Systematic Review

Anterolateral Ligament Reconstruction Techniques, Biomechanics, and Clinical Outcomes: A Systematic Review

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Purpose: To perform a systematic review of the described anterolateral ligament (ALL) reconstruction techniques, biomechanical performance, and clinical outcomes of ALL reconstruction in the setting of concurrent anterior cruciate ligament (ACL) reconstruction. **Methods:** A systematic review was performed according to PRISMA guidelines using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed, MEDLINE, and Embase, from 1980 to present. Inclusion criteria were as follows: ALL reconstruction techniques, ALL reconstruction biomechanical studies, ALL surgical outcomes, English language, human studies with at least 2 years of follow-up, and cadaveric studies. Exclusion criteria were lateral extra-articular tenodesis, ALL anatomic studies, ALL radiographic studies, animal studies, clinical studies with <2 years of follow-up, editorial articles, and surveys. **Results:** The systematic review identified 12 articles that met the inclusion criteria: 6 techniques, 5 biomechanical studies, and 1 outcome study were available. Five studies described ALL reconstruction in the setting of ACL reconstruction, whereas 1 study described isolated ALL reconstruction. Femoral tunnel location was most commonly placed posterior and proximal to the lateral epicondyle, whereas 2 studies reported a distal tunnel location. There was little variability in tibial tunnel location. The most common ALL reconstruction graft used was the gracilis tendon. Review of the biomechanical studies revealed internal rotation overconstraint with the posterior/proximal femoral tunnel position but not anterior/distal, although fixation angle and graft tension were inconsistent. Only 1 clinical study with 2 years' follow-up was available and reported improvement in the majority of cases. Complications occurred in 15 patients, including a residual pivot shift in 8% of patients at 2 years after a combined ACL and ALL reconstruction. **Conclusions:** There is inconsistency in the selection of ALL graft femoral attachment location as well as in the biomechanical performance of ALL reconstruction techniques. **Level of Evidence:** Level IV, systematic review of Level IV studies.

The description of the anterolateral ligament (ALL) and its effect on controlling internal rotation has led to the development of ALL reconstruction techniques in an effort to better restore native knee biomechanics and stability.[1] As a model, anatomic-based and biomechanically validated reconstructions have led to improved outcomes for other knee ligaments.[2-6] However, up to 25% of all anterior cruciate ligament (ACL) reconstruction patients have been reported to have residual rotational instability.[7] Moreover, isolated ACL reconstruction failure rates range from 1.8% to 14%.[8-11] Thus, the need for improving rotational laxity control in the setting of ACL injuries has led to the development of various anterolateral knee reconstruction techniques.

Historically, multiple extra-articular procedures were developed to reduce anterolateral rotational instability (ALRI), collectively referred to as lateral extra-articular tenodesis (LET) procedures.[12,13] However, concerns regarding the nonanatomic nature of LET procedures and the potential for overconstraint led to a decrease in their popularity.[14,15] Additionally, overconstraint can potentially lead to graft elongation, changes in the knee biomechanics, and ultimately to accelerated joint

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degeneration.[14,15] Several ALL reconstruction techniques have emerged as a result of the recharacterization of the anterolateral knee structures, along with their potential role in resisting tibial internal rotation.[16,17]

It has been proposed that the ALL assists the ACL as a stabilizer against internal rotation and anterior tibial translation, thus reducing anterolateral rotatory instability (ALRI).[18-20] However, because of variability in anatomic descriptions, authors have proposed different ALL reconstruction techniques, specifically involving different femoral attachment positions.[16,17] Renewed concerns have been raised, because biomechanical studies have suggested that this procedure can overconstrain internal rotation.[1] Given the relative paucity of literature reviewing the techniques, biomechanics, and outcomes of ALL reconstructions, the purpose of this study was to perform a systematic review of the described ALL reconstruction techniques, biomechanical performance, and clinical outcomes of ALL reconstruction in the setting of concurrent ACL reconstruction. We hypothesized that there would be inconsistency in techniques and therefore biomechanical characteristics, as well as a relative paucity of clinical outcomes studies.

Methods

Article Identification and Selection

A systematic review of ALL reconstruction techniques, biomechanics, and clinical outcomes was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1980-2016), MEDLINE (1980-2016), and Embase (1980-2016). Registration of this systematic review was performed in August 2016 using the PROSPERO International prospective register of systematic reviews (registration number 42016047200), and the queries were performed in August 2016. The following search protocol was performed:

