The knee anterolateral ligament is present in 82% of the North American, in 65% of the European but only in 46% of Asian studies. A systematic review of frequency and morphology of anatomy studies

Erik Hohmann

MBBS, FRCS, FRCS (Tr & Orth), MD, PhD

Medical School, Faculty of Health Sciences, University of Pretoria

Pretoria, South Africa

Department of Orthopaedic Surgery and Sports Medicine

Burjeel Hospital for Advanced Surgery, Dubai, UAE

drerik@burjeelspecialty.com

Natalie Keough

PhD

BSc, BSc (Hons), MSc, PhD

Department of Health Sciences, Clinical Anatomy and Imaging, Warwick Medical School, University of Warwick, Coventry, UK

Department of Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa

natalie.keough@warwick.ac.uk

Maketo Molepo

MBChB, FCS Ortho (SA), MMed Orth., PhD

Medical School, Faculty of Health Sciences, University of Pretoria

Pretoria, South Africa

mkamolepo@gmail.com

Robert Arciero

Department of Orthopaedic Surgery

University of Connecticut, Farmington, USA

arciero@uchc.edu

Andreas Imhoff

Department of Orthopaedic Sports Medicine

Technical University Munich, Germany

imhoff@tum.de

Corresponding Author:
Erik Hohmann
Burjeel Hospital for Advanced Surgery
Dubai, United Arab Emirates
drerik@burjeelspecialty.com

Abstract

Purpose:

To perform an updated systematic review on the prevalence and morphological characteristics of the anterolateral ligament (ALL) in human cadaveric specimens.

Methods:

Medline, Embase, Scopus, and Google Scholar were searched for studies from 2012 to 2024 describing the morphology. Study quality was assessed using CASP checklist and QUACS scale. Heterogeneity was analysed with the I^2 statistic, funnel plot, and Q-test. Mean effect size and 95% prediction intervals were calculated. Prevalence and anatomical measurements (length, width, thickness) were analysed using mean and standard deviations.

Results:

Thirty studies were included. CASP identified three low-quality studies. Twelve studies met the QUACS quality threshold. The prevalence of the ALL was 61.7% (82% North America, 64.9% Europe, 45.8% Asia). The femoral insertion showed variability near the lateral femoral epicondyle and lateral collateral ligament, while the tibial insertion was midway between Gerdy's tubercle and fibular head. Histological analysis revealed 60% of studies identified ligamentous tissue similar to

the ACL. The mean ALL length was 39.7 mm, width 5.5 mm, and thickness 1.5 mm, with no significant morphological differences among populations.

Conclusion:

This systematic review reveals that the ALL is present in 61.7%, with prevalence rates of 82% in North American studies, 65% in European studies, and 46% in Asian studies. The femoral insertion exhibited substantial variability at/around the lateral femoral epicondyle and LCL, lacking consistency. The tibial insertion was more consistently described as being located about halfway between Gerdy's tubercle and the fibular head. Histological analysis showed that 60% of the included studies identified the ALL as containing ligament-like or ligamentous tissue. The mean length of the ALL was 39.9 mm (range 31-59 mm), the mean width was 5.7 mm (range 2.2-9.0 mm), and the mean thickness was 1.5 mm (range 1.3-2.7 mm). No significant ethnic population differences were observed in the morphological measures.

Keywords:

ALL; anterolateral ligament; anterolateral ligament complex; lateral capsular ligament; ALL prevalence, ALL morphology

Clinical Relevance:

The ALL is not consistently present in all patients with knee instability, and the indications for performing an ALL reconstruction or lateral tenodesis remain unclear based solely on morphological factors. As a result, the decision to perform these procedures may need to be made on an individualized basis.

Introduction

The anterolateral ligament (ALL) was first described over 140 years ago. Paul Segond, described an avulsion fracture of the proximal anterolateral tibia, noting the presence of a resistant fibrous band that was subjected to substantial tension forces during forced internal rotation of the tibia. [1] It took 133 years for this ligament to be "rediscovered" by Vincent et al., who subsequently named it the anterolateral ligament. [2] Vincent et al. described the ALL as a relatively flat structure originating near or on the popliteus tendon and inserting onto the lateral meniscus and the tibial condyle, approximately 5 mm distal to the articular surface and posterior to Gerdy's tubercle. [2] The authors speculated that the ALL may play a role in preventing anterior tibial translation. [2] However, two years later, the ALL received renewed attention when Claes et al. published a detailed description of it in a series of embalmed cadaveric knees, for which they were given credit for its rediscovery. [3] Similar to Vincent et al., [2] the authors suggested that, due to its structure and anatomical location, the ALL could play a significant role in knee stability and in controlling internal rotation. [3]

Currently, the anatomy, function, and existence of the ALL is still hotly debated and a controversial topic. [4] Several anatomical studies have reported that the ALL cannot always be identified as a distinct structure, with its presence documented in 45-83% of cases. [5-9] In contrast, other studies have reported that this ligament is consistently present. [10-13] De Lima conducted a systematic review encompassing 53 anatomical, radiographic, histological, and fetal studies. The review revealed that the ALL was present in 83% of anatomical studies, 74% of fetal dissections, and 85% of magnetic resonance imaging (MRI) studies. [14] In 2017, the Anterolateral Complex Consensus

Group stated that the anterolateral complex of the knee includes the ALL as a component of its structure. [15] The ALL is a capsular structure located within Seebacher's Layer 3, with variable gross morphology in terms of size and thickness among individuals. [15] It predominantly originates posterior and proximal to the lateral femoral epicondyle (LFE), runs superficially to the LCL, and attaches to the tibial condyle midway between the anterior border of the fibular head and the posterior border of Gerdy's tubercle. [15]

The purpose of this study was therefore to perform an updated systematic review on the prevalence and morphological characteristics of the anterolateral ligament in human cadaveric specimens. It was hypothesized that the prevalence of the anterolateral ligament complex is high and that its morphology varies significantly across different studies.

Methods

This study was conducted following the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [16] and the updated procedures described in the Cochrane Handbook. [17]

Eligibility criteria

The published literature was screened for studies from 2012 to 2024 that reported on the anatomy, histology, and morphology of the anterolateral ligament. This timeframe was selected to encompass contemporary research following the description and definition of the anterolateral ligament by Vincent et al., [2] to reflect the renewed

interest following Claes et al.'s [3] publication, and to acknowledge Vincent et al.'s [2] contribution.

Basic science anatomy studies were included if they specifically described the morphology of the anterolateral ligament, anterolateral ligament complex, or anterolateral knee capsule using standard surgical dissection techniques in embalmed, fresh, or fresh-frozen anatomical specimens. Biomechanical cadaveric studies were also included if they included a clear anatomical component and reported on the prevalence or existence of the ALL in their specimens. Clinical studies reporting outcomes or biomechanical studies examining mechanical parameters such as load to failure and viscoelastic properties of the native ALL complex or post-surgical reconstruction were excluded. Conference proceedings, abstracts, expert opinions (level V), systematic reviews, meta-analyses, editorials, case reports, animal studies, and review articles were excluded. However, relevant references from these sources that met the inclusion criteria were examined and included if they met the criteria. It is acknowledged that omitting grey data could potentially introduce publication bias, this approach also helps reduce selection bias and excludes publications that are not peer-reviewed or do not meet commonly accepted publication standards.

Information Sources and Literature Search

A systematic review of the literature was conducted to identify all relevant publications, with databases including PubMed, Embase, Scopus, and Google Scholar being screened. These databases were screened using the following terms and Boolean operators: “anterolateral ligament” AND/OR “anterolateral ligament complex” AND/OR “ALL” AND/OR “morphology”; AND/OR “anatomy” AND/OR

“Segond” AND/OR “Segond fracture” AND/OR “lateral capsular ligament”. For the Medline search the MeSH term “ligament, knee” was used with the following qualifiers: anatomy & histology, injuries. One reviewer conducted independent title and abstract screening. After screening the abstracts, full-text articles were reviewed by two independent reviewers. Disagreements were resolved through consensus; if consensus could not be reached, the senior author made the final decision on the inclusion or exclusion of the article.

Data extraction and quality assessment

An electronic data extraction form was utilized to gather a comprehensive set of data from each article, including author, country, sample size, prevalence, and morphological measurements such as length, width, thickness, as well as origin and insertion points. If measurements were reported at various knee flexion angles, figures obtained at 30 degrees of knee flexion were used for analysis. Kittl et al. has demonstrated that resistance to internal rotation and combined internal rotation/valgus is greatest in both ACL-intact and ACL-deficient knees at this flexion angle. [18] Additionally, histological findings were recorded if applicable.

