General

A Review of Current Concepts of the Anterolateral Complex of the Knee

Vasileios Athanasiou[1] [a], Andreas Panagopoulos[1], Antonios Kouzelis[1], Zinon T. Kokkalis[1], John Lakoumentas[2], Konstantinos Katsanos[3], John Gliatis[1]

[1] Orthopaedic Department, Patras University Hospital, Greece, [2] Medical Physics Department, Medical School, University of Patras, Patras, Greece, [3] Department of Interventional Radiology, Patras University Hospital, Greece

Keywords: "Anterolateral complex of the knee", "Anterolateral ligament", "Anterior cruciate ligament", "Lateral extra-articular tenodesis", "Anterolateral ligament reconstruction"

https://doi.org/10.52965/001c.38651

Orthopedic Reviews

Vol. 14, Issue 4, 2022

The anterolateral complex (ALC) of the knee has gained increased interest over the last decades due to the high revision rates of anterior cruciate ligament reconstruction (ACLR). Furthermore, in patients with an ACL tear, the injury of at least one of the ALC's anatomic structures has been shown to be significantly higher, thus affecting its secondary stabilizing role at the knee joint. As such, ACLR augmentation techniques, that embrace the ALC, have been proposed recently, and indications for these procedures are still evolving. This review aims to present and discuss the most current anatomical, biomechanical, and imaging data, current reconstruction techniques, and the clinical results of ALC reconstruction.

INTRODUCTION

The anterolateral complex (ALC) of the knee has recently regained interest mainly due to the high revision rates in ACLR surgery, despite the recent concepts of anatomical and individualized ACL reconstruction and the vast improvements of fixation methods.[1–4] New evidence shows that ACLR revision rates remain unacceptably high, up to 18%, especially in the younger population.[5] These failures have a variety of factors, but one of the most concerning is the persisting anterolateral rotatory instability, which may not be fully restored with the current ACLR procedures. It is imperative to search for concomitant pathology in high-grade rotatory knee laxity and revision cases. The pivot shift test following ACLR plays an important role and correlates with functional outcomes. A successful anatomic ACLR is essential before considering an anterolateral extra-articular augmentation procedure.

Research studies have shown that the anterolateral ligament (ALL), a distinct anatomical structure, may play a key role in controlling internal tibial rotation.[4,5] Andrade et al., in a recent Systematic Review of MRI studies, comprising of 2,427 knees in 2,388 patients, found that the ALL appeared injured in 11% to 79% of the ACL tears.[6] Dhong Won Lee et al., recently reported that ~70% of acute ALL injuries showed poor healing at 1-year follow-up.[7] Other studies have shown that the remaining anterolateral rotatory instability after ACLR, is a factor that is associated with poor functional outcomes.[8,9] Anterolateral ligament reconstruction and the modified Lemaire technique are two popular procedures for restoring the anterolateral complex (ALC). The indication of Extra-Articular Augmentation (Lateral Extra-Articular Tenodesis [LET] or Anterolateral Ligament [ALL] Reconstruction lately) is well understood, although ALLR has not been thoroughly studied.[4,5] Biomechanical studies have reached varied conclusions; however, there is an increase of research that suggests both procedures enhance stability in the surgical treatment of anterolateral instability, whereas ACLR alone is not sufficient in the setting of complex anterolateral injury.[10–14]

This review aims to present and discuss the most current anatomical, biomechanical, and imaging data, current reconstruction techniques, and the clinical results of ALC reconstruction.

ANATOMY AND BIOMECHANICS

It has been challenging to distinguish and characterize the anatomical structures of the anterolateral side of the knee joint. Initially, it has been divided into parts and layers.

a **Corresponding author:**
Vasileios Athanasiou MD, Ph.D
Orthopaedic Department, Patras University Hospital, Greece
Tel: +302613603883, Mob:+306936774403
Email: vassathanasiou@yahoo.com

Hughston et al., in 1976 divided the lateral compartment of the knee into three parts: anterior, medium, and posterior.[15] Seebacher et al., in 1982 divided the lateral structures of the knee into three layers and described the deepest layer (Layer 3), as splitting into a deep lamina (true knee capsule) and a superficial lamina (ALL), that inserts anterior to the lateral collateral ligament (LCL), and enveloping it.[16] Recently, in 2017, it has been proposed that the components of the anterolateral complex (ALC) of the knee joint include (a) the iliotibial band (ITB), (b) the anterolateral ligament (ALL) as a separate ligamentous structure, (c) the anterolateral joint capsule, and (d) the lateral meniscus.[17,18]

Since 1879, when the French surgeon described the eponymous Segond fracture, numerous anatomic and biomechanical studies with regard to the ALC have been published.[4,12,13,19] However, there has been much controversy over the existence or not of the ALL,[20–24] the nomenclature,[5,14,25–27] the anatomical position,[4,14] the stabilizing role[4,14,28] and the associated injury with ACL tear.[4,14] This anatomical structure has been referred to by a different names. It was not named "anterolateral ligament " until Steven Claes et al. published their study in 2013.[14] This term was used by Terry et al., who were the first described the iliotibial tract as the “true anterolateral ligament of the knee”.[14,25,29] Hence, in order to clarify the existing confusion, the International ALC Consensus Group Meeting reached a consensus in 2017; the anatomic structures of the anterolateral complex of the knee are: the superficial iliotibial (IT) and the iliopatellar band, the deep IT band incorporating the Kaplan fiber system (supracondylar attachment, proximal and distal) and retrograde (condylar) attachment continuous with the capsulo-osseous layer of the IT band, the ALL and the capsule [Figure 1]. The ALL is considered a capsular structure within Seebacher’s Layer 3 of the anterolateral capsule of the knee. The deep lamina is the true knee capsule and the superficial lamina is the ALL, which has variable gross morphology between individuals with regard to size and thickness, is predominantly attached posterior and proximal to the lateral femoral epicondyle and LCL’s origin, runs superficial to the LCL, attaches to the tibia midway between the anterior border of the fibular head and the posterior border of Gerdy’s Tubercle, and there is an attachment of the ALL to the lateral meniscus.[15,17]

However, research on ALL is still continuing, and there are still some controversies regarding its existence, in what form and its anatomic point of insertion, especially proximally.[17,18]

Anatomical studies of the ALL have reported a total length of 30.4-59.0 mm, thicknes of 1.0-2.5 mm and variable widths of 4.0-11.0 mm at the origin, 4.0-8.0 mm at the midpoint, and 11.0-12.0 mm at the insertion.[3,30–33]