- Search 1: “Anterolateral”[All Fields] AND “ligament”[All Fields] OR “anterolateral ligament”[All Fields] OR “anterolateral ligament”[All Fields] AND reconstruction technique[All Fields]
- Search 2: Anterolateral[All Fields] AND (“ligaments”[MeSH Terms] OR “ligaments”[All Fields] OR “ligament”[All Fields]) AND (“reconstructive surgical procedures”[MeSH Terms] OR (“reconstructive”[All Fields] AND “surgical”[All Fields] AND “procedures”[All Fields]) OR “reconstructive surgical procedures”[All Fields] OR “reconstruction”[All Fields]) AND biomechanics[All Fields]
- Search 3: Anterolateral[All Fields] AND (“ligaments”[MeSH Terms] OR “ligaments”[All Fields] OR “ligament”[All Fields]) AND (“reconstructive surgical procedures”[MeSH Terms] OR (“reconstructive”[All Fields] AND “surgical”[All Fields] AND “procedures”[All Fields]) OR “reconstructive surgical procedures”[All Fields] OR “reconstruction”[All Fields]) AND outcomes[All Fields]

Inclusion criteria were English language, human studies, and cadaveric studies on techniques, biomechanics, and clinical outcomes for ALL reconstruction procedures. Exclusion criteria were as follows: lateral extra-articular tenodesis surgical techniques, ALL anatomic and radiographic studies, animal studies, editorial articles, and surveys.

Two investigators (initials blinded for review) independently reviewed the abstracts from all identified articles. If necessary, full-text articles were obtained for review to allow for further application of inclusion and exclusion criteria. Additionally, reference lists from the included studies were reviewed and reconciled to verify that all eligible articles were considered.

Data Collection

Specific parameters of the surgical technique used in each study were collected, including the femoral attachment, tibial attachment, graft type, fixation method, knee angle during fixation, graft tension at fixation, and associated ligament reconstruction procedures as well as biomechanical data if available. Findings from biomechanical studies of ALL reconstructions were collected, specifically including knee translation, rotational torque, kinematics, and position of knee during testing, as well as other relevant reported results.

The level of evidence of all available clinical studies was assigned according to the classification as specified by Wright et al.[21] Two studies (Ferreira et al.[22] and Sonnery-Cottet et al.[23]) were Level IV studies, and the remaining did not have an associated level of evidence. Patient demographics, follow-up, and subjective and objective outcomes were extracted and recorded. For continuous variables (e.g., age, duration of follow-up, outcome scores), the mean and range were collected if reported.

Results

The literature search identified 520 studies from the aforementioned databases. After duplicates were removed, 472 articles were screened and 12 articles met the inclusion criteria (Fig 1). There were 6 technique descriptions, 5 biomechanical studies, and 1 clinical outcomes study (Fig 2).

ALL Reconstruction Techniques

Five technique articles described a combined ALL/ACL reconstruction,[22-26] whereas 1 article described an isolated ALL reconstruction.[27] Four studies used a femoral ALL graft fixation position posterior and proximal to the femoral attachment of the fibular

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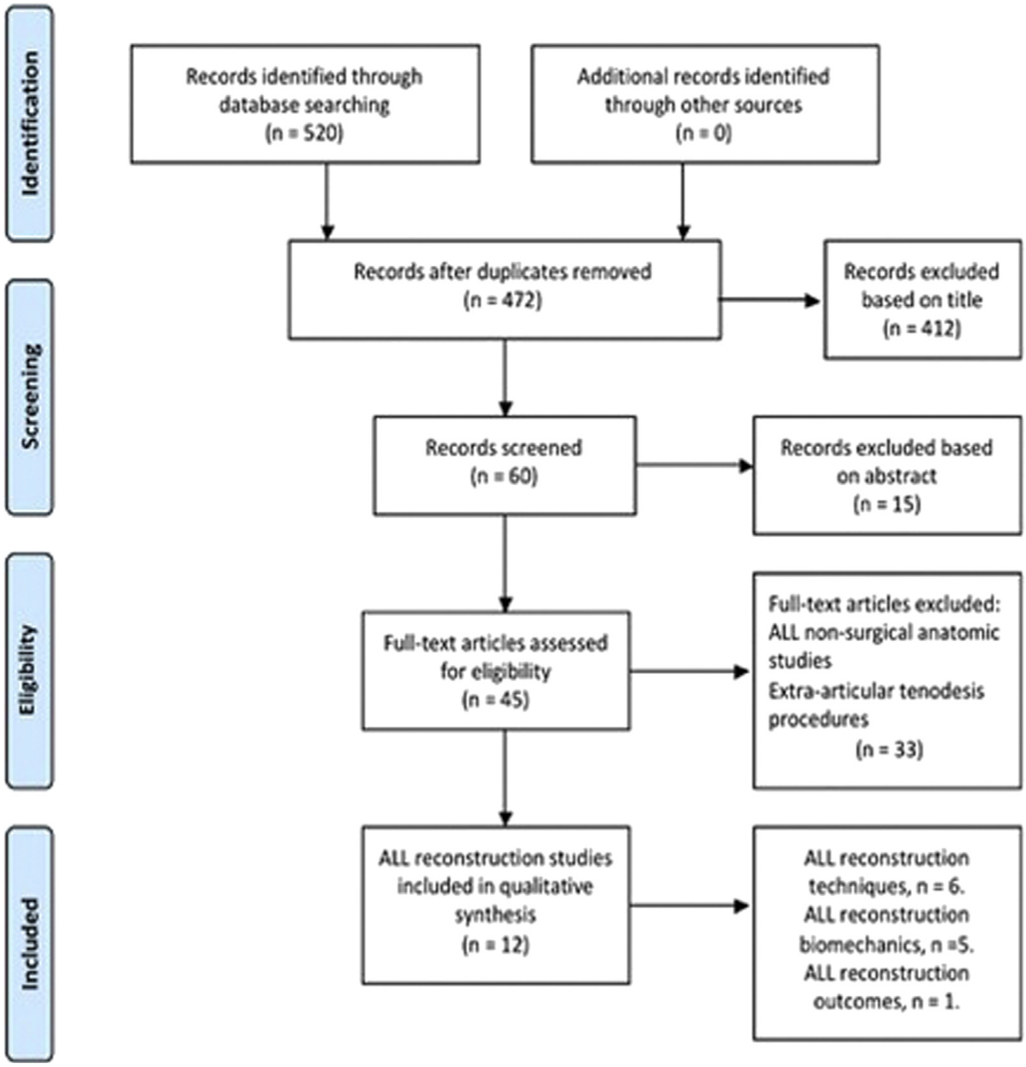