Unfortunately, no established instrument is available to assess the risk of bias in basic science studies, and therefore, risk of bias could not be evaluated. However, the CASP (Critical Appraisal Skills Programme) checklist for qualitative research was used as an appraisal tool. [19,20] This checklist addresses three broad issues: the validity of the study results, the nature of the results, and their potential local impact. It consists of 10 questions that should be answered with "yes," "no," or "can't tell." The checklist is not designed for scoring but rather to guide researchers in systematically

evaluating potential issues. For this systematic review, a study was considered to have satisfactory quality and a low risk of bias if it received a "yes" response to at least 6 of the 9 questions and the ethics item [7] was answered with no. Item 6 of the CASP checklist was excluded from consideration as it pertains specifically to the relationship between the researcher and participants. Study quality was evaluated using the QUACS (Quality Appraisal for Cadaveric Studies) scale, which comprises 13 items. [21] Each item is scored as "yes/present" (1 point) or "no/not present". [21] The final quality percentage is derived from the total score, with scores above 75% deemed satisfactory. [21]

Statistical analysis

Heterogeneity within and between studies was evaluated using the I^2 statistic, funnel plot and the Q-test for heterogeneity. The mean effect size was calculated, and a prediction interval was determined to assess whether the true effect size would fall within this interval in 95% of comparable populations. For studies that utilized paired cadaveric samples, the effective sample size was halved under the assumption that measurements from paired samples, such as those from both knees, would exhibit high similarity and could not be treated as independent data points. The prevalence and morphological measures were analyzed based on the location of the studies. Three principal regions were examined: North America (including the United States and Canada), Europe, and Asian countries (excluding those on the Indian subcontinent, such as India and Sri Lanka). However, if at least three studies were conducted in these or other regions, they were also included in the analysis. Publication bias was examined using funnel plots and Egger's test. The prevalence of the ALL was analysed using the event rate, calculated from the number of events and

sample size, employing the logit event rate and standard error within a random-effects model. The event rate and 95% confidence intervals were reported. The anatomical measurements length, width and thickness were analysed using mean and standard deviations. Funnel and forest plots, and all statistical analyses, were performed using STATA SE (Version 13.0; StataCorp, College Station, Texas, USA) for Windows, and the comprehensive meta-analysis software package (CMA), version 4 (Biostat Inc, Englewood, NJ, USA).

Results

Study selection and characteristics

The initial literature search identified 607 studies for consideration (Figure 1). Of those, 213 studies were excluded for duplication and 293 studies were removed for other reasons. The records of the remaining 101 publications were scrutinized leading to the exclusion of 47 studies. The abstracts of 54 studies were evaluated and assessed for eligibility. Further 14 review studies, 4 editorials, two studies describing foetus anatomy, two imaging studies and one infographic were excluded. Ultimately, 30 studies were included, and all studies were published in English between 2012 and 2023 encompassing a total of 1127 specimens. [2,3,5-13,22,23,26-40] Of these specimens, 600 (53.2%) were either fresh or fresh-frozen, while 527 (46.8%) were embalmed. Additionally, 173 (15.3%) of the specimens were included by North American studies, 530 (47%) of the specimens by European studies and 236 (21%) of the specimens by Asian studies. A summary of the study characteristics and ALL morphology is provided in Table 1.

Table 1: Study Characteristics and Morphology of the ALL

Author	Country	Sample	Presence of ALL	Measures (in mm)	Morphology	Histology
Vincent 2012	France	N=10 Fresh Non-paired	N=10	Length 34.1+3.4 Width 8.2+1.5 Thickness 2-3	Origin n=9 anterior to popliteus tendon LFC; n=1 arose from popliteus Insertion proximal to antero-lateral tibia 5 mm distal to articular cartilage and posterior to Gerdy's tubercle Closely associated lateral meniscus junction anterior and mid-third adherence to meniscus	Collagenous fibers dense central core, parallel orientation suggestive of ligamentous or tendinous tissue
Claes 2013	Belgium	N=41 Embalmed Non-paired	N=40	Length41.5+6.7 Width 6.7+3.0 Thickness 1.3+0.6	Origin LFE, anterior to LCL and proximal and posterior popliteus tendon Insertion AL proximal tibia posterior to Gerdy's tubercle Proximal fibers blended with LCL, connection to middle third of meniscus Distinguishable from joint capsule lying anterior	
Helito 2013	Brazil	N=20 Fresh Non-paired	N=20	Length 37.3+4 Width 7.4+1.7 Thickness 2.7+0.6	Origin: LFE anterior and distal to LCL insertion (2.2mm ant + 3.5 distal) At 52% of length bifurcated, Insertion 4.4 distal to cartilage at tangent fibula head and Gerdy's tubercle 38% away from fib head Attach to lateral meniscus 19.4mm ant to popliteus tendon – refers to meniscal portion of ALL	Dense connective tissue, arranged fibers, little cells
Dodds 2014	United Kingdom	N=40 Fresh Non-paired	N=33	Length 59+4 Width 6+1	Origin: proximal and distal to LFE and LCL attach; 8 mm prox+4.3 mm distal to most prominent point of LFE, fan like blending, no meniscus attachment but branching fibers, Insertion post to Gerdy's tubercle (18) anterior to head of fibula (17), distal to joint line (11) Separate from capsule	
Caterine 2015	Canada	N=19 Fresh Non-paired	N=19	Length 40.3+6.2 Width 4.8+1.4 Thickness 1.4+0.6	Origin LFE (2 variations) – fanned over and integrated with FCL attachment (difficult to locate) – LFE anterior and distal to FCL; LFE posterior and proximal to FCL Insertion ALL proximal tibia posterior to Gerdy's tubercle Proximal fibers blended with LCL, connection to	Dense regular organized collagenous structure similar to ligament tissue (comparable with ACL); fascicular organization Immunohistochemistry – ALL has peripheral nervous innervation

					middle third of meniscus (referred to Claes), attached to lateral meniscus	
Kennedy 2015	United States	N=15 Fresh Non-paired	N=15	Length 40.1 (38.3-42.9}	Origin: LFE posterior and proximal to FCL; 7.0mm from LFE and 26.1mm proximal to joint line Distances from; FCL to ALL (4.7) posterior and proximal: popliteal tendon to ALL (12.2) proximal to lateral gastrocnemius tendon (8.6) distal. Tibial attachment distance to Gerdy's tubercle 24.7 (posterior), ant margin of fibular head 26.1, distal joint line 9.5 ALL attach to lateral meniscus	
Rahnemai-Azar 2016	United States	N=9 Fresh Non-paired	N=2	Thickness ALC 4.0+1.5	Origin: distinct thickening of anterolateral capsule – fibers running from LFE to halfway between Gerdy's T and fibula head	
Daggett 2016	United States	N=52 Embalmed Non-paired	N=52	Mean diameter origin: 11.85	23% direct attachment to LFE, 58% proximal and posterior to LFE, 19% more proximal and posterior to LFE, size of origin 11.8+2.2 Not report insertion (tibial)	
Kosy 2016	United Kingdom	N=11 Fresh Non-paired	N=10	Length 40.1+5.5 Width 4.63+1.4 Thickness 0.87+0.18	Origin posterior and lateral to LCL n=6, anterior and distal to LCL n=3; LFE with LCL n=1 tibial attachment 17.7+2.9 from GT and 12.3 from fibula head, difficult to define borders as continuous c capsule in all cases	
Stijak 2016	Serbia	N=14 Embalmed Non-paired	N=7	Length 41+3 Width 4+1 Thickness 1mm	Origin LFC ant to FCL insertion, insertion halfway between GT and FH	
Potu 2016	Bahrain	N=24 Embalmed Paired Not declared		Length 34.2 Width 4.04 Thickness 1.78	Outside joint capsule, origin LFC at level of LCL with LCL, insertion posterior to GT + anterior and proximal to FH (halfway between GT and FH)	Dense connective tissue collagen bundles with fibroblasts
Roessler 2016	Germany	N=20 Fresh Paired	N=12	Length 39.6+0.8 Width 5.28+0.33 Thickness 1.52+0.31	Origin merged with LCL over LFE, insertion feathered with firm attachment to periosteum 9.5 distance to FH, 22 to GT, 9.54 to joint line Meniscal fibers (n=11) Above joint capsule with connection to meniscus	
Runer 2016	Austria	N=44 Fresh	N=20	Length 42.2 Width 5.6	Origin LFE with LCL (45%), or posterior and proximal 55%	