The role of the ALC of the knee in patients suffering from ACL tears is still controversial although many reports suggest that contributes significantly in the rotational stability of the knee.[1,5,22] Nevertheless, many studies reported their results without the participation of ITB, which plays a significant role during the pivot-shift testing.[34] In a cadaveric study, Junjie Xu et al. reported that the ALC of the knee, played a minor role in controlling anterior translation or pivot shift stability in ACL tear but with the ITB in tension it showed a significant role in restraining internal rotation from 45º to 90º.[34] Ahn et al., in a cadaveric biomechanical study investigated ALL behavior during knee flexion-extension, internal-external rotation, anteroposterior translation, and varus-valgus angulation.[35] Littlefield et al., in a systematic review of the literature, reported that the ALL plays a secondary stabilizing role to the ACL and helps resisting internal knee rotation and anterior tibial translation.[3]

Biomechanical studies have reached varied conclusions, suggesting that more research is necessary to reach a conclusion on the biomechanics of ALC of the knee.[1,36,37]

IMAGING

Imaging includes radiographs, magnetic resonance imaging (MRI), and ultrasound (US). Standard knee radiographs including anteroposterior, lateral, Merchant or posteroanterior weight-bearing (Rosenberg view), are usually recommended.[5] Saita et al. found that a small lateral femoral condyle and genus recurvartum are associated with greater rotatory instability and should be considered as predictors of a poor outcome from an ACL reconstruction.[38]

The presence of a Segond fracture is strongly associated with an ALL injury. This fracture presents on conventional radiographs as an elliptic bone fragment (about 10 x 3 mm in size), commonly 3–6 mm lateral tibial plateau, known as the “lateral capsular sign”.[39]

MRI [Figure 2 (From the authors’ archive)] is the gold standard for assessing the ALC injury.[3,40,41] On the coronal and axial images, the ALL is better evaluated.[5] In their study, Liebensteiner et al. assessed the ALL and the deep structures of the ITT in healthy knees, and they found that the anterolateral structures of the knee can be determined using MRI.[42] Puzzitiello et al., in a systematic review, found that concomitant ALL injuries, in patients with an ACL tear, can be identified on MRI or US with high levels of inter- and intraobserver reliability, and are often associated with a high-grade pivot-shift examination, lateral collateral ligament injury, and lateral femoral condyle and tibial plateau bone bruises.[40] However, in patients with chronic ACL injury, determining the extent of ALL injury can be difficult.[35]

Ultrasound (US) is a valuable imaging tool for ALC injury assessment. However, the number of studies utilizing it is limited and may be more difficult to compare with MRI.[3]

CLASSIFICATION AND TREATMENT

The grade and the location (tibial or femoral side) of ALL tearing are variable and can impact the decision for surgical intervention.[43] Ji Hyun Ahn et al. classified the ALL injury based on MRI findings into four grades (intact ALL, partial tear, nearly complete tear, and complete tear). The intact and partial tears are low-grade injuries and the nearly complete and complete tear are high-grade injuries.[44] Ferretti

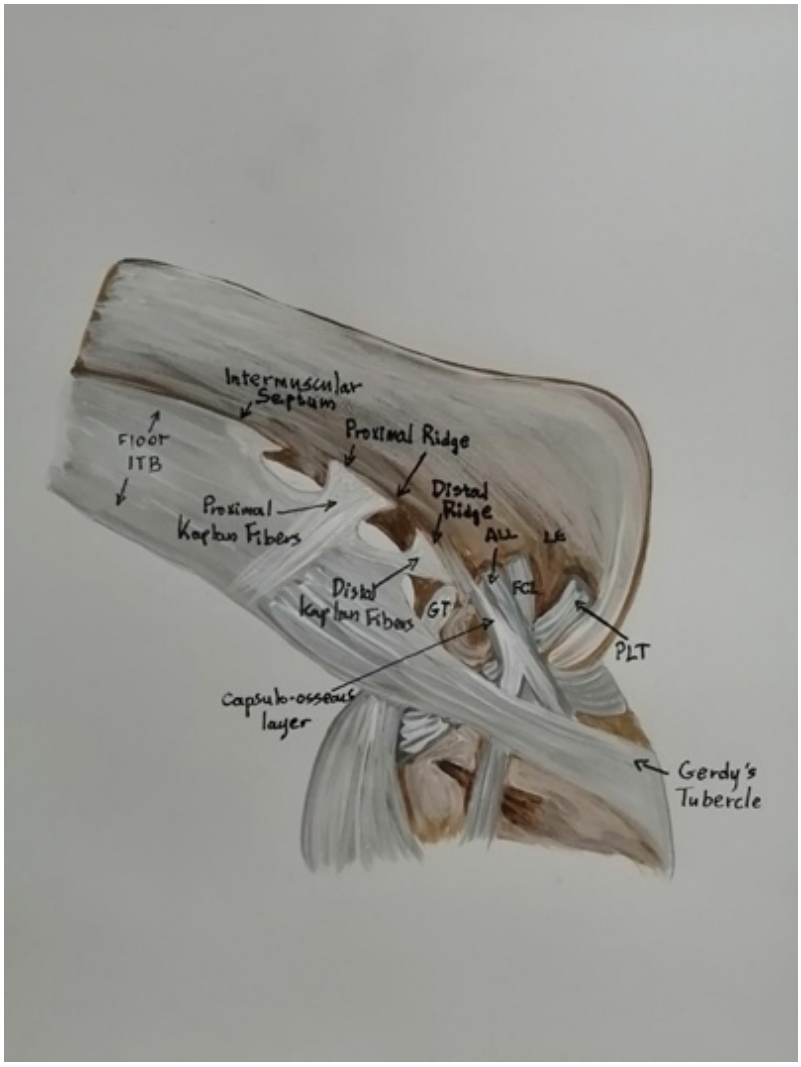

Figure 1. Anterolateral complex of the knee.

ALL = anterolateral ligament; FCL = fibular collateral ligament; GT = lateral gastrocnemius tendon; ITB = iliotibial band; LE = lateral epicondyle; PLT = popliteus tendon

et al. classified ALC injuries in the setting of ACL tears in 4 types [Table 1].[6]

The combination of ALL and ACL injury has been reported to range from 32% up to 88%.[45] Balendra et al. recently reported the presence of an ALC injury in 63% of the patients with ACL tears (39% isolated Kaplan fibre (KF) injuries; 2% isolated ALL injuries and 22% combination of both.[45] Dhong Won Lee found that the ALL injury was associated highly with lateral meniscus tears, especially affecting the posterior horn.[46] Ji Hyun Ahn et al. found higher incidence in medial meniscus, especially in the posterior horn.[44] During clinical assessment, ALC injury is associated with an increased pivot shift, especially in combination with an ACL tear.[44,47,48]

There is no consensus regarding the best treatment strategy for ALC injury, although there has been significant consensus recently.[47] Surgical options include two basic techniques: (a) anterolateral extra-articular tenodesis (AEAPs), with the modified Lemaire being the most preferred technique, and (b) anterolateral complex reconstruction (ALLR).[47,49] ALLR is not advised as a routine treatment during ACL reconstruction.[50,51] Most surgeons' indications include young and active patients with rotatory laxity on clinical examination, grade 2–3 pivot-shif testing, generalized ligamentous laxity/genu recurvartum, and imaging findings of acute ALC injury as well as patients who require revision of ACL after a previously well-performed reconstruction when no other reason for failure was identified.[44,47]