Fig 1. Preferred Reporting Items for Systematic Review and Meta-Analysis flowchart showing application of selection criteria to the studies identified with the search strategy.

collateral ligament (FCL),[22-24,27] whereas 2 studies used an attachment site anterior and distal to the lateral epicondyle.[24,26] Tibial ALL graft fixation was performed at a point equidistant between the Gerdy tubercle and the fibular head, with a range of 5 to 11 mm below the lateral joint line in 5 studies.[22,24-26,27] The remaining study did not quantify the precise tibial fixation point[23] (Fig 2; Table 1).

ALL Reconstruction Biomechanical Performance

Five ALL reconstruction techniques with biomechanical evaluation were identified; anterior tibial translation, internal rotation, pivot shift, and knee kinematics are reported in Table 2. Four studies conducted testing using combined ACL and ALL reconstructions,[1,28-30] whereas 1 study first evaluated an ALL reconstruction and compared it to an LET procedure without an ACL reconstruction.[31]

Two of 4 studies reported overconstraint of internal rotation using the posterior/proximal ALL femoral attachment point.[1,29] In contrast, the 2 other studies reported no overconstraint using the anterior/distal ALL femoral attachment point.[30,31] However, both of the latter studies did not report a significant difference between the ALL reconstruction and the ALL-deficient knee during internal rotation or pivot shift testing.

One study investigated the effects of different femoral tunnel positions on ALL graft tension throughout the 0° to 120° of knee range of motion.[28] The femoral position of 4 mm posterior and 8 mm proximal to the lateral epicondyle had the least tension change during knee range of motion, with only a slight increase in tension as the knee extended ($P < .001$). The authors recommended that the posterior and proximal femoral position be used in ALL reconstructions to better control ALRI, because ALRI was more clinically significant in an extended knee position. However, knee kinematics were not evaluated and the pivot shift test was not performed.[28]