		Paired Not declared		Thickness 1.2	Insertion 8.9 to tib plateau, 18.6 to GT, 15.2 to FH Additional meniscal fibers – but not part of ALL; ALL not attach to lateral meniscus Extracapsular structure	
Watanabe 2016	Japan	N=94 Fresh Paired	N=35		Origin LFE superficial to LCL (13.8%); post to FCL (3.2%); ant to FCL (3.2%); ant to post of LCL (20%); mostly on or posterior to LCL site Insertion between GT and FH at Segond fracture location 35% connection to lateral meniscus	
Neri 2017	France	N=84 Fresh Paired	N=80	Length 45.3+4.1 Thickness 1.35+0.18 Width 6.75+0.9	Origin posterior (5.5mm) and proximal (1.5mm) to LFE (also posterior and proximal to popliteal tendon) Insertion proximal to GT anterior and proximal to FH distal to tibial cartilage	
Cai 2017	China	N=16 Embalmed Paired Not declared	N=12	Length 44.8+5.1 Thickness 2.0+.08 Width 6.8+1.5	Origin LFE proximal and posterior to LCL Insertion post to GT (23.9) lateral margin FH (23.8) Connection to lateral meniscus	
Goncharov 2018	Russia	N=60 Fresh Non-paired	N=34	Length 38.5+4.4 Width 4.45+0.85	Origin LFE posterior-proximal to LCL (64%), ant to LCL (23%), @ popliteus tendon insertion (12%) Insertion halfway between FH+GT Attached to lateral meniscus Fibers attach to LCL	
Neri 2018	France	N=30 Fresh-frozen Paired	N=29			Network of dense collagen surrounded by loose collagen fibers, ligamentous nature
Olewnik 2018	Poland	N=111 Embalmed Paired	N=70	Length 25-56 Width 1.38-2.18 Thickness 1.02-1.4	Type 1 single tendon (64%), LFE proximal and anterior to LCL, insertion post to GT Type 2: single or two bands (13%) LFE posterior and proximal to LCL insertion post to GT Type 3 fan shaped (6%) LFE and postero-lateral joint capsule, post to FCL insertion blends with deep fascia of leg Type 4 double ALL (3%) LFE ant to LCL, insertion post to GT + blends with deep fascia Type 5 complex (13%) origin from LCL, insertion post to GT	
Parker 2018	United States	N=53 Embalmed	N=51	Length 38.4+4.3 Width 4.26+0.84	Origin prominence of LFE ant to LCL, insertion antero-lateral proximal tibia halfway btw GT and	

		Non-paired			FH Attached to lateral meniscus (aid in ID of ALL)	
Zhang 2018	China	N=20 Fresh Non-paired	N=18	Length 35.8+7.2 Width 6.2+2.3 Thickness 1.4+0.9	Thin fibrous tissue Origin prominence of LFE proximal and anterior or overlap with FCL, insertion midway between GT and FH	parallel regularly organized collagen bundles crimping pattern similar to ligamentous tissue; fascicular organization
Brockmeyer 2019	Germany	N=23 Embalmed 20 N=3 Fresh Paired	N=23	Length 39.13+7.26 Width 8.99+1.47 Thickness 2.06+0.34	Origin posterior and proximal to LFE and LCL overlapping with LCL, insertion midway between GT+FH Attach to lateral meniscus (65% 15/23)	Thin ligamentous structure with organized densely packed collagen fibrils; parallel fibers, wavelike
Cho 2019	Korea	N=120 Fresh Paired	N=51	Length 32.4+6.8 Width 5.2+2.0 Thickness 1.3+0.7	N=27 within capsule Origin LFE post to popliteus tendon, insertion midway between GT+FH (15.8) Some fibers attach lateral meniscus	
Sabatini 2019	Italy	N=25 Surgical Post TKR Non-paired	N=25		Origin – LFC Insertion – slightly below tibial articular surface at level of GT	Histological characteristics different from joint capsule and similar to ACL, architectural orientation of collagen fibers
Urban 2019	Austria	N=40 Embalmed Nonpaired	N=0		No ALL – but is most ant fibers of ant arm of short head of biceps femoris (artificially isolated by previous authors)	Aponeurosis ALL part of knee joint fibrous capsule
Nasu 2020	Japan	N=25 Embalmed Paired	N=0		Origin proximal postero-superior to LFE, insertion lateral and posterior to GT and proximal tibia, sheet like structure (fascia lata, intermuscular septum, gastrocnemius tendon, fabellofibular ligament) - only visible with internal rotation and flexion	Fibrous tissue, taut fibrous tissue, pearly fibrous bands
Patel 2021	United States	N=25 Fresh Non-paired	N=3		Origin LFE, insertion halfway ant aps FH + post margin GT	
Shetty 2021	India	N=42 Embalmed Non-paired	N=4	Length 35+0.9	Cord type n=2, membranous wide band type n=2 Origin: LFE ant to LCL, insertion GT	
Fernandes 2023	Spain	N=20 Embalmed Paired	N=16	Length 35.8+4.6 Width 4.2+1.3	Origin 1mm posterior and proximal to LFE, insertion 2.1 distal to tibial joint line, 20.6 post to GT, 20.3 from FH Connection to lateral meniscus	

Suh 2023	Korea	N=20 Fresh Non-paired	N=20	Length 47.83+8.05	Origin around LFE (with variations),70% posterior and proximal LFE; insertion midway between GT (18.3) and tip FH (19,9mm)	

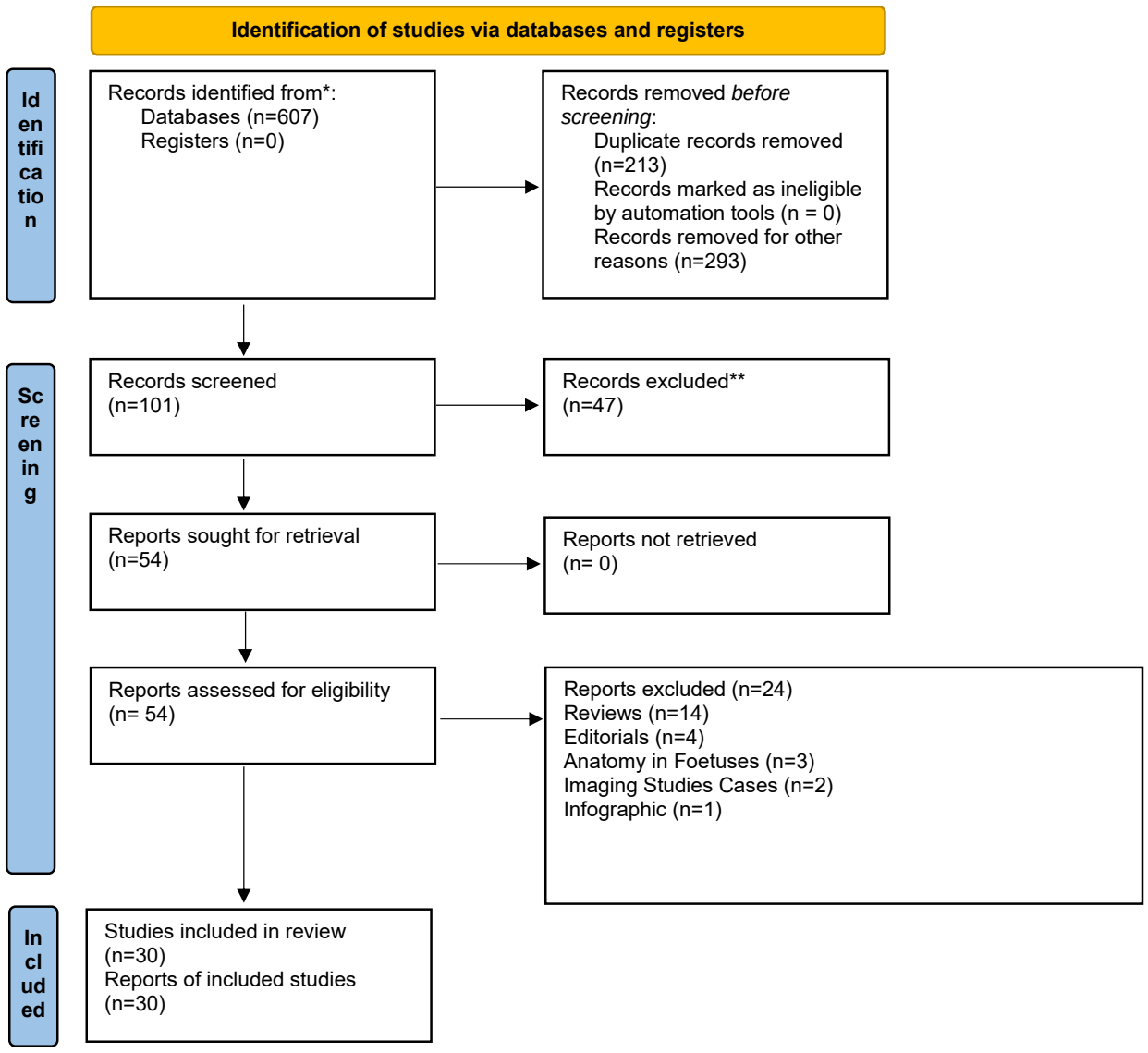

Figure 1:

PRISMA Flow Diagram. From the initial 607 records, 30 studies were included in the quantitative synthesis.

Quality assessment and publication bias

The findings of the quality assessment are summarized in Table 2 and 3.

