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Anatomy of the anterolateral ligament of the knee

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Abstract

In 1879, the French surgeon Segond described the existence of a 'pearly, resistant, fibrous band' at the anterolateral aspect of the human knee, attached to the eponymous Segond fracture. To date, the enigma surrounding this anatomical structure is reflected in confusing names such as '(mid-third) lateral capsular ligament', 'capsulo-osseous layer of the iliotibial band' or 'anterolateral ligament', and no clear anatomical description has yet been provided. In this study, the presence and characteristics of Segond's 'pearly band', hereafter termed anterolateral ligament (ALL), was investigated in 41 unpaired, human cadaveric knees. The femoral and tibial attachment of the ALL, its course and its relationship with nearby anatomical structures were studied both qualitatively and quantitatively. In all but one of 41 cadaveric knees (97%), the ALL was found as a well-defined ligamentous structure, clearly distinguishable from the anterolateral joint capsule. The origin of the ALL was situated at the prominence of the lateral femoral epicondyle, slightly anterior to the origin of the lateral collateral ligament, although connecting fibers between the two structures were observed. The ALL showed an oblique course to the anterolateral aspect of the proximal tibia, with firm attachments to the lateral meniscus, thus enveloping the inferior lateral geniculate artery and vein. Its insertion on the anterolateral tibia was grossly located midway between Gerdy's tubercle and the tip of the fibular head, definitely separate from the iliotibial band (ITB). The ALL was found to be a distinct ligamentous structure at the anterolateral aspect of the human knee with consistent origin and insertion site features. By providing a detailed anatomical characterization of the ALL, this study clarifies the long-standing enigma surrounding the existence of a ligamentous structure connecting the femur with the anterolateral tibia. Given its structure and anatomic location, the ALL is hypothesized to control internal tibial rotation and thus to affect the pivot shift phenomenon, although further studies are needed to investigate its biomechanical function.

Key words: anatomy; anterior cruciate ligament; anterolateral ligament; pivot-shift; Segond fracture.

Introduction

In 1879, years before the discovery of X-rays, Dr. Paul Segond described a remarkably constant avulsion fracture pattern at the anterolateral proximal tibia as a result of forced internal rotation at the knee (Segond, 1879). This eponymous Segond fracture was reported to occur in the tibial region 'above and behind the tubercle of Gerdy'. At this anatomical location, he furthermore designated the existence of 'a pearly, resistant, fibrous band which invariably showed extreme amounts of tension during forced internal rotation (of the knee)'.

Inspired by the work of Dr. Jack Hughston, the first correlation of the Segond fracture with the presence of significant knee instability was demonstrated by Woods et al. (1979). In all of the four acute cases with a positive 'lateral capsular sign' on X-ray, a concomitant rupture of the anterior cruciate ligament (ACL) was demonstrated. This study, together with the work of Goldman et al. (1988) and Hess et al. (1994) has founded the current belief that Segond fractures are pathognomonic for ACL tears.

Whereas Segond described a 'pearly, fibrous band' attached to his flake fracture, later literature has only rarely mentioned the presence of a ligamentous structure connecting the femur with the anterolateral tibia. These sporadic reports mention the 'anterior band of the lateral collateral ligament' (Irvine et al. 1987), the '(mid-third) lateral capsular ligament' (Hughston et al. 1976b; Johnson, 1979; Haims et al. 2003; Moorman & LaPrade, 2005), 'anterior oblique band' (Campos et al. 2001) or the 'anterolateral

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ligament' (Vieira et al. 2007; Vincent et al. 2012). The different terms applied, together with the vague descriptions and lack of detailed illustrations, have led to much confusion about the precise anatomy and function of this structure.

The goal of this manuscript was to provide a detailed anatomical characterization of this presumed ligamentous structure at the anterolateral side of the human knee joint, further termed anterolateral ligament (ALL).

Materials and methods

The presence and characteristics of the ALL were investigated in 41 unpaired, embalmed human cadaveric knees [22 men and 19 women; mean age at death, 79 years (range 61–93)]. Specimens were obtained by the body donation programs of the University of Leuven and University of Ghent. Specimens with signs of osteoarthritis of the lateral tibio-femoral joint were excluded in case frank osteophytes were present. Furthermore, specimens showing gross deformity at the knee or a damaged anterior cruciate ligament (ACL) were excluded as well.