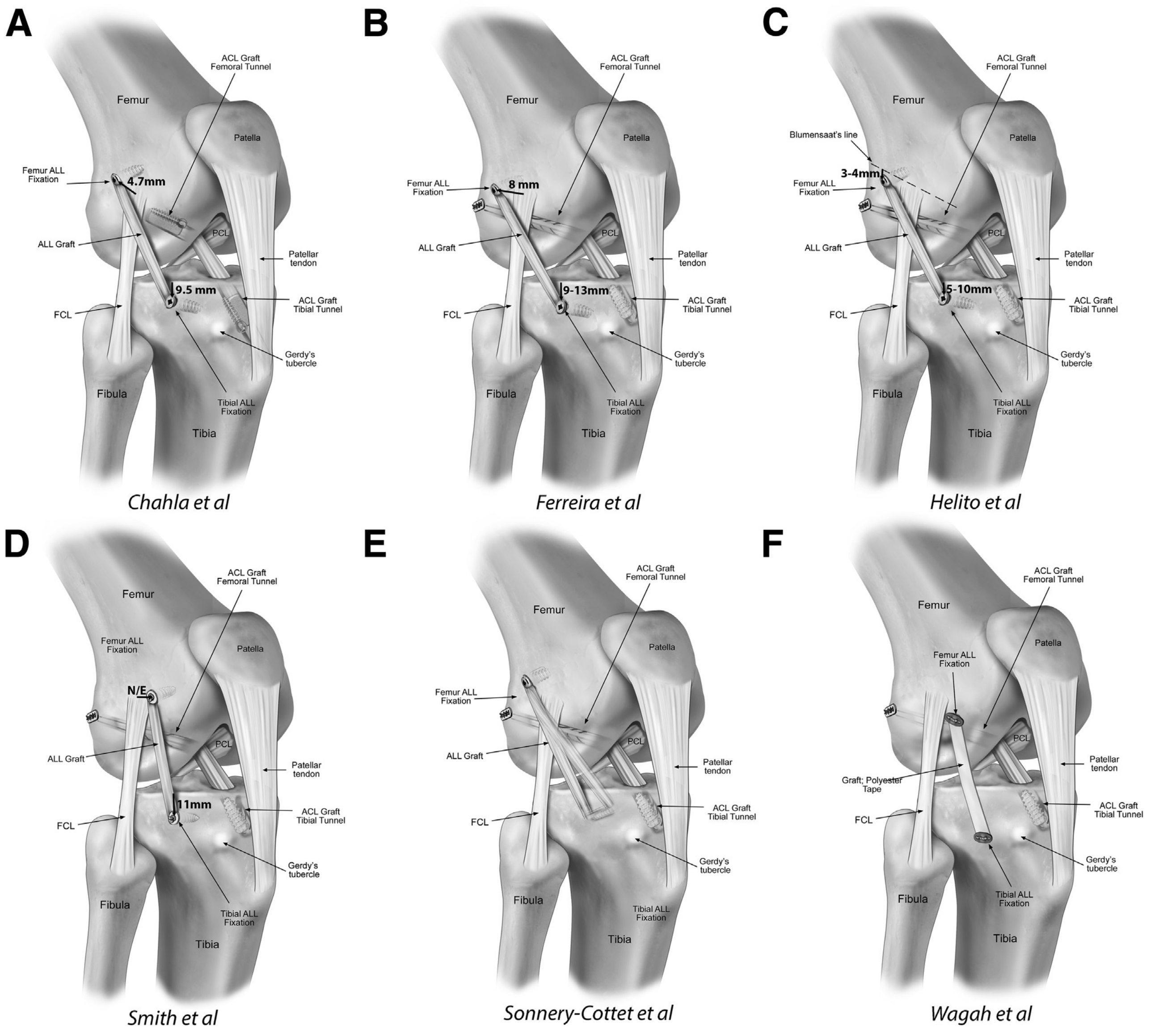

Fig 2. (A-F) Anterolateral ligament reconstruction technique illustrations from the various authors on a right knee. (ACL, anterior cruciate ligament; ALL, anterolateral ligament; FCL, fibular collateral ligament; PCL, posterior cruciate ligament.)

ALL Reconstruction Outcomes

A single ALL reconstruction outcome study was identified. Sonnery-Cottet et al.[32] reported on 92 patients who underwent combined ACL and ALL reconstructions with a minimum 2-year follow-up (32.4 ± 3.9 months) (Table 3). Complications or reinterventions were noted in 16.3% of patients. One patient (1.1%) had an ACL graft rupture 1 year after the combined surgical procedure and 7 patients (7.6%) had a contralateral ACL rupture. One patient underwent a second arthroscopy for a cyclops lesion and 1 for a partial lateral meniscectomy; 5 patients underwent a second operation for partial medial meniscectomy after failed meniscal repairs. Preoperatively, 49.4% of patients had a low-grade pivot shift on clinical examination, with 8.4% of patients having a residual low-grade pivot shift at 2 years after combined ACL and ALL reconstruction (Table 3). However, because half of the patients had low-grade (1) rather than high-grade pivot shifts, the influence of the ALL reconstruction on patient outcomes is unclear. Seventy-one percent of patients returned to their preinjury level of activity.[32]

Discussion

The most important finding of this systematic review was inconsistency in the surgical technique and biomechanical performance of described ALL reconstructions and the limited clinical evidence on ALL reconstruction. Although biomechanical evidence is available, clinical evidence is unable to guide ALL reconstruction technique selection in regard to anatomic positioning on the femur, graft fixation angle,

