

# The Role of Anterolateral Ligament Reconstruction or Lateral Extra-articular Tenodesis for Revision Anterior Cruciate Ligament Reconstruction

CME

## A Systematic Review and Meta-analysis of Comparative Clinical Studies

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**Background:** After its success in restoring rotational stability and reducing failure rates in primary anterior cruciate ligament reconstruction (ACLR), lateral extra-articular tenodesis (LET) or anterolateral ligament reconstruction (ALLR) has been endorsed for use in revision ACLR surgery, where failure rates are historically higher.

**Purpose:** To perform a systematic review and meta-analysis on whether the addition of a LET or ALLR results in superior clinical outcomes and stability compared with isolated revision ACLR (iACLR).

**Study Design:** Meta-analysis; Level of evidence, 4.

**Methods:** The Cochrane Controlled Register of Trials, PubMed, Medline, and Embase were used to perform a systematic review and meta-analysis of comparative studies using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria with the following search terms: (“extra-articular” OR “tenodesis” OR “anterolateral ligament” OR “iliotibial”) AND (“anterior cruciate ligament”) AND (“revision” OR “re-operation”). Data pertaining to all patient-reported outcome measures (PROMs), rotational stability, and postoperative complications were extracted from each study.

**Results:** After abstract and full-text screening, 10 clinical comparative studies were included. There were 793 patients, of whom 390 had an iACLR while 403 had an ACLR augmented with a LET or an ALLR (augmented ACLR [aACLR]). The mean time for assessment of PROMs was 35 months. The aACLR group had superior International Knee Documentation Committee (IKDC) scores (standardized mean difference [SMD], 0.27; 95% CI, 0.01 to 0.54;  $P = .04$ ), rotational stability (odds ratio [OR], 2.77; 95% CI, 1.91 to 4.01;  $P < .00001$ ), and lower side-to-side difference (OR, -0.53; 95% CI, -0.81 to -0.24;  $P = .0003$ ) than those without the augmentation. Furthermore, they were less likely to fail (OR, 0.44; 95% CI, 0.24 to 0.80;  $P = .007$ ). Subgroup analysis in the higher-grade laxity cohort (grade  $\geq 2$ ) revealed an even greater IKDC score (SMD, 0.51; 95% CI, 0.16 to 0.86;  $P = .005$ ) and an improved Lysholm score (SMD, 0.45; 95% CI, 0.24 to 0.67;  $P < .0001$ ) in the aACLR group.

**Conclusion:** Revision aACLR with a LET or an ALLR can improve subjective IKDC scores, restore rotational stability, and reduce failure rates compared with iACLR. Although controversy remains on the necessity of augmenting all revision ACLRs, the present meta-analysis advocates adding a lateral procedure, particularly in those with a higher-grade pivot shift.

**Keywords:** anterior cruciate ligament; anterolateral ligament; lateral extra-articular tenodesis; patient-reported outcome measure; rotational stability

The rate of success of anterior cruciate ligament (ACL) reconstruction (ACLR) ranges<sup>13,59</sup> from 75% to 95%, with most patients returning to a desired performance level and regaining knee stability. However, as the incidence of ACLR procedures has increased, the number of revision

surgeries has concurrently risen.<sup>29</sup> A residual positive pivot shift has been described as a significant negative predictive factor and is associated with failure in patients undergoing ACLR,<sup>4,24,26,57</sup> a phenomenon that mandates revision surgery.<sup>8</sup>

Several technical factors—such as optimal tunnel placement and aperture fixation—as well as graft considerations—such as double-bundle and anatomic single-bundle reconstructions—have been explored as means to prevent the failure of ACL reconstruction.<sup>6,8,36,46,47</sup>

There has been a renewed interest in the anterolateral complex of the knee, with many biomechanical studies stressing its importance as a secondary restraint to anterior displacement and internal rotation of the tibia.<sup>10,17,21,32,33</sup> If the anterolateral complex is disrupted, a higher-grade pivot shift and marked anterolateral laxity can occur.<sup>19,39,44</sup>

After its success in restoring rotational stability and reducing failure rates in primary ACLR for high-risk patients,<sup>31,41,50</sup> the use of lateral extra-articular tenodesis (LET) or anterolateral ligament (ALL) reconstruction (ALLR) for revision surgery, where failure rates have historically been higher than primary procedures, has been endorsed by authors.<sup>37,42</sup> In addition, its load-sharing effects can provide a protective element from undesired stresses during the early phases of rehabilitation.<sup>7,12</sup> A recent consensus meeting of leading experts suggests that LET or ALLR should be considered when performing ACLR revision, particularly in patients with clinical rotatory instability.<sup>40</sup>

Whether the addition of a LET or ALLR is truly superior to isolated revision ACLR is unclear. A recent qualitative synthesis supported the use of LET/ALLR.<sup>14</sup> However, this was predominantly evaluating case series, as not enough comparative studies were present at the time to support the technique.

We therefore performed a systematic review and meta-analysis on clinical comparative studies to investigate whether ACLR revision augmented with LET/ALLR (aACLR) had superior clinical outcomes and rotational stability compared with isolated revision of ACLR (iACLR).

## METHODS

### Literature Review

A systematic review and meta-analysis was performed and reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.<sup>30</sup> The Cochrane Controlled Register of Trials, PubMed, Medline, and Embase were searched from the inception of the databases to August 2, 2022. The search

terms included “extra-articular” OR “tenodesis” OR “ante-lateral ligament” OR “iliotibial” AND “anterior cruciate ligament” AND “revision” OR “re-operation.” No restriction was made on language, and efforts were made to obtain translated versions of all included studies. No restrictions were placed on the date of publication or the impact factor of the journal. All relevant articles and reviews were examined for further relevant citations that could be included in the analysis.

### Eligibility Criteria

Each identified study was reviewed and included if it was a clinical comparative study between revision ACLR surgery by aACLR with LET/ALLR or iACLR. Articles were excluded if they were primary reconstructions, nonhuman studies, purely biomechanical evaluations, case reports, expert opinions, technical tips, and publications pertaining to surgical techniques. All forms of patient-reported outcome measures (PROMs), return to pre-injury level, post-operative rotational stability, failure, and complications were included.

### Study Selection and Quality of Studies Assessment

Two authors (K.B. and H.H.C.) independently reviewed the titles and abstracts from the search results. Each author independently reviewed potentially suitable papers, and any discrepancies regarding the eligibility criteria of the papers were resolved by consensus from the senior authors (R.A. and N.S.).

The same 2 authors (K.B. and H.H.C.) assessed the quality of the studies. This was undertaken using the Modified Coleman Methodological Score (MCMS), modified to account for the subject matter<sup>5</sup> (Table 1). The MCMS is based on a scale ranging from 0 to 100, where a score of 85 to 100 is considered excellent, 70 to 84 good, 55 to 69 fair, and <55 poor.

The risk of bias in the included studies was assessed and reported in accordance with the Risk of Bias In Non-randomized Studies of Interventions tool.<sup>55</sup> Each item was judged according to high, moderate, low, or unclear risk of bias. Studies were deemed to have the highest risk of bias if they scored a high or unclear risk of bias.

### Data Synthesis and Statistical Analysis

Review Manager 5.4 software was used for data synthesis. Odds ratios (ORs) were used for all dichotomous variables and standard mean differences for continuous parameters. Statistical heterogeneity was assessed using the  $I^2$  and the chi-square result. A  $P < .1$  and an  $I^2 > 50\%$  were

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TABLE 1  
The MCMS Criteria Used for the Quality of Studies Assessment<sup>a</sup>

Criteria	Domain	Score
<b>Part A</b>		
Study size, N	>60	15
	41-60	10
	20-40	5
	<20, not stated	0
Mean follow-up (months)	>24	10
	12-24	5
	<12, not stated or unclear	0
Type of study (methodology)	Randomized controlled trial	12
	Prospective cohort study	7
	Prospective/ retrospective mixed	3
	Retrospective cohort	0
Diagnostic certainty (clinical examination, Magnetic Resonance Imaging)	In all	5
	≥ 80%	3
	< 80%	0
<b>Part B</b>		
Outcome criteria (12 points)	Clearly defined outcome	3
	Timing of outcome assessment clearly stated	3
	PROMs used	3
	Radiological assessment/ clinical examination	3
Procedures for assessing outcome (8 points)	Clearly defined and objective	2
	Objective	2
	Computer algorithm, blinding	2
	Multiple observers	2
Description of the patient population (10 points)	Inclusion criteria reported and unbiased	4
	Recruitment rate reported ≥ 80%	3
	Recruitment rate reported < 80%	2
	Recruitment rate not reported	0
Details of surgical procedure (8 points)	All eligible patients accounted for in the methodology	3
	Well described	8
	Not adequately described	4
Post-operative rehabilitation (6 points)	Inadequate, not stated, or unclear	0
	Well described	6
	Not adequately described	3
Complications recorded (8 points)	Protocol not reported	0
	All with explanations	8
	Selected complications recorded	4
	Incomplete record	2
Reruptures reported (6 points)	None	0
	Time to failure	3
	No failures in the study	3

<sup>a</sup>MCMS, Modified Coleman Methodological Score; MRI, magnetic resonance imaging; PROM, patient-reported outcome measure.

considered suggestive of statistical heterogeneity, prompting a random-effects model. Otherwise, a fixed-effects model was used.