Dissection was started by creating a large rectangular cutaneous flap, centered on the lateral aspect of the flexed knee. The iliotibial band (ITB), extensor apparatus and the short head of the biceps femoris as well as the tendon were cleared of subcutaneous fat tissue. The ITB was cut transversely at approximately 6 cm proximal to the lateral femoral epicondyle and then carefully released from its tibial attachment on Gerdy's tubercle, sharply cutting the deep iliotibial tract layer (also called Kaplan's fibers; Kaplan, 1958; Terry et al. 1993) attached to the lateral intermuscular septum, and the lateral retinaculum. Indeed, according to Seebacher et al. (1982), the ITB forms the most superficial distinct tissue layer (Layer I) on the lateral aspect of the knee, only attached to the deeper Layer II anteriorly at the lateral patellar retinaculum. With the ITB reflected, the 'superficial lamina of the capsule' (Seebacher et al. 1982) was visualized. The lateral collateral ligament (LCL) was palpated with the knee in slight varus, and the lamina encompassing the LCL was then carefully incised posteriorly and parallel to the LCL. With the knee flexed to 60°, an internal torque was subsequently applied on the foot, thereby revealing taught, distinct fibers running from the region of the lateral femoral epicondyle to the proximal tibia posterior to Gerdy's tubercle. These fibers could be clearly delineated from the slack and thin joint capsule (Layer III) lying anterior of it (Fig. 1). Subsequently, all visible fibers of this ligamentous structure were carefully isolated at its insertional zone at the proximal tibia, posterior and proximal to Gerdy's tubercle, along its upwards course to the lateral femur. Care was taken not to damage fibers intersecting with the proximal LCL. Furthermore, the lateral meniscus, the lateral inferior geniculate artery, the LCL and the popliteus tendon were isolated to study the relationship with the ALL. Origins and insertions of the ALL, LCL, ITB and popliteus tendon were then delineated *in situ* using small metal pins.

Finally, a qualitative and a quantitative characterization of the ALL were performed. Each ALL was described with regard to origin, insertion, interconnecting fibers with the LCL, lateral intermuscular septum and lateral meniscus, ligamentous tension in different flexion and rotation angles. A digital caliper with an accuracy of 0.01 mm (Mit500196-20; Mitutoyo, Japan) was used to measure the following aspects of the ALL: length, width at tibial insertion, width at the joint line, width at the femoral origin, thickness at the level of the joint line (after resecting the lateral meniscus), and depth of the 'tibial synovial recess' (distance between the tibial cartilage surface and the insertional fold of the ALL at the proximal tibia). Furthermore, distances between the center of the ALL insertion and Gerdy's tubercle and the tip of the fibular head, respectively, were measured as well. To standardize the quantitative measurements, care was taken to position the tibia in its reduced position with respect to the femur with the foot in neutral rotation. Finally, to investigate a potential correlation between the dimensions of the ALL and the general size of the knee, both width of the distal femoral bone (measured as the distance from the tip of the lateral epicondyle to the tip of the medial femoral epicondyle) and width of the femoral intercondylar notch were recorded.