LATERAL EXTRA-ARTICULAR TENODESIS (LET)

Lemaire since 1967, developed a surgical technique using a strip of ITB, 12 mm wide and 70 to 80 mm long, fixing it posteriorly to the LCL on the femur within a tunnel and distally to the Gerdy tubercle.[32] Since then, different modified surgical techniques have been proposed [Figure 3 (From the authors' archive)], such as those by Dejour et al., Lutz et al., Pavão et al., Jesani et al., and recently Muller et al., and Henri et al.[40,52] Other authors have proposed a hamstring graft with Henri et al. having recently published a new surgical technique.[52]

However, the nonanatomic nature of the LET procedure and the potential over-constraining of the joint can lead to

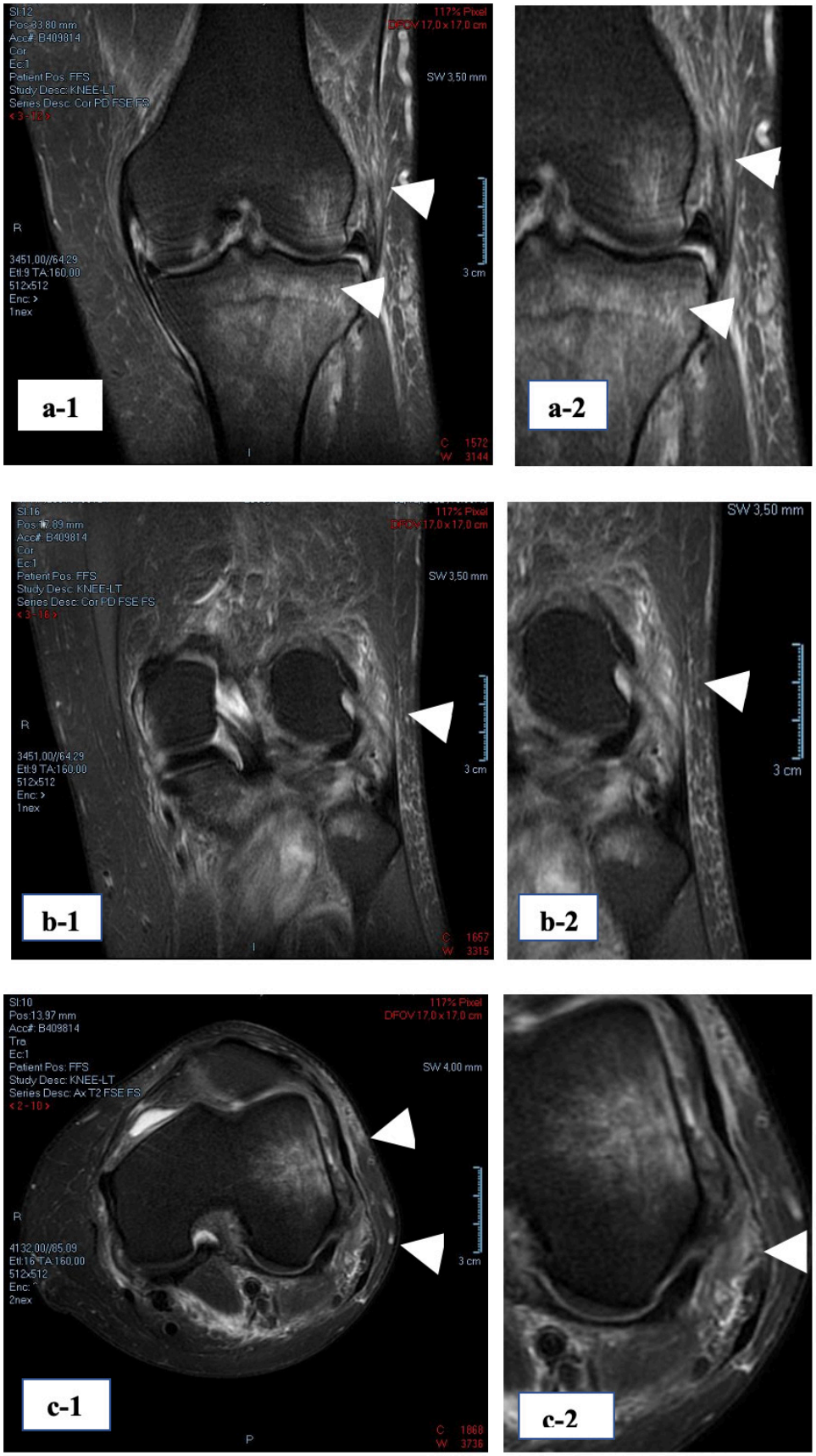

Figure 2. Shows a combination of ALC injury with bone edema.

The row in a-1,2, b-1,2, c-1,2 indicates an ALL tear (From the authors' archive).

Table 1. Ferretti et al. classified ALC injuries[6]

Type I	Multilevel rupture with individual layers torn at different levels with macroscopic hemorrhage involving the area of the anterolateral ligament (ALL) and extended to the anterolateral capsule.
Type II	Multilevel rupture with individual layers torn at different levels with macroscopic hemorrhage extended from the area of the ALL and capsule to the posterolateral capsule.
Type III	Complete transverse tear involving the area of the ALL near its insertion to the lateral tibial plateau, distal to the lateral meniscus.
Type IV	Bony avulsion (Segond fracture).

