

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/330137203>

Anatomy of the Anterolateral Ligament of the Knee: A Systematic Review

Article in *Arthroscopy The Journal of Arthroscopic and Related Surgery* · February 2019

DOI: 10.1016/j.arthro.2018.09.006

CITATIONS

18

READS

341

6 authors, including:



Diego Ariel de Lima

Universidade Federal Rural do Semi-Árido - UFERSA

12 PUBLICATIONS 30 CITATIONS

[SEE PROFILE](#)



Camilo Partezani Helito

University of São Paulo

131 PUBLICATIONS 1,701 CITATIONS

[SEE PROFILE](#)



Maria Luzete C Cavalcante

Universidade Federal do Ceará

20 PUBLICATIONS 123 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Nerve endings and mechanoreceptors in the tissues, ligaments and cartilage [View project](#)



The knee anterolateral ligament [View project](#)

Systematic Review

Anatomy of the Anterolateral Ligament of the Knee: A Systematic Review

Diego Ariel de Lima, M.D., M.S., Camilo Partezani Helito, M.D., Ph.D.,
Lana Lacerda de Lima, M.D., M.S., Daniel de Castro Silva, M.D.,
Maria Luzete Costa Cavalcante, M.D., Ph.D., and José Alberto Dias Leite, M.D., Ph.D.

Purpose: To conduct a systematic literature review to search for studies on the anatomy of the anterolateral ligament (ALL) of the knee, presenting the most accepted findings, as well as the evolution of anatomic information on this structure. **Methods:** We reviewed the PubMed, MEDLINE, and ClinicalKey databases for anatomic studies on the ALL, involving cadaveric, histologic, and biochemical dissection and/or anatomic imaging. The primary data researched were the presence of the ligament; measures of length, width, and thickness; ligament path; insertions; number of bands; histologic assessment; and innervation. **Results:** We identified 53 studies. The ALL was found in 82.87% of adult dissections (more easily visualized in fresh cadavers), 74.07% of fetal dissections, and 84.80% of magnetic resonance imaging (MRI) studies. In 29 articles, the ALL was found in 100% of cases. There are 3 ALL insertion points: femoral, tibial, and meniscal. Histologic sections showed dense, well-organized collagen fibers, with an average of 121 fibroblasts/mm² in adults, in addition to the presence of vascular and nervous tissue. MRI was shown to be a good examination tool to visualize the ALL, primarily in the coronal plane and with T2-weighted images. **Conclusions:** The ALL is a distinct structure in the anterolateral portion of the knee. It exhibits typical ligament characteristics and can be visualized on imaging examinations, especially MRI. It has a femoral attachment near the lateral epicondyle, with a trend in recent years showing it to be located posterior and proximal to it, following an anteroinferior trajectory, with an insertion into the lateral meniscus and proximal tibia at the midpoint between the fibular head and Gerdy tubercle. Among the studies, the length of the ALL varied from 30.41 to 59.0 mm, the width ranged between 4.0 and 7.0 mm, and the thickness ranged between 1.0 and 2.0 mm. **Clinical Relevance:** During the past few years, much controversy has been raised about the correct anatomy of the ALL. The main clinical relevance of this study is not only to end the discussion about the ALL's existence but also to clarify and synthesize the main evidence on the ALL's anatomy, mainly the currently most accepted attachments according to the recent literature, to enable more precise development of biomechanical settings and surgical techniques.

Even before the X-ray was discovered by Wilhelm Conrad Röntgen,¹ in 1879 Paul Segond² described a pattern of avulsion fracture in the anterolateral

proximal tibia as a result of forced internal rotation of the knee. Later, this fracture was considered a pathognomonic sign of anterior cruciate ligament (ACL) injury.^{3,4} In 2014, Claes et al.⁵ concluded that it is an avulsion fracture of the anterolateral ligament (ALL) of the knee, a possible predictor of rotational instability⁶ (Fig 1).

Since the studies by Vincent et al.,⁷ Claes et al.,⁸ and Helito et al.,⁹ research on the lateral compartment of the knee has attracted increasing interest. Several studies have sought to prove the existence (or not) of the ALL.

In recent years, many variations in anatomic landmarks have been described, with an apparent change in the understanding of the femoral position of the ALL. Thus, the purpose of this study was to conduct a systematic literature review to search for studies on the anatomy of the ALL, presenting the most accepted

From Universidade Federal Rural do Semi-Árido (D.A.d.L.), Mossoró; Grupo de Joelho, Instituto de Ortopedia e Traumatologia, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (C.P.H.), São Paulo; Hospital Sírio Libanês (C.P.H.), São Paulo; Universidade do Estado do Rio Grande do Norte (L.L.d.L.), Mossoró; and Departamento de Cirurgia da Universidade Federal do Ceará (D.d.C.S., M.L.C.C., J.A.D.L.), Fortaleza, Brazil.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received May 11, 2018; accepted September 3, 2018.

Address correspondence to Diego Ariel de Lima, M.D., M.S., Federal University Rural of the Semi-Arid, R. Francisco Mota, 572 - Pres. Costa e Silva, Mossoró-RN, Brazil, CEP 59625-900. E-mail: arieldelima.diego@gmail.com

© 2018 by the Arthroscopy Association of North America

0749-8063/18568/\$36.00

<https://doi.org/10.1016/j.arthro.2018.09.006>

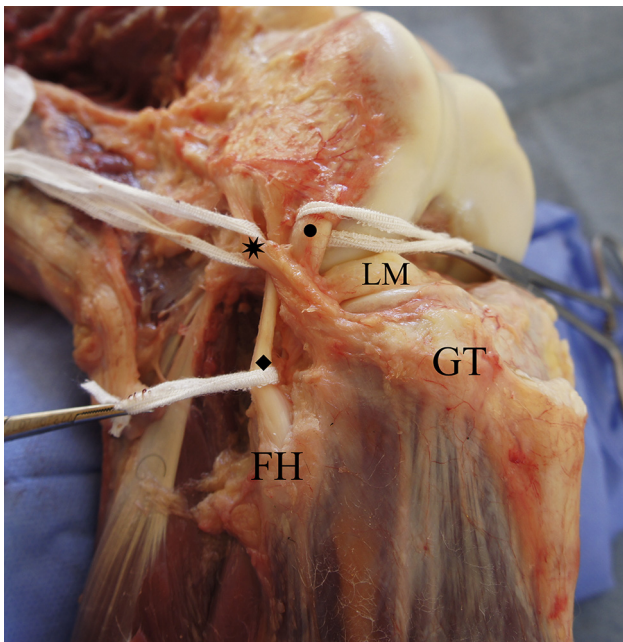


Fig 1. Anterolateral aspect of right knee, showing relation between anterolateral ligament (star), lateral collateral ligament (diamond), and popliteus tendon (circle). (FH, fibular head; GT, Gerdy tubercle; LM, lateral meniscus.)

findings, as well as the evolution of anatomic information on this structure. The hypothesis of this study was that the ALL would be a distinct structure in the anterolateral aspect of the knee. It would display histologic characteristics typical of ligaments, and it could be clearly identified by anatomic dissection and could be seen on imaging examinations, especially magnetic resonance imaging (MRI).