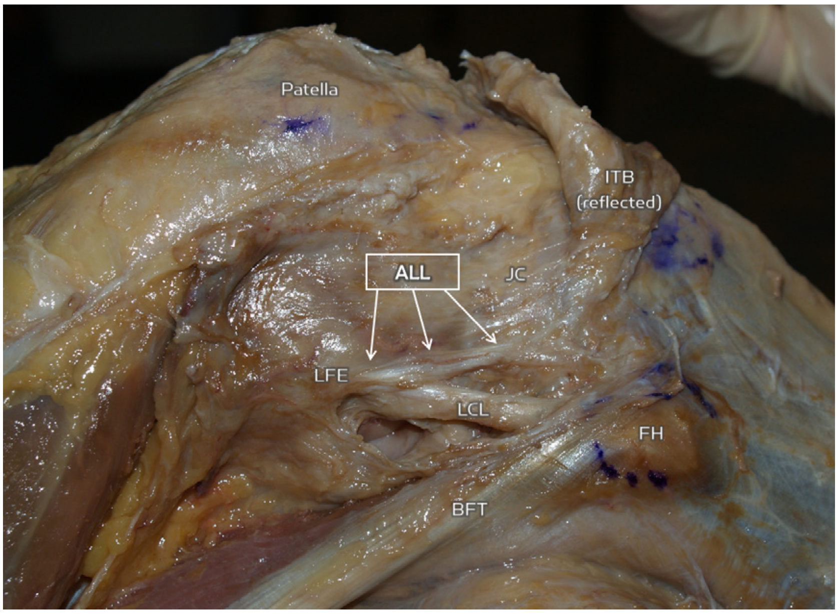

Fig. 1 Lateral view of a typical right knee during dissection. With the ITB reflected, the ALL fibers are clearly distinguishable from the thin anterolateral joint capsule anterior to it. ALL, anterolateral ligament; LCL, lateral collateral ligament; LFE, lateral femoral epicondyle; BFT, biceps femoris tendon; FH, fibular head; JC, joint capsule.

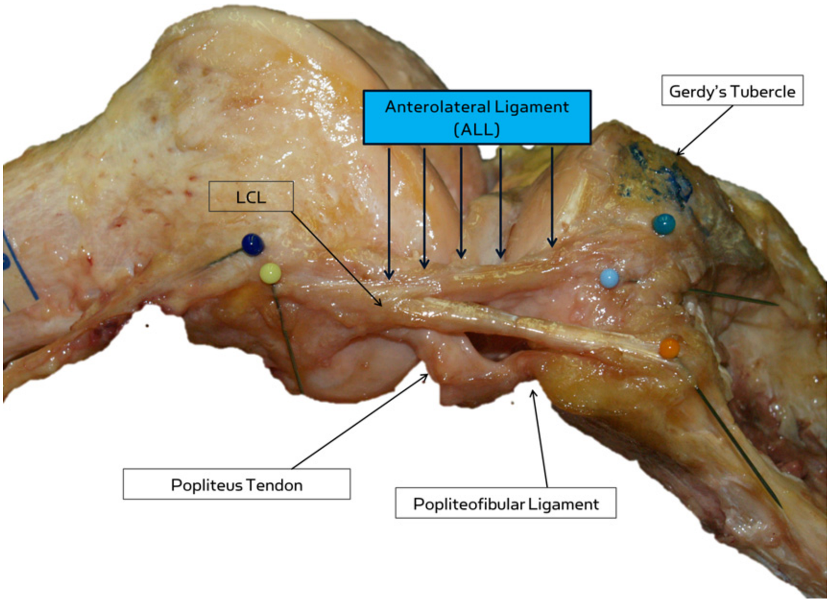

Fig. 2 Photograph of a typical right knee after complete dissection of the ALL, popliteus tendon, popliteofibular ligament and lateral collateral ligament.