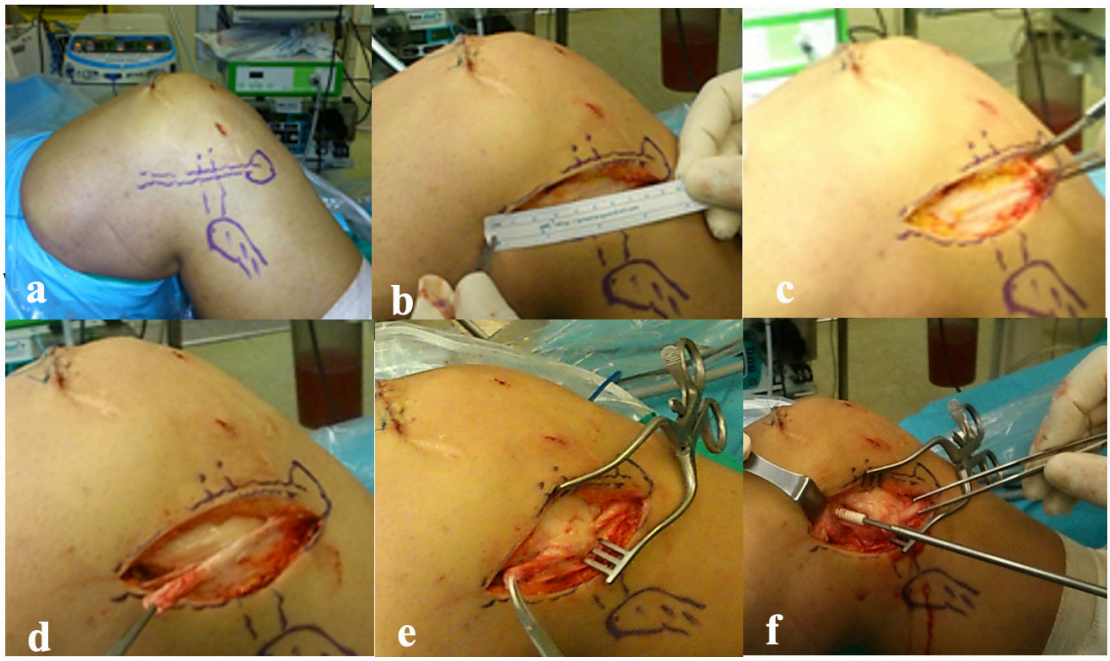

Figure 3. Modified Lemaire procedure.

A, B, Landmarks of surgical approach, lateral epicondyle, gerdy's tubercle and fibular head; C, D, Surgical approach and harvesting 1cm width of the fascia lata; E, D, Fascia lata strip preparation and fixation (Linndsay et al, Arthroscopy TechniquesVolume 9, Issue 1, January 2020, Pages e111-e116).

graft over tensioning and degenerative changes in the lateral knee compartment.[53] Ferretti et al. and Zaffagnini et al published a long-term study that combined extra- and intra-articular reconstructions, reporting no increased rate of degenerative changes in the lateral compartment.[54,55]

ANTEROLATERAL LIGAMENT RECONSTRUCTION (ALLR)

Recently, the renewed interest in the ALC of the knee has led to notable progress in appreciation of anatomy and biomechanics, resulting in the development of new surgical procedures such as the anterolateral ligament reconstruction (ALLR) [Figure 4 (From the authors' archive)].[3,56–59]

There is a consensus regarding the ideal positioning of the ALL proximally to the femur and distally to the tibia.[12,52] However, there is some disagreement in the literature regarding the precise anatomy of the ALL (in particular, the femoral insertion) and the optimal procedure for reconstruction.[56] Some published studies have used an inconsistent surgical technique but the current consensus is in favor of the anatomic ALLR.[60–63] This is important to avoid the potential malpositioning or fixation of the graft in an incorrect knee position, which could impact the functional results, render the graft ineffective, or overconstrain the knee.[64,65] Based on a cadaveric study, Ahn et al. suggest that during the ALL graft fixation, the knee should be close to full extension.[30] The combination of ACLR and ALLR has shown remarkable improvement in clinical results compared with isolated ACLR.[66–70]

Studies have shown that the most common femoral fixation sites were posterior and proximal to the lateral femoral epicondyle, and for the tibial fixation, the most common sites were between Gerdy's tubercle and the fibular head.[3,70] Regarding the graft's tension, Kunze et al., in a recent Systematic Review and Meta-Analysis of Randomized Controlled Trials, found that in 9 of 14 studies, the graft was tensioned at 30º.[70] The most common grafts used were the gracilis and semitendinosus, and the least used grafts

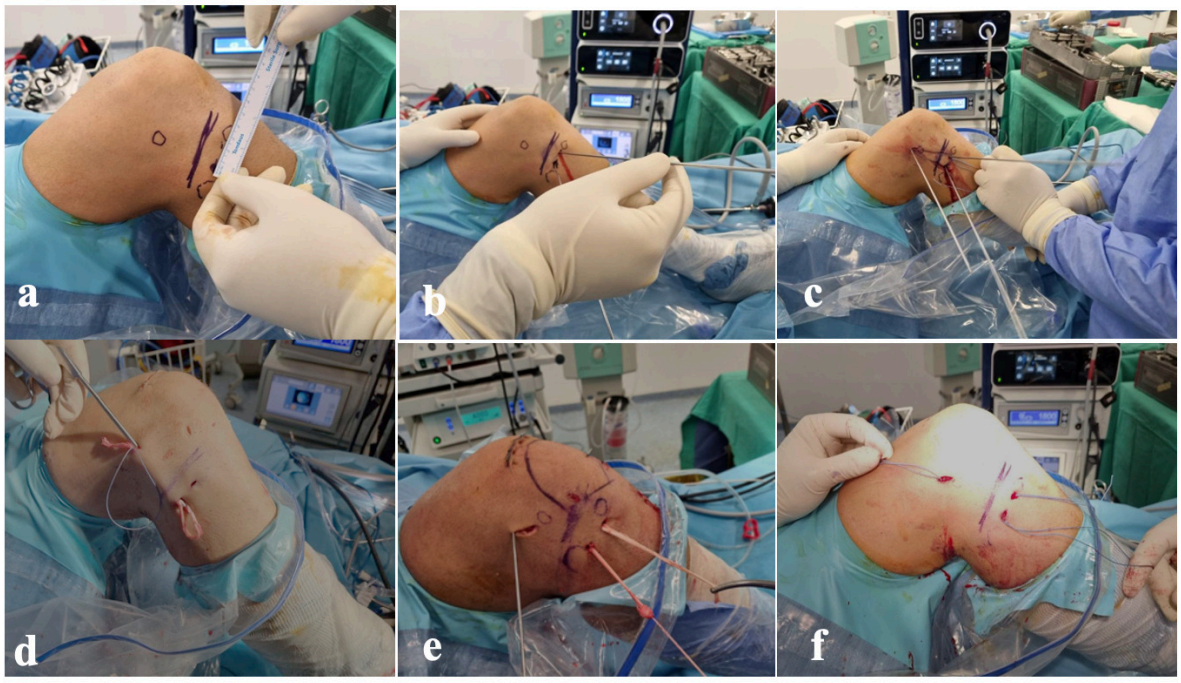

Figure 4. Combined ACL/ALL reconstruction.