## RESULTS

The electronic search yielded 581 studies. After removing 157 duplicates, 424 studies remained, of which 380 were excluded after reviewing the abstracts. An additional 34 studies were excluded based on the aforementioned inclusion and exclusion criteria. This left 10 studies for final qualitative and quantitative analyses (Figure 1).<sup>§</sup>

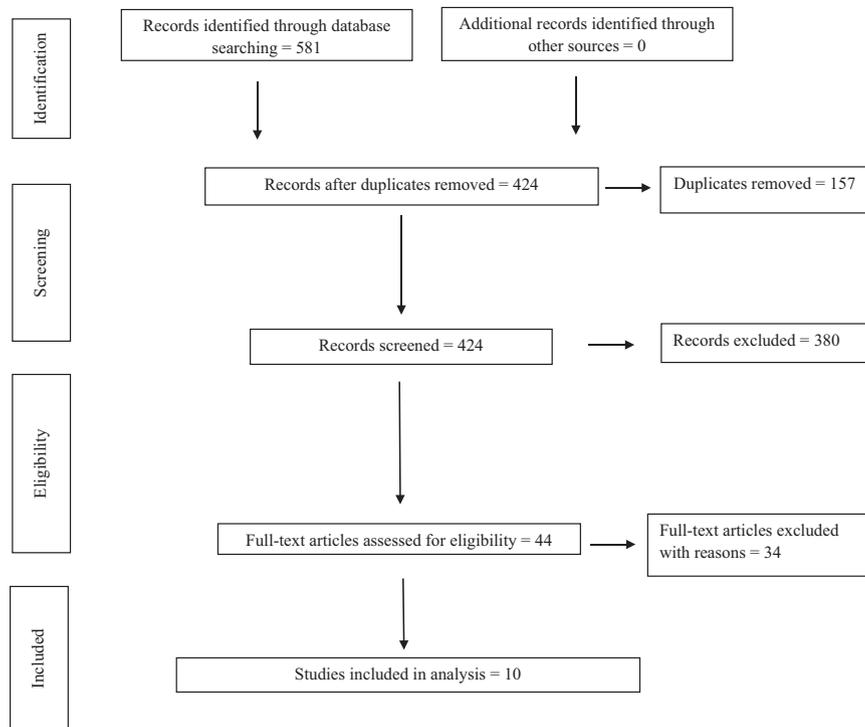
<sup>§</sup>References 2, 9, 18, 25, 27, 28, 48, 56, 58, 61.

## Methodological Quality of Included Studies

Regarding the MCMS of the 10 included studies, there were a mixture of good-<sup>2,18,27</sup> fair-<sup>9,28,48,56,61</sup> and poor-quality studies.<sup>25,58</sup> The overall quality of the studies was fair (mean score, 63.2). The baseline characteristics and surgical techniques of these studies are provided in Tables 2 and 3, respectively.

## Baseline Characteristics

In total, there were 793 patients, of whom 390 had an iACLR while 403 had an aACLR with either a LET or an ALLR. The mean age and time for assessment of PROMs were 29.2 years and 35 months, respectively. Where



**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram for study selection.

described, trauma was the common cause for failure of the primary ACL graft.<sup>9,18,27,61</sup> Three studies described the initial primary graft,<sup>18,25,56</sup> of which the hamstring autograft was the most common in 2 studies.<sup>18,25</sup> Six studies described the extent of knee laxity before revision,<sup>2,9,18,27,48,61</sup> with 4 studies primarily investigating higher-grade ( $\geq 2$ ) pivot shift.<sup>2,18,27,61</sup>

Five studies reported on their rehabilitation protocol.<sup>18,27,28,58,61</sup> All studies differed from each other in regard to full weightbearing, degree of knee motion, and return to sport (RTS).

To conduct a meta-analysis, we ensured certain outcomes were measured in  $\geq 4$  studies with precise means and similar metrics.

The most common PROMs measured were the International Knee Documentation Committee (IKDC), Tegner, and Lysholm scores, with  $\geq 7$  studies for each. Three studies looked at the Knee Injury and Osteoarthritis Outcome Score (KOOS) and RTS at the same level.<sup>9,25,27</sup> In regard to postoperative stability, the grade of the pivot shift and the side-to-side difference (SSD) was measured in the majority of studies, with only 5 studies measuring anterior laxity with Lachman.<sup>2,9,27,58,61</sup>

### Surgical Characteristics (Table 3)

Six studies compared iACLR  $\pm$  LET augmentation,<sup>2,9,25,48,56,58</sup> 3  $\pm$  ALLR,<sup>27,28,61</sup> and 1  $\pm$  LET or ALLR.<sup>18</sup> In 5 studies, there were different harvesting options,<sup>2,9,18,56,61</sup> and in the cases where they were described, they were similarly distributed between

groups.<sup>9,18,61</sup> Two studies used contralateral hamstring autograft,<sup>48,58</sup> 1 ipsilateral bone–patellar tendon–bone (BPTB) autograft,<sup>25</sup> and 2 tibialis anterior allograft.<sup>27,28</sup>

Eight studies described intraoperative meniscal lesions,<sup>9,18,25,27,48,56,58,61</sup> but only 5 directly compared this between groups.<sup>9,18,25,27,61</sup> The distribution of meniscal repair and meniscectomy were similar. Although there were variations between studies in the techniques for revising the ACL, all studies ensured the ACL construct was stabilized in the same way for the group that also underwent anterolateral complex augmentation.

The modified Lemaire procedure was performed in all but 1 study using LET,<sup>2,9,18,25,48</sup> with the remaining study undertaking the Coker-Arnold modification of MacIntosh.<sup>58</sup> ALLR was similarly performed in 3 studies,<sup>27,28,61</sup> where the gracilis allograft was fixed into a tibial and femoral socket at 30° of knee flexion and neutral. The remaining study fixed the graft in extension.<sup>18</sup>

### Study Risk of Bias Assessment

Given the nonrandomized design of all included studies, the risk of selection bias was moderate to high. The risk of all other bias, particularly attrition bias, was generally low. Based on this, we thought the overall risk of bias was moderate to high. The Cochrane risk of bias graph is shown in Figure 2 and the summary in Table 4.

### Clinical Outcomes

A qualitative synthesis of the data is presented in Table 5.

TABLE 2  
Baseline Characteristics of the Included Studies<sup>a</sup>

Study (Year)	Study Design	Age in years (mean +/- SD or range)	Male Sex, n (%)	Study Participants, n (%)		Reason for Failure of Primary ACL Reconstruction, n (%)	Interval Between Reinjury and Revision Surgery (months)	Primary ACL Reconstruction Graft, n (%)	Exclusion
				ACL Revision, n (%)	ACL Revision ± LET/ALLR, n (%)				
Trojani et al <sup>56</sup> (2012)	Retrospective cohort	27.6 (14- 63)	127 (69.4)	79 (48.5)	LET: 84 (51.5)	NR	60 (5-180)	BPTB: 117 (71.8) ST/G: 43 (26.4) QT: 3 (1.8)	MCL/LCL injuries failure of synthetic graft
Porter et al <sup>48</sup> (2018)	Prospective cohort	25.2 ± 6.	18 (47.4)	20 (52.6)	LET: 18 (47.4)		aACLR + LET > iACLR 15.2 ± 11.3 vs 5.8 ± 4.4 (P = .002)	NR	Revision surgery not indicated, unfit for GA, 2-stage revision
DW Lee et al <sup>27</sup> (2019)	Retrospective cohort	27.1 ± 6.9	67 (77)	45 (51.7)	ALLR: 42 (48.3)	Trauma: 73 (83.9) Surgical technique: 14 (16.2)	NR	NR	Multiple ligamentous injuries, contralateral injury, meniscectomized state, OB ≥3, >16-mm tunnel widening
Alm et al <sup>2</sup> (2020)	Prospective cohort	31 ± 10.4	39 (53.4)	14 (19.2)	LET: 59 (80.8)	NR	NR	NR	PCL lesion, knee infection, Beighton ≥5
Ventura et al <sup>58</sup> (2021)	Retrospective cohort	30.4 ± 9.9	19 (79.2)	12 (50)	LET: 12 (50)	NR	NR	NR	NR
Yoon et al <sup>61</sup> (2021)	Retrospective cohort	31.1 ± 10.5	33 (84.6)	21 (53.8)	ALLR: 18 (46.2)	Trauma: 25 (64.1)	NR	NR	≤ grade 1 pivot shift, multiple or bilateral ligament injuries, double-bundle reconstruction, early graft failure, loss of follow-up at 2 years
Eggeling et al <sup>9</sup> (2022)	Retrospective cohort	32.3 ± 10.6	48 (61.5)	55 (70.5)	LET: 23 (29.5)	Trauma: 45 (57.7)	NR	NR	Desire to return to pivoting activities, high-grade anterior knee laxity (SSD ≥5, grade 3 pivot shift) additional injury
Keizer et al <sup>25</sup> (2022)	Retrospective cohort	29.3 ± 8.2	57 (73.1)	36 (46.2)	LET: 42 (53.8)	NR	iACLR > aACLR + LET 62.4 ± 35.2 vs 30.7 ± 12.9; P < .001	Hamstrings; aACLR + LET ~ iACLR 42 (53.8) vs 39 (50); P > .05	Contralateral ACL injury, rerupture revision ACL reconstruction
Helito et al <sup>18</sup> (2022)	Prospective cohort	30.4 ± 6.7	ID	88 (50.6)	ALLR: 41 (23.6) LET: 45 (25.9)	Trauma: 174 (100)	aACLR + LET/ ALL ~ iACLR 10.5 ± 7.7 vs 10.1 ± 7.8; P = .631	Hamstrings, BPTB and QT: aACLR + LET/ALL ~ iACLR 64 (74.4) vs 64 (72.3); 18 (20.9) vs 23 (26.1), 4 (4.7) vs 1 (1.1); P > .05	Associated ligament injuries, osteotomy, cartilage repair, patients lost to follow-up, ≥1 revision surgery
JK Lee et al <sup>28</sup> (2022)	Retrospective cohort	26.4 ± 8.9	32 (82.1)	20 (51.3)	ALLR: 19 (48.7)	NR	NR	NR	<1-year follow-up, age >45 years, multiple ligament or contralateral injury, meniscectomized state, ≥grade 3 OB