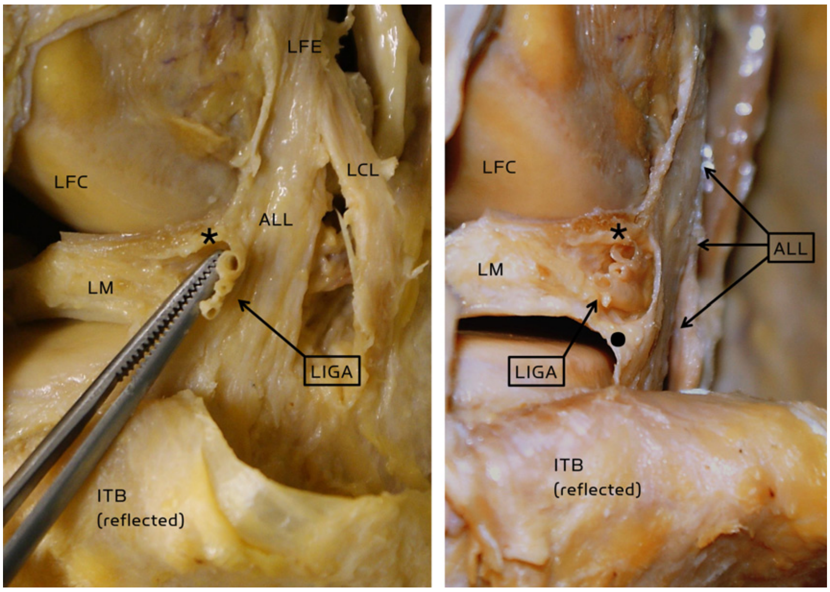

Fig. 3 Photograph of a left knee detailing the close relationship of the ALL with the lateral meniscus. ALL, anterolateral ligament; *(asterisk), meniscofemoral portion of the ALL; •(dot), meniscotibial portion of the ALL; ITB, iliotibial band; LCL, lateral collateral ligament; LIGA, lateral inferior geniculate artery and veins; LFC, lateral femoral condyle; LFE, lateral femoral epicondyle; LM, lateral meniscus.

Results

Qualitative ALL characterization

All 41 knees met the inclusion criteria. In all but one of the 41 dissected knees (97%) a distinct ligamentous structure was identified at the anterolateral side of the knee joint connecting the femur with the tibia. The structure was easily distinguishable from the thinner joint capsule lying anterior to it (Fig. 1). In all cases, the major origin of the ALL was located on the prominence of the lateral femoral epicondyle, anterior to the socket from which the LCL originated, and proximal and posterior to the insertion of the popliteus tendon (Fig. 2). However, in the majority of cases the most superficial fibers of the ALL continued over the lateral aspect of the distal femur in the direction of the lateral intermuscular septum of the thigh. Furthermore, the most posterior fibers of the proximal ALL blended with the proximal part of the LCL in the majority of the dissected knees. The body of the ALL ran an oblique course to the anterolateral side of the proximal tibia. A strong connection was seen between the ALL and the periphery of the middle third of the meniscal body of the lateral meniscus, which was divided into the meniscofemoral and meniscotibial portions of the ALL, above and under the meniscal rim, respectively (Fig. 3). After sharply detaching the ALL from the meniscus, the lateral inferior geniculate artery (LIGA) and vein were invariably found, situated in between the lateral meniscal rim and the ALL at the level of the joint line. More distally, the ALL inserted on the proximal tibia, thereby forming a thick capsular insertional fold. The tibial insertion of the ALL was always clearly situated posterior to Gerdy's tubercle, with no connecting fibers to the ITB. Grossly, the tibial ALL insertion could be found in the middle of the line connecting Gerdy's tubercle and the tip of the fibular head. A graphic illustration of the ALL and its neighboring structures is provided in Figs 4 and 5.

Quantitative ALL characterization

The mean length of the ALL measured in neutral rotation and at 90º flexion was 41.5 ± 6.7 and 38.5 ± 6.1 mm in extension, illustrating some tensioning of the ligament during mid-flexion. This increase in length during flexion was significant ($P < 0.001$). During manipulation of the knee joint, we observed a maximal tension of the ALL during combined flexion and internal rotation of the tibia.

The mean width of the femoral origin measured 8.3 ± 2.1 mm. The ALL slightly narrowed near the level of the joint line, with an average width of 6.7 ± 3.0 mm. The ALL then broadened further distally, inserting on the proximal tibia with a width of 11.2 ± 2.5 mm. This distal flaring of the ligament was clearly visible and highly significant ($P < 0.0001$; proximal vs. distal width). The thickness of the ALL at the level of the joint line, and after resection of the lateral meniscus, was 1.3 ± 0.6 mm.