Anterolateral ligament reconstruction using gracilis graft. A, B, C, Tunnel preparation, check isometry; D, E, F, Gracillis graft passing under the fascia and fixation (Combined ACL and Anterolateral Ligament Reconstruction. B. Saithna A, et al. JBJS Essent Surg Tech. 2018 Jan 10;8(1):e2.)

were the quadriceps, Achilles tendon, plantaris, and polyester tape construct.[3,70]

OUTCOME

Recent studies have shown that both surgical techniques, ACLR/ALLR and ACLR/LET, are effective procedures to restore ALC stability. In a recent systematic review and meta-analysis, Beckers et al. found a significant reduction in graft ruptures in patients treated with ACLR and lateral augmentation (3%) compared to isolated ACLR (12%) and rotational laxity significantly higher in isolated ACLR (14% vs. ACLR + LA (6%).[71] In another recent systematic review, Littlefield et al. reported lower ACL graft failure rates for combined ACLR/ALLR (0.0% - 15.7%) when compared to isolated ACLR patients (7.4% - 21.7%), whereas Kunze et al. reported a failure rate of 2.7%-11.1%, and significant improvement in the IKDC, Lysholm, and Tegner outcome scores postoperatively.[3,70] Recent systematic reviews showed that ACLR + ALLR improved patient-reported outcomes at short-term follow-up compared to those who underwent isolated ACLR.[3,70] Lee et al., in a comparative study of revision ACLR in combination with ALLR and isolated revision ACLR, found that revision ACLR in combination with ALLR significantly reduced rotational laxity and showed a higher rate of return to the same level of sports activity than revision ACLR alone.[72] In a comparative study, Helito et al. found that combined ACL and ALL reconstruction had better rotational stability as evaluated by the pivot-shift test and a lower reconstruction failure rate compared with isolated ACL reconstruction (3.3% vs 21.7%).[73] Also, Laboudie et al. found that combined ALL + ACL reconstruction reduced the rate of graft failure and secondary meniscal injury in young athletes when compared to ACL reconstruction alone.[74]

Recent meta-analysis shows that there is high-level evidence that the LET procedure in addition to ACLR is preferable in terms of functional outcome and graft failure.[75] Getgood et al., in a multicenter, prospective, randomized clinical trial comparing a single-bundle, hamstring tendon ACLR with or without LET performed using a strip of iliotibial band, found that the addition of LET to a single-bundle hamstring tendon autograft ACLR in young patients at high risk of failure results in a statistically significant, clinically relevant reduction in graft rupture and persistent rotatory laxity at 2 years after surgery.[76] Castoldi et al. in a 19-Year Clinical and Radiological Follow-Up comparative study between ACLR with and without LET found graft failure (29% vs. 13%) and lateral compartment osteoarthritis (59% vs. 22%), correlated with partial meniscectomy.[77]

Madhan et al in a recent study children and adolescent patients found that 56% of pediatric sports surgeons sometimes perform anterolateral augmentation with primary ACLR and 79% with revision ACLR.[78]

Another systematic review with the meta-analysis by Na et al.; found that anterolateral ligament reconstruction (ALLR) appeared to be a better option for improving rotational stability compared than extra-articular tenodesis (LET).[79]

However, more prospective comparative studies are needed to assess if there is a significant difference between two surgical techniques with a view to clinical outcomes.[3]

CONCLUSION

Despite some remaining controversies, recent literature shows that there is a consensus regarding the ALL as a ligament and its anatomic location. A combination of anterior cruciate ligament reconstruction (ACLR) and anterolateral ligament reconstruction (ALLR), when ALC injury is associated with an increasing pivot shift, has shown encouraging results in regaining knee function. Further biomechanical studies and long-term clinical studies are necessary.

ACKNOWLEDGEMENT

None

AUTHOR CONTRIBUTIONS

V.A.: Study Design, Literature review, Writing manuscript, Editing manuscript

A.P.: Literature review, Writing manuscript, Editing manuscript, Final manuscript approval

A.K.: Literature review, Writing manuscript, Editing manuscript

Z.K.: Literature review, Editing manuscript, Final manuscript approval

J.L.: Data collection, Editing manuscript, Final manuscript approval

K.K.: Writing manuscript, Editing manuscript, Final manuscript approval

J.G.: Literature review, Writing manuscript, Editing manuscript, Final manuscript approval

DISCLOSURES

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ADDITIONAL INFORMATION

None

REFERENCES

1. Kim SH. Editorial Commentary: Knee Anterolateral Ligament Cadaveric, Biomechanical Analysis Should Include Tensioning of All Knee Dynamic Structures. *Arthroscopy*. 2021;37(4):1192-1193. doi:10.1016/j.arthro.2020.12.229

2. Santoso A, Anwar IB, Sibarani T, et al. Research on the Anterolateral Ligament of the Knee: An Evaluation of PubMed Articles From 2010 to 2019. *Orthop J Sports Med*. 2020;8(12):232596712097364. doi:10.1177/2325967120973645

3. Littlefield CP, Belk JW, Houck DA, et al. The Anterolateral Ligament of the Knee: An Updated Systematic Review of Anatomy, Biomechanics, and Clinical Outcomes. *Arthroscopy*. 2021;37(5):1654-1666. doi:10.1016/j.arthro.2020.12.190

4. Musahl V, Rahnemai-Azar AA, van Eck CF, Guenther D, Fu FH. Anterolateral ligament of the knee, fact or fiction? *Knee Surg Sports Traumatol Arthrosc*. 2016;24(1):2-3. doi:10.1007/s00167-015-3913-0

5. Lau BC, Rames J, Belay E, Riboh JC, Amendola A, Lassiter T. Anterolateral Complex Reconstruction Augmentation of Anterior Cruciate Ligament Reconstruction: Biomechanics, Indications, Techniques, and Clinical Outcomes. *JBJS Rev*. 2019;7(11):e5. doi:10.2106/jbjs.rvw.19.00011

6. Ferretti A, Monaco E, Fabbri M, Maestri B, De Carli A. Prevalence and Classification of Injuries of Anterolateral Complex in Acute Anterior Cruciate Ligament Tears. *Arthroscopy*. 2017;33(1):147-154. doi:10.1016/j.arthro.2016.05.010

7. Lee DW, Kim JG, Kim HT, Cho SI. Evaluation of Anterolateral Ligament Healing After Anatomic Anterior Cruciate Ligament Reconstruction. *Am J Sports Med*. 2020;48(5):1078-1087. doi:10.1177/0363546520908805

8. Porter M, Shadbolt B. Modified Iliotibial Band Tenodesis Is Indicated to Correct Intraoperative Residual Pivot Shift After Anterior Cruciate Ligament Reconstruction Using an Autologous Hamstring Tendon Graft: A Prospective Randomized Controlled Trial. *Am J Sports Med*. 2020;48(5):1069-1077. doi:10.1177/0363546520910148

9. Sobrado MF, Giglio PN, Bonadio MB, et al. Outcomes After Isolated Acute Anterior Cruciate Ligament Reconstruction Are Inferior in Patients With an Associated Anterolateral Ligament Injury. *Am J Sports Med*. 2020;48(13):3177-3182. doi:10.1177/0363546520956266

10. Delaloye JR, Hartog C, Blatter S, et al. Anterolateral Ligament Reconstruction and Modified Lemaire Lateral Extra-Articular Tenodesis Improve Knee Stability After Anterior Cruciate Ligament Reconstruction: A Biomechanical Study. *Arthroscopy*. 2020;36(7):1942-1950. doi:10.1016/j.arthro.2020.03.027

11. Shybut TB. Editorial Commentary: Anterior Cruciate Ligament Reconstruction Alone Is Not Sufficient in Anterolateral Complex Injury: Extra-Articular Augmentation (Lateral Extra-Articular Tenodesis [LET] or Anterolateral Ligament [ALL] Reconstruction) Allows Surgeons to Indicate Tight (LET) or Just Right (ALL) on a Case-by-Case Basis. *Arthroscopy*. 2022;38(3):925-927. doi:10.1016/j.arthro.2021.08.016