(continued)

TABLE 2  
(continued)

Study	Pivot-Shift Grade	Rehabilitation	Follow-up in months (mean +/- SD or range)	Outcomes	MCMS	Value
Trojani et al <sup>56</sup> (2012)	Not described	NR	44 (24-120)	IKDC, pivot shift KT-1000 arthrometric evaluation	59	Fair
Porter et al <sup>48</sup> (2018)	aACL: ≥2 iACL: ≤1	NR	24	Tegner, infrared computerized navigation for pivot shift (anterior translation and internal rotation)	58	Fair
DW Lee et al <sup>27</sup> (2019)	≥2: 84/87	Day 0: extension brace with WBAT 3/52: progressive ROM 0°-90° 6/52: full flexion 2/12: kinetic exercises and specialized training program 6/12: running 9/12: RTS	39.9 ± 7.6	IKDC, Lysholm, Tegner, ACL-RSI, Lachman, pivot shift, KT-2000 arthrometric evaluation, RTS	83	Good
Alm et al <sup>2</sup> (2020)	≥ 2: 71/73	NR	26.4 ± 3.3	IKDC, Lysholm, Tegner, VAS, KOOS, Lachman, pivot shift, Rolimeter arthrometric evaluation	73	Good
Ventura et al <sup>58</sup> (2021)	Not described	0-3/52: crutches and WBAT Proprioception exercises with complete ROM encouraged; 3/12: swimming and indoor cycling 5/12: jogging 6/12: RTS	54 (24-84)	IKDC, Lysholm, Tegner, Lachman, pivot shift, KT-1000 arthrometric evaluation	47	Poor
Yoon et al <sup>61</sup> (2021)	≥: 2: 39/39	0-3/52: extension brace with restricted ROM 4-6/52: ROM to 90°. 6/62: FWB and removal of brace Meniscal repair: NWB and no 90° ROM for first 6 weeks	24	IKDC, Lysholm, Tegner, Lachman, pivot shift, Telos stress arthrometric evaluation	61	Fair
Eggeling et al <sup>9</sup> (2022)	≥2: 36 ≤1: 42	NR	28.7 ± 8.8	IKDC, Lysholm, Tegner, VAS, KOOS, Lachman, pivot shift, Rolimeter arthrometric evaluation, RTS	63	Fair
Keizer et al <sup>25</sup> (2022)	Not described	NR	43.9 ± 29.2	IKDC, Tegner, KOOS, RTS	49	Poor
Helito et al <sup>18</sup> (2022)	≥2: 152/174	Day 1: WBAT with free ROM 12/12: RTS Meniscal repair- extension brace for WB and 0°-90° restricted ROM for 4 weeks	34.1 ± 11	IKDC, Lysholm, pivot shift, KT-1000 arthrometric evaluation	82	Good
JK Lee et al <sup>28</sup> (2022)	Not described	Day 0: extension brace with WBAT 3/52: progressive ROM 0°-90° 6/52: full flexion and closed kinetic chain exercises 6/12: running 9/12: RTS	12	IKDC, Lysholm, Tegner, knee muscle strength, single-leg hop	57	Fair

<sup>a</sup>aACL, augmented ACL reconstruction; ACL, anterior cruciate ligament; ACL-RSI, ACL-Return to Sport after Injury scale; ALL, anterolateral ligament; ALLR, anterolateral ligament reconstruction; BPTB, bone-patellar tendon-bone; FB, full weightbearing; GA, general anaesthetic; iACL, isolated ACL reconstruction; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; LCL, lateral collateral ligament; LET, lateral extra-articular tenodesis; MCL, medial collateral ligament; MCMS, Modified Coleman Methodological Score; NR, not reported; NWB, nonweightbearing; OB, Outerbridge Classification of chondral lesions; PCL, posterior cruciate ligament; QT, quadriceps tendon; ROM, range of motion; RTS, return to sports; SSD, side-to-side difference; ST/G, semitendinous and gracilis; VAS, visual analog scale; WB, weightbearing; WBAT, weightbearing as tolerated.

### Lysholm Score

There were no differences between the 2 groups pre- and postoperatively (preoperative standardized mean difference [SMD], 0.03; 95% CI, -0.20 to 0.25;  $P = .82$ . postoperative SMD, 0.28; 95% CI, -0.09 to 0.66;  $P = .14$ ) (Figure 3, A and B).

### Subjective IKDC Score

Preoperatively, there were no differences between the 2 groups (SMD, -0.12; 95% CI, -0.16 to 0.37;  $P = .64$ ) (Figure

3C). Postoperatively, those patients who had a LET/ALLR augmentation in addition to the revision of the ACL construct had better IKDC scores than those without the augmentation (SMD, 0.27; 95% CI, 0.01 to 0.54;  $P = .04$ ) (Figure 3D).

### Tegner Score

Preoperatively, those without LET/ALLR augmentation had better Tegner scores (SMD, -0.33; 95% CI, -0.64 to -0.02;  $P = .04$ ) (Figure 3E). However, the scores were