CASP

Table 2: CASP Qualitative Study Assessment

Item	[1] Statement	[2] Methodology	[3] Research Design	[4] Recruitment Strategy	[5] Data Collection	[6] N/A	[7] Ethical Issues	[8] Data Analysis	[9] Clear Statement	[10] Valuable	YES [n] And no for [7]	≥75% Score *
Vincent	Yes	Yes	Yes	Yes	Yes		No	No	Yes	Yes	8	89%
Claes	Yes	Yes	Yes	Yes	Yes		Can't tell	Yes	Yes	Yes	8	89%
Helito	Yes	Yes	Yes	No	Yes		Yes	Yes	Yes	Yes	7	78%
Dodds	Yes	Yes	Yes	No	Yes		No	Yes	Yes	No	7	78%
Caterine	Yes	Yes	Yes	No	Yes		No	No	Yes	Yes	7	78%
Kennedy	Yes	Yes	Yes	No	Yes		Can't tell	Yes	Yes	Yes	7	78%
Rahnemai-Azar	Yes	Yes	No	No	No		No	Yes	Yes	No	5	78%
Daggett	No	Yes	Yes	Yes	Yes		No	No	Yes	Yes	7	78%
Kosy	Yes	Yes	Yes	No	Yes		No	No	Yes	Yes	7	78%
Potu	Yes	Yes	Yes	No	No		Yes	No	Yes	No	7	78%
Roessler	No	Yes	Yes	Yes	Yes		Can't tell	Yes	Yes	Yes	7	78%
Runner	No	Yes	Yes	Yes	Yes		Can't tell	Yes	Yes	Yes	7	78%
Stijak	No	Yes	Yes	Yes	Yes		Can't tell	No	Yes	Yes	6	67%
Watanabe	No	Yes	Yes	Yes	Yes		No	No	Yes	Yes	7	78%
Neri (2017)	Yes	Yes	Yes	No	Yes		No	Yes	Yes	Yes	9	100%
Cai	Yes	Yes	Can't tell	Yes	Yes		No	Yes	Yes	Yes	7	78%
Goncharev	Yes	Yes	Yes	No	No		No	No	Yes	Yes	7	78%

Neri (2018)	Yes	Yes	Yes	No	Yes		No	No	Yes	Yes	7	78%
Olewnik	Yes	Yes	Yes	Yes	Yes		No	Yes	Yes	Yes	9	100%
Parker	Yes	Yes	Yes	Yes	Yes		No	Yes	Yes	Yes	9	100%
Zhang	Yes	Yes	Yes	Yes	Yes		No	Yes	Yes	Yes	9	100%
Brockmeyer	Yes	Yes	Yes	Yes	Yes		No	Yes	Yes	Yes	9	100%
Cho	Yes	Yes	Yes	Yes	Yes		No	No	Yes	Yes	9	100%
Sabatini	Yes	Yes	Yes	Yes	Yes		No	Yes	Yes	Yes	9	100%
Urban	Yes	Yes	Yes	Yes	Yes		Yes	No	Yes	Yes	9	100%
Nasu	Yes	Yes	Yes	Yes	Yes		No	No	Yes	Yes	8	89%
Patel	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	8	89%
Shetty	Yes	Yes	Yes	Yes	Yes		Yes	No	Yes	No	6	67%
Fernades	Yes	Yes	Yes	Yes	Yes		Yes	Can’t tell	Can’t tell	Can’t tell	5	55%
Suh	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	8	89%

Table 3: QUACS Quality Assessment

Item	[1] Objective Stated	[2] Basic Information	[3] Applied Methods	[4] Specimen Condition	[5] Education	[6] Findings	[7] Results	[8] Statistics	[9] Details	[10] Photographs	[11] Study Discussion	[12] Clinical Implications	[13] Limitations	Quality >75%
Vincent	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	77%
Claes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	61%
Helito	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	85%
Dodds	No	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	54%
Caterine	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	77%
Kennedy	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	85%
Rahnemai-Azar	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	85%
Daggett	No	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	61%
Kosy	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	54%
Potu	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	46%
Roessler	No	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	69%
Runner	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	92%
Stijak	No	No	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes	No	38%
Watanabe	No	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	46%
Neri (2017)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	77%
Cai	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No	69%
Goncharev	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	46%
Neri (2018)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes	No	Yes	84%
Olewnik	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	69%

Parker	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	77%
Zhang	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	92%
Brockmeyer	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	61%
Cho	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	61%
Sabatini	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	77%
Urban	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	No	61%
Nasu	No	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	61%
Patel	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	92%
Shetty	No	Yes	No	No	No	No	Yes	No	Yes	Yes	No	No	No	31%
Fernades	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	69%
Suh	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	84%

Among the 30 studies evaluated, only 3 studies were deemed to lack reasonable quality and a low risk of bias. [26,38,39] Stijak et al. did not provide a clear statement of the aims of research, it was not clear whether ethical issues were taken into consideration and the reviewers considered that the data analysis was not sufficiently rigorous. [26] Shetty et al. offered only a general statement regarding ethical clearance, which the reviewers deemed insufficient. [38] Additionally, the data analysis was not conducted with adequate rigor, and the overall impact of the study was low. In the study by Fernandes, the reviewers were unable to determine whether the data analysis was conducted with sufficient rigor. [39] Additionally, the study lacked a clear statement of findings, and its overall impact was considered low [Table 2]. [39]

QUACS

Of the 30 studies included, only 13 studies [2,5,10-12,22,28,29,31,32,35,37,40] met the 75% threshold required to be considered of sufficient quality [Table 3]. Two primary limitations were consistently observed in studies not meeting the 75% threshold. First, the educational background and qualifications of the researchers conducting dissections were not reported, which raises concerns about the reliability of the findings. Second, the observations from the dissections were not corroborated by multiple researchers, limiting the objectivity and reproducibility of the results. Additionally, several studies failed to acknowledge or discuss their inherent limitations, further compromising the validity of their conclusions.

Publication bias

Egger's regression intercept was 2.345 with a *p-value* of 0.00468 and the funnel plot exhibits asymmetry, suggesting the possibility of publication bias. (Figure 2).

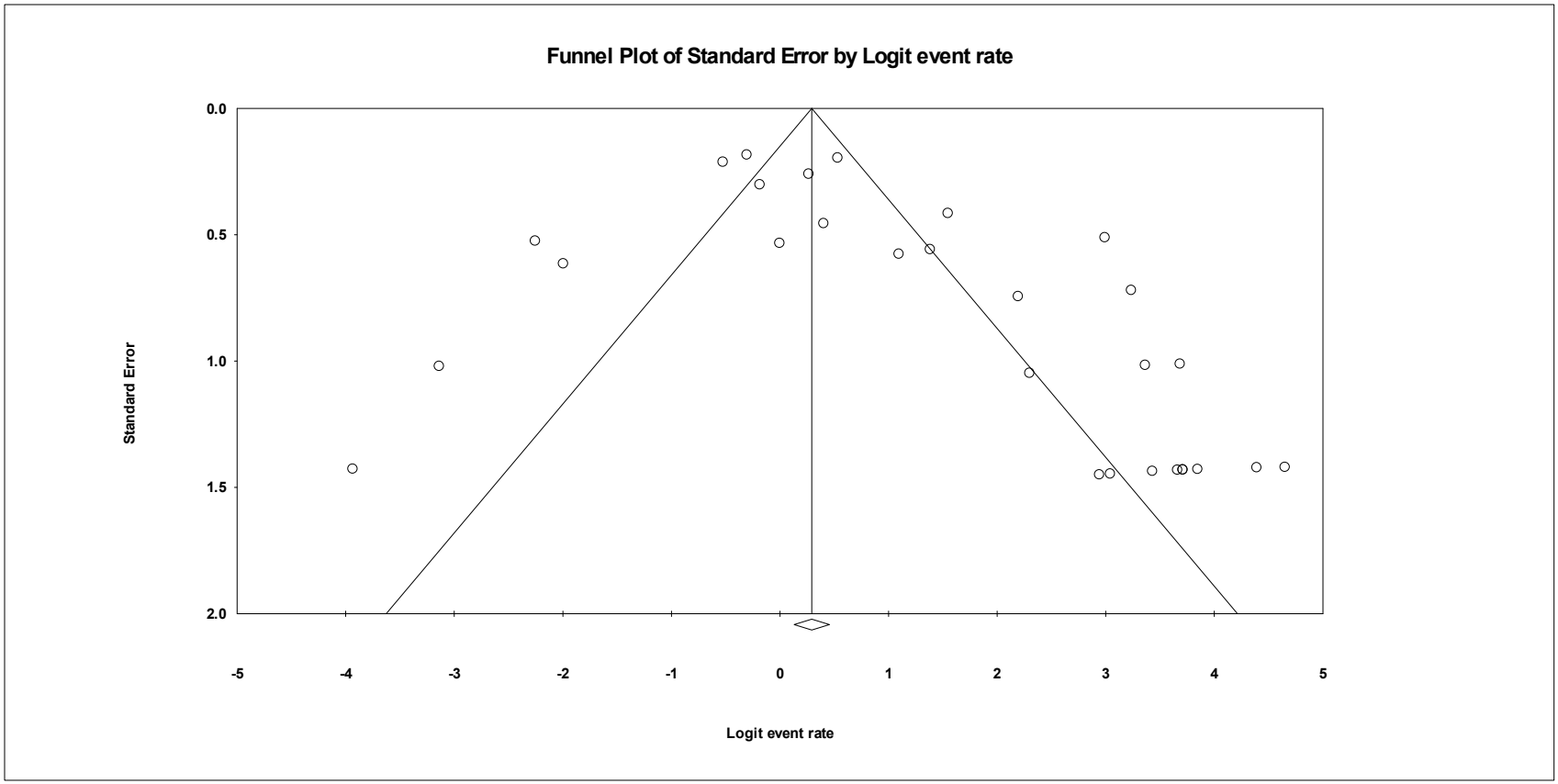

Figure 2:

The funnel plot displays asymmetry, indicating publication bias.