12. Thaunat M, Ingale PS, de Guise J, Dumas R, Blache Y. The effect of anterolateral ligament reconstruction on knee constraint: A computer model-based simulation study. *Knee*. 2020;27(4):1228-1237. doi:10.1016/j.knee.2020.05.006

13. Nitri M, Rasmussen MT, Williams BT, et al. 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. doi:10.1177/0363546515620183

14. Rhatomy S, Ariyanto MW, Fiolin J, Dilogo IH. Comparison of clinical outcomes between isolated ACL reconstruction and combined ACL with anterolateral ligament reconstruction: a systematic review and meta-analysis. *Eur J Orthop Surg Traumatol*. Published online January 19, 2022. doi:10.1007/s00590-021-03194-8

15. Hughston JC, Andrews JR, Cross MJ, Moschi A. Classification of knee ligament instabilities. Part II. The lateral compartment. *J Bone Joint Surg Am*. 1976;58(2):173-179. doi:10.2106/00004623-197658020-00002

16. Seebacher JR, Inglis AE, Marshall JL, Warren RF. The structure of the posterolateral aspect of the knee. *J Bone Joint Surg Am*. 1982;64(4):536-541. doi:10.2106/00004623-198264040-00008

17. Getgood A, Brown C, Lording T, et al. The anterolateral complex of the knee: results from the International ALC Consensus Group Meeting. *Knee Surg Sports Traumatol Arthrosc*. 2018;27(1):166-176. doi:10.1007/s00167-018-5072-6

18. Brockmeyer M, Orth P, Höfer D, et al. The anatomy of the anterolateral structures of the knee — A histologic and macroscopic approach. *Knee*. 2019;26(3):636-646. doi:10.1016/j.knee.2019.02.017

19. 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. doi:10.1111/joa.12087

20. Cavaignac E, Ancelin D, Chiron P, et al. Historical perspective on the "discovery" of the anterolateral ligament of the knee. *Knee Surg Sports Traumatol Arthrosc*. 2016;25(4):991-996. doi:10.1007/s00167-016-4349-x

21. Guenther D, Rahnemai-Azar AA, Bell KM, et al. The Anterolateral Capsule of the Knee Behaves Like a Sheet of Fibrous Tissue. *Am J Sports Med*. 2016;45(4):849-855. doi:10.1177/0363546516674477

22. Nasu H, Nimura A, Yamaguchi K, Akita K. Morphology of the anterolateral ligament: a complex of fibrous tissues spread to the anterolateral aspect of the knee joint. *Anat Sci Int*. 2020;95(4):470-477. doi:10.1007/s12565-020-00543-1

23. 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. doi:10.1016/j.aanat.2019.06.005

24. Ariel de Lima D, Helito CP, Lacerda de Lima L, de Castro Silva D, Costa Cavalcante ML, Dias Leite JA. Anatomy of the Anterolateral Ligament of the Knee: A Systematic Review. *Arthroscopy*. 2019;35(2):670-681. doi:10.1016/j.arthro.2018.09.006

25. Terry GC, Hughston JC, Norwood LA. The anatomy of the iliopatellar band and iliotibial tract. *Am J Sports Med*. 1986;14(1):39-45. doi:10.1177/036354658601400108

26. Cruells Vieira EL, Vieira EÁ, da Silva RT, dos Santos Berlfein PA, Abdalla RJ, Cohen M. An Anatomic Study of the Iliotibial Tract. *Arthroscopy*. 2007;23(3):269-274. doi:10.1016/j.arthro.2006.11.019

27. Landreau P, Catteeuw A, Hamie F, Saithna A, Sonnery-Cottet B, Smigielski R. Anatomic Study and Reanalysis of the Nomenclature of the Anterolateral Complex of the Knee Focusing on the Distal Iliotibial Band: Identification and Description of the Condylar Strap. *Orthop J Sports Me*. 2019;7(1):232596711881806. doi:10.1177/2325967118818064

28. Thein R, Boorman-Padgett J, Stone K, Wickiewicz TL, Imhauser CW, Pearle AD. Biomechanical Assessment of the Anterolateral Ligament of the Knee. A Secondary Restraint in Simulated Tests of the Pivot Shift and of Anterior Stability. *J Bone Joint Surg Am*. 2016;98(11):937-943. doi:10.2106/jbjs.15.00344

29. Cruells Vieira EL, Vieira EÁ, da Silva RT, dos Santos Berlfein PA, Abdalla RJ, Cohen M. An Anatomic Study of the Iliotibial Tract. *Arthroscopy*. 2007;23(3):269-274. doi:10.1016/j.arthro.2006.11.019

30. Patel RM, Brophy RH. Anterolateral Ligament of the Knee: Anatomy, Function, Imaging, and Treatment. *Am J Sports Med*. 2017;46(1):217-223. doi:10.1177/0363546517695802

31. De Carli A, Monaco E, Mazza D, et al. Assessment of the Anterolateral Ligament of the Knee by Magnetic Resonance Imaging. *Joints*. 2018;6(3):153-156. doi:10.1055/s-0038-1675163

32. Ariel de Lima D, Helito CP, Lacerda de Lima L, de Castro Silva D, Costa Cavalcante ML, Dias Leite JA. Anatomy of the Anterolateral Ligament of the Knee: A Systematic Review. *Arthroscopy*. 2019;35(2):670-681. doi:10.1016/j.arthro.2018.09.006

33. Park YB, Lee HJ, Ro DH, Lee GY, Kim S, Kim SH. Anterolateral ligament injury has a synergic impact on the anterolateral rotatory laxity in acute anterior cruciate ligament-injured knees. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(10):3334-3344. doi:10.1007/s00167-019-05347-z

34. Xu J, Han K, Su W, et al. A Secondary Injury of the Anterolateral Structure Plays a Minor Role in Anterior and Anterolateral Instability of Anterior Cruciate Ligament-Deficient Knees in the Case of Functional Iliotibial Band. *Arthroscopy*. 2021;37(4):1182-1191. doi:10.1016/j.arthro.2020.10.038

35. Ahn JH, Koh IJ, McGarry MH, Patel NA, Lin CC, Lee TQ. Elongation Patterns of the Anterior and Posterior Borders of the Anterolateral Ligament of the Knee. *Arthroscopy*. 2019;35(7):2152-2159. doi:10.1016/j.arthro.2019.02.042

36. Cavaignac E, Ancelin D, Chiron P, et al. Historical perspective on the "discovery" of the anterolateral ligament of the knee. *Knee Surg Sports Traumatol Arthrosc*. 2016;25(4):991-996. doi:10.1007/s00167-016-4349-x