TABLE 3  
Description of Surgical Techniques by Author<sup>a</sup>

Study (Year)	Revision ACLR Graft, n (%)	Intraoperative Meniscectomy/Repair, n (%)	Surgical Technique	
			Isolated ACLR	ACLR + LET/ALLR (All Surgical Techniques for ACL as per iACLR)
Trojani et al <sup>56</sup> (2012)	BPTB: 83 (50.9) ST/G: 64 (39.3) QTG: 16 (9.8)	Meniscectomy: 81 (49.7)	NR	NR
Porter et al <sup>48</sup> (2018)	Contralateral autograft DGST: 38 (100)	Meniscectomy: 7 (18.4) Meniscal repair: 2 (5.3)	Tunnels positioned in femoral and tibial ACL footprint Femoral fixation: titanium screw (Smith & Nephew) hand tensioned in full extension Tibial fixation: Bio-screws (BioRCI HA; Smith & Nephew)	LET: Modification of the Modified Lemaire procedure 2 × 6-mm diameter and 25-mm depth reams: one for femoral socket proximal and posterior to lateral femoral epicondyle; one for tibial tunnel line between Gerdy and fibular head Femoral fixation: 7-mm bio-screw (Matryx) Tibial fixation: 7-mm bio-screw tightened with 30° knee flexion and neutral rotation
DW Lee et al <sup>27</sup> (2019)	9-mm TA allograft, 87 (100)	Meniscal repair. aACLR + ALLR ~ iACLR 22 (52.4) vs 20 (44.4); <i>P</i> > .05 Meniscectomy aACLR + ALLR ~ iACLR 4 (8.9) vs 3 (7.1); <i>P</i> > .05	Microfracture lateral and posterior to previous femoral tunnel; Arthrex guide tip inserted into new tunnel via outside-in technique, guide pin drilled 3 cm proximal to lateral epicondyle toward guide tip 9-mm diameter and 25 to 30 mm–depth femoral socket created postgraft passage through tibial tunnel, compression of femoral lateral cortex via ACL Tightrope (Arthrex) tensioned by distal pulling; tibial fixation: biointerference screw (ConMed Linvatec) and staple	ALLR: 6 mm–diameter gracilis allograft 2 × 6-mm diameter and 25-mm depth reams: one for femoral socket proximal and posterior to lateral femoral epicondyle; one for tibial tunnel line between Gerdy and fibular head Femoral fixation: 7-mm bio-screw (Matryx) Tibial fixation: 7-mm bio-screw tightened with 30° knee flexion and neutral rotation
Alm et al <sup>2</sup> (2020)	Single-bundle autograft BPTB, ST/G or quadriceps	NR	Femoral tunnel placement via anteromedial portal; nil other description	LET: Modified Lemaire Procedure 6 to 8 cm–long and 6 to 8 mm–wide strip of distal tractus connected to Gerdy tubercle dissected; proximal end sutured, 2.4-mm K-wire placed 1 cm proximal and posterior to lateral femoral epicondyle; tenodesis tensioned 45° knee flexion
Ventura et al <sup>58</sup> (2021)	Contralateral autograft DGST; 24 (100)	Meniscectomy: 5 (20.8)	Tibial and femoral tunnels drilled through previous tunnels; if previous femoral tunnel malposition: new half-tunnel with knee ROM 90°–120°; femoral fixation: Tightrope (Arthrex) Tibial fixation: Bio-screw (Smith & Nephew), 1 to 2 mm larger than graft with 20° knee flexion with maximal tension	LET: Coker-Arnold modification of MacIntosh ITB detached proximally and redirected under LCL; sutured distally on itself with tibial valgus and external rotation
Yoon et al <sup>61</sup> (2021)	Auto: aACLR + ALLR ~ iACLR 2 (11.1) vs 4 (19); <i>P</i> > .05 Allo: aACLR + ALLR ~ iACLR 16 (88.9) vs 15 (71.4); <i>P</i> > .05	Meniscal repair: aACLR + ALLR ~ iACLR 8/18 (44.4) vs 10/21 (47.6); <i>P</i> > .05 Meniscectomy: aACLR + ALLR ~ iACLR 8 (44.4) vs 4 (19.0); <i>P</i> > .05	Allograft bone into femoral and tibial tunnel if previous >9 mm tibial tunnel: at ACL footprint; curettage and drilling in the old tunnel if overlapping new tunnel; femoral tunnel: at ACL footprint with transportal technique; if previous tunnel malposition: new one placed based on bony landmarks of ACL footprint; after tunnel preparation, revision performed same manner as primary procedure (nil further description)	ALLR: 6 mm–diameter gracilis allograft surgical technique as per DW Lee et al. <sup>27</sup> Femoral fixation: 6-mm biointerference screw Tibial graft fixation: 6-mm biointerference screw 30° knee flexion and neutral
Eggeling et al <sup>9</sup> (2022)	Hamstrings, BPTB and QT: aACLR + LET ~ iACLR 9 (39.1) vs 13 (23.6) 7 (30.4) vs 31 (56.4), 7 (30.4) vs 11 (20); <i>P</i> > .05	Meniscal repair: aACLR + LET ~ iACLR 5 (21.7) vs 12 (21.8); <i>P</i> > .05 Meniscectomy: aACLR + LET ~ iACLR 10 (47.6) vs 24 (43.6); <i>P</i> > .05	Single-bundle ACLR in anterolateral portal (nil further description)	LET: Modified Lemaire Procedure 6 to 8 cm–long and 6 to 8 mm–wide strip of distal tractus connected to Gerdy dissected. Strip secured with Vicryl and attached 1cm proximal and posterior to lateral epicondyle with interference screw at 45° knee flexion
Keizer et al <sup>25</sup> (2022)	Auto ipsilateral BPTB: 78 (100)	Meniscal repair aACLR + LET ~ iACLR 4 (9.5) vs 4 (11.1); <i>P</i> > .05 Meniscectomy aACLR + LET ~ iACLR 26 (61.9) vs 30 (54.5); <i>P</i> > .05	1-stage or 2-stage ACL graft fixed with interference screws 20° knee flexion	Surgical technique as per iACLR LET: Modified Lemaire Procedure

(continued)

TABLE 3  
(continued)

Study (Year)	Revision ACLR Graft, n (%)	Intraoperative Meniscectomy/Repair, n (%)	Surgical Technique	
			Isolated ACLR	ACLR + LET/ALLR (All Surgical Techniques for ACL as per iACLR)
Helito et al <sup>18</sup> (2022)	Hamstrings, BTB and QT: aACLR + ALLR/LET ~ iACLR 27 (31.4) vs 24 (27.3) 27 (31.4) vs 42 (47.7) 13 (15.1) vs 9 (10.2); <i>P</i> > .05	Meniscal repair: aACLR + ALLR/LET ~ iACLR 26 (30.2) vs 22 (25); <i>P</i> > .05 Meniscectomy: aACLR + ALLR/LET ~ iACLR 17 (19.8) vs 11 (12.5); <i>P</i> > .05	Femoral tunnel: outside-in technique close to ACL AM bundle, avoiding previous tunnels; tibial tunnel: drilled from medial tibial plateau using anterior horn lateral meniscal and tibial spines as landmark; tunnel diameters similar to graft diameter; femoral and tibial fixation: interference screw, knee full extension	ALLR: auto or allograft depending on the main ACL graft. Femoral fixation: interference screw proximal and posterior to lateral epicondyle; tibial fixation: tunnel between Gerdy and fibular head Fixation in full extension and neutral knee LET: Modified Lemaire procedure 10 cm-long and 10 mm-wide strip of distal tractus connected to Gerdy tubercle dissected; fixed onto femur posterior and proximal to lateral epicondyle in 0°-30° knee flexion and neutral; fixation: interference screw or suture anchor
JK Lee et al <sup>28</sup> (2022)	9-mm TA allograft 39 (100)	NR	Femoral tunnel: outside-in technique— posterior and lateral than initial femoral tunnel with FlipCutter (Arthrex) Femoral fixation: ACL Tightrope (Arthrex) tensioned by distal pulling of graft; tibial fixation: bio-screw (ConMed LinvateX) and staple	ALLR: Surgical description as per DW Lee et al <sup>27</sup>

<sup>a</sup>ACL, anterior cruciate ligament; aACLR, augmented ACLR; ACLR, ACL reconstruction; ALL, anterolateral ligament; Allo, allograft; ALLR, ALL reconstruction; AM, anteromedial; Auto, autograft; Bio-screw, biointerference screw; BPTB, bone-patellar tendon-bone; DGST, doubled gracilis semitendinosus; iACLR, isolated ACLR; ITB, iliotibial band; LCL, lateral collateral ligament; LET, lateral extra-articular tenodesis; NR, not reported; ST/G, semitendinosus and gracilis; TA, tibialis anterior; QT, quadriceps tendon; ROM, range of motion; ~, equal or similar to.

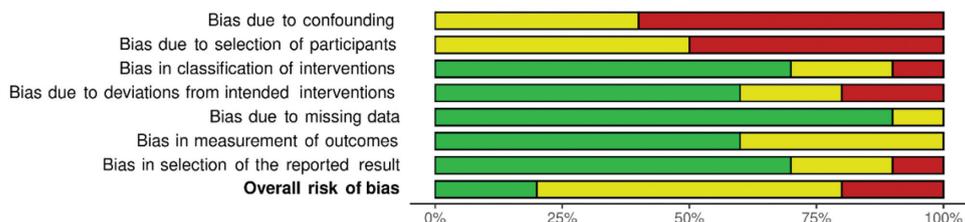


Figure 2. Risk of bias graph.

similar between both groups postoperatively (SMD, 0.21; 95% CI, -0.11 to 0.54; *P* = .20) (Figure 3F).

All Other PROMs

Two of the 3 studies showed significant improvement in KOOS scores,<sup>2,9</sup> particularly on Symptoms, Activities of Daily Living, and Sport and Recreation function when there was a LET/ALLR augmentation to the revised ACL construct. The remaining study showed similar scores between the groups.<sup>25</sup>

Furthermore, 2 of 3 studies showed that adding a LET/ALLR augmentation led to a significantly higher proportion of athletes returning to the same level of sports compared with those without this added augmentation.<sup>25,27</sup> The remaining study showed no difference.<sup>9</sup>

Visual analog scale scores were similar between both groups.<sup>2,9</sup>

Subgroup Analysis: Preoperative High-Grade Knee Laxity

The majority of patients in 4 studies,<sup>2,18,27,61</sup> had preoperative high-grade knee laxity  $\geq 2$  (100%, 97.3%, 97%, and 87.4%, respectively).

When performing a meta-analysis on these studies, an even greater IKDC score in the ALLR/LET augmentation group was observed (SMD, 0.51; 95% CI, 0.16-0.86; *P* = .005) (Figure 4A). The Lysholm score was better in this group compared with those without the additional construct (SMD, 0.45; 95% CI, 0.24-0.67; *P* < .0001) (Figure 4B).

