tibial attachments.12,13 The suture was tensed only by the weight of the sliding core of the LVDT (0.5 N). Changes in length were recorded using Solartron ‘Orbit’ Excel software (Solartron Metrology). The experiment was repeated three times and the mean calculated.

The experiment was repeated with an internal rotation torque of 5 Nm applied to the tibia using a weight, string and pulley arrangement, and again with a 5 Nm external rotation torque.

Statistical analysis. Changes in the length of the ALL caused by flexion of the knee were examined using one-way analysis of variance (ANOVA) with pairwise comparisons, with significance and 95% confidence intervals (CIs) having Bonferroni adjustment for multiple comparisons. Changes in length of the ALL caused by internal or external tibial rotation were examined using two-way repeated-measures ANOVA, the two primary variables being flexion of the tibia and rotational torque. The dependent variable was the length of the ALL. Differences of length at specific angles of flexion were examined using paired t-tests, with Bonferroni correction for three-way comparisons between internal, neutral, and external rotation. A p-value of < 0.05 was considered statistically significant.

Results
When the iliotibial band had been removed, the soft tissues overlying the lateral femoral condyle could be seen clearly. An extracapsular structure, which appeared to be a ligament, was observed, passing obliquely over the superficial aspect of the LCL (Figs 1 and 2). In view of its location, appearance and orientation, it seemed appropriate to call it...
the anterolateral ligament (ALL). This structure was found in 33 knees (83%), and was more distinct in some specimens than others. Its anatomical relationships are shown in Figure 3 and its dimensions in Table I.

The femoral attachment of the ALL was a mean of 8 mm (-2 to 12) proximal and 4.3 mm (0 to 12) posterior to the most prominent point of the lateral epicondyle (Table I, Figs 1 and 3). The femoral attachment was complex, with a fan-like blending of fibres at the lateral aspect and from far posterior on the lateral femoral condyle; there was no distinct area of direct attachment to the femur, but a blending with the dense and locally adherent fibres of the capsule. The cross-section of the ALL appeared relatively constant along the main body of the ligament. The ALL passed superficial to the proximal- to mid-third of the LCL when the knee was flexed, and was a completely separate structure (Fig. 2).

It was also superficial to and distinct from the capsule of the knee, from which it could be readily separated in the distal half of its course (Fig. 2). Thus, it did not insert into the rim of the lateral meniscus, although there were branching attachments to it. The tibial attachment of the ALL was

Table I. Anatomical measurements of the anterolateral ligament (ALL) (in eight specimens)

<table>
<thead>
<tr>
<th>Mean (mm) (SD; range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL Length</td>
</tr>
<tr>
<td>Lateral collateral ligament (LCL) length</td>
</tr>
<tr>
<td>Distance from Gerdy's tubercle to most prominent point of fibula</td>
</tr>
<tr>
<td>Distance between Gerdy's tubercle to tibial attachment of ALL</td>
</tr>
<tr>
<td>Distance from ALL tibial attachment to most prominent point of fibula</td>
</tr>
<tr>
<td>Width of LCL</td>
</tr>
<tr>
<td>Width of ALL</td>
</tr>
<tr>
<td>Distance to ALL attachment from tip of lateral epicondyle Proximal</td>
</tr>
<tr>
<td>Posterior</td>
</tr>
<tr>
<td>Distance from tibial joint line to attachment of ALL</td>
</tr>
</tbody>
</table>
broader than its main body, and was posterior to Gerdy’s tubercle and anterior to the head of the fibula (Fig. 2). Distally, some fibres from the anterior edge of the LCL fanned out to attach to the tibia at the posterior part of the attachment of the ALL in several knees.

After the ALL was removed, we observed a thickening of fibres that ran antero-distally from the insertion of the tendon of popliteus, to insert at the anterolateral rim of the lateral meniscus. These fibres passed circumferentially around the rim of the meniscus, then continued onto the tibia near the lateral edge of the patellar tendon. These fibres were visible proximal to the lateral meniscus when the knee had been disarticulated and the anterolateral capsule was viewed from the deep aspect with transillumination (Figs 4a and 4b). The capsule distal to the lateral meniscus in the area between Gerdy’s tubercle and the head of the fibula was transparently thin, with no discreet ligamentous structure visible (Figs 4c and 4d).

The ALL could be tensed by manual examination inducing internal tibial rotation, and also with varus loading, at all angles of flexion of the knee. Manipulation of the tibia in anterior drawer and internal rotation suggested that the
capsular structure, which corresponded to the capsular ALL described by Vincent et al, was acting more as an anterolateral menisco-femoral ligament, rather than as a direct stabiliser of the tibiofemoral joint. When the knee was moved into extension with the tibia free to rotate, the distance between the attachments of the ALL was longer than in flexion (Fig. 5). Although there was inter-specimen variation, the most common behaviour was close to isometric from 0° to 60° flexion. The mean change in length was 1.7 mm (SD 1.1; 95% CI -2.3 to 5.7) (p = 0.980), followed by shortening of 4.1 mm (SD 0.9; 95% CI 1.0 to 7.2) (p = 0.011) from 60° to 90° of flexion. Internal tibial rotation increased the length between the attachments, and external rotation reduced it (Fig. 5). When the knee was in extension (0° flexion) tibial rotations in response to 5 Nm torque were not large enough to cause significant change in the length of the ALL (p > 0.26). Internal tibial rotation increased the mean length between the ALL attachments from 3.6 mm (SD 1.5 to 5.7) at 30° (p = 0.003) to 9.9 mm (SD 1.4; 5.7 to 14.2) at 90° of flexion of the knee (p < 0.001). External tibial rotation reduced the mean length between the attachments of the ALL (that is, a tendency for the ALL to slacken), for example by 5.9 mm (SD 0.7; 3.7 to 8.1) at 90° of flexion of the knee (p < 0.001).