Prevalence

Twenty-nine studies [2,3,5-13,22,23,26-34,36-40] reported on the prevalence of the ALL in human specimens from various population groups and one study [35] focused only on histology (Figure 3). Across these studies, 1001 knee specimens were examined, and the presence of the ALL was identified in 618 of them. The reported prevalence of the ALL in these individual studies ranged from 0% to 100% with an overall prevalence was 61.7%.

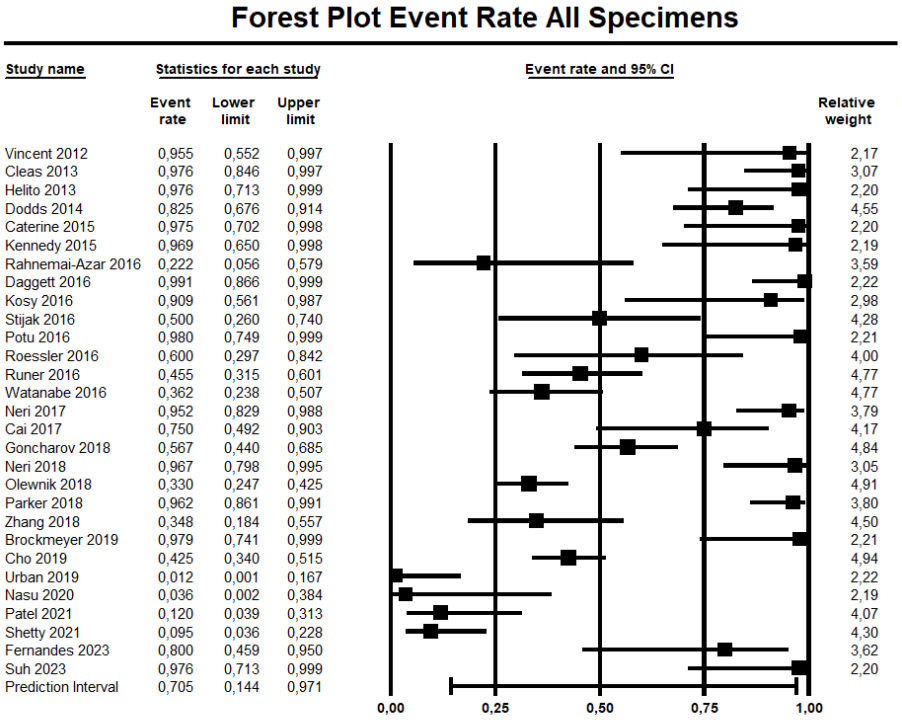

Figure 3:

The forest plot shows that the overall mean effect across the entire study population was calculated to be 0.705.

A total of 6 studies [11,12,22,23,31,37] reported on the prevalence of the ALL in North American human specimens (Supplementary Figure 1). Across these studies, 173

specimens were examined, and the presence of the ALL was identified in 142 specimens. The reported prevalence of the ALL in these individual studies ranged from 22% to 100% with an overall prevalence was 82.1%. A total of 17 studies [2,3,5,6,8,9,24-26,28-30,33,39] reported on the prevalence of the ALL in European human specimens (Supplementary Figure2). Across these studies, 530 specimens were examined, and the presence of the ALL was identified in 344 specimens. The reported prevalence of the ALL in these individual studies ranged from 33% to 100% with an overall prevalence was 64.9%. A total of 6 studies [7,27,32,34,36,40] reported on the prevalence of the ALL in Asian human specimens (Supplementary Figure 3). Across these studies, 236 specimens were examined, and the presence of the ALL was identified in 108 specimens. The reported prevalence of the ALL in these individual studies ranged from 0% to 75% with an overall prevalence was 45.8%. Additional details regarding the statistical data on prevalence can be found in the supplementary materials.

Anatomic Measurements

Femoral Insertion

Significant variability was observed across studies regarding the femoral origin of the ALL. Twenty-seven studies reported on some form of origin or femoral footprint of the ALL. [2,3,5-12,23-28,30-40] Several studies [5,6,9,11,32,33,40] described mixed origins for the ALL attachment. The ALL was found to either attach directly (or overlapping) to the LCL, [5,32,33] anterior to the LCL, [9] anterior distal to the LCL, [6,11] anterior proximal, [32] posterior proximal to the LCL, [5,9,11,33] and/or posterior lateral to the LCL. [6]

Tibial Insertion

Twenty-six studies reported some form of the ALL insertion onto the tibia [2,3,5-8,10,12,22,24-28,31-40] Seven studies [9,22,24,26-28,31-34,40] provided a general and simple description of the insertion point of the ALL as being located about midway between Gerdy's tubercle and the fibular head. Four studies [2,3,11,36] provided a more general and simple description, noting the ALL insertion as being located on the proximal tibia, posterior to Gerdy's tubercle, with Vincent et al. [2] adding that the attachment was around 5mm distal to the articular cartilage. One study observed the ALL attaching below the tibial articular surface at the level of Gerdy's tubercle. [35] Eight studies [5-8,10,12,25,39] provided detailed measurements of the anterolateral ligament (ALL) insertion point, confirming its location between Gerdy's tubercle and the fibular head.

Length

A total 22 studies [2,3,5-12,24-26,28,30-34,39,40] studies reported on the length of the ALL in human specimens (Figure 4). The pooled sample size was 476 specimens, and the reported length ranged from 31 to 59 mm. The overall mean effect size was calculated to be 39.684 with a 95% confidence interval ranging from 37.173 to 42.196. A total 3 studies [11,12,31] studies reported on the length of the ALL in North American (Supplementary Figure 4). The pooled sample size was 85 specimens, and the reported length ranged from 38.4 to 40.3 mm. The overall mean effect size was calculated to be 39.452 with a 95% confidence interval ranging from 38.132 to 40.772. A total 13 studies [2,3,5,6,8,9,24-26,28.30,33,39] studies reported on the length of the ALL in European human specimens (Supplementary Figure 5). The pooled sample size was 291 specimens and the reported length ranged from 31 to 59 mm. The overall mean effect size was calculated to be 40.135 with a 95% confidence interval ranging

from 36.108 to 44.161. A total 4 studies [7,32,34,40] reported on the length of the ALL in various Asian populations (Supplementary Figure 6) The pooled sample size was 76 specimens and the reported length ranged from 32.4 to 47.8 mm. The overall mean effect size was calculated to be 40.128, with a 95% confidence interval ranging from 32.724 to 47.533. Additional details regarding the statistical data on prevalence can be found in the supplementary materials.

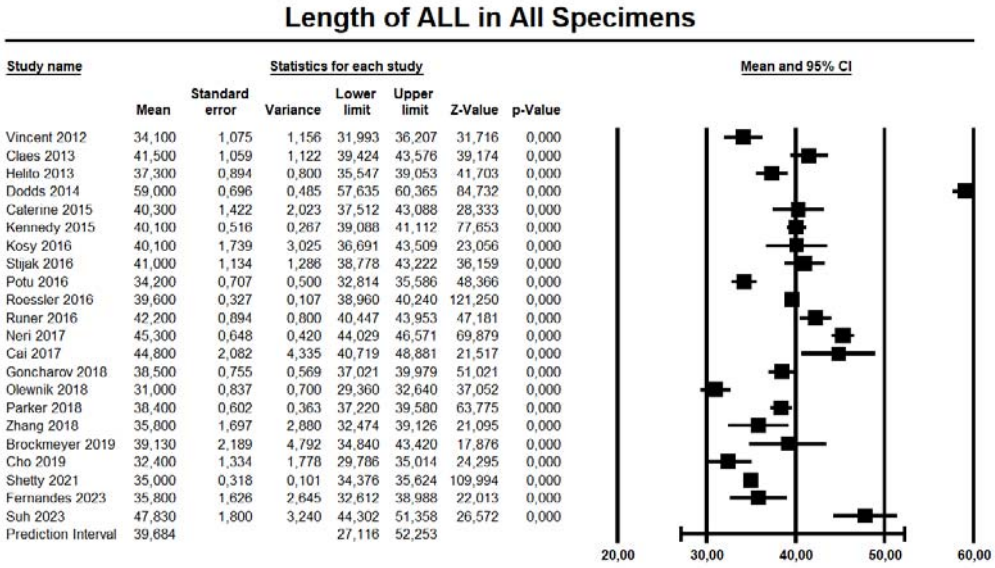

Figure 4:

The forest plot shows that the overall mean effect size for length across the entire study population was calculated to be 39.684.