Postoperative Stability and Failure

A qualitative synthesis of the data is presented in Table 6.

There was significant improvement in rotational stability in the aACLR group compared with the iACLR group (OR, 2.77; 95% CI, 1.91 to 4.01; *P* < .00001) (Figure 5A).

TABLE 4  
Risk of Bias Summary<sup>a</sup>

	D1	D2	D3	D4	D5	D6	D7
Trojani 2012	⊗	⊗	⊕	⊗	⊕	⊖	⊕
Porter 2018	⊗	⊗	⊗	⊕	⊕	⊕	⊕
Lee 2019	⊖	⊗	⊕	⊕	⊕	⊕	⊕
Alm 2020	⊗	⊖	⊕	⊕	⊕	⊖	⊖
Ventura 2021	⊗	⊖	⊖	⊖	⊕	⊖	⊕
Yoon 2021	⊖	⊖	⊕	⊕	⊕	⊕	⊕
Eggeling 2022	⊖	⊗	⊕	⊖	⊕	⊕	⊕
Keizer 2022	⊗	⊗	⊕	⊕	⊕	⊕	⊖
Helito 2022	⊗	⊖	⊕	⊗	⊕	⊖	⊗
Lee 2022	⊖	⊖	⊖	⊕	⊖	⊕	⊕

<sup>a</sup>⊗, high risk of bias; ⊖, moderate risk of bias; ⊕, low risk of bias. D1, bias due to confounding data (selection bias); D2, bias in selection of participants into the study (selection bias); D3, bias in the classification of interventions (information bias); D4, bias due to deviations from intended interventions (performance bias); D5, bias due to missing data (attrition data); D6, bias in the measurement of outcomes (detection bias); D7, bias in selection of the reported result (outcome reporting bias)

Both groups had similar restoration in anterior laxity (OR, 1.61; 95% CI, 0.81 to 3.21;  $P = .17$ ) (Figure 5B). Preoperatively, there was no difference in the SSD between the 2 groups (OR, 0.15; 95% CI, -0.06 to 0.35;  $P = .16$ ) (Figure 5C). However, postoperatively, this was significantly elevated in the iACLR group (OR, -0.53; 95% CI, -0.81 to -0.24;  $P = .0003$ ) (Figure 5D).

Five studies defined graft failure after revision.<sup>2,9,18,56,61</sup> All but 1 study had similar definitions,<sup>61</sup> which included a grade  $\geq 2+$  pivot shift and/or SSD  $\geq 5$  mm. Failure was less likely to occur with aACLR (OR, 0.44; 95% CI, 0.24-0.80;  $P = .007$ ) (Figure 5e).

Complications

Four studies reported complications,<sup>18,27,48,58</sup> although only 3 provided adequate descriptions.<sup>18,27,48</sup> There were very few complications, with hematoma formation, cyclops lesion, and superficial infection being the most common.

DISCUSSION

Revision of an ACLR with an extra-articular augmentation leads to better subjective postoperative IKDC scores, a lower incidence of rotational laxity, greater stability in the SSD in stress radiographs, and a lower failure rate compared with those without an augmentation.

Although the Lysholm and Tegner scores were similar, the importance of the favorable subjective IKDC scores in the augmented group should not be underestimated. It is a point-based calculation system, which minimizes confounding patient factors such as age or sex, as it takes various knee-related problems into account.<sup>34,45,49</sup> This is in contrast to the Lysholm score, with concerns of its greater ceiling effects that need to be addressed when assessing the knee function postoperatively.<sup>49</sup>

One explanation regarding the insignificant Tegner scores is that the preoperative activity scores were higher in the group without augmentation. This would favor this cohort rather than the LET/ALLR group in regard to final scores, which were similar in both groups.

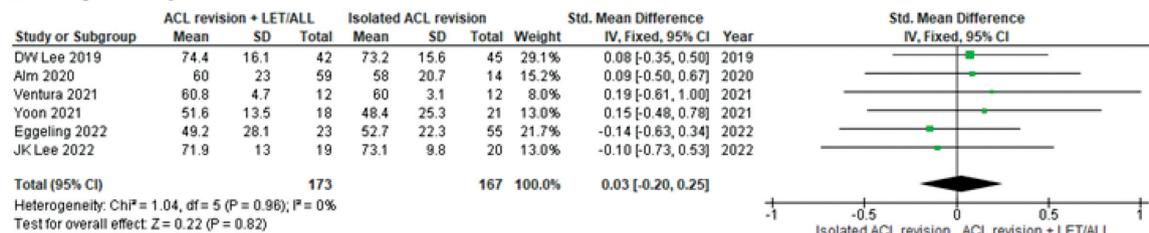
A correlation between cartilage damage and meniscal injuries and the clinical outcomes of revision surgery has previously been demonstrated.<sup>11,23,43</sup> However, this is unlikely to have contributed to the lower IKDC scores in the iACLR group, as such pathology and its treatment, where described, were equally distributed among both cohorts.

Revision ACL is often not expected to yield the same results as primary ACLR and should be considered a salvage procedure with limited goals, such as restoring stability to allow work, activities of daily living, and light recreational sports.<sup>15</sup> As several reports have shown its inferior functional outcomes compared with primary surgery, closer attention should be paid to the cause of failure and the presenting symptoms.<sup>1,16</sup> Based on extensive research, the primary reason for ACLR revision is an unrecognized anterolateral complex injury.<sup>39,51</sup> This can cause persistent rotational instability,<sup>3</sup> and the pivot shift is the most clinically useful test in detecting such pathology.<sup>38</sup> The significantly lower incidence of rotational laxity and side-to-side difference in this meta-analysis after augmentation of the ACLR, with either LET or ALLR, supports the role of the anterolateral complex as an important stabilizer of the knee. In addition, there is the added benefit of protecting the ACL graft from excessive stresses, particularly in the early postoperative period.<sup>28</sup>

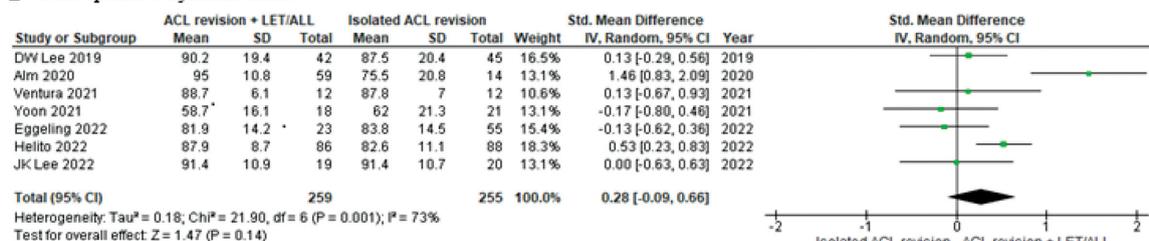
The augmented ACLR could explain the lower incidence of graft failure, as the shared distribution of load minimizes micromovement of the graft in the tunnel, enabling a successful bone-tendon healing interface, and a satisfactory RTS.<sup>53,54,60</sup> The latter is qualitatively supported by 2 of the 3 included studies reporting RTS<sup>25,27</sup>, both of which had a larger LET/ALLR cohort, and showed a higher incidence of returning to the same level of sporting activity in the augmentation group. Despite no differences in the remaining study, the authors did show that lateral extra-articular augmentation led to a more functional knee when performing sports in the KOOS questionnaire.<sup>9</sup>

There are concerns that the extra-articular procedure may result in the overconstraint of the knee with potential adverse effects, including lateral knee pain and reduced range of motion.<sup>10,20,35</sup> The challenge for the orthopaedic surgeon, therefore, is how to select those patients undergoing revision ACLR who would benefit from the addition of an anterolateral procedure. One potential subgroup of patients is those who present with a persistent pivot shift,