Table 1. Anterolateral Ligament Reconstruction Techniques Characteristics

Author/Year	Authors' Reported Indications for ALL Reconstruction	ALL Fixation Points	ALL Graft Types	ALL Graft Fixation	ALL Graft Tension Angle
Chahla et al., 2016[27]	1. Grade III + pivot shift 2. Multiple ACL reconstruction with residual laxity 3. Clinically significant instability after ACL reconstruction	F: 4.7 mm proximal and posterior to FCL insertion site T: Equidistant between the Gerdy tubercle and anterior margin fibular head (9.5 mm distal to joint line)	Semitendinosus	7 × 28-mm interference screw	30° of flexion
Ferreira et al., 2016[22]	1. Asymmetry of lateral plateau with internal rotation of tibia in flexion between 60° and 90° 2. Grade II/III pivot shift 3. ALL tear confirmed on MRI 4. Segond fractures	F: 8 mm posterosuperiorly from lateral epicondyle T: 9-13 mm distal to lateral joint line	Double gracilis	Interference screw 2 mm larger than tunnel	45°-60° of flexion
Helito et al., 2015[24]	1. High-grade pivot shift examination 2. ACL reconstruction revision cases without apparent cause for failure	F: 3-4 mm below the halfway point on the Blumensaat line in the AP direction T: 5-10 mm below the lateral tibial plateau	Gracilis	Inference screw 1 size greater than tunnel diameter	60°-90° of flexion
Smith et al., 2015[25]	1. Marked laxity on examination under anesthesia	F: Anterior to lateral femoral epicondyle T: Equidistant between fibular head and the Gerdy tubercle, 11 mm distal to joint line	Gracilis	5.5-mm suture anchors	30° of flexion with foot in neutral rotation
Sonnery-Cottet et al., 2016[23]	1. Segond fractures 2. Chronic ACL tears 3. Grade III pivot shift 4. High-level sports participation 5. Participation in pivot sports 6. Lateral femoral notch sign	F: Proximal and posterior to lateral epicondyle T: Site of Segond fracture, at tibial footprint of ALL	Gracilis	4.75 or 5.5 mm interference screw	Not Reported
Wagih and Elguindy, 2016[26]	1. Grade III pivot shift examination	F: Anterior and distal to lateral femoral condyle T: Midpoint between the Gerdy tubercle and the fibular head	Polyester tape	Cortical suspension button	30° of flexion

ACL, anterior cruciate ligament; ALL, anterolateral ligament; AP, anteroposterior; F, femoral attachment; FCL, fibular collateral ligament; MRI, magnetic resonance imaging; T, tibial attachment.

Table 2. Anterolateral Ligament Reconstruction Biomechanical Results

Author/Year	Reconstruction	Anterior Translation	Internal Rotation Torque	Pivot Shift (IR + Valgus)	Kinematics
Katakura et al., 2016[28]	ACLR: single-bundle autologous quadrupled semitendinosus ALLR femoral attachment 1: 2 mm anterior and 2 mm distal to LE ALLR femoral attachment 2: 4 mm posterior and 8 mm proximal to LE LET: Lemaire and Combelles[12]	Not reported	Increase in graft tension with all femoral attachment sites	Not reported	ALLR femoral attachment 1: decrease in tension with extension and increase in tension with flexion ALLR femoral attachment 2: least tension change during knee range of motion with only a slight increase in tension as the knee extended
Nitri et al., 2016[29]	ACLR: single-bundle BPTB allograft ALLR: posterior and proximal to FCL[17]	ACLR + ALL intact = 1.0 mm > normal ACLR + ALL deficient = 1.2 mm > normal ACLR + ALLR = 1.1 mm > normal	ACLR + ALLR = 1.0° < ACLR + ALL intact ACLR + ALL deficient = 2.2° > normal ACLR + ALLR = 2.7° < ACLR + ALL deficient	ACLR + ALL deficient = 2.4° > normal ACLR + ALLR = 2.1° < normal	Overconstraint
Schon et al., 2016[1]	ACLR: single-bundle BPTB allograft ALLR: posterior and proximal to FCL[17]	ACLR + ALL intact = 0.5-0.9 mm > normal at 0°, 15°, 30°, 60° ACLR + ALL deficient = 0.5-1.0 mm > normal at 0°-75° ACLR + ALLR = 0.4-1.3 mm > normal	ACLR + ALL deficient = 0.8°-1.2° > normal at 15°-75° ACLR + ALLR = 1°-3.7° < normal at all angles ≥30°	ACLR + ALL deficient = 1.1°-1.5° > normal at 15°-60° ACLR + ALLR = 1.7°-2.9° < normal at 45° and 60°	Overconstraint
Spencer et al., 2015[31]	ALLR, F: anterior and distal to lateral femoral condyle[16] ALLR, T: midpoint between the Gerdy tubercle and the fibular head LET: Lemaire and Combelles[12]	Intact = 3.24 ± 1.43 mm ALL + ACL deficient = 8.69 ± 2.62 mm ALLR + ACL deficient = 7.84 ± 4.01 mm LET + ACL deficient = 7.56 ± 2.71 mm	Not reported	ALLR = No significant difference from ALL-deficient knee	No overconstraint
Tavlo et al., 2016[30]	ACLR: 8-mm synthetic nylon graft ALLR, F: anterior and distal to lateral femoral condyle[16] ALLR, T: site of Segond fracture	ALLR = No significant difference from intact knee	ALLR = No significant difference from intact knee	Not reported	No overconstraint

ACLR, anterior cruciate ligament reconstruction; ALL, anterolateral ligament; ALLR, anterolateral ligament reconstruction; BPTB, bone–patellar tendon–bone; F, femoral attachment; FCL, fibular collateral ligament; IR, internal rotation; LE, lateral epicondyle; LET, lateral extra-articular tenodesis; T, tibial attachment.