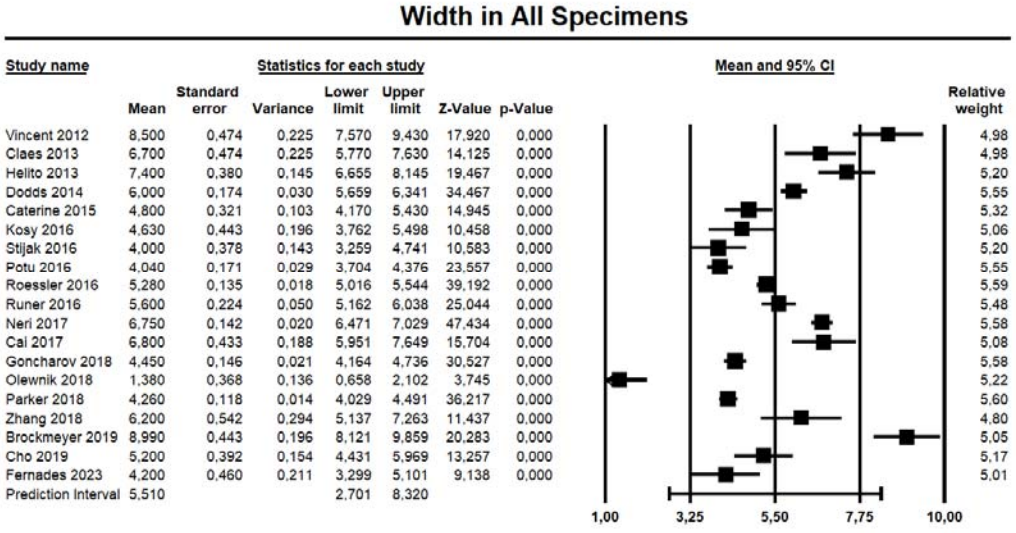

Figure 5:

The forest plot shows that the mean effect size for width across the entire study population was calculated to be 5.510.

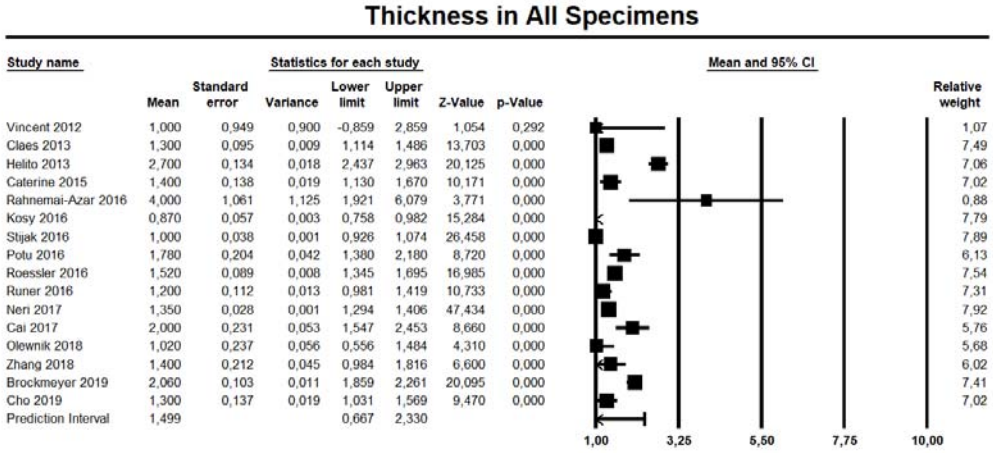

Figure 6:

The forest plot shows that the overall mean effect size for thickness across the entire study population was calculated to be 1.499.

Width

A total 19 studies [2,3,5,6,7,8,910,11,24-26,28,30-34,39] reported on the width of the ALL in human specimens. (Figure 5) The pooled sample size was 424 specimens and the reported width ranged from 1.4 to 9 mm. The overall mean effect size was calculated to be 5.51, with a 95% confidence interval ranging from 4.907 to 6.114. Only 2 studies [11,31] reported on the width of the ALL in North American human specimens. The pooled sample size was 70 specimens and the reported width ranged from 4.3 to 4.8 mm. The calculation of the mean effect size, prediction interval, Q-test, and I-squared statistic requires a minimum of three studies. Consequently, the data regarding width in North American specimens must be regarded as unreliable. A total 13 studies [2,3,5,6,8,9,24-26,28,30,33,39] reported on the width of the ALL in European human specimens. (Supplementary Figure 7) The pooled sample size was 278 specimens and the reported width ranged from 1.4 to 9 mm. The overall mean effect size was calculated to be 5.406, with a 95% confidence interval ranging from 4.635 to 6.178. A total 3 studies [7,32,34] reported on the width of the ALL in Asian human specimens. (Supplementary Figure 8) The pooled sample size was 56 specimens and the reported width ranged from 5.2 to 6.8 mm. The overall mean effect size was calculated to be 6.048, with a 95% confidence interval ranging from 5.043 to 7.052. Additional details regarding the statistical data on prevalence can be found in the supplementary materials.

Thickness

A total 16 studies [2,3,5-7,10,11,22,24-26,28,30,32-34] reported on the thickness of the ALL in human specimens. (Figure 6) The pooled sample size was 306 specimens and the reported width ranged from 0.9 to 2.7 mm. The overall mean effect size was calculated to be 1.499, with a 95% confidence interval ranging from 1.292 to 1.705.

Only 2 studies [11,22] reported on the thickness of the ALL in North American human specimens. The pooled sample size was 21 specimens and the reported width ranged from 1.4 to 4.0 mm. The calculation of the mean effect size, prediction interval, Q-test, and I-squared statistic requires a minimum of three studies. Consequently, the data regarding width in North American specimens must be regarded as unreliable. A total 10 studies [2,3,5,6,24-26,28,30,33] reported on the thickness of the ALL in European human specimens. (Supplementary Figure 9) The pooled sample size was 209 specimens and the reported width ranged from 0.9 to 2.1 mm. The overall mean effect size was calculated to be 1.333, with a 95% confidence interval ranging from 1.124 to 1.542. A total 3 studies [7,32,34] reported on the thickness of the ALL in Asian human specimens. (Supplementary Figure 10) The pooled sample size was 56 specimens and the reported width ranged from 1.3 to 2 mm. The overall mean effect size was calculated to be 1.538 with a 95% confidence interval ranging from 1.136 to 1.940. Additional details regarding the statistical data on the anatomical measurements, meniscal attachments and histology can be found in the supplementary materials.

Discussion

The findings from this systematic review indicate that the ALL is present in nearly 62% of the total sample population. Additionally, its prevalence varies significantly by region: 82% in North American studies, 65% in European studies, and 46% in Asian studies. The length of the ALL was observed to range from 25 to 59 mm, with 95% of the samples falling between 30 and 50 mm, and a pooled mean length of 39.9 mm. The width of the ALL ranged from 2.2 to 9 mm, with 95% of the samples measuring between 4.6 and 6.8 mm, resulting in a pooled mean width of 5.7 mm. The

thickness of the ALL varied from 1.3 to 2.7 mm, with 95% of the samples lying between 1.3 and 1.7 mm, and a pooled mean thickness of 1.5 mm.

The authors employed the Critical Appraisal Skills Programme (CASP) for subjective and qualitative quality assessment of the 30 included studies. The evaluation revealed that 27 studies (90%) were deemed to be of inadequate quality. These perceptions are supported by the results of the QUACS quality assessment, in which only 12 studies (40%) surpassed the 75% threshold, indicating satisfactory quality. One might of course argue that the absence of detailed information regarding the educational background and professional qualifications of the researchers, which significantly influenced this assessment, as well as the lack of clarity on the number of researchers involved in direct measurements and observations of cadaver specimens, may not be critical indicators of study quality. However, these potential shortcomings may have led to a reduction in the reliability of the findings and could compromise the overall validity of the results.

In cadaveric studies, randomization is generally not feasible. However, when the objective of these studies is to quantify morphological parameters such as length, width, or thickness, as well as the prevalence of anatomical structures, pooling data from multiple studies can still yield reliable summary estimates. The reliability and validity of such pooled analyses depend on the inclusion of studies with sufficient methodological quality. Given the above considerations, it is important to view the results with some caution.

Additionally, statistical analysis revealed significant heterogeneity among the included studies, indicating that the true effect size varied substantially across different studies. Study heterogeneity refers to variability in outcomes that exceeds what can be attributed to measurement error alone, often indicated by wide prediction intervals across the measured parameters. While random-effects models can partially account for this heterogeneity, excluding outlier studies is another method to reduce variability. However, in this analysis, no clear outliers were identified among the included studies, but the prediction intervals were wide for all measures. Therefore, the most likely explanation for the observed heterogeneity lies in the intrinsic morphological variability of the anatomical measures under investigation. Despite these potential issues, it can be concluded with reasonable confidence that the ALL is not a consistently present anatomical structure and is more frequently observed in the Caucasian population.

The origin and femoral footprint of the ALL exhibit significant variability across studies, with majority of studies referencing its attachment point in proximity to the LCL attachment on the lateral femoral epicondyle. For instance, Claes et al., [3] Stijak et al., [26] Shetty et al. [38] and Parker et al. [31] observed the attachment to be anterior to the LCL, while Helito et al. [10] described the femoral footprint as being anterior and distal to the insertion of the LCL. In contrast, Kennedy, Cai and Fernandes identified the footprint to be posterior and proximal to the LCL while Watanabe et al. [27] reported the footprint as being posterior and superficial to the LCL insertion. Several studies found multiple varieties of attachments across their sample, with Caterine et al. [11] observing the footprint to be either antero-distal or postero-proximal to the LCL insertion while Suh's et al. study [40] indicated that although the femoral footprint

predominantly occupies a postero-proximal location, it also appears in smaller percentages in proximal, antero-proximal, and posterodistal positions. Daggett et al. [23] observed that in 23% of cases, the ALL was directly attached to the LCL, a finding consistent with the observations made by both Roessler et al. [25] and Potu et al. [24]. In the largest series, Olwenik et al. [30] described five distinct types of ALL morphology: a single tendon-like structure, single or double band-like structures, a fan-shaped structure, a double ALL blending into the deep fascia, and a complex type. Olewnik et al.'s [30] study possibly offers the most thorough depiction of the diversity in the origin of the ALL and emphasizes the substantial variability in its femoral footprint.