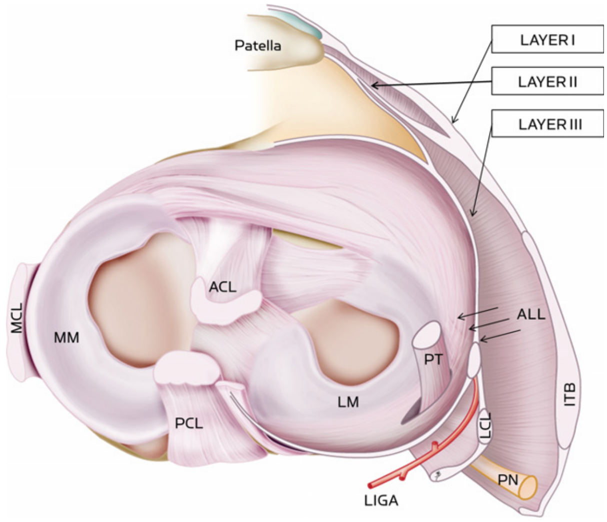

Fig. 5 Anatomic drawing of the axial view of a right knee at a level above the meniscal surface. The intra-capsular course of the ALL is appreciated, as well as the triple layered anatomy of the lateral knee. ALL, anterolateral ligament; ITB, iliotibial band; LCL, lateral collateral ligament; GT, Gerdy's tubercle; LIGA, lateral inferior geniculate artery; PN, peroneal nerve; PCL, posterior cruciate ligament; ACL, anterior cruciate ligament; LM, lateral meniscus; MM, medial meniscus; MCL, medial collateral ligament.

The insertion of the ALL on the tibia was quantified relative to bone landmarks of the proximal lower leg. The average distance between the proximal cartilage edge of the lateral tibia and the ALL insertion, i.e. the 'lateral tibial recess', was 6.5 ± 1.4 mm. The center of the tibial ALL insertion was on average located 21.6 ± 4.0 mm posterior to the center of Gerdy's tubercle and 23.2 ± 5.7 mm anterior to the tip of the fibular head. Individual ALL recordings of all dissected cases are summarized in Table 1.

No correlation ($P > 0.05$) using a Student's *t*-test was found between the individual ALL dimensions and knee size as measured by the distal femoral width at the level of the epicondyles and the intercondylar width.

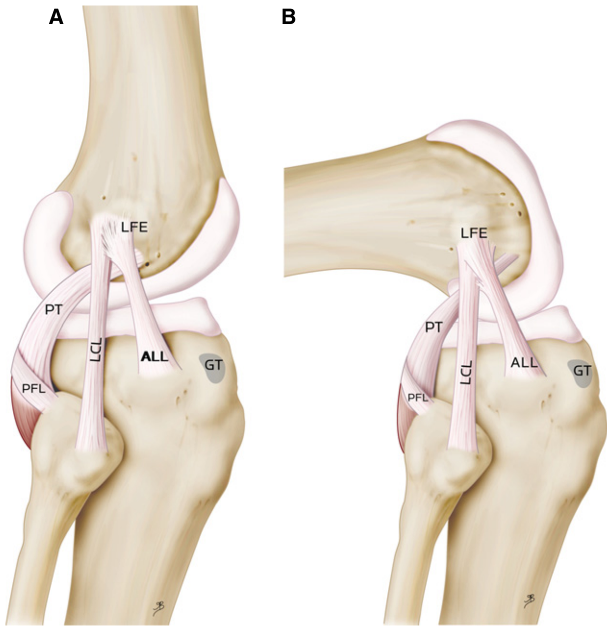

Fig. 4 Anatomic drawing considering the ALL and its relationship with well-known anatomical landmarks on the lateral aspect of the human knee. (A) Knee in full extension. (B) Knee in 90° of flexion. ALL, anterolateral ligament; LCL, lateral collateral ligament; GT, Gerdy's tubercle; LFE, lateral femoral epicondyle; PT, popliteus tendon; PFL, popliteo-fibular ligament.

Discussion

The main finding of this study is that the anterolateral ligament (ALL) can be identified as a distinct ligamentous structure at the anterolateral aspect of the human knee. Although there have been sporadic reports (Campos et al. 2001; Haims et al. 2003; Vincent et al. 2012) mentioning the existence of a capsulo-ligamentous structure connecting the femur with the tibia at the (antero)lateral region of the knee joint, information on the precise anatomy and function of this entity has always been vague and confusing.

Table 1 Table summarizing the most important features of the individual anterolateral ligaments (ALLs). Note cadaver 18 is the only one without an identifiable ALL.