Methods

An electronic survey was conducted by 2 of the authors (C.P.H. and D.A.d.L.) in January 2018 using the PubMed, MEDLINE, and ClinicalKey databases, with no date restrictions. The following index terms were used in the search: “anterolateral ligament anatomy” and “anterolateral ligament anatomic.”

Titles and abstracts were used to select articles that met the objective of the research. As such, only original articles that described anatomic studies of the ALL in the titles or abstracts were selected. The selected articles were read in their entirety, and their references were researched manually to find additional relevant studies. Discrepancies in data extraction were resolved through discussion among the authors.

The inclusion criteria were anatomic studies of the ALL of the knee; these involved cadaveric dissections, histologic and/or biological investigations, and/or imaging of anatomy. Only English-language articles and those with at least an English-language abstract were included. Studies containing only biochemical and/or

intraoperative data, as well as review articles with no original data, were excluded.

The following data were collected from the selected studies: authors; date of publication; type of study; anthropometric data; presence of the ligament; measures of length, width, and thickness; ligament path; number of bands; histologic assessment; and innervation. The data were tabulated and analyzed using IBM SPSS software (version 20.0). Categorical variables were expressed as absolute count and percentage and quantitative variables as mean $\pm$ standard deviation. The categorical variables in different groups were compared using the χ^2 -square test. The Shapiro-Wilk test was applied to check for quantitative data normality in the groups. When appropriate, the Mann-Whitney and Student *t* tests were used to compare the means for independent groups. A 95% confidence interval and 5% significance level were established ($P < .05$).

Results

A total of 994 articles were found (523 in PubMed, 318 in ClinicalKey, and 153 in MEDLINE). After articles indexed in more than 1 database or not related to the ALL were excluded, 84 articles remained.

Of the 84 articles, 31 were excluded for being review studies or containing intraoperative findings (Fig 2). The 53 remaining articles were read in their entirety, and the data were tabulated for analysis.

Publication Date

Since the first reports on the ALL in 2012 and 2013 (Helito et al.,⁹ Claes et al.,⁸ and Vincent et al.⁷), the number of articles on the anatomy of the ALL has risen significantly. We found 14 articles in 2017 and only 3 in 2013, whereas the largest number (17) was published in 2016. The first study exclusively related to the anatomy of the ALL was conducted in 2012 by Vincent et al.⁷ (Fig 3).

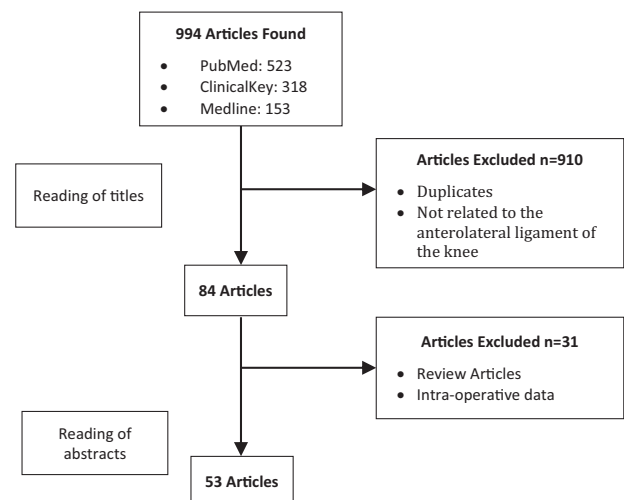


Fig 2. Flowchart of articles selected.

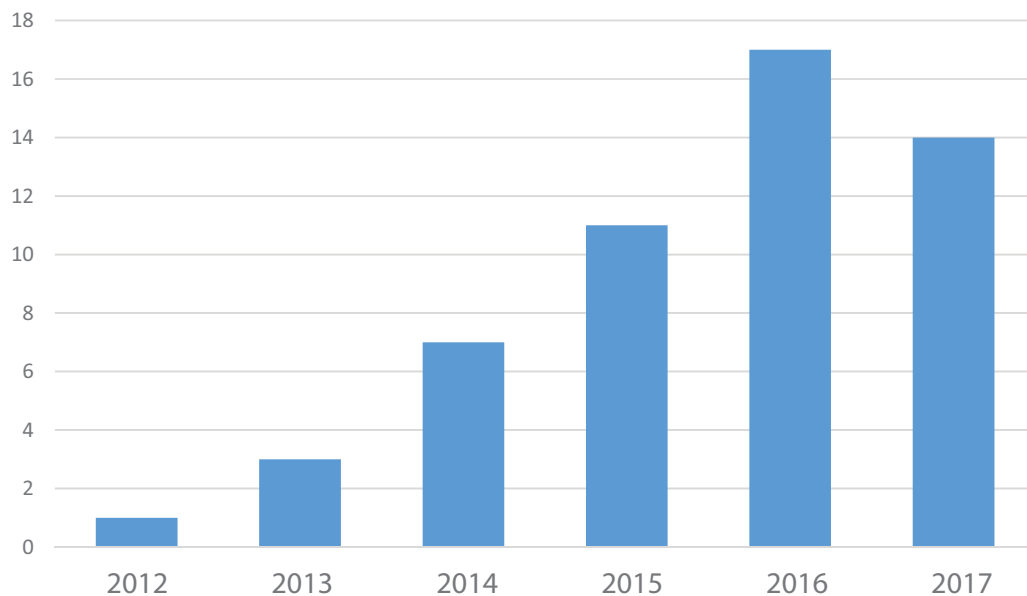


Fig 3. Articles published in past 6 years.

Type of Study

Of the 53 studies assessed, 39 involved cadaveric dissection, 16 used MRI, 4 used radiographs, 5 used ultrasonography, and 2 used arthroscopy (Table 1).^{5,7-39}

Anthropometric Data

It is important to underscore that 3 populations were used in the studies: fetuses, young adults, and elderly persons (aged >60 years). Dissections were conducted mainly on fetuses and elderly persons, and images were studied largely in young adults.

Presence of Ligament

In 29 articles, the ALL was found in 100% of cases.^{5,7,9,11,15-19,21,22,31-37,39-49} Among these articles, the presence of the ligament was reported primarily by fresh cadaveric dissection and MRI. In 12 articles, the ALL was observed in between 80% and 100% of cases.^{8,10,25,27,30,38,42,43,45,50-52} The incidence was between 60% and 80% of cases in 4 articles,^{13,14,53,54} between 40% and 60% in 3 articles,^{24,29,50} and between 0% and 40% in 3 articles^{23,26,28} (Table 2). In 2 studies, the ALL could not be isolated properly, 1 using fresh fetus cadaveric dissection¹² and the other using adult cadaveric dissection preserved in a 4% formalin solution, a methodology that is less accurate in characterizing the ALL²⁰ (Fig 4).