Alterations in the femoral footprint origin of the ALL may significantly impact length changes during knee flexion and these morphological variations are crucial considerations in ALL reconstructions, particularly in the selection of femoral tunnel placement as it can influence knee kinematics and kinetics. [18] For example, Zens et al. demonstrated that the length of the ALL increases with greater knee flexion angles when its femoral footprint is located antero-distal. [41] In contrast, when the ALL's footprint is positioned posterior-proximal relative to the lateral femoral condyle, its length decreases during knee flexion. It appears that a graft which is attached proximal to the lateral femoral epicondyle and coursing deep to the LCL will exhibit favourable biomechanical behaviour, avoiding excessive tightening or slackening during knee motion. [18] Interestingly, the modified Lemaire technique positions the femoral tunnel immediately proximal and posterior to the lateral epicondyle, which satisfies the criteria for achieving optimal graft behaviour. [42]

The tibial footprint and insertion of the ALL exhibit significantly greater consistency compared to the femoral footprint. Several studies [9,11,24,27,28,32-34,37,40] describe the insertion of the ALL as located midway between Gerdy's tubercle and the fibular head. Other researchers [2,3,5-8,12,25,39] have more specifically measured the distance from Gerdy's tubercle to the fibular head and have reached similar conclusions. When performing an ALL reconstruction using the modified Lemaire technique, the precise tibial insertion point seems to become less critical, as the procedure utilizes a strip of the iliotibial band and does not necessitate a tibial tunnel. However, when using tendon autografts or allografts for ALL reconstruction, the creation of a tibial tunnel is necessary, and tunnel location may influence the isometry of the reconstructed ALL. Surgical technique studies [43,44] recommend positioning the tibial tunnel midway between Gerdy's tubercle and the fibular head, which aligns with the anatomical insertion points of the ALL identified in anatomical studies.

When the ALL is present, histological findings consistently reveal densely arranged connective tissue fibers with a parallel orientation, characteristic of ligamentous tissue [2,10,11,24,29,32,33,35] Only three [10,13,36] of the ten studies that included histological analysis deviated from the expected findings. Urban et al. [13] identified aponeurotic tissue as part of the knee capsule, which did not exhibit ligamentous characteristics, while Nasu et al. [36] and Helito et al. [10] observed fibrous tissue with pearly fibrous bands. The majority of the studies, therefore, support the theory that the ALL possesses ligament-like characteristics.

A key finding of this systematic review was the notable variation in the prevalence of the ALL across different regions. Specifically, the prevalence was 82% in North

American studies, 62% in European studies, and 46% in Asian studies. This finding contrasts with previous work. Cho et al. examined the frequency of the ALL in Japanese and Korean populations compared to an Austrian population and found similar frequencies. [34] However, this comparison may lack scientific rigor, as the authors did not account for other studies reporting ALL frequency in various population subgroups. The reasons for these substantial differences are not yet clear and may be attributed to genetic factors. Additionally, these findings should be considered when planning ALL reconstruction for different population groups.

The clinical implications of the results from this systematic review remain unclear. While the goal of surgical intervention is typically to restore anatomical structures, the fact that the ALL is absent in nearly 20% of North American, 35% of European and over 50% of Asian individuals raises questions. This substantial prevalence of absence suggests that ALL reconstruction may not solely aim to restore anatomy but could also serve alternative functions and could be defined as a non-anatomic reconstruction procedure. Interestingly, basic biomechanical studies have yielded varying results. Some studies employed robotic simulated pivot shift tests to assess anterior tibial translation, internal rotation, and combined movements. [45,46] These studies observed significant differences between ACL-intact knees, ACL-reconstructed knees with deficient ALL, and ACL-reconstructed knees with ALL reconstruction and did not recommend ALL reconstruction. Conversely, other studies [47-49] demonstrated a stabilizing effect of ALL reconstruction. A concern with ALL reconstruction is the potential for over-constraining internal rotation which could theoretically affect patients who lack a native ALL. [50]

Limitations

This systematic review has several limitations. Frequently, the age of the cadavers used in the studies is quite advanced, and several studies have small sample sizes. Nevertheless, it can be reasonably assumed that the age of the cadavers does not substantially affect the morphology, size, or location of the knee structures assessed.

The included specimens comprised a mix of fresh, fresh-frozen, and embalmed samples. It is theoretically possible that the embalming process may have influenced the size and characteristics of the ALL, potentially introducing bias into the findings. The identification of the ALL may depend on the dissection technique used. Although all studies employed open dissection and adhered to "standard dissection techniques," including the removal of skin, subcutaneous tissue, and careful dissection of the iliotibial band (ITB), the extent of knee capsule exposure might have influenced whether the ALL was identified. However, this seems to be an unlikely factor, and the identification of the ALL may not be due to the dissection method but rather to the skill or experience of the dissector. In studies utilizing paired cadaveric samples, the effective sample size was halved. This adjustment may have introduced random error, potentially impacting the accuracy of the summary estimates. Ethnicity was inferred based on the geographical location where each study was conducted, which may introduce bias due to potential discrepancies between the assumed and actual ethnic composition of the sample populations. The search engines used in general are optimized for English-language queries, potentially excluding studies published in other languages. Both Egger’s test results and the funnel plot were suggestive of publication bias. Publication bias can lead to an overestimation of the treatment effect; therefore, the actual certainty of the evidence may be lower than indicated.

Conclusions

This systematic review reveals that the ALL is present in 61.7%, with prevalence rates of 82% in North American studies, 65% in European studies, and 46% in Asian studies. The femoral insertion exhibited substantial variability at/around the lateral femoral epicondyle and LCL, lacking consistency. The tibial insertion was more consistently described as being located about halfway between Gerdy's tubercle and the fibular head. Histological analysis showed that 60% of the included studies identified the ALL as containing ligament-like or ligamentous tissue. The mean length of the ALL was 39.9 mm (range 31-59 mm), the mean width was 5.7 mm (range 2.2-9.0 mm), and the mean thickness was 1.5 mm (range 1.3-2.7 mm). No significant ethnic population differences were observed in the morphological measures.

References

[1] Segond P (1879) Recherses cliniques et experimentales sur les epanchements sanguins du genou par entorse: Aux Bureaux du Progres medical.

[2] Vincent JP, Magnussen RA, Gezmez F, Uguen A, Jacobi M, Weppe F, et al. The anterolateral ligament of the human knee: an anatomic and histological study. *Knee Surg Sports Traumatol Arthrosc* 2012; 20 (1): 147-152

[3] Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. *J Anat* 2013; 223 (4); 321-328

[4] Hohmann E. Editorial Commentary: Another take on the anterolateral ligament: high-grade are worse than low-grade injuries, but the categorization is problematic. *Arthroscopy* 2021; 37 (1): 231-233

[5] Runer A, Birkmaier S, Pamminger M, Reider S, Herbst E, Künzel KH, et al. The anterolateral ligament of the knee: a dissection study. *Knee* 2016; 23 (1): 8-12

[6] Kosy JD, Soni A, Venkatesh R, Mandalia VI. The anterolateral ligament of the knee: unwrapping the enigma. Anatomical study and comparison of previous reports. *J Orthop Traumatol* 2016; 17 (4): 303-308

[7] Cai J, Jin W, Sheng D, Chen S. Anatomical study on anterolateral ligament in a Chinese population. *Chin J Rep Recon Surg* 2017; 31 (12): 1452-1455

[8] Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA. The anterolateral ligament: anatomy, length changes and association with the Segond fracture. *Bone Joint J* 2014; 96B: 325-331

[9] Goncharov EN. Koval OA, Bezuglov EN, Goncharov NG. Anatomical features and significance of the anterolateral ligament of the knee. *Int Orthop* 2018; 42 (12): 2859-2864

[10] Helito CP, Demange MK, Bonadio MB, Tirico LEP, Gobbi RG, Pecora JR, et al. Anatomy and histology of the knee anterlateral ligament. *Orthop J Sports M*ed 2013; 1 (7): 2325967113513546

[11] Caterine S, Litchfield R, Johnson M, Chronic B, Getgood A. A cadaveric study of the anterolateral ligament: reintroducing the lateral capsular ligament. *Knee Surg Sports Traumatol Arthrosc* 2015; 23 (11): 3186-3195

[12] Kennedy MI, Claes S, Fuso FAF, Williams BT, Goldsmith MT, Turnbull TL, et al. The anterolateral ligament: an anatomic, radiographic, and biomechanical analysis. *Am J Sports Med* 2015; 43 (7): 1606-1615