			ALL length (mm)		ALL width (mm)			ALL thickness (mm)	Femoral bone width (mm)				
Specimen	L/R	Sex	Extension	Flexion (90)	Femoral origin	Joint line	Tibial insertion	Joint line	Epicondylar	Intercondylar	Tibial recess (mm)	Distance GT-ALL (mm)	Distance FH-ALL (mm)
1	Right	Male	41	50	13	6	13	3	75	17	6	18	34
2	Right	Female	37	47.3	x	5.2	10.6	1.6	67.6	20	5.8	15.5	15.8
3	Right	Male	48.8	50.12	x	6.9	8.9	2.1	84.3	18.4	9.3	28.8	23.7
4	Left	Male	40.35	41.43	x	13.08	17.55	1.09	110	19.05	7.9	24.2	26.2
5	Left	Male	34.3	37.1	8.5	8.3	12.4	0.5	86.8	x	5.2	19.9	20.8
6	Right	Male	37.62	39.42	10.04	7.26	10.07	0.88	102.92	x	5.5	27.4	26.09
7	Left	Male	37.61	40.15	6.55	3.65	9.95	0.41	95.08	x	5.97	24.97	23.57
8	Left	Male	46.94	50.22	11.39	4.71	13.88	1.75	98.86	x	6.27	26.76	13.64
9	Right	Female	41.82	43.34	4.92	1.4	5.8	0.28	82.59	x	3.57	27.44	15.43
10	Left	Male	35.28	36.72	7.23	5.96	10.37	0.48	92.6	x	9.88	23.44	17.26
11	Left	Female	30.11	34.08	8.52	8.48	13.16	0.43	91.21	x	5.51	19.78	24.27
12	Right	Male	33.16	35.92	9.65	2.37	9	0.37	80.18	x	5.3	19.74	22.4
13	Right	Female	29.25	30.83	4.02	2.88	9.43	0.38	87.95	x	9.16	25.35	25.65
14	Right	Male	26.1	27.7	9.2	6.3	10.1	1.4	71.9	19.4	6.4	24.5	22.3
15	Right	Female	23.2	27.4	8.78	4.42	11.62	0.88	76.26	18.55	5.24	23.89	19.68
16	Right	Male	43.25	49.22	12.28	3.541	14.65	1.37	77.48	23.07	6.41	25.88	19.76
17	Right	Male	33.73	30.63	8.92	6.23	12.35	1.69	75.89	16.01	6.13	21.6	19.48
18	Right	Female	x	x	x	x	x	x	74.25	19.03	x	x	x
19	Left	Female	35.87	39.46	7.23	10.84	9.76	1.69	77.51	13.63	5.52	20.66	24.96
20	Left	Female	30.88	38.72	8.61	10.54	15.62	1.86	66.97	18.26	6.33	16.65	15.23
21	Left	Male	40.16	35.12	5.68	6.19	15.82	1.43	90.27	19.92	7.2	24.69	21.83
22	Left	Female	37.9	37.33	8.28	5.5	10.22	1.34	72.32	15.35	6.86	17.02	14.67
23	Left	Male	44.29	41.12	9.01	5.84	13.75	1.82	85.95	22.94	5.15	18.45	25.85
24	Left	Male	41.18	45.05	8.74	5.96	10.81	2.2	80.96	22.07	5.94	21.63	20.81
25	Right	Female	37.68	39.23	12.61	8.69	10.01	1.94	77.55	16.32	6.07	19.65	17.1
26	Left	Female	32.25	39.16	7.74	7.45	11.63	1.35	79.38	17.52	4.64	15.54	26.84
27	Left	Female	34.81	44.42	8.32	4.04	11.51	1.15	79.82	18	7.2	15.09	25.41
28	Right	Male	36.57	37.8	6.9	8.9	13.08	1.2	89.47	21.6	7.35	18.55	22.42
29	Left	Male	45.56	48.99	8.28	7.75	11.74	1.9	83.81	16.4	6.8	24.1	33.02
30	Right	Female	40.65	42.22	6.3	13.49	13.49	0.6	71.31	17.8	5.97	16.3	32.6
31	Left	Male	42.29	36.86	5.1	14.19	14.19	1.4	80.91	15.51	8.25	26.78	20.66
32	Right	Female	38.39	40.97	9.1	6.7	9.1	0.7	84.13	20.8	5.6	24.25	21.22
33	Right	Male	43.5	46	6.8	4.3	9.1	0.9	88.5	16.4	8.1	20.5	21.6
34	Right	Male	35.37	41.81	10.03	5.51	9.36	1.05	89.27	16.04	6.47	25.84	31.42
35	Left	Female	44.47	47.19	5.166	5.4	8.15	1.39	79.3	17.06	5.69	19.36	23.39
36	Left	Male	47.52	50.86	x	x	8.41	1.34	82.99	21.7	6.64	20.87	27.91
37	Right	Female	x	46.46	x	x	11.42	0.85	80.81	13.13	7.84	21.01	23.37