**Discussion**

We were able to demonstrate the presence of a ligamentous structure at the anterolateral aspect of the knee, which was separate from the capsule; we defined it as the ALL. This passes in an oblique orientation antero-distally, from a femoral attachment proximal and slightly posterior to both the lateral epicondyle and the femoral attachment of the lateral collateral ligament (LCL), to a tibial attachment just distal to the anterolateral rim of the plateau, approximately midway between the head of the fibula and Gerdy's tubercle. When the knee was in extension (0°), tibial rotations in response to a 5 Nm torque were not large enough to cause significant change in the length of the ALL (p > 0.26). Internal tibial rotation increased the mean length between the ALL attachments from 3.6 mm (SD 1.5 to 5.7) at 30° (p = 0.003) to 9.9 mm (SD 1.4; 5.7 to 14.2) at 90° of flexion of the knee (p < 0.001). External tibial rotation reduced the mean length between the attachments of the ALL (that is, a tendency for the ALL to slacken), for example by 5.9 mm (SD 0.7; 3.7 to 8.1) at 90° of flexion of the knee (p < 0.001).

**Table II. Summary of previous names of structures around the knee**

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterolateral ligament</td>
<td>Vieira et al,24 Vincent et al,3 Claes et al 4</td>
</tr>
<tr>
<td>Anterior oblique band</td>
<td>Campos et al 22</td>
</tr>
<tr>
<td>Capsulo-osseous layer of iliotibial tract</td>
<td>Terry et al 21</td>
</tr>
<tr>
<td>Lateral capsular ligament</td>
<td>Dietz et al,6 Johnson 8</td>
</tr>
<tr>
<td>Mid-third lateral capsular ligament</td>
<td>Hughston et al,25 LaPrade et al,18 Goldman et al 7</td>
</tr>
</tbody>
</table>

Graph showing the mean variation of the length between the attachments of the anterolateral ligament with flexion of the knee, with tibial rotation unconstrained (neutral rotation), with 5 Nm internal rotation (IR) torque, or 5 Nm external rotation (ER) torque. (Mean +/- SD; n = 8).
(Table II). This is due to the complex relationships of the structures, with some blending together towards their attachments, or having multiple attachments, such as, for example, the combined insertion of the LCL and the tendon of biceps femoris.16 There is also variation of insertion of some structures, such as the tendon of popliteus.17 The ALL was seen clearly in 33 of 40 knees in this study, and in 40 of 41 knees by Claes et al.4 Most previous studies have described structures as intimate parts of the capsule, while our observations demonstrate that the ALL was superficial to the LCL and not attached directly to the meniscus.

The ALL in the present study is not the same structure as the capsular ligament described by Vincent et al; it had different attachments and a mean length of 59 mm as compared with 34 mm for the capsular ligament. Our study did not reproduce their findings because although there was a thickening of the capsule, which attached to the lateral meniscus, it did not continue below the meniscus to the tibial plateau.

Claes et al4 described the same structure as the ALL, but with the femoral attachment described as being over the epicondyle, anterior to the attachment of the LCL. We found that the femoral attachment was variable, but approximately 8 mm proximal to the epicondyle and 4 mm posterior to it. The movements and attachment of the ALL may have been seen more readily with the fresh specimens used in this study than with embalmed tissues used previously. Hughston et al5 and others emphasised the importance of the ‘mid-third lateral capsular ligament’2,18 or ‘lateral capsular ligament’6,8 as a restraint against anterolateral rotational instability. The capsule may have a role in controlling rotational laxity, but it appears to be flimsy.5 The lateral soft tissues have been described in three layers.19 There are interconnections between these layers, particularly of the iliotibial band to the retinaculum.20 Terry et al21,22 described the deep and capsulo-osseous layer of the iliotibial band, but not the ALL.

The soft tissue which avulses the bony fragment of the Segond fracture9 has not been defined with confidence; the mid-third capsular ligament was suggested,6,7 but it is an insubstantial structure. Traction from the anterior arm of the short head of the biceps femoris muscle has also been suggested.23 In the present study, the ALL was distinct from both the capsule and the biceps femoris. This study and that of Claes et al4 found that the ALL was separate from the posterior fibres of the iliotibial band described by Vieira et al.24 Other authors23 have described an ‘anterior oblique band’ originating from the anterior-distal edge of the LCL and attaching to the rim of the tibia, which may relate to the Segond fracture. Although some fibres were noted in several of the knees in the present study, they were not a significant structure. This leaves the ALL described in Claes et al4 and this study as the structure most likely to be associated with the Segond fracture.

It is tempting to speculate that the ALL may have a role in controlling pivot shift. However, more work is needed to confirm its function. Persistent rotatory instability after intra-articular ACL reconstruction may result from unaddressed incompetence of the anterolateral structures. The Segond fracture is evidence of damage to these structures in association with rupture of the ACL.6,7,18 The unreliable results of lateral extra-articular tenodesis in the past may have resulted from incomplete knowledge of the anatomy and biomechanics25; understanding the function of the ALL may be a part of the solution to these problems.

A. L. Dodds was supported by an Educational Fellowship grant from Smith & Nephew (Endoscopy) Company. The authors would also like to thank Dr V. Duthon for anatomical work.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This article was primarily edited by D. Rowley and first proof edited by J. Scott.

**References**