Among the cadaveric dissection studies^{5,7-11,13,14,16,18-39} (Table 1), a total of 952 specimens were used, with the ALL described in 789 (82.87%). Among the 3 articles that dissected fetuses,^{12,15,17} 81 specimens were dissected, with the ALL found in 60 (74.07%). In MRI studies, the ALL was visualized in 709 of the 836 specimens included (84.80%).^{30,32,36,40,41,43,44,46,50-52,54-56}

ALL Measures

The length of the ALL varied among studies from 30.41 mm²⁶ to 59.0 mm.³⁸ However, most of the studies showed lengths between 33.0 and 42.0 mm.^{7-9,11,13,14,16,21,24-27,32-34,36,39}

With the exception of 3 articles,^{26,28,38} all articles showed that the length of the ALL increased with knee flexion and tibial internal rotation. In most cases, the width of the ALL varied between 4.0 and 7.0 mm and the thickness varied between 1.0 and 2.0 mm. According to Daggett et al.,¹¹ in a study with 160 specimens, the average ALL thickness in men was twice that in women.

Trajectory and Insertions

The ALL has 3 insertions: femoral, tibial, and meniscal. After its origin in the femur, close to the lateral epicondyle, it exhibits an anteroinferior trajectory toward the anterolateral region of the tibia.

The meniscal insertion is located between the body and anterior horn of the lateral meniscus.^{15,17} Of the dissection studies (Table 1), 22 showed the presence of this insertion.^{5,7-9,11,13,15,17-19,21,25-28,30-34,36,39} Eight made no mention of this insertion,^{10,14,16,22-24,35,37} and 2 questioned its existence.^{29,38} Helito et al.³¹ showed spreading of the fibers of the ALL before its contact with the lateral meniscus, increasing the area of this insertion.

Tibial insertion varied the least among the studies. This structure is located at the midpoint between the fibular head and Gerdy tubercle, between 4.0 and 7.0 mm below the tibial plateau.^{9,32,37,39}

The femoral origin varied most in the study descriptions. The primary anatomic references for the

Table 1. Characteristics of Cadaveric Dissection Studies

Authors	Year	n	Type of Study	Anthropometric Data	Presence of Ligament	Length	Width and/or Thickness	Femoral Insertion	Tibial Insertion
Neri et al. ¹⁰	2017	84	Fresh cadaveric dissection	79 ± 11 yr, 173 ± 9 cm	95%	50.39 ± 6.64 mm (30° and internal rotation)	Thickness: 1.35 ± 0.18 mm	Posterior and proximal to LEF (5.52 ± 0.93 mm and 1.51 ± 0.75 mm, respectively)	Posterior and proximal to GT, anterior and proximal to FH, and distal to ACT
Daggett et al. ¹¹	2017	165	Fresh cadaveric dissection	60 yr, 170.8 ± 8.9 cm in men and 160.6 ± 7.3 cm in women	100%	38.42 ± 2.9 mm in men 35.7 ± 3.9 mm in women	Thickness: 2.09 ± 0.6 mm in men and 1.05 ± 0.5 mm in women	Center of LEF	Anterolateral in tibia
Sabzevari et al. ¹²	2017	21	Fresh cadaveric dissection	Fetuses (18-22 wk)	No ligament found				
Roessler et al. ¹³	2017	20	Fresh cadaveric dissection	79.4 ± 9.4 yr	60%	39.63 ± 0.78 mm (0°) 42.91 ± 1.01 mm (90°)	Midpoint width: 5.28 ± 0.33 mm Midpoint thickness: 1.52 ± 0.31 mm	Center of LEF	Between GT and FH
Shea et al. ¹⁴	2017	14	Fresh cadaveric dissection	8 yr	64%	33 mm	Femoral origin width: 3 mm Tibial insertion width: 4 mm	10 mm distal to distal femoral physis	Between GT and FH (9 mm proximal to tibial physis)
Helito et al. ¹⁵	2017	20	Embalmed cadaveric dissection (10% formalin)	Fetuses (28.64 ± 3.20 wk)	100%	7.19 ± 1.86 mm (0°) 9.11 ± 1.60 mm (90°)	Midpoint width: 2.12 ± 0.47 mm Midpoint thickness: 0.39 ± 0.16 mm	Center of LEF, posterior and proximal to LEF	Between GT and FH (6.29 ± 1.62 mm posterior to posterior edge of GT)
Farhan et al. ¹⁶	2017	26	Embalmed cadaveric dissection		100%	39.2 ± 7.2 mm	Femoral origin width: 6.5 ± 2.7 mm Tibial insertion width: 7.4 ± 3.4 mm Thickness: 1.0 ± 0.5 mm	Posterior and proximal to LEF (4.0 ± 2.9 mm and 7.1 ± 3.4 mm, respectively)	20.4 ± 3.1 mm posterior to GT and 21.33 ± 4.6 mm anterior to FH
Toro-Ibarguen et al. ¹⁷	2017	40	Fresh cadaveric dissection	Fetuses (28-36 wk)	100%	12.3 ± 2.3 mm (0°) 14.3 ± 2.3 mm (90°)	Midpoint width: 1.5 ± 0.6 mm Midpoint thickness: 1.1 ± 0.5 mm	Posterior and proximal to LCL (55%), alongside LCL (25%), anterior and distal to LCL (20%)	Between GT and FH
Brockmeyer et al. ¹⁸	2017	5	Fresh cadaveric dissection (3) and embalmed cadaveric dissection (2)		100%			Posterior and proximal to LCL	Between GT and FH
Corbo et al. ¹⁹	2017	14	Fresh cadaveric dissection	79 yr	100%		Width: supra-meniscal, 9.3 ± 1.3 mm; infra-meniscal, 16.5 ± 2.1 mm Thickness: supra-meniscal, 2.7 ± 0.6 mm; infra-meniscal, 1.4 ± 0.6 mm	Center of LEF, posterior and proximal to LEF	Between GT and FH

(continued)

Table 1. Continued

Authors	Year	n	Type of Study	Anthropometric Data	Presence of Ligament	Length	Width and/or Thickness	Femoral Insertion	Tibial Insertion
Fardin et al. ²⁰	2017	15	Embalmed cadaveric dissection (4% formalin solution)	50 yr	No ligament found				
Helito et al. ²¹	2016	13	Fresh cadaveric dissection		92.30% superficial, 100% deep	Superficial ALL: 53.0-53.3 mm (0°) and 50.0-53.9 mm (flexion) Deep ALL: 33.5-36.7 mm (0°) and 36.7-38.0 mm (flexion)		Superficial: posterior and proximal to LEF, deep, center of LEF (61.5%), posterior and proximal to LEF (30.7%), distal to LEF (7.6%)	Between GT and FH
Daggett et al. ²²	2016	52	Embalmed cadaveric dissection	80 yr	100%		Femoral origin width: 11.85 mm	Center of LEF, posterior and proximal to LEF	Between GT and FH
Shea et al. ²³	2016	8	Fresh cadaveric dissection	3 mo, 4 mo, 1 yr, 2 yr, 3 yr, 3 yr, 8 yr, and 10 yr	12.5%			Next to LCL	Posterior to GT
Stijak et al. ²⁴	2016	14	Embalmed cadaveric dissection	78 yr	50%	41 ± 3 mm	Width: 4 ± 1 mm Thickness: 1 mm	Anterior to LCL	Between GT and FH
Parker and Smith ²⁵	2016	53	Embalmed cadaveric dissection	67 yr	96.2%	38.39 ± 4.30 mm (0°) 42.95 ± 4.35 mm (90°)	Midpoint width: 4.26 ± 0.84 mm	Center of LEF	Between GT and FH (proximal to imaginary line connecting these 2 bony features; in 30.2% of cases, inserted substantially more laterally, closer to FH)
Potu et al. ²⁶	2016	24	Embalmed cadaveric dissection		4.16%	34.23 mm (0°) 30.41 mm (90°)	Femoral origin width: 4.83 mm Midpoint width: 4.04 mm Tibial insertion width: 6.06 mm Midpoint thickness: 1.78 mm	Lateral femoral condyle	Between GT and FH
Kosy et al. ²⁷	2016	11	Fresh cadaveric dissection	79 yr	90.9%	40.1 ± 5.53 mm	Width: 4.63 ± 1.39 mm Thickness: 0.87 ± 0.18 mm	Posterior and proximal to LCL (60%), alongside LCL (10%), anterior and distal to LCL (30%)	Between GT and FH (59.5% ± 5.44% from GT to FH)