Table 3. ALL Reconstruction Outcomes According to Sonnery-Cottet et al.[32] (n = 83)

	Subjective Outcomes	Objective Outcomes
Preoperative	IKDC: 58.7 ± 15.4 Lysholm: 51.4 ± 5.2 Tegner: 7.3 ± 1.7	Anterior laxity: 8 ± 1.9 Pivot shift: Grade 1 = 49% Grade 2 = 28% Grade 3 = 23% IKDC: 63% grade C, 37% grade D
Postoperative	IKDC: 86.7 ± 12.3* Lysholm: 92 ± 9.8* Tegner: 7.1 ± 1.8 KOOS: 88 ± 11.3	Anterior laxity: 0.7 ± 0.8* Pivot shift*: Negative = 92% Grade 1 = 8% Grade 2/3 = 0% IKDC*: 92% grade A, 8% grade B

ALL, anterolateral ligament; IKDC, International Knee Documentation Committee; KOOS, Knee injury Osteoarthritis Outcome Score.
*Significant difference $P < .01$.

and the tensioning force applied prior to fixation. Further biomechanical studies are needed to define the optimal ALL reconstruction technique, including tunnel location, graft type, graft tension, and most importantly, objective indications. Additionally, medium- and long-term clinical studies, ideally Level I or II, are necessary to further refine the surgical indications.

Many variations in regard to ALL reconstruction techniques have been reported, all of which propose slightly different attachments for femoral graft fixation. These variations are perhaps due to the different reported femoral footprints of the ALL. The 2 most common reported femoral attachment locations are between the fibular collateral ligament origin and insertion of the popliteus tendon on the lateral femoral condyle, as described by Claes et al.,[16] and posterior and proximal to the fibular collateral ligament, as described by Kennedy et al.[17]

Length change for varying anatomic attachment points has been used as a surrogate for graft tension and allows evaluation of the isometry of the selected tunnel locations. The difference between the Claes[16] and Kennedy[17] ALL femoral origins has been shown to alter the length change patterns of the ALL. An increase in length (i.e., graft tension) occurs with an attachment point anterior/distal to the lateral epicondyle when moving from extension to flexion. In contrast, a decrease in length (i.e., graft tension) occurs with a posterior/proximal attachment point when moving from extension to flexion.[18,33-35] Katakura et al.[28] reported similar graft tensioning results with their combined ACL and ALL reconstruction, because the posterior/proximal femoral attachment point had the least tension change during knee range of motion compared with the anterior/distal femoral attachment and an LET procedure. Subsequently, they recommended using the posterior/proximal femoral point for an ALL reconstruction to better restore anterolateral rotational stability.[28]

Review of the included ALL reconstruction biomechanical studies also revealed inconsistencies. Two of the 4 studies reported significant overconstraint of internal rotation using the posterior/proximal ALL femoral attachment point.[1,29] In contrast, the 2 other studies reported no knee overconstraint but also no change in knee kinematics when using the anterior/distal ALL femoral attachment point.[30,31] We theorize that the inability to restore internal rotation stability could be due to the low graft tensioning forces or the anterior femoral fixation of the ALL grafts used in both studies, rendering the respective ALL reconstructions insignificant.[30,31]

Nitri et al.[29] investigated the kinematics of ALL reconstruction in the setting of an ACLR, compared with intact and sectioned ALL states. Results indicated that combined anatomic ACLR and ALL reconstruction improved the rotatory stability of the knee compared with isolated ACLR in the setting of a concurrent ALL deficiency.[29] In this regard, Schon and colleagues[1] evaluated the influence of knee flexion angles for graft fixation to identify the optimal angle for avoidance of overconstraint. Anterolateral ligament reconstruction resulted in significant overconstraint compared with the intact state at every knee fixation angle between 0° and 90°. The authors concluded that the ALL reconstruction was not capable of restoring stability without overconstraint of normal joint kinematics.[1]

In contrast, Spencer et al.[31] reported that ALL reconstruction did not result in a significant reduction in internal rotation or anterior translation, indicating no overconstraint. Isolated ALL reconstruction using a single Fiber-Tape (Arthrex, Naples, FL) was compared with an LET procedure to determine if either procedure was capable of reducing anterolateral rotational laxity in an ACL-deficient knee. The ALL reconstruction femoral tunnel was placed anterior and distal to the lateral epicondyle. The LET procedure was superior for controlling anterolateral rotational laxity and anterior translation compared with the ALL reconstruction. Moreover, Spencer et al.[31] reported that using an ALL reconstruction simply with fiber-tape did not influence knee kinematics and thus failed to have an effect on controlling anterolateral rotation.[31] Similarly, Tavlo et al.[30] found no knee overconstraint with an ALL reconstruction technique using a femoral tunnel position as described by Claes et al.[16] Sectioning the ALL had a significant effect on internal rotation stability in the ACL-deficient knees. Reconstruction of the ALL in the ACL-deficient knees resulted in improved anterior stability; however, ALL reconstruction failed to influence internal rotation ($P = .136$).[30]