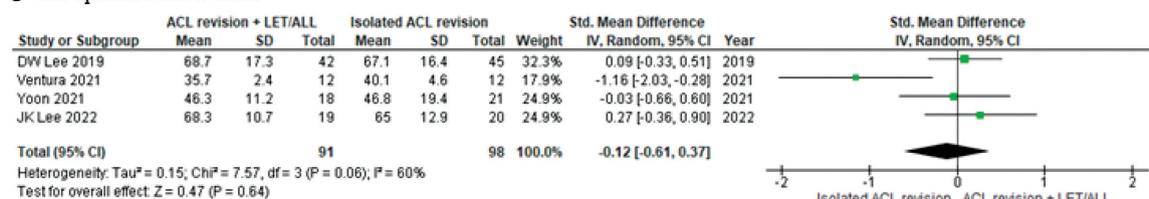
**A Pre-operative Lysholm Score**



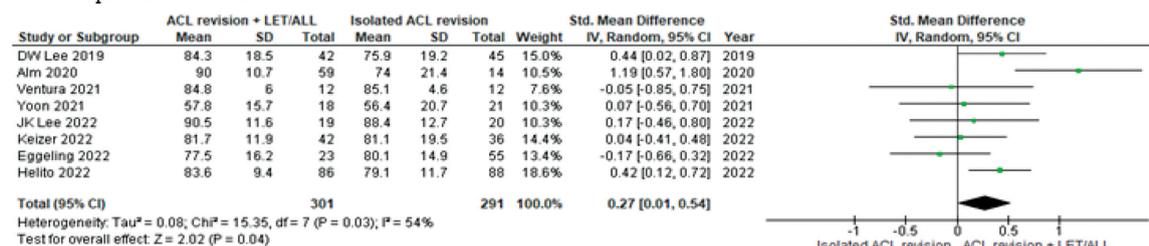
**B Post-operative Lysholm Score**



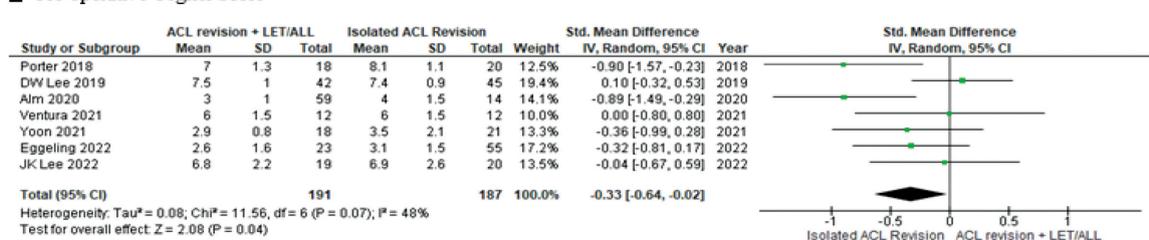
**C Pre-operative IKDC score**



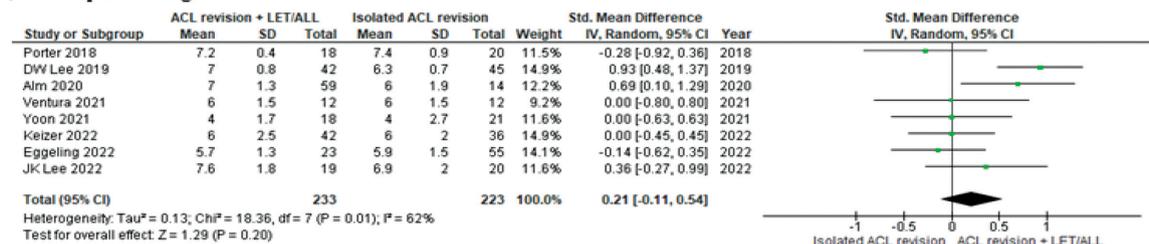
**D Post-operative IKDC score**



**E Pre-operative Tegner Score**



**F Post-operative Tegner score**



**Figure 3.** Forest plots of the comparison between groups for Lysholm, IKDC, and Tegner scores. ACL, anterior cruciate ligament; ALL, anterolateral ligament; IKDC, International Knee Documentation Committee; IV, inverse variance; LET, lateral extra-articular tenodesis.

TABLE 5  
PROMs of Revision of ACLR With and Without Lateral Extra-articular Augmentation<sup>a</sup>

Study (Year)	PROMs					RTS in months (mean +/- SD) (%)
	Lysholm	Subjective IKDC	Tegner	VAS	KOOS	
Trojani et al <sup>56</sup> (2012)	-	-	-	-	-	NR
Porter et al <sup>48</sup> (2018)	-	-	Pre: iACLR > aACLR + LET 8.1 ± 1.1 vs 7 ± 1.3; P < .05 Post: aACLR ~ iACLR 7.2 ± 0.4 vs 7.4 ± 0.9; P = .29	-	-	-
DW Lee et al <sup>27</sup> (2019)	Pre: aACLR + ALLR ~ iACLR 74.4 ± 16.1 vs 73.2 ± 15.6; P = .725 Post: aACLR + ALLR ~ iACLR 90.2 ± 19.4 vs 87.5 ± 20.4; P = .529	Pre: aACLR + ALLR ~ iACLR 68.7 ± 17.3 vs 67.1 ± 16.4; P = .659 Post: aACLR + ALLR > iACLR 84.3 ± 18.5 vs 75.9 ± 19.2; P = .041	Pre: aACLR + ALLR ~ iACLR 7.5 ± 1 vs 7.4 ± 0.9; P = .697 Post: aACLR + ALLR > iACLR 7 ± 0.8 vs 6.3 ± 0.7; P < .001	-	-	Time: aACLR + ALLR > iACLR 9.6 ± 3.4 vs 11.5 ± 3; P = .015 At the same level: aACLR + ALLR > iACLR 24 (57.1) vs 11 (25.6); P = .008
Alm et al <sup>2</sup> (2020)	Pre: aACLR + LET ~ iACLR 60 ± 23 vs 58 ± 20.7; P > .05 Post: aACLR + LET > iACLR 95 ± 10.8 vs 75.5 ± 20.8; P < .001	Post: aACLR > iACLR 90 ± 10.7 vs 74 ± 21.4; P = .001	Pre: aACLR + LET ~ iACLR 3 ± 1 vs 4 ± 1.5; P > .05 Post: aACLR + LET > iACLR 7 ± 1.3 vs 6 ± 1.9; P = .01	Pre: iACLR > aACLR + LET 4 ± 2 vs 3 ± 2.7; P = .023 Post: aACLR + LET ~ iACLR 0 vs 1 ± 2.7; P > .05	Symptoms: aACLR + LET > iACLR 100 ± 9.7 vs 87.6 ± 20.8; P = .02 ADL: aACLR + LET > iACLR 100 ± 4.1 vs 94.3 ± 12.2; P = .003 Sport/Rec: aACLR + LET > iACLR 95 ± 16.1 vs 80 ± 26.3; P = .024 QoL: aACLR ~ iACLR 68.8 ± 17.7 vs 56 ± 24.6; P > .05	-
Ventura et al <sup>58</sup> (2021)	Pre: aACLR + LET ~ iACLR 60.8 ± 4.7 vs 60.0 ± 3.1; P > .05 Post: aACLR + LET ~ iACLR 88.7 ± 6.1 vs 87.8 ± 7; P > .05	Pre: aACLR + LET ~ iACLR 35.7 ± 2.4 vs 40.1 ± 4.6; P > .05 Post: aACLR + LET ~ iACLR 84.8 ± 6.0 vs 85.1 ± 4.6; P > .05	Pre: aACLR + LET ~ iACLR 6 ± 1.5 vs 6 ± 1.5; P > .05 Post: aACLR + LET ~ iACLR 6 ± 1.5 vs 6 ± 1.5; P > .05	-	-	-
Yoon et al <sup>61</sup> (2021)	Pre: aACLR + ALLR ~ iACLR 51.6 ± 13.5 vs 48.4 ± 25.3; P = .855 Post: aACLR + ALLR ~ iACLR 58.7 ± 16.1 vs 62.0 ± 21.3; P = .195	Pre: aACLR + ALLR ~ iACLR 46.3 ± 11.2 vs 46.8 ± 19.4; P = .924 Post: aACLR + ALLR ~ iACLR 57.8 ± 15.7 vs 56.4 ± 20.7; P = .816	Pre: aACLR + ALLR ~ iACLR 2.9 ± 0.8 vs 3.5 ± 2.1; P = .350 Post: aACLR + ALLR > iACLR 4 ± 1.7 vs 4 ± 2.7; P = .919	-	-	-
Eggeling et al <sup>9</sup> (2022)	Pre: aACLR + LET ~ iACLR 49.2 ± 28.1 vs 52.7 ± 22.3; P = .779 Post: aACLR + LET ~ iACLR 81.9 ± 14.2 vs 83.8 ± 14.5; P = .493	Post: aACLR + LET ~ iACLR 77.5 ± 16.2 vs 80.1 ± 14.9; P = .479	Pre: aACLR + LET ~ iACLR 2.6 ± 1.6 vs 3.1 ± 1.5; P = .211 Post: aACLR + LET ~ iACLR 5.7 ± 1.3 vs 5.9 ± 1.5; P = .577	Pre: aACLR + LET ~ iACLR 4.3 ± 2.9 vs 4.2 ± 2.2; P = .855 Post: aACLR + LET ~ iACLR 1.9 ± 2.2 vs 1.2 ± 1.7; P = .142	Symptoms: aACLR + LET ~ iACLR 100 ± 9.7 vs 87.6 ± 20.8; P = .02 ADL: aACLR + LET ~ iACLR 100 ± 4.1 vs 94.3 ± 12.2; P = .003 Sport/Rec: aACLR + LET ~ iACLR 95 ± 16.1 vs 80 ± 26.3; P = .024 QoL: aACLR + LET ~ iACLR 63.8 ± 18.9 vs 58.4 ± 19.7; P = .245	At the same level: aACLR + LET ~ iACLR 11 (47.8) vs 24 (43.6); P = .734