(continued)

Table 1. Continued

Authors	Year	n	Type of Study	Anthropometric Data	Presence of Ligament	Length	Width and/or Thickness	Femoral Insertion	Tibial Insertion
Watanabe et al. ²⁸	2016	94	Embalmed cadaveric dissection	85.6 yr	37.2%		Thickness Type I: (a) 1.3-3.2 mm (13.8%), (b) 1.2-2.2 mm (3.2%), and (c) 1.6-2 mm (3.2%) Type II: (a) 0.45-1 mm (10.6%) and (b) 0.7- 0.9 mm (6.4%)	Type I: (a) alongside LCL, (b) posterior to LCL, and (c) anterior to LCL Type II: from anterior to posterior to LCL	Type I and II-a: between GT and FH (exact location of Segond fracture) Type II-b: lateral aspect of tibial plateau (near FH)
Runer et al. ²⁹	2016	44	Embalmed cadaveric dissection	78.1 yr	45.5%	42.2 ± 6.2 mm (0°) 46.9 ± 6.8 mm (60°) 45.9 ± 6.6 mm (90°)	Femoral origin width: 7.2 ± 1.8 mm Midpoint width: 5.6 ± 1.3 mm Tibial insertion width: 12.2 ± 3.0 mm Midpoint thickness: 1.2 ± 0.3 mm	Posterior and proximal to LCL (55%), next to LCL (45%)	Between GT and FH
Klontzas et al. ³⁰	2016	9	Embalmed cadaveric dissection	28.71 ± 9.29 yr	88.89%			Center of LEF	Between GT and FH
Helito et al. ³¹	2016	33	Fresh cadaveric dissection	60.1 ± 10.2 yr	100%			Center of LEF	Between GT and FH
Helito et al. ³²	2015	13	Fresh cadaveric dissection	66.0 ± 10.0 yr	100%	36.62 ± 4.053 mm	Width: 6.08 ± 1.038	Anterior and distal to LCL	Between GT and FH, 5.3 mm below ACT
Kennedy et al. ³³	2015	15	Fresh cadaveric dissection	58.2 yr	100%	36.8 mm (0°) 41.6 mm (90°)		Posterior and proximal to LCL (4.7 mm posterior)	Between GT and FH
Kennedy et al. ³⁴	2015	15	Fresh cadaveric dissection	58.2 yr	100%	36.8 mm (0°) 41.6 mm (90°)		Posterior and proximal to LCL (4.7 mm posterior)	Between GT and FH
Zens et al. ³⁵	2015	6	Fresh cadaveric dissection	86.7 yr	100%			Anterior and distal to LCL	Between GT and FH
Caterine et al. ³⁶	2015	19	Fresh cadaveric dissection	70 yr	100%	40.3 ± 6.2 mm (0°)	Femoral origin width: 4.8 ± 1.4 mm Midpoint width: 5.1 ± 1.8 mm Tibial insertion width: 11.7 ± 3.3 mm Midpoint thickness: 1.4 ± 0.6 mm	Posterior and proximal to LCL, anterior and distal to LCL	Between GT and FH

(continued)

Table 1. Continued

Authors	Year	n	Type of Study	Anthropometric Data	Presence of Ligament	Length	Width and/or Thickness	Femoral Insertion	Tibial Insertion
Claes et al. ⁵	2014	29	Embalm cadaveric dissection	81 yr	100%		Tibial insertion width: 11.3 ± 2.8 mm	Center of LEF	Between GT and FH (center of tibial ALL footprint to center of GT, 22.0 ± 4.0 mm)
Helito et al. ³⁷	2014	10	Fresh cadaveric dissection	62.8 ± 8.79 yr, 57.2 ± 12.16 kg, 170.5 ± 10 cm	100%			Anterior and distal to LCL (1.9 ± 1.4 mm and 4.1 ± 1.1 mm, respectively)	Between GT and FH (42.1% ± 3.9% distance relative to FH and GT and 4.4 ± 0.8 mm below ACT)
Dodds et al. ³⁸	2014	40	Fresh cadaveric dissection	75 yr	83%	59.0 ± 4.0 mm	Width: 6.0 ± 1.0 mm	Posterior and proximal to LEF (4.3 mm and 8 mm, respectively)	Between GT and FH
Helito et al. ³⁹	2013	6	Fresh cadaveric dissection	61.3 yr, 65.7 kg, 170 cm	100%	35.1 mm	Width: 6.8 mm Thickness: 2.6 mm	Anterior and distal to LCL (2.5 mm and 0.5 mm, respectively)	Between GT and FH, 4.5 mm below ACT
Helito et al. ⁹	2013	20	Fresh cadaveric dissection	61.5 yr, 71.0 kg, 180 cm	100%	37.3 ± 4.0 mm	Width: 7.4 ± 1.7 mm Thickness: 2.7 ± 0.6 mm	Anterior and distal to LCL (2.2 mm and 3.5 mm, respectively)	Between GT and FH, 4.4 mm below ACT
Claes et al. ⁸	2013	41	Embalm cadaveric dissection	79 yr	97%	38.5 ± 6.1 mm (0°) 41.5 ± 6.7 mm (90°)	Femoral origin width: 8.3 ± 2.1 mm Midpoint width: 6.7 ± 3.0 mm Tibial insertion width: 11.2 ± 2.5 mm Midpoint thickness: 1.2 ± 0.3 mm	Center of LEF	Between GT and FH
Vincent et al. ⁷	2012	Part 1: 3 Part 2: 10	Part 1: in vivo dissection of patients undergoing TKA Part 2: fresh cadaveric dissection	Part 2: 85.3 ± 5.1 yr	100%	34.1 ± 3.4 mm	Width: 8.2 ± 1.5 mm Thickness: 2-3 mm	On lateral femoral condyle, closely associated with popliteus tendon	Insertion was always posterior to line drawn vertically from posterior border of GT to joint line

NOTE. Data are presented as mean ± standard deviation unless otherwise indicated.
ACT, articular cartilage of tibia; ALL, anterolateral ligament; FH, fibular head; GT, Gerdy tubercle; LCL, lateral collateral ligament; LEF, lateral epicondyle of femur; TKA, total knee arthroplasty.