37. Lubowitz JH, Provencher MT, Brand JC, Rossi MJ. The Knee Anterolateral Ligament. *Arthroscopy*. 2014;30(11):1385-1388. doi:10.1016/j.arthro.2014.08.007

38. Saita Y, Schoenhuber H, Thiébat G, et al. Knee hyperextension and a small lateral condyle are associated with greater quantified antero-lateral rotatory instability in the patients with a complete anterior cruciate ligament (ACL) rupture. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(3):868-874. doi:10.1007/s00167-018-5143-8

39. Venkatasamy A, Ehlinger M, Bierry G. Acute traumatic knee radiographs: beware of lesions of little expression but of great significance. *Diagn Interv Imaging*. 2014;95(6):551-560. doi:10.1016/j.diii.2013.09.012

40. Puzzitiello RN, Agarwalla A, Zuke WA, Garcia GH, Forsythe B. Imaging Diagnosis of Injury to the Anterolateral Ligament in Patients With Anterior Cruciate Ligaments: Association of Anterolateral Ligament Injury With Other Types of Knee Pathology and Grade of Pivot-Shift Examination: A Systematic Review. *Arthroscopy*. 2018;34(9):2728-2738. doi:10.1016/j.arthro.2018.04.025

41. Monaco E, Helito CP, Redler A, et al. Correlation Between Magnetic Resonance Imaging and Surgical Exploration of the Anterolateral Structures of the Acute Anterior Cruciate Ligament–Injured Knee. *Am J Sports Med*. 2019;47(5):1186-1193. doi:10.1177/0363546519831686

42. Liebensteiner M, Runer A, Kranewitter C, et al. MRI visibility of the anterolateral ligament and the deep structures of the iliotibial tract. *J Exp Ortop*. 2020;7(1):25. doi:10.1186/s40634-020-00244-8

43. Barber FA. Editorial Commentary: Lateral Extra-Articular Tenodesis Results in Better Stability After Anterior Cruciate Ligament Reconstruction for Patients With High-Grade Pivot Shifts. *Arthroscopy*. 2021;37(3):985-988. doi:10.1016/j.arthro.2020.12.180

44. Ahn JH, Lee SK, Mun JW, Kim SW. Degree of anterolateral ligament injury impacts outcomes after double-bundle anterior cruciate ligament reconstruction. *Arthroscopy*. 2021;37(1):222-230. doi:10.1016/j.arthro.2020.09.003

45. Balendra G, Willinger L, Pai V, et al. Anterolateral complex injuries occur in the majority of 'isolated' anterior cruciate ligament ruptures. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(1):176-183. doi:10.1007/s00167-021-06543-6

46. Lee DW, Lee JH, Kim JN, et al. Evaluation of Anterolateral Ligament Injuries and Concomitant Lesions on Magnetic Resonance Imaging After Acute Anterior Cruciate Ligament Rupture. *Arthroscopy*. 2018;34(8):2398-2406. doi:10.1016/j.arthro.2018.02.048

47. Musahl V, Herbst E, Burnham JM, Fu FH. The Anterolateral Complex and Anterolateral Ligament of the Knee. *J Am Acad Orthop Surg*. 2018;26(8):261-267. doi:10.5435/jaaos-d-16-00758

48. Puzzitiello RN, Agarwalla A, Zuke WA, Garcia GH, Forsythe B. Imaging Diagnosis of Injury to the Anterolateral Ligament in Patients With Anterior Cruciate Ligaments: Association of Anterolateral Ligament Injury With Other Types of Knee Pathology and Grade of Pivot-Shift Examination: A Systematic Review. *Arthroscopy*. 2018;34(9):2728-2738. doi:10.1016/j.arthro.2018.04.025

49. Muller B, Willinge GJA, Zijl JAC. Minimally Invasive Modified Lemaire Tenodesis. *Arthrosc Tech*. 2020;10(1):e29-e36. doi:10.1016/j.eats.2020.09.006

50. Gürpınar T, Polat B, Polat AE, Mutlu İN, Tüzüner T. Is anterolateral ligament rupture a reason for persistent rotational instability after anterior cruciate ligament reconstruction? *Knee*. 2018;25(6):1033-1039. doi:10.1016/j.knee.2018.08.010

51. Yoo JS, Kim SH, Park HG, Yoon SH, Park SG. Influence of anterolateral ligament injuries on stability and second-look arthroscopic findings after allograft transtibial anterior cruciate ligament reconstruction. *Knee*. 2019;26(1):132-141. doi:10.1016/j.knee.2018.10.003

52. Robert H, Vincent JP. Combined Anterior and Anterolateral Stabilization of the Knee With the Hamstring Tendons. *Arthrosc Tech*. 2021;10(2):e275-e282. doi:10.1016/j.eats.2020.10.003

53. Na BR, Kwak WK, Seo HY, Seon JK. Clinical Outcomes of Anterolateral Ligament Reconstruction or Lateral Extra-articular Tenodesis Combined With Primary ACL Reconstruction: A Systematic Review With Meta-analysis. *Orthop J Sports Med*. 2021;9(9):232596712110230. doi:10.1177/23259671211023099

54. Ferretti A, Monaco E, Ponzo A, et al. Combined Intra-articular and Extra-articular Reconstruction in Anterior Cruciate Ligament–Deficient Knee: 25 Years Later. *Arthroscopy*. 2016;32(10):2039-2047. doi:10.1016/j.arthro.2016.02.006

55. Zaffagnini S, Marcheggiani Muccioli GM, Grassi A, et al. Over-the-top ACL Reconstruction Plus Extra-articular Lateral Tenodesis With Hamstring Tendon Grafts: Prospective Evaluation With 20-Year Minimum Follow-up. *Am J Sports Med*. 2017;45(14):3233-3242. doi:10.1177/0363546517723013

56. Saithna A, Helito CP, Carrozzo A, Kim JG, Sonnery-Cottet B. Regarding "The Effect of Combined Anterolateral and Anterior Cruciate Ligament Reconstruction on Reducing Pivot Shift Rate and Clinical Outcomes: A Meta-analysis." *Arthroscopy*. 2021;37(3):787-789. doi:10.1016/j.arthro.2020.12.200

57. Sonnery-Cottet B, Saithna A, Cavalier M, et al. Anterolateral Ligament Reconstruction Is Associated With Significantly Reduced ACL Graft Rupture Rates at a Minimum Follow-up of 2 Years: A Prospective Comparative Study of 502 Patients From the SANTI Study Group. *Am J Sports Med*. 2017;45(7):1547-1557. doi:10.1177/0363546516686057

58. de Lima DA, Helito CP, de Lima FRA, Leite JAD. Surgical indications for anterior cruciate ligament reconstruction combined with extra-articular lateral tenodesis or anterolateral ligament reconstruction. *Rev Bras Ortop*. 2018;53(6):661-667. doi:10.1016/j.rboe.2018.09.007

59. Fayard JM, Penet A, Bauwens PH, Thaunat M. Combined Anterior Cruciate Ligament Repair and Anterolateral Ligament Reconstruction With a Single-Strand Gracilis Graft. *Arthrosc Tech*. 2021;10(11):e2607-e2617. doi:10.1016/j.eats.2021.01.041

60. Ibrahim SA, Shohdy EM, Marwan Y, et al. Anatomic Reconstruction of the Anterior Cruciate Ligament of the Knee With or Without Reconstruction of the Anterolateral Ligament: A Randomized Clinical Trial. *Am J Sports Med*. 2017;45(7):1558-1566. doi:10.1177/0363546517691517

61. Zhang H, Qiu M, Zhou A, Zhang J, Jiang D. Anatomic Anterolateral Ligament Reconstruction Improves Postoperative Clinical Outcomes Combined with Anatomic Anterior Cruciate Ligament Reconstruction. *J Sports Sci Med*. 2016;15(4):688-696.