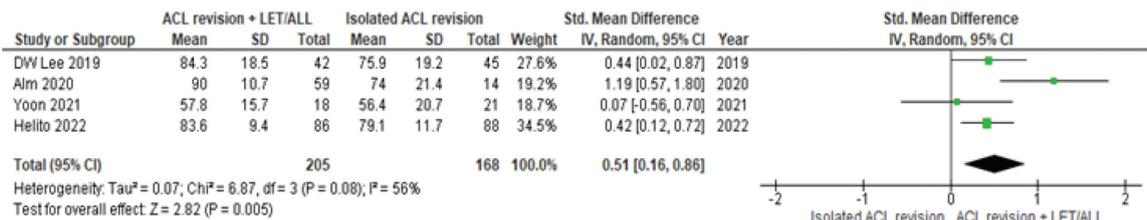
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TABLE 5  
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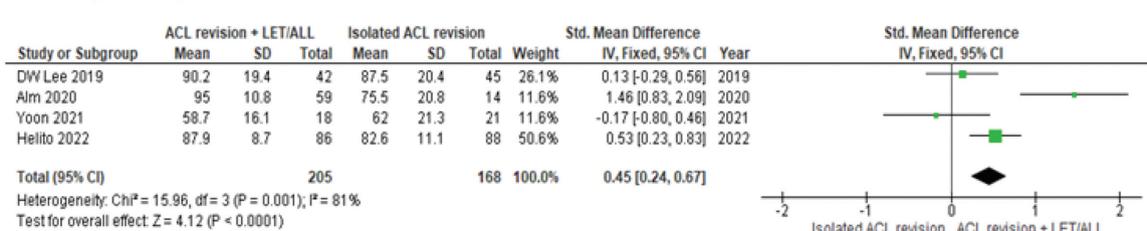
Study (Year)	PROMs					RTS in months (mean +/- SD) (%)
	Lysholm	Subjective IKDC	Tegner	VAS	KOOS	
Keizer et al <sup>25</sup> (2022)	-	Post: aACL + LET ~ iACL 81.7 ± 11.9 vs 81.1 ± 19.5; P > .05	Post: aACL + LET ~ iACL 6 ± 2.25 vs 6 ± 2; P > .05	-	Symptoms: aACL + LET ~ iACL 60.7 ± 13.4 vs 60.7 ± 20.5; P > .05 ADL: aACL + LET ~ iACL 98.5 ± 9.55 vs 98.5 ± 17.3; P > .05 Sports/Rec: aACL + LET ~ iACL 75 ± 20 vs 70 ± 25; P > .05 QoL: aACL + LET ~ iACL 6 ± 2.25 vs 6 ± 2; P > .05	At the same level: aACL + LET > iACL 13 (31) vs 7 (19.4); P < .05
Helito et al <sup>18</sup> (2022)	Post: aACL + LET/ALL > iACL 87.9 ± 8.7 vs 82.6 ± 11.1; P < .001	Post: aACL + LET/ALL ~ iACL 83.6 ± 9.4 vs 79.1 ± 11.7; P = .896				
JK Lee et al <sup>28</sup> (2022)	Pre: aACL + ALLR ~ iACL 71.9 ± 13.0 vs 73.1 ± 9.8; P = .755 Post: aACL + ALLR ~ iACL 91.4 ± 10.9 vs 91.4 ± 10.7; P = .678	Pre: aACL + ALLR ~ iACL 68.3 ± 10.7 vs 65 ± 12.9; P = .383 Post: aACL + ALLR ~ iACL 90.5 ± 11.6 vs 88.4 ± 12.7; P = .581	Pre: aACL + ALLR ~ iACL 6.8 ± 2.2 vs 6.9 ± 2.6; P = .989 Post: aACL + ALLR ~ iACL 7.6 ± 1.8 vs 6.9 ± 2; P = .196	-	-	-

<sup>a</sup>All values are presented as mean +/- SD. ~, similar or equal to; aACL, augmented ACL; ACL, anterior cruciate ligament reconstruction; ADL, Activities of Daily Living; ALLR, anterolateral ligament reconstruction; iACL, isolated ACL; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; LET, lateral extra-articular tenodesis; NR, not reported; Post, postoperative; Pre, preoperative; PROM, patient-reported outcome measure; QoL, Quality of Life; RTS, return to sport; Sport/Rec, Sport and Recreation; VAS, visual analog scale. Dashes indicate not looked into/not explored.

**A Post-operative IKDC score**



**B Post-operative Lysholm score**



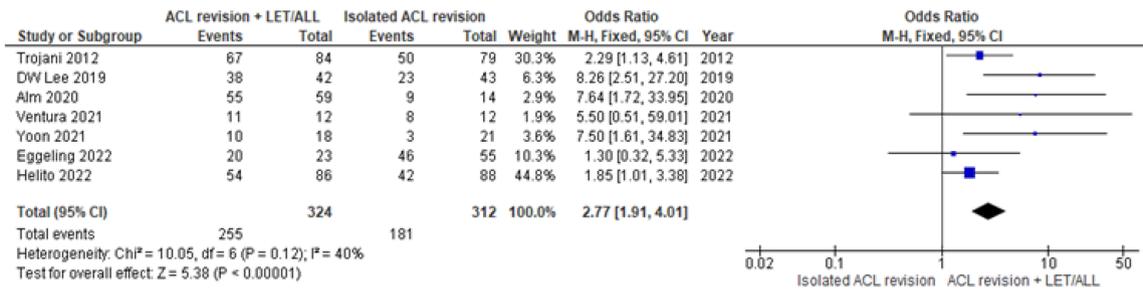
**Figure 4.** Forest plot of subgroup analysis for preoperative high-grade knee laxity. ACL, anterior cruciate ligament; ALL, anterolateral ligament; IKDC, International Knee Documentation Committee; IV, inverse variance; LET, lateral extra-articular tenodesis.

TABLE 6  
Postoperative Stability, Failure Rates, and Complications Between the 2 Groups<sup>a</sup>