Table 2. Number of Studies and Incidence of ALL

Presence of ALL	No. of Studies
100% ALL incidence	29
ALL incidence $\geq 80\%$ to $< 100\%$	12
ALL incidence $\geq 60\%$ to $< 80\%$	4
ALL incidence $\geq 40\%$ to $< 60\%$	3
ALL incidence $> 0\%$ to $< 40\%$	3
No ligament found	2

ALL, anterolateral ligament.

femoral insertion were the lateral epicondyle of the femur and the origin of the lateral collateral ligament. Using the epicondyle as a reference, most of the articles described the ALL insertion as (1) posterior and proximal^{10,15,16,19,21,22,38} or (2) at the center of the epicondyle.^{5,8,11,13,15,19,21,22,25,30,31} Using the origin of the collateral ligament, the articles described the ALL insertion as (1) posterior and proximal,^{17,18,27-29,33,34,36} (2) alongside the origin of the lateral collateral ligament,^{17,23,27-29} or (3) anterior and distal to the origin of the lateral collateral ligament.^{9,17,24,27,28,32,35-37,39} Over the years, descriptions of the ALL have shifted from the center to posterior and proximal to the lateral epicondyle, and no study on adult cadavers in 2017 described the ALL anterior to the epicondyle.

Number of Bands

The presence of more than 1 band in the structure of the ALL was reported in 1 study: Helito et al.²¹ dissected 13 knees, observing the presence of 2 bands in 12 of them. The surface band of the ALL displayed an origin

posterior and proximal to the center of the lateral epicondyle, and its length increased when the knee was extended and showed no insertion in the lateral meniscus. The deep band originated in the center of the lateral epicondyle, its length increased with knee flexion, and it inserted on the meniscus. Both structures had a similar tibial insertion site, and the deep band was situated slightly more posterior.

Histology

The histologic sections of the ALL showed dense and well-organized collagen fibers (predominantly type I collagen), with an average of 121 fibroblasts/mm² in adults and 1,631 fibroblasts/mm² in fetuses^{9,15,39} with the presence of vascular tissue,²⁶ displaying typically ligamentous morphology.^{19,36} Helito et al.³¹ and Vincent et al.,⁷ among other authors, observed a clear relation between the ALL and the lateral meniscus, with insertions of collagen fibers from the ALL into the meniscus and no evident cleavage plane.

Macchi et al.⁵¹ reported that the ALL was composed primarily of type I collagen (90%), followed by type III collagen (5%), type VI collagen (3%), and scarce elastic fibers (1%). Type I collagen was parallelly arranged, with wavy fibrils surrounded by type VI collagen. In the study that described the presence of more than 1 band in the ALL structure, Helito et al.²¹ found a similar number of fibroblasts per square millimeter in both bands: 301 fibroblasts/mm² in the outer region and 245 fibroblasts/mm² in the inner region, slightly lower than the number in the adult ACL.

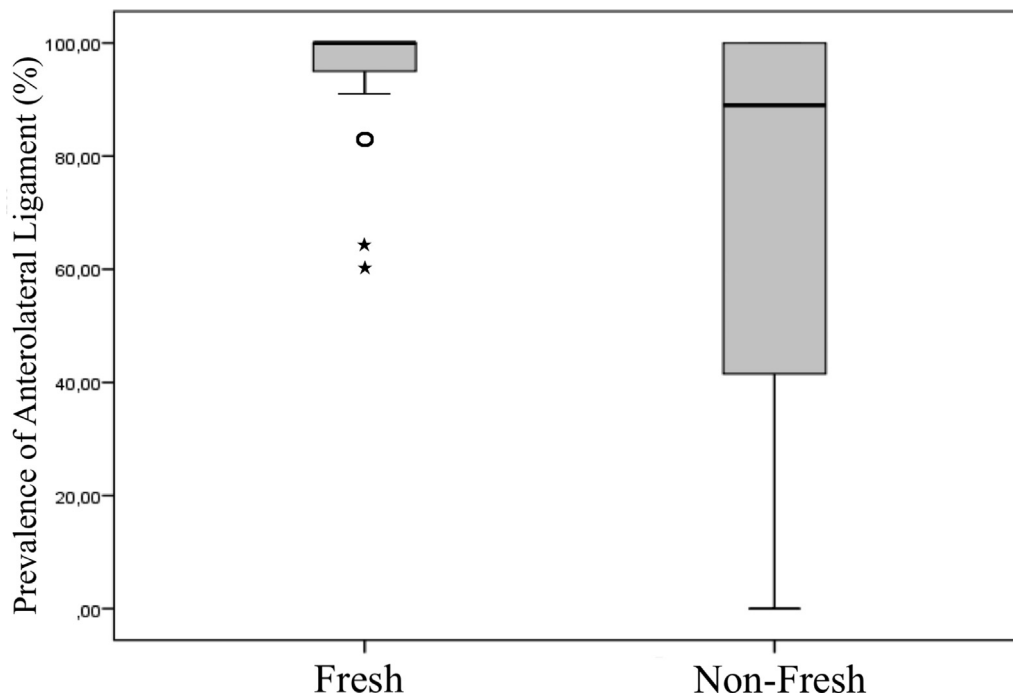


Fig 4. Box plot representing presence of anterolateral ligament according to type of dissection: dissection performed on fresh cadavers or dissection performed on cadavers preserved in formalin (embalmed). A statistically significant difference ($P < .05$) was found between the 2 groups according to the Mann-Whitney test. The horizontal lines, gray squares, whiskers, circle, and stars indicate medians, 25th and 75th quartiles, non-outlier ranges, an outlier, and extreme outliers, respectively.

Innervation

Few studies have focused on histologic assessment of ALL innervation. Catherine et al.³⁶ detected neurofilament proteins in the ALL, indicating peripheral nerve innervation. Their study showed circular structures that could be classified as small peripheral nerves or mechanoreceptors. Macchi et al.⁵¹ found nerve structures similar to small nerves and type I mechanoreceptors.

Ultrasonography

Cavaignac et al.^{41,42} and Cianca et al.⁴⁹ used ultrasonography, obtaining an ALL visualization rate of 100%. Oshima et al.⁵⁷ reported that most of the ALL segments could be identified, making ultrasonography a useful examination for diagnosing ALL injuries.

However, Capo et al.,⁵³ who found an ALL visualization rate of 75%, observed that ultrasonography was unable to reliably identify the femoral and tibial origins.

Magnetic Resonance Imaging

The ALL could be visualized on conventional 1.5-T magnetic resonance images, mainly in the coronal plane and on T2-weighted images with fat saturation. Helito et al.⁵⁶ assessed 39 MRI examinations, obtaining 97.8% ALL visualization, the meniscal portion being the most commonly visualized (94.8%).

In a study of 3-T MRI studies of fresh cadavers, Catherine et al.³⁶ obtained 100% ALL visualization. The images obtained in the coronal plane showed that the femoral origin was not clearly visible in many of the specimens studied, mainly because of the close relation between the ALL and other ligamentous structures. However, meniscal and tibial insertions were identified, especially the latter.

Helito et al.⁵⁵ and Kosy et al.⁵² studied 1.5-T MRI studies and obtained good results in identifying the meniscal portion of the ALL. By contrast, Taneja et al.⁵⁰ were unable to identify the meniscal insertion of the ALL in a study of 1.5- and 3.0-T MRI scans.