62. Zaffagnini S, Marcacci M, Lo Presti M, Giordano G, Iacono F, Neri MP. Prospective and randomized evaluation of ACL reconstruction with three techniques: a clinical and radiographic evaluation at 5 years follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(11):1060-1069. doi:10.1007/s00167-006-0130-x

63. Goncharov EN, Koval OA, Dubrov VE, Bezuglov EN, Filimonova AM, Goncharov NG. Clinical experience with combined reconstruction of the anterior cruciate and anterolateral ligaments of the knee in sportsmen. *Int Orthop*. 2019;43(12):2781-2788. doi:10.1007/s00264-019-04409-8

64. Saithna A, Thaunat M, Delaloye JR, Ouanezar H, Fayard JM, Sonnery-Cottet B. Combined ACL and Anterolateral Ligament Reconstruction. *JBJS Essent Surg Tech*. 2018;8(1):e2. doi:10.2106/jbjs.st.17.00045

65. Helito CP. Editorial Commentary: Extension of Knowledge—and the Knee! New Biomechanical Study Suggests the Clinical Practice of Anterolateral Ligament Fixation Near Extension. *Arthroscopy*. 2019;35(7):2160-2163. doi:10.1016/j.arthro.2019.03.026

66. Rosenstiel N, Praz C, Ouanezar H, et al. Combined Anterior Cruciate and Anterolateral Ligament Reconstruction in the Professional Athlete: Clinical Outcomes From the Scientific Anterior Cruciate Ligament Network International Study Group in a Series of 70 Patients With a Minimum Follow-Up of 2 Years. *Arthroscopy*. 2019;35(3):885-892. doi:10.1016/j.arthro.2018.09.020

67. Xu C, Chen J, Cho E, Zhao J. The Effect of Combined Anterolateral and Anterior Cruciate Ligament Reconstruction on Reducing Pivot Shift Rate and Clinical Outcomes: A Meta-analysis. *Arthroscopy*. 2021;37(2):694-705. doi:10.1016/j.arthro.2020.10.017

68. Erden T. Comparison of the outcomes of isolated anterior cruciate ligament reconstruction and combined anterolateral ligament suture tape augmentation and anterior cruciate ligament reconstruction. *Jt Dis Relat Surg*. 2021;32(1):129-136. doi:10.5606/ehc.2020.78201

69. Yin J, Yang K, Zheng D, Xu N. Anatomic reconstruction of the anterior cruciate ligament of the knee with or without reconstruction of the anterolateral ligament: A meta-analysis. *J Orthop Surg (Hong Kong)*. 2021;29(1):230949902098519. doi:10.1177/2309499020985195

70. Kunze KN, Manzi J, Richardson M, et al. Combined Anterolateral and Anterior Cruciate Ligament Reconstruction Improves Pivot Shift Compared With Isolated Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Arthroscopy*. 2021;37(8):2677-2703. doi:10.1016/j.arthro.2021.03.058

71. Beckers L, Vivacqua T, Firth AD, Getgood AMJ. Clinical outcomes of contemporary lateral augmentation techniques in primary ACL reconstruction: a systematic review and meta-analysis. *J Exp Orthop*. 2021;8(1):10118640634-021-00368-5. doi:10.1186/s40634-021-00368-5

72. Lee DW, Kim JG, Cho SI, Kim DH. Clinical Outcomes of Isolated Revision Anterior Cruciate Ligament Reconstruction or in Combination With Anatomic Anterolateral Ligament Reconstruction. *Am J Sports Med*. 2019;47(2):324-333. doi:10.1177/0363546518815888

73. Helito CP, Sobrado MF, Giglio PN, et al. Combined Reconstruction of the Anterolateral Ligament in Patients With Anterior Cruciate Ligament Injury and Ligamentous Hyperlaxity Leads to Better Clinical Stability and a Lower Failure Rate Than Isolated Anterior Cruciate Ligament Reconstruction. *Arthroscopy*. 2019;35(9):2648-2654. doi:10.1016/j.arthro.2019.03.059

74. Laboudie P, Douiri A, Bouguennec N, Biset A, Graveleau N. Combined ACL and ALL reconstruction reduces the rate of reoperation for graft failure or secondary meniscal lesions in young athletes. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(10):3488-3498. doi:10.1007/s00167-022-06956-x

75. Aryana IGNW, Subawa IW, Dusak IWS, Dharmayuda CGO, Nugraha HK, Deslivia MF. Functional Outcome of Lateral Extraarticular Tenodesis (LET) Procedure in Addition to Anterior Cruciate Ligament Reconstruction: A Metaanalysis. *Rev Bras Ortop (Sao Paulo)*. 2022;57(1):33-40. doi:10.1055/s-0041-1736514

76. Getgood AMJ, Bryant DM, Litchfield R, et al. Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction: 2-Year Outcomes From the STABILITY Study Randomized Clinical Trial. *Am J Sports Med*. 2020;48(2):285-297. doi:10.1177/0363546519896333

77. Castoldi M, Magnussen RA, Gunst S, et al. A Randomized Controlled Trial of Bone–Patellar Tendon–Bone Anterior Cruciate Ligament Reconstruction With and Without Lateral Extra-articular Tenodesis: 19-Year Clinical and Radiological Follow-up. *Am J Sports Med*. 2020;48(7):1665-1672. doi:10.1177/0363546520914936

78. Madhan AS, Ganley TJ, McKay SD, Pandya NK, Patel NM. Trends in Anterolateral Ligament Reconstruction and Lateral Extra-articular Tenodesis With ACL Reconstruction in Children and Adolescents. *Orthop J Sports Med*. 2022;10(4):232596712210880. doi:10.1177/23259671221088049

79. Na BR, Kwak WK, Seo HY, Seon JK. Clinical Outcomes of Anterolateral Ligament Reconstruction or Lateral Extra-articular Tenodesis Combined With Primary ACL Reconstruction: A Systematic Review With Meta-analysis. *Orthop J Sports Me*. 2021;9(9):232596712110230. doi:10.1177/23259671211023099