Table 1. (continued)

Specimen	L/R	Sex	ALL length (mm)		ALL width (mm)			ALL thickness (mm)	Femoral bone width (mm)		Tibial recess (mm)	Distance GT-ALL (mm)	Distance FH-ALL (mm)
			Extension	Flexion (90)	Femoral origin	Joint line	Tibial insertion	Joint line	Epicondylar	Intercondylar			
38	Right	Female	45.65	47.07	10.49	5.22	10.22	1.14	76.02	17.8	4.52	18.8	25.68
39	Right	Female	42.12	38.68	8.5	8.95	8.14	1.07	72.55	17.06	6.04	23.61	13.6
40	Right	Female	49.46	48.09	8.58	x	7.98	x	72.41	15.5	6.8	25.12	34.46
41	Right	Male	36.5	57.32	6.18	x	10.4	1.05	82.45	19.85	9.22	13.76	33.02
Average			38.5	41.5	8.3	6.7	11.2	1.2	82.3	18.2	6.5	21.6	23.2
SD			6.1	6.7	2.1	3.0	2.5	0.6	9.2	2.5	1.4	4.0	5.7
MIN			23.2	27.4	4.0	1.4	5.8	0.3	67.0	13.1	3.6	13.8	13.6
MAX			49.5	57.3	13.0	14.2	17.6	3.0	110.0	23.1	9.9	28.8	34.5

The existence of a ligamentous structure between the lateral femur and tibia was first described by Paul Segond in 1897 (Segond, 1879) when he noted that 'a pearly, resistant, fibrous band which invariably showed extreme amounts of tension during forced internal rotation' was attached to his eponymous fracture. However, the notion of this structure was eventually forgotten, until Jack Hughston published his findings on rotatory knee instability patterns in the late 1970s (Hughston et al. 1976a,b). Those authors described a 'mid-third lateral capsular ligament' intimately attached to the meniscus and divided into meniscofemoral and meniscotibial portions. According to Hughston, this capsular ligament is 'strong and supported superficially by the iliotibial band' (Hughston et al. 1976a). It was thought to play an important role in the so-called 'anterolateral instability' (ALRI) pattern of the knee (Hughston et al. 1976b; Norwood et al. 1979), a clinical term which has become obsolete with the advent of knee arthroscopy (and its inherent predominance in the diagnosis of intra-articular pathology) a few years later. Although the term 'mid-third lateral capsular ligament' is sporadically encountered in more recent literature (LaPrade, 1997; Haims et al. 2003; Moorman & LaPrade, 2005), no further anatomical characterization, drawings or photographs have been provided, adding to the mystery surrounding this enigmatic structure. Recently, Vincent et al. (2012) reported their observations during total knee arthroplasty procedures, when the authors noticed 'a relatively consistent structure in the lateral knee, linking the lateral femoral condyle, the lateral meniscus, and the lateral tibial plateau' (Vincent et al. 2012). The structure was named 'anterolateral ligament', a term which has previously been used by Vieira et al. (2007) in describing the 'capsulo-osseous' layer of the iliotibial band (ITB).