[13] Urban S, Pretterklieber B, Pretterklieber ML. The anterolateral ligament of the knee and the lateral meniscotibial ligament – anatomical phantom versus constant structure within the anterolateral complex. *Ann Anat* 2019; 226: 64-72

[14] de Lima DA, Helito CP, de Lima LL, Silva D, Cavalcante MLC, Leite JAD. Anatomy of the anterolateral ligament of the knee: a systematic review. *Arthroscopy* 2019; 35 (2): 670-681

[15] Getgood A, Brown C, Lording T, Amis A, Claes S, Geeslin A, et al. The anterolateral complex of the knee: results from the International ACL Consensus Group Meeting. *Knee Surg Sports Traumatol Arthrosc* 2019; 27 (1): 166-176

[16] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Syst Rev* 2021; 10 (1): 89

[17] Cumpston M, Li T, Page MJ, Chandler J, Welch VA, Higgins JPT, et al. Updated guidance for trusted symptomatic reviews of the Cochrane handbook for systematic reviews of interventions. *Cochrane Database Syst Rev* 2019; 10:ED000142. https://doi.org/10.1002/14651858.ED000142

[18] Kittl C, Halewood C, Stephen JM, Gupte CM, Weiler A. Williams A, et al. Length change patterns in the lateral extra-articular structures of the knee and related reconstructions. *Am J Sports Med* 2015; 43 (2): 354-362

[19] Long HA, French DP, Brooks JM. Optimizing the value of the critical appraisal skills programme (CASP) tool for quality appraisal in qualitative evidence synthesis. *Res Meth Med Health Sci* 2020; 1 (1): 31-42

[20] Critical appraisal skills programme. 2018 Available at: https://casp-uk.net/casp-tools-checklists/qualitative-studies-checklist/. Accessed 15 July 2024

[21] Wilke J, Krause F, Niederer D, Engerhoff T, Nürnberger F, Vogt L, et al. Appraising the methodological quality of cadaveric studies: validation of the QUACS scale. *J Anat* 2015; 226 (5): 440-446

[22] Rahnemai-Azar AA, Miller RM, Guenther D, Fu FH, Lesniak BP, Musahl V, Debski RE. Structural properties of the anterolateral capsule and iliotibial band of the knee. *Am J Sports Med* 2016; 44 (4): 892-897

[23] Daggett M, Ockuly AC, Cullen M, Busch K, Lutz C, Imbert P, et al. Femoral origin of the anterolateral ligament: an anatomic analysis. *Arthroscopy* 2016; 32 (5): 835-841

[24] Potu BK, Salem AH, Abu-Hijleh MF, Morphology of the anterolateral ligament of the knee: a cadaveric observation with clinical insight. *Adv Med* 2016;: 9182863

[25] Roessler PP, Schüttler KF, Stein T, Gravius S, Heyse TJ, Prescher A, et al. Anatomic dissection of the anterolateral ligament (ALL) in paired fresh-frozen cadaveric knee joints. *Arch Orthop Trauma Surg* 2017; 137 (2): 249-255

[26] Stijak L, Bumbasirevic M, Radonjic V, Kadija M, Puskas L, Milovanovic D. Anatomic description of the anterolateral ligament of the knee. *Knee Surg Sports Traumatol Arthrosc* 2016; 24 (7): 2083-2088

[27] 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 (5): 647-651

[28] Neri T, Palpacuer F, Testa R, Berhandi F, Boyer B, Farizon F, Philppot R. The anterolateral ligament: anatomic implications for its reconstruction. *Knee* 2017; 24 (5): 1083-1089

[29] Neri T, Dalcol P, Palpacuer F, Bergandi F, Prades JM, Farizon F, et al. The anterolateral ligament is a distinct ligamentous structure: a histological explanation. *Knee* 2018; 25 (5): 360-366

[30] Olewnik L, Gonera B, Kurtys K, Podgorski M, Polguj M, Sibinksi M, et al. The anterolateral ligament of the knee: a proposed classification system. *Clin Anat* 2018; 31 (7): 966-973

[31] Parker M, Smith HF. Anatomical variation in the anterolateral ligament of the knee and a new dissection technique for the embalmed cadaveric specimens. *Anat Sci Int* 2018; 93 (2): 177-187

[32] Zhang H, Qiu M, Xu Z, Wang W, Chen S, Zhang J. The prevalence and morphological characteristics of the knee anterolateral ligament in a Chinese population. *J Anat* 2018; 233 (2): 213-221

[33] Brockmeyer M, Orth P, Höfer D, Seil R, Paulsen F, Menger MD. The anatomy of the anterolateral structures of the knee – a histologic and macroscopic approach. *Knee* 2019; 26 (3): 636-646

[34] Cho HJ, Kwak DS. Anatomical consideration of the anterolateral ligament of the knee. *Biomed Res Int* 2019: 5740473

[35] Sabatini L, Risitano S, Atzori F, Volante M, Aprato A, Indelli PF, et al. Histological analysis of the anterolateral ligament of the knee. *J Orthop* 2019; 16 (5): 368-372

[36] Nasu H, Nimura A, Yamaguchi K, Akita K. Morphology of the anterolateral ligament: a complex of fibrous tissue spread to the anterolateral aspect of the knee. *Anat Sci Int* 2020; 95 (4): 470-477

[37] Patel RM, Castile RM, Jenkins MJ, Lake SP, Brophy RH. Microstructural and mechanical properties of the anterolateral ligament of the knee. *Am J Sports Med* 2021; 49 (1): 172-182

[38] Shetty A, Prabath S, Alapatt K, Kn LK, Bhat N, Sumalatha S. Lateral collateral ligament and anterolateral ligament of the knee – a morphological analysis with orthopaedic significance. *Knee* 2021: 202-206

[39] Fernandes JC, Pinho AR, Pereira PA, Madeira MD, Raposo FA, Sousa AN, Lobo JM, et al. Anterolateral ligament of the knee – Cadaver study in a Caucasian population. *Rev Esp Cir Ortop Traumatol* 2023; 67 (2): 134-138

[40] Suh DK, Cho IY, Noh S, Yoon DJ, Jang KM. Anatomical and biomechanical characteristics of the anterolateral ligament: a descriptive Korean cadaveric study using a triaxial accelerometer. *Medicina (Kaunas)* 2023; 59 (2): 419

[41] Zens M, Niemeyer P, Ruhhammer J, Bernstein A, Woias P, Mayr HO, Südkamp MP, Feucht MJ. Length changes of the anterolateral ligament during passive knee motion: a human cadaveric study. *Am J Sports Med* 2015; 43 (10): 2545-2552

[42] Haus A, Chand A, Dawson K, Lang S, Gilmer BB, Wahl CJ. Modified Lemaire lateral extra-articular tenodesis using an inlay technique and all-suture knotless anchor fixation. *Arthrosc Techn* 2023; 12 (9): e1607-e1613

[43] Barroso BG, Canuto SM, Helito CP, Rego MCF, Martins FS. Combined anterior cruciate ligament and anterolateral ligament reconstruction using the superficial layer quadriceps tendon graft surgical technique description. *Arthrosc Tech* 2024; [article in press]

[44] da Silva AGM, Macedo RS, Souza MO, Giglio PN, Videira LD, Gobbi RG, et al. Combined anterior cruciate ligament and anterolateral ligament reconstruction using a single tendon peroneus longus graft. *Arthrosc Tech* 2023; 13 (1): 102823

[45] Noyes FR, Huser LE, Jurgensmeier D, Walsh J, Levy MS. Is an anterolateral ligament reconstruction required in ACL-reconstructed knees with associated injury to the anterolateral structures? A robotic analysis of rotational knee stability. Am J Sports Med 2017; 45 (5): 1018-1027

[46] Stentz-Olesen K, Nielsen ET, de Raedt S, Jorgensen PB, Sorensen OG, Kaptein B, et al. Reconstructing the anterolateal ligament does not decrease rotational knee laxity in ACL-reconstructed knees. *Knee Surg Sports Traumatol Arthrosc* 2017; 25 (4): 1125-1131

[47] Rasmussen MT, Nitri M, Williams BT, Moulton SG, Cruz RS, Dornan GJ, et al. An in vitro robotic assessment of the anterolateral ligament, part 1: secondary role of the anterolateral ligament in the setting of an anterior cruciate ligament injury. *Am J Sports Med* 2016; 44 (3): 585-592

[48] Nitri M, Rasmussen MT, Williams BT, Moulton SG, Cruz RS, Dornan GJ. An in vitro robotic assessment of the anterolateral ligament, part 2: anterolateral ligament reconstruction combined with anterior cruciate ligament reconstruction. *Am J Sports Med* 2016; 44 (3); 593-601

[49] Herbst E, Arilla FV, Guenther D, Yacuzzi C, Rahnemai-Azar AA, Fu FH. Lateral extra-articular tenodesis has no effect in knees with isolated anterior cruciate ligament injury. *Arthroscopy* 2018; 34 (1): 251-260

[50] Schon JM, Moatshe G, Brady AW, Cruz RS, Chahla J, Dornan GJ, et al. Anatomic anterolateral ligament reconstruction of the knee leads to overconstraint at any fixation angle. *Am J Sports Med* 2016; 44 (10): 2546-2556