Porrino et al.⁴⁶ examined the MRI studies of 20 patients with a Segond fracture and found that 19 cases exhibited an ALL insertion in the fragment of the tibia corresponding to the Segond fracture. Coquart et al.⁴³ concluded that the ALL could be identified in routine 1.5-T MRI studies, suggesting that a better radiologic description of this anatomic structure may be beneficial in preoperative planning in patients with ACL injuries.

Arthroscopy

Zein⁵⁸ described an arthroscopic technique that showed that the meniscotibial insertion of the ALL could be seen and touched with a probe on the lateral meniscus. Similarly, Sonnery-Cottet et al.⁴⁸ published an arthroscopic technique that identifies the ALL. A shaver is introduced through an accessory superolateral portal and used to debride the synovial tissue between

the fasciae latae and lateral cortex of the femur, thereby defining the ALL. This allows the surgeon to examine the ALL's integrity, particularly the femoral insertion.

Radiography

Four of the articles selected described the radiographic anatomic references of the femoral and tibial insertions of the ALL (Fig 5). All the authors reached their conclusions by dissecting fresh cadavers, combined with radiographic examinations. All the studies obtained 100% visualization of the ALL on dissection.

Heckmann et al.⁴⁴ described the femoral origin as being 18.4 ± 4.3 mm from the posterior edge of the femoral condyle, along the Blumensaat line, and 8.4 ± 2.6 mm distal to the same line in the profile view (Fig 5). In the tibia, in the profile view, the insertion was 32.6 ± 4.9 mm from the posterior edge and 13.0 ± 4.1 mm below the lateral tibial plateau.

Kennedy et al.^{33,34} reported that the femoral origin was 22.3 mm proximal to the articular line in the anteroposterior (AP) view and 8.4 mm posterior and proximal to the lateral epicondyle in the profile view. The tibial insertion was 13.1 mm distal to the lateral tibial plateau in the AP view and 19.0 mm posterior and superior to the Gerdy tubercle in the profile view (Fig 5).

In the study by Rezansoff et al.⁴⁷ (Fig 5), the ALL femoral origin was described as overlying the posterior femoral cortical line, between the Blumensaat line and a line from the posterior condylar articular edge parallel

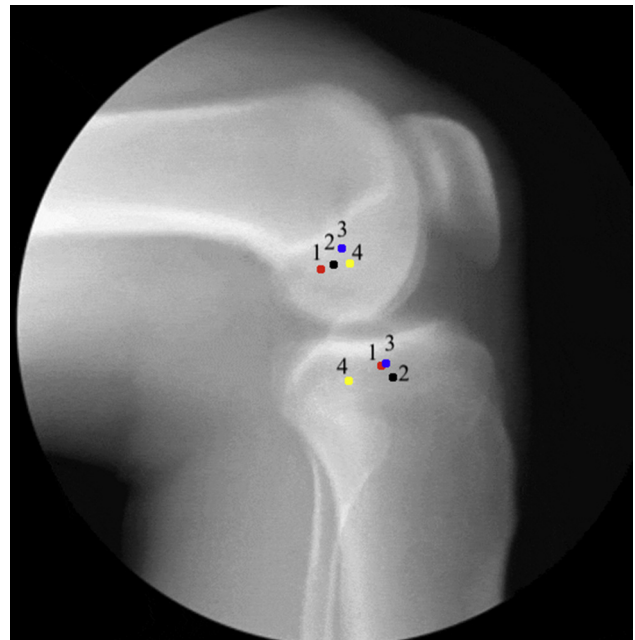


Fig 5. Fluoroscopy of right knee in profile view showing approximate reference points described by Kennedy et al.^{33,34} (1, red), Heckmann et al.⁴⁴ (2, black), Helito et al.³⁷ (3, blue), and Rezansoff et al.⁴⁷ (4, yellow).

to the Blumensaat line. The tibial ALL insertion was described between the posterior tibial cortical line and a parallel line drawn down from the apex of the tibial spine, and overlying a line drawn perpendicular to the posterior tibial cortical line starting from the apex of the posterior tibial condyle.

Helito et al.³⁷ described the femoral origin as being 15.8 ± 1.9 mm from the posterior bicondylar line in the AP view and $47.5\% \pm 4.3\%$ from the anterior edge of the femoral condyle and about 3.7 ± 1.1 mm below the Blumensaat line in the profile view. The tibial insertion was 7.0 ± 0.5 mm below the lateral tibial plateau in the AP view and $53.2\% \pm 5.8\%$ from the anterior edge of the lateral tibial plateau in the profile view (Fig 5).

Discussion

The most important finding of this study is the confirmation of the ALL as a distinct structure in the anterolateral portion of the knee. It exhibits typical ligament characteristics and can be visualized on imaging examinations. It has a femoral attachment near the lateral epicondyle following an anteroinferior trajectory, with an insertion into the lateral meniscus and proximal tibia.

The number of articles on the ALL's anatomy in cadaveric dissections increased from 2013 to 2017. Despite this growing number, some recent studies have concluded that the ALL cannot be found in cadaveric dissections.^{12,20} However, in most studies that detected or did not detect the ALL, fewer than 50% of dissections were performed on embalmed cadavers. We believe that the use of embalmed specimens hinders dissections, given that the ALL is adjacent to the anterolateral articular capsule and the complete separation of the planes is compromised in embalmed specimens.

Another difficulty with ALL dissection is the high number of different protocols used in the studies. With so much discrepancy in the protocols, it stands to reason that the dissection results would also differ. For example, Roessler et al.¹³ described a dissection through arthrotomy using the lateral parapatellar approach, followed by retrograde dissection and reflection of the iliotibial tract. They applied this technique to dissect 20 fresh cadavers, observing the ALL in 60% of cases. In another study, Helito et al.⁹ performed tenotomy of the quadriceps tendon, arthrotomy using a medial parapatellar approach, and osteotomy of the tibial tubercle to access the anterolateral region of the knee, obtaining a 100% ALL visualization rate.^{32,37} Even after the study by Daggett et al.,⁵⁹ who sought to standardize a simple reproducible technique for ALL dissection, authors continued to select different protocols.

As important landmarks, the femoral and tibial insertions stand out in the anatomic studies of the ligament, given that the definition of these landmarks

may influence ALL reconstruction techniques. The femoral insertion, unlike the tibial insertion, exhibits a large number of described locations and remains an object of discussion.¹⁰ Several studies described the femoral insertion in relation to the lateral epicondyle^{10,13,15,16,21} or the origin of the lateral collateral ligament.^{24,28,32,40} Over time and with increased anatomic knowledge, in addition to greater standardization of dissection techniques, the literature has shown a trend toward more often locating the femoral origin of the ALL posterior and proximal to the epicondyle. In addition to the reconstruction parameters, determining the femoral origin is important in understanding the biomechanical behavior of the ALL.

As observed in our systematic review, the number of studies on the ALL has grown considerably in recent years. Solid evidence of the presence of this ligamentous structure in basic research has been reported, although with some controversy regarding its anatomic parameters that were compiled in this study.