Although Vincent et al. (2012) provide a schematic diagram of the ALL and its suggested relation with well-known lateral stabilizing structures, our findings do not agree with their description. They describe the origin of the ALL 'to be on the lateral femoral condyle, closely associated with the popliteus tendon', as in nine of 10 cases, its insertion was found 'just anterior to the popliteus tendon insertion, blending with its fibers'. In all of our 40 cadaveric dissections, however, the ALL was found to originate proximal and posterior to the popliteus tendon insertion, on the lateral femoral epicondyle. A close relationship was noted with the proximal part of the lateral collateral ligament and not with the popliteus tendon, the latter running an intra-articular but extra-synovial course in its proximal part. Logically, one would expect the ALL to insert close to the center of rotation of the knee joint (i.e. the surgical epicondylar axis) but the drawing provided by Vincent et al. would imply an extremely anisometric ALL. Furthermore, it remains unclear whether they found the ALL to be a part of the ITB. In our view, fibers connecting the ITB with the lateral femoral condyle and the intermuscular septum do exist but originate proximal to the level of the epicondyle (the so-called 'deep layer of the iliotibial tract', or 'Kaplan's fibers') (Kaplan, 1958; Terry et al. 1993; Fairclough et al. 2006; Vieira et al. 2007), not from the tibia.

In contrast to previous publications, we found no connection at all between the distal ITB and the ALL: the center of their respective insertion sites are separated by more than 20 mm on the proximal tibia, and as (Seebacher et al. 1982) have shown, the only connection between the ITB (Layer I) and the deepest layer (Layer III) occurs at the patellar retinaculum (Layer II). Indeed, our dissections consistently demonstrated that, with the ITB transversely cut at a level well above the knee (6 cm proximal to the epicondyle), only its medial connection with the lateral intermuscular septum proximally (Kaplan's fibers) and its connection to the patellar retinaculum anteriorly necessitated sharp transsection to enable blunt dissection of the whole ITB until reaching Gerdy's tubercle. Terry and Laprade (Terry et al. 1993; Terry & LaPrade, 1996) have described the so-called 'capsulo-osseous layer of the ITB' as originating from the investing fascia of the lateral gastrocnemius and medial head of the biceps femoris muscle; we also conclude that the ALL is a ligamentous structure which is clearly distinct from the ITB, and that both its 'deep layer' (Kaplan's fibers) and its 'capsulo-osseous layer' should not be confused with the ALL. In our view, the closest description of an ALL-like structure in the current literature would be the one by Jack Hughston, depicting the 'middle-third of the lateral capsular ligament' as attaching 'proximally to the lateral epicondyle of the femur and distally at the tibial joint margin' (Hughston et al. 1976b).

With both the LCL and ALL being part of Layer III, and given the fact that the femoral origins of ALL and LCL are so closely associated, we propose to envelop both structures in the term 'lateral collateral ligament complex' (LCLC), as has been previously introduced for the medial collateral ligaments (Robinson et al. 2004; LaPrade et al. 2007)l. In this view, the ALL can be regarded as the lateral counterpart of the deep medial collateral ligament (dMCL) (LaPrade et al. 2007).

Given its anatomical location at the anterolateral edge of the knee, we hypothesize that the ALL functions as a stabilizer for internal rotation. Indeed, our findings during cadaveric dissections are in line with Segond, who described 'invariably (…) extreme amounts of tension during forced internal rotation'. Although during dissections we found the ALL to become tense with forced internal rotation between 30° and 90° of knee flexion, further kinematic analysis is needed to confirm this hypothesis formally. Furthermore, as the Segond fracture is often regarded as pathognomonic for a lesion of the anterior cruciate ligament (ACL), this bony avulsion of the ALL could provide a clue to an important role for the ALL in rotatory knee instability patterns witnessed in many ACL-deficient knees (i.e. the pivot-shift phenomenon; Leitze et al. 2005; Lane et al. 2008).

Concluding remarks

This study is the first to provide a detailed anatomical description of the anterolateral ligament (ALL) of the human knee. The ALL is found to be a distinct ligamentous structure showing consistent origin and insertion site features in 97% of the dissected specimens. Given its suggested role in common knee instability patterns such as the pivot-shift, the precise anatomical knowledge of this enigmatic structure delivered by this study could be highly relevant for clinical practice. However, further research is needed to establish the function of the ALL and to determine its role in clinical knee injuries.

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Author's contributions

S.C., J.B.: conception and study design. S.C., E.V., M.M.: acquisition of data. S.C., E.V., J.B.: data analysis, statistics, writing of the article. S.C., E.V., J.V., P.V., J.B.: interpretation of the data, critical revision of the manuscript, drafting the article. All authors approved the final version of the manuscript.

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