In the single clinical outcome study identified for inclusion, Sonnery-Cottet et al.[32] noted significant improvements in subjective and objective outcome scores after combined ACL and ALL reconstruction at the 2-year follow-up, with complications or reinterventions reported in 16% and residual pivot shift in 8% of patients. However, a reported indication for supplementing an anterolateral ligament reconstruction with an ACL reconstruction is to address ALRI in patients with a high-grade pivot shift on clinical examination.[16,23,29,36] Approximately half of the patients in this study did not have a high-grade pivot shift (grade 2/3) preoperatively, which we theorize had an effect on their reported outcomes. Additional follow-up studies are needed to determine whether combined ALL reconstructions improve the results of existing ACL treatment.

Limitations

We acknowledge some limitations to this systematic review. The heterogeneity of biomechanical studies, including graft selection, attachment points, and fixation angle, limit direct comparisons when evaluating biomechanical results. The in vitro time-zero biomechanical results would reflect only the initial stability and overconstraint achieved immediately postoperatively and not the final results experienced after the in vivo healing process. Also, variability of the experimental setting among the biomechanical studies limits the ability for direct comparison. Additionally, the 2 studies that reported overconstraint of knee internal rotation with combined ACL/ALL reconstruction were performed at the same institution with nearly identical experimental settings, thus making the external validity uncertain. Furthermore, only a single outcome study with low evidence level was available for evaluation of clinical efficacy of this procedure, thus limiting clinical interpretation and recommendation of optimal ALL reconstruction technique.

Conclusions

There is inconsistency in the selection of ALL graft femoral attachment location as well as in the biomechanical performance of ALL reconstruction techniques.

References

1. Schon JM, Moatshe G, Brady AW, et al. Anatomic anterolateral ligament reconstruction of the knee leads to overconstraint at any fixation angle. *Am J Sports Med* 2016;44:2546-2556.
2. LaPrade RF, Moulton SG, Nitri M, Mueller W, Engebretsen L. Clinically relevant anatomy and what anatomic reconstruction means. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2950-2959.
3. Goldsmith MT, Jansson KS, Smith SD, Engebretsen L, LaPrade RF, Wijdicks CA. Biomechanical comparison of anatomic single- and double-bundle anterior cruciate ligament reconstructions: An in vitro study. *Am J Sports Med* 2013;41:1595-1604.
4. Geeslin AG, LaPrade RF. Outcomes of treatment of acute grade-III isolated and combined posterolateral knee injuries: A prospective case series and surgical technique. *J Bone Joint Surg Am* 2011;93:1672-1683.
5. LaPrade RF, Spiridonov SI, Coobs BR, Ruckert PR, Griffith CJ. Fibular collateral ligament anatomical reconstructions: A prospective outcomes study. *Am J Sports Med* 2010;38:2005-2011.
6. Laprade RF, Wijdicks CA. The management of injuries to the medial side of the knee. *J Orthop Sports Phys Ther* 2012;42:221-233.
7. Chambat P, Guier C, Sonnery-Cottet B, Fayard JM, Thaunat M. The evolution of ACL reconstruction over the last fifty years. *Int Orthop* 2013;37:181-186.
8. Chouliaras V, Ristanis S, Moraiti C, Stergiou N, Georgoulis AD. Effectiveness of reconstruction of the anterior cruciate ligament with quadrupled hamstrings and bone-patellar tendon-bone autografts: An in vivo study comparing tibial internal-external rotation. *Am J Sports Med* 2007;35:189-196.
9. Mariscalco MW, Flanigan DC, Mitchell J, et al. The influence of hamstring autograft size on patient-reported outcomes and risk of revision after anterior cruciate ligament reconstruction: A Multicenter Orthopaedic Outcomes Network (MOON) Cohort Study. *Arthroscopy* 2013;29:1948-1953.
10. van Eck CF, Schkrohowsky JG, Working ZM, Irrgang JJ, Fu FH. Prospective analysis of failure rate and predictors of failure after anatomic anterior cruciate ligament reconstruction with allograft. *Am J Sports Med* 2012;40:800-807.
11. Webster KE, Feller JA, Leigh WB, Richmond AK. Younger patients are at increased risk for graft rupture and contralateral injury after anterior cruciate ligament reconstruction. *Am J Sports Med* 2014;42:641-647.
12. Lemaire M, Combelles F. Plastic repair with fascia lata for old tears of the anterior cruciate ligament. *Rev Chir Orthop Reparatrice Appar Mot* 1980;66:523-525 [in French].
13. Zarins B, Rowe CR. Combined anterior cruciate-ligament reconstruction using semitendinosus tendon and iliotibial tract. *J Bone Joint Surg Am* 1986;68:160-177.
14. Engebretsen L, Lew WD, Lewis JL, Hunter RE, Benum P. Anterolateral rotatory instability of the knee. Cadaver study of extraarticular patellar-tendon transposition. *Acta Orthop Scand* 1990;61:225-230.
15. Matsumoto H, Seedhom BB. Treatment of the pivot-shift intraarticular versus extraarticular or combined reconstruction procedures. A biomechanical study. *Clin Orthop Relat Res* 1994;299:298-304.
16. Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. *J Anat* 2013;223:321-328.
17. Kennedy MI, Claes S, Fuso FA, et al. The anterolateral ligament: An anatomic, radiographic, and biomechanical analysis. *Am J Sports Med* 2015;43:1606-1615.
18. Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA. The anterolateral ligament: Anatomy, length changes and