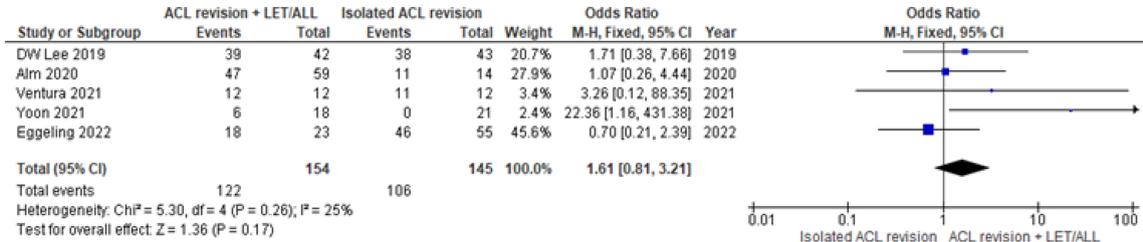
Study (Year)	Negative Pivot-Shift Test, mm, n (%)	Negative Lachman Test (%)	Arthrometric Evaluation SSD, mm	Graft Failure		Complications (%)
				Definition	Outcome (%)	
Trojani et al <sup>56</sup> (2012)	Negative pivot shift test: aACLr + LET > iACLr 6 (80) vs 50 (63); P = .03	NR	>5mm SSD aACLr + LET ~ iACLr 6 (7) vs 12 (15); P > .05	≥2 + pivot shift and/or KT-1000 arthrometer SSD ≥5 mm	aACLr + LET ~ iACLr 6 (7) vs 12(15); P > .05	NR
Porter et al <sup>48</sup> (2018)	Pre-LET added AT: aACLr ~ iACLr 18.5 ± 3 vs 17.7 ± 3.5; P = .48 IR: aACLr ~ iACLr 25.4° ± 3.7° vs 24.2° ± 4.0°; P = .33 Post-LET added AT: aACLr + LET > iACLr 5.3 ± 1.5 vs 6.6 ± 1.9; P = .03 IR: aACLr + LET > iACLr 8.3° ± 2.6° vs 10.3° ± 1.1°; P = .02	-	-	NR	NR	aACLr + LET: 1 superficial infection, 1 meniscal tear and 1 arthrofibrosis requiring surgery iACLr: 1 meniscal tear and 1 rotational instability requiring surgery
DW Lee et al <sup>27</sup> (2019)	Pre: aACLr + ALLr ~ iACLr 0 (0) vs 0 (0); P = .387 Post: aACLr + ALLr > iACLr 38 (90.5) vs 23 (53.5); P < .001	Pre: aACLr + ALLr ~ iACLr 0 (0) vs 0 (0); P = .295 Post: aACLr + ALLr ~ iACLr 39 (92.9) vs 38 (88.4); P = .102	Pre: aACLr + ALLr ~ iACLr 9.8 ± 1.7 vs 9.4 ± 1.4; P = .323 Post: aACLr + ALLr ~ iACLr 1.9 ± 1.3 vs 2.2 ± 1.4; P = .304	Not described	ACL revision: 2 graft reruptures requiring re-revision: 7 grade 2 + pivot but stable	aACLr + ALLr: 1 femoral screw removal for protrusion
Alm et al <sup>2</sup> (2020)	Pre: aACLr + LET ~ iACLr 1 (1.7) vs 0 (14); P > .05 Post: aACLr + LET > iACLr 55 (93.2) vs 9 (64.3); P = .012	Pre: aACLr + LET ~ iACLr 0 (0) vs 0 (0); P > .05 Post: aACLr + LET ~ iACLr 47 (79.7) vs 11 (78.6); P > .05	Pre: aACLr + LET ~ iACLr 5.86 ± 2.8 vs 5.95 ± 2.3; P > .05 Post: iACLr + LET > aACLr 3.8 ± 2.5 vs 1.7 ± 1.4; P = .001	Rolimeter SSD ≥5 mm	iACLr + LET > aACLr 3 (12.4) vs 3 (5.1); P = .045	NR
Ventura et al <sup>58</sup> (2021)	Pre: aACLr + LET ~ iACLr 0/12 (0) vs 0 12 (0); P > .05 Post: aACLr + LET > iACLr 11 (91.7) vs 8 (66.7); P < .05	Pre: aACLr + LET ~ iACLr 0/12 (0) vs 0/12 (0); P > .05 Post: aACLr + LET ~ iACLr 12 (100) vs 11 (91.7); P > .05	Pre: aACLr + LET ~ iACLr 5.6 ± 1.2 vs 5.4 ± 1.3; P > .05 Post: aACLr + LET ~ iACLr 2.8 ± 0.4 vs 3 ± 0.9; P > .05	NR	NR	No major complications
Yoon et al <sup>61</sup> (2021)	Pre: aACLr + ALLr ~ iACLr 0 (0) vs 0 (0); P = .510 Post: aACLr + ALLr > iACLr 10 (55.6) vs 3 (14.3); P = .03	Pre: aACLr + ALLr ~ iACLr 0 (0) vs 0 (0); P = .649 Post: aACLr + ALLr > iACLr 6 (33.3) vs 0 (0); P = .005	Pre: aACLr + ALLr ~ iACLr 7.7 ± 2.9 vs 8 ± 3.6; P = .746 Post: iACLr > aACLr + ALLr 5.9 ± 2.8 vs 3.9 ± 3; P = .018	Further ACLr revision Full tear ACL graft grade 3 pivot	aACLr + ALLr ~ iACLr 2 (11.1) vs 3 (14.3); P = .999	NR
Eggeling et al <sup>9</sup> (2022)	Pre: iACLr > aACLr + LET 5 (9.1) vs 0 (0); P = .005 Post: aACLr + LET ~ iACLr 20 (87) vs 46 (83.6); P = .934	Pre: aACLr + LET ~ iACLr 0 (0) vs 0 (0); P = .146 Post: aACLr + LET ~ iACLr 18 (78.3) vs 46 (83.6); P = .701	Post: aACLr + LET ~ iACLr 1.3 ± 2 vs 1.8 ± 2.1; P = .121	Rolimeter SSD ≥5 mm and/or ≥2 + pivot shift	aACLr + LET ~ iACLr 3 (13) vs 6 (10.9); P = .53	NR
Keizer et al <sup>25</sup> (2022)	-	-	-	NR	NR	NR
Helito et al <sup>18</sup> (2022)	Pre: aACLr + ALLr/LET ~ iACLr 0 (0) vs 0 (0); P = .665 Post: aACLr + ALLr/LET > iACLr 54 (62.8) vs 42 (47.7); P = .035	-	Pre: aACLr + ALLr/LET ~ iACLr 7.3 ± 1.1 vs 7.1 ± 1; P = .234 Post: iACLr > aACLr + ALLr/LET 2.4 ± 1.6 vs 1.6 ± 0.9; P < .001	≥2 + pivot shift and/or KT-1000 arthrometer SSD ≥5 mm or MRI showing graft rupture	iACLr > aACLr + ALLr/LET 13 (14.8) vs 4 (4.7); P = .038	iACLr: 5. 1 hematoma, 1 joint infection. 2 cyclops lesions, and 1 superficial infection aALCR + ALLr/LET: 7. 1 cyst, 1 superficial infection, 1 joint stiffness, 1 loss of extension, 1 lateral pain, 1 cyclops lesion, and 1 haematoma
JK Lee et al <sup>28</sup> (2022)	-	-	-	NR	NR	NR

<sup>a</sup>~, similar or equal to; aACLr, augmented ACL reconstruction; ACL, anterior cruciate ligament; ALL, anterolateral ligament; ALLr, ALL reconstruction; AT, anterior translation; iACLr, isolated ACL reconstruction; IR, internal rotation; LET, lateral extra-articular tenodesis; MRI, magnetic resonance imaging; NR, not reported; Post, postoperative; Pre, preoperative; SSD, side-to-side difference. Dashes indicate not looked into/not explored.

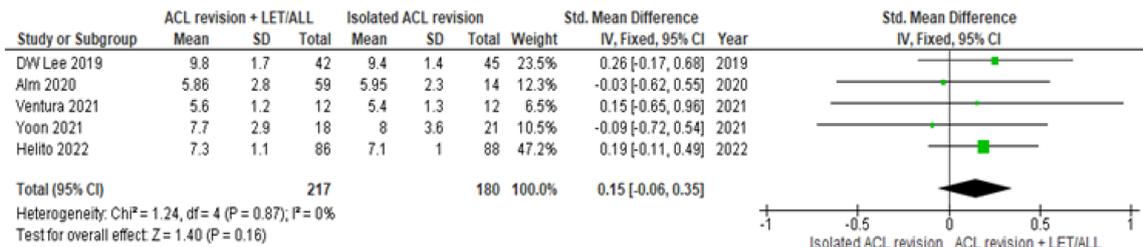
**A Post-operative negative Pivot shift**



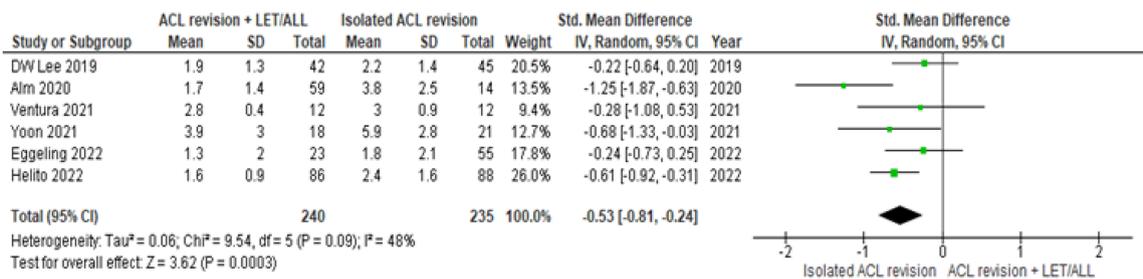
**B Post-operative negative Lachman**



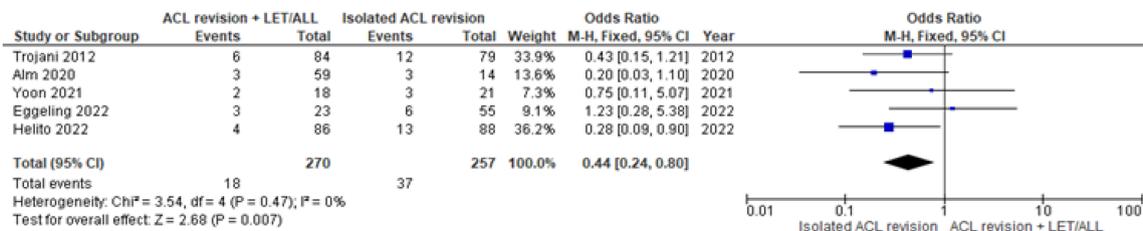
**C Pre-operative side to side difference**



**D Post-operative side-to-side difference**



**E Post-operative failure**



**Figure 5.** Forest plot of postoperative stability and failure between both groups, along with comparison of preoperative to postoperative side-to-side difference. ACL, anterior cruciate ligament reconstruction; ALL, anterolateral ligament; LET, lateral extra-articular tenodesis; M-H, Mantel-Haenszel.

particularly a high-grade ( $\geq 2$ ) laxity, in the revision setting.<sup>8</sup> Subgroup analysis of the studies reporting high-grade pivot shift revealed an even greater postoperative IKDC score in the augmentation group as well as a significantly improved Lysholm score.<sup>2,18,27,61</sup> This suggests that the extent of preoperative anterior knee laxity may be an important, previously underestimated risk factor for revision ACLR failure. Additionally, a low-grade pivot shift ( $< 2$ ) could indicate intact anterolateral structures, thus rendering the additional ALLR/LET procedure ineffective,<sup