Limitations

As with the reviews of Van der Watt et al.⁶⁰ and Pomajzl et al.,⁶¹ this article has some limitations. Our major difficulty was the lack of standardization among studies, mainly in cadaveric dissections. The different dissection techniques and types of cadavers used (fresh or embalmed) may have caused variations in the results obtained and their interpretation. Similarly, imaging examinations exhibited different methodologies; some used 1.5-T MRI, and others used 3.0-T MRI.

Another noteworthy factor is that we only searched for the ligament denominated "anterolateral," disregarding other names such as "lateral capsular ligament," "anterolateral complex," and "anterior oblique band." An additional bias in this study is that no database search was performed for any article that purported to show the ALL was insignificant or did not exist.

Conclusions

The ALL is a distinct structure in the anterolateral portion of the knee. It exhibits typical ligament characteristics and can be visualized on imaging examinations, especially MRI. It has a femoral attachment near the lateral epicondyle, with a trend in recent years showing it to be located posterior and proximal to it, following an anteroinferior trajectory, with an insertion into the lateral meniscus and proximal tibia at the midpoint between the fibular head and Gerdy tubercle. Among the studies, the length of the ALL varied from 30.41 to 59.0 mm, the width ranged between 4.0 and 7.0 mm, and the thickness ranged between 1.0 and 2.0 mm.

References

1. Röntgen WC. On a new kind of rays. *Science* 1896;3: 227-231.

2. Segond P. *Recherches cliniques et expérimentales sur les épanchements sanguins du genou par entorse*. Paris: Aux Bureaux du Progrès Médical, 1879.
3. Goldman AB, Pavlov H, Rubenstein D. The Segond fracture of the proximal tibia: A small avulsion that reflects major ligamentous damage. *AJR Am J Roentgenol* 1988;151:1163-1167.
4. Hess T, Rupp S, Hopf T, Gleitz M, Liebler J. Lateral tibial avulsion fractures and disruptions to the anterior cruciate ligament: A clinical study of their incidence and correlation. *Clin Orthop Relat Res* 1994;303:193-197.
5. Claes S, Luyckx T, Vereecke E, Bellemans J. The Segond fracture: A bony injury of the anterolateral ligament of the knee. *Arthroscopy* 2014;30:1475-1482.
6. Vundelinckx B, Herman B, Getgood A, Litchfield R. Surgical indications and technique for anterior cruciate ligament reconstruction combined with lateral extra-articular tenodesis or anterolateral ligament reconstruction. *Clin Sports Med* 2017;36:135-153.
7. Vincent J-P, Magnussen RA, Gezmez F, et al. The anterolateral ligament of the human knee: An anatomic and histologic study. *Knee Surg Sports Traumatol Arthrosc* 2012;20:147-152.
8. Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. *J Anat* 2013;223:321-328.
9. Helito CP, Demange MK, Bonadio MB, et al. Anatomy and histology of the knee anterolateral ligament. *Orthop J Sports Med* 2013;1:2325967113513546.
10. Neri T, Palpacuer F, Testa R, et al. The anterolateral ligament: Anatomic implications for its reconstruction. *Knee* 2017;24:1083-1089.
11. Daggett M, Helito C, Cullen M, et al. The anterolateral ligament: An anatomic study on sex-based differences. *Orthop J Sports Med* 2017;5:2325967116689387.
12. Sabzevari S, Rahnama-Azar AA, Albers M, Linde M, Smolinski P, Fu FH. Anatomic and histological investigation of the anterolateral capsular complex in the fetal knee. *Am J Sports Med* 2017;45:1383-1387.
13. Roessler PP, Schüttler KF, Stein T, et al. Anatomic dissection of the anterolateral ligament (ALL) in paired fresh-frozen cadaveric knee joints. *Arch Orthop Trauma Surg* 2017;137:249-255.
14. Shea KG, Milewski MD, Cannamela PC, et al. Anterolateral ligament of the knee shows variable anatomy in pediatric specimens. *Clin Orthop Relat Res* 2017;475:1583-1591.
15. Helito CP, do Prado Torres JA, Bonadio MB, et al. Anterolateral ligament of the fetal knee: An anatomic and histological study. *Am J Sports Med* 2017;45:91-96.
16. Farhan PS, Sudhakaran R, Thilak J. Solving the mystery of the antero lateral ligament. *J Clin Diagn Res* 2017;11:AC01-AC04.
17. Toro-Ibarguen AN, Pretell-Mazzini J, Pérez E, Pedrajas I, Cano-Egea JM, Ramón Sanudo J. The anterolateral ligament: A cadaveric study in fetuses. *Clin Anat* 2017;30:625-634.
18. Brockmeyer M, Höfer D, Schäfer K, et al. The anterolateral ligament (ALL) of the knee—Part of the iliotibial tract or a truly separate structure? *Ann Anat* 2017;212:1-3.
19. Corbo G, Norris M, Getgood A, Burkhart TA. The infra-meniscal fibers of the anterolateral ligament are stronger and stiffer than the supra-meniscal fibers despite similar histological characteristics. *Knee Surg Sports Traumatol Arthrosc* 2017;25:1078-1085.
20. Fardin PBA, Lizardo JHF, Baptista JDS. Study of the anterolateral ligament of the knee in formalin-embedded cadavers. *Acta Ortop Bras* 2017;25:89-92.
21. Helito CP, do Amaral C Jr, Nakamichi YD, et al. Why do authors differ with regard to the femoral and meniscal anatomic parameters of the knee anterolateral ligament? Dissection by layers and a description of its superficial and deep layers. *Orthop J Sports Med* 2016;4:2325967116675604.
22. Daggett M, Ockuly AC, Cullen M, et al. Femoral origin of the anterolateral ligament: An anatomic analysis. *Arthroscopy* 2016;32:835-841.
23. Shea KG, Polowsky JD, Jacobs JC Jr, Yen Y-M, Ganley TJ. The anterolateral ligament of the knee: An inconsistent finding in pediatric cadaveric specimens. *J Pediatr Orthop* 2016;36:e51-e54.
24. Stijak L, Bumbaširević M, Radonjić V, et al. Anatomic description of the anterolateral ligament of the knee. *Knee Surg Sports Traumatol Arthrosc* 2016;24:2083-2088.
25. Parker M, Smith HF. Anatomical variation in the anterolateral ligament of the knee and a new dissection technique for embalmed cadaveric specimens [published online December 18, 2016]. *Anat Sci Int*. doi:10.1007/s12565-016-0386-2.
26. Potu BK, Salem AH, Abu-Hijleh MF. Morphology of anterolateral ligament of the knee: A cadaveric observation with clinical insight [published online December 18, 2016]. *Adv Med*. doi:10.1007/s12565-016-0386-2.
27. Kosy JD, Soni A, Venkatesh R, Mandalia VI. The anterolateral ligament of the knee: Unwrapping the enigma. Anatomical study and comparison to previous reports. *J Orthop Traumatol* 2016;17:303-308.
28. Watanabe J, Suzuki D, Mizoguchi S, Yoshida S, Fujimiya M. The anterolateral ligament in a Japanese population: Study on prevalence and morphology. *J Orthop Sci* 2016;21:647-651.
29. Runer A, Birkmaier S, Pamminger M, et al. The anterolateral ligament of the knee: A dissection study. *Knee* 2016;23:8-12.
30. Klontzas ME, Maris TG, Zibis AH, Karantanis AH. Normal magnetic resonance imaging anatomy of the anterolateral knee ligament with a T2/T1-weighted 3-dimensional sequence: A feasibility study. *Can Assoc Radiol J* 2016;67:52-59.
31. Helito CP, Bonadio MB, Soares TQ, et al. The meniscal insertion of the knee anterolateral ligament. *Surg Radiol Anat* 2016;38:223-228.
32. Helito CP, Helito PVP, Bonadio MB, et al. Correlation of magnetic resonance imaging with knee anterolateral ligament anatomy: A cadaveric study. *Orthop J Sports Med* 2015;3:2325967115621024.
33. Kennedy MI, Claes S, Fuso FAF, et al. The anterolateral ligament: An anatomic, radiographic, and biomechanical analysis. *Am J Sports Med* 2015;43:1606-1615.
34. Kennedy MI, Claes S, Fuso F, et al. The anterolateral ligament (ALL): A comprehensive study encompassing