association with the Segond fracture. *J Bone Joint Br* 2014;96:325-331.
19. Vincent JP, Magnussen RA, Gezmez F, et al. The anterolateral ligament of the human knee: An anatomic and histologic study. *Knee Surg Sports Traumatol Arthrosc* 2012;20:147-152.
20. Hughston JC, Andrews JR, Cross MJ, Moschi A. Classification of knee ligament instabilities. Part II. The lateral compartment. *J Bone Joint Surg Am* 1976;58:173-179.
21. Wright JG, Swiontkowski MF, Heckman JD. Introducing levels of evidence to the journal. *J Bone Joint Surg Am* 2003;85:1-3.
22. Ferreira Mde C, Zidan FF, Miduati FB, Fortuna CC, Mizutani BM, Abdalla RJ. Reconstruction of anterior cruciate ligament and anterolateral ligament using interlinked hamstrings—Technical note. *Rev Bras Ortop* 2016;51:466-470.
23. Sonnery-Cottet B, Barbosa NC, Tuteja S, Daggett M, Kajetanek C, Thaunat M. Minimally invasive anterolateral ligament reconstruction in the setting of anterior cruciate ligament injury. *Arthrosc Tech* 2016;5:e211-e215.
24. Helito CP, Bonadio MB, Gobbi RG, et al. Combined intra- and extra-articular reconstruction of the anterior cruciate ligament: The reconstruction of the knee anterolateral ligament. *Arthrosc Tech* 2015;4:e239-e244.
25. Smith JO, Yasen SK, Lord B, Wilson AJ. Combined anterolateral ligament and anatomic anterior cruciate ligament reconstruction of the knee. *Knee Surg Sports Traumatol Arthrosc* 2015;23:3151-3156.
26. Wagih AM, Elguindy AMF. Percutaneous reconstruction of the anterolateral ligament of the knee with a polyester tape. *Arthrosc Tech* 2016;5:e691-e697.
27. Chahla J, Menge TJ, Mitchell JJ, Dean CS, LaPrade RF. Anterolateral ligament reconstruction technique: An anatomic-based approach. *Arthrosc Tech* 2016;5:e453-e457.
28. Katakura M, Koga H, Nakamura K, Sekiya I, Muneta T. Effects of different femoral tunnel positions on tension changes in anterolateral ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2016 May 25. [Epub ahead of print.]
29. 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;44:593-601.
30. Tavlo M, Eljaja S, Jensen JT, Siersma VD, Krogsgaard MR. The role of the anterolateral ligament in ACL insufficient and reconstructed knees on rotatory stability: A biomechanical study on human cadavers. *Scand J Med Sci Sports* 2016;26:960-966.
31. Spencer L, Burkhart TA, Tran MN, et al. Biomechanical analysis of simulated clinical testing and reconstruction of the anterolateral ligament of the knee. *Am J Sports Med* 2015;43:2189-2197.
32. Sonnery-Cottet B, Thaunat M, Freychet B, Pupim BH, Murphy CG, Claes S. Outcome of a combined anterior cruciate ligament and anterolateral ligament reconstruction technique with a minimum 2-year follow-up. *Am J Sports Med* 2015;43:1598-1605.
33. Kittl C, Halewood C, Stephen JM, et al. Length change patterns in the lateral extra-articular structures of the knee and related reconstructions. *Am J Sports Med* 2015;43:354-362.
34. Lutz C, Sonnery-Cottet B, Niglis L, Freychet B, Clavert P, Imbert P. Behavior of the anterolateral structures of the knee during internal rotation. *Orthop Traumatol Surg Res* 2015;101:523-528.
35. Helito CP, Helito PV, Bonadio MB, et al. Evaluation of the length and isometric pattern of the anterolateral ligament with serial computer tomography. *Orthop J Sports Med* 2014;2:2325967114562205.
36. Rasmussen MT, Nitri M, Williams BT, 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;44:585-592.