- anatomic and radiographic landmarks and native structural properties. *Orthop J Sports Med* 2015;3(suppl 2):2325967115S2325900126.
35. Zens M, Niemeyer P, Ruhhammer J, et al. Length changes of the anterolateral ligament during passive knee motion: A human cadaveric study. *Am J Sports Med* 2015;43:2545-2552.
 36. Catherine S, Litchfield R, Johnson M, Chronik B, Getgood A. A cadaveric study of the anterolateral ligament: Re-introducing the lateral capsular ligament. *Knee Surg Sports Traumatol Arthrosc* 2015;23:3186-3195.
 37. Helito CP, Demange MK, Bonadio MB, et al. Radiographic landmarks for locating the femoral origin and tibial insertion of the knee anterolateral ligament. *Am J Sports Med* 2014;42:2356-2362.
 38. Dodds A, Halewood C, Gupte C, Williams A, Amis A. The anterolateral ligament: Anatomy, length changes and association with the Segond fracture. *Bone Joint J* 2014;96:325-331.
 39. Helito CP, de Souza Miyahara H, Bonadio MB, et al. Anatomical study on the anterolateral ligament of the knee. *Rev Bras Ortop* 2013;48:368-373.
 40. Kernkamp WA, Van de Velde SK, Hosseini A, et al. In vivo anterolateral ligament length change in the healthy knee during functional activities—A combined magnetic resonance and dual fluoroscopic imaging analysis. *Arthroscopy* 2017;33:133-139.
 41. Cavaignac E, Faruch M, Wytrykowski K, et al. Ultrasonographic evaluation of anterolateral ligament injuries: Correlation with magnetic resonance imaging and pivot-shift testing. *Arthroscopy* 2017;33:1384-1390.
 42. Cavaignac E, Wytrykowski K, Reina N, et al. Ultrasonographic identification of the anterolateral ligament of the knee. *Arthroscopy* 2016;32:120-126.
 43. Coquart B, Le Corroller T, Laurent P, et al. Anterolateral ligament of the knee: Myth or reality? *Surg Radiol Anat* 2016;38:955-962.
 44. Heckmann N, Sivasundaram L, Villacis D, et al. Radiographic landmarks for identifying the anterolateral ligament of the knee. *Arthroscopy* 2016;32:844-848.
 45. Yokosawa K, Sasaki K, Muramatsu K, Ono T, Izawa H, Hachiya Y. Visualization of anterolateral ligament of the knee using 3D reconstructed variable refocus flip angle-turbo spin echo T2 weighted image. *Nihon Hoshasen Gijutsu Gakkai Zasshi* 2016;72:416-423 [in Japanese].
 46. Porrino J Jr, Maloney E, Richardson M, Mulcahy H, Ha A, Chew FS. The anterolateral ligament of the knee: MRI appearance, association with the Segond fracture, and historical perspective. *AJR Am J Roentgenol* 2015;204:367-373.
 47. Rezansoff AJ, Catherine S, Spencer L, Tran MN, Litchfield RB, Getgood AM. Radiographic landmarks for surgical reconstruction of the anterolateral ligament of the knee. *Knee Surg Sports Traumatol Arthrosc* 2015;23:3196-3201.
 48. Sonnery-Cottet B, Archbold P, Rezende FC, Neto AM, Fayard J-M, Thaunat M. Arthroscopic identification of the anterolateral ligament of the knee. *Arthrosc Tech* 2014;3:e389-e392.
 49. Cianca J, John J, Pandit S, Chiou-Tan FY. Musculoskeletal ultrasound imaging of the recently described anterolateral ligament of the knee. *Am J Phys Med Rehab* 2014;93:186.
 50. Taneja AK, Miranda FC, Braga CA, et al. MRI features of the anterolateral ligament of the knee. *Skeletal Radiol* 2015;44:403-410.
 51. Macchi V, Porzionato A, Morra A, et al. The anterolateral ligament of the knee: A radiologic and histotopographic study. *Surg Radiol Anat* 2016;38:341-348.
 52. Kosy JD, Mandalia VI, Anaspure R. Characterization of the anatomy of the anterolateral ligament of the knee using magnetic resonance imaging. *Skeletal Radiol* 2015;44:1647-1653.
 53. Capo J, Kaplan DJ, Fralinger DJ, et al. Ultrasonographic visualization and assessment of the anterolateral ligament. *Knee Surg Sports Traumatol Arthrosc* 2017;25:3134-3139.
 54. Claes S, Bartholomeeusen S, Bellemans J. High prevalence of anterolateral ligament abnormalities in magnetic resonance images of anterior cruciate ligament-injured knees. *Acta Orthop Belg* 2014;80:45-49.
 55. Helito CP, Demange MK, Helito PVP, et al. Evaluation of the anterolateral ligament of the knee by means of magnetic resonance examination. *Rev Bras Ortop* 2015;50:214-219.
 56. Helito CP, Helito PVP, Costa HP, et al. MRI evaluation of the anterolateral ligament of the knee: Assessment in routine 1.5-T scans. *Skeletal Radiol* 2014;43:1421-1427.
 57. Oshima T, Nakase J, Numata H, Takata Y, Tsuchiya H. Ultrasonography imaging of the anterolateral ligament using real-time virtual sonography. *Knee* 2016;23:198-202.
 58. Zein A. Step-by-step arthroscopic assessment of the anterolateral ligament of the knee using anatomic landmarks. *Arthrosc Tech* 2015;4:e825-e831.
 59. Daggett M, Busch K, Sonnery-Cottet B. Surgical dissection of the anterolateral ligament. *Arthrosc Tech* 2016;5:e185-e188.
 60. Van der Watt L, Khan M, Rothrauff BB, et al. The structure and function of the anterolateral ligament of the knee: A systematic review. *Arthroscopy* 2015;31:569-582.e3.
 61. Pomajzl R, Maerz T, Shams C, Guettler J, Bicos J. A review of the anterolateral ligament of the knee: Current knowledge regarding its incidence, anatomy, biomechanics, and surgical dissection. *Arthroscopy* 2015;31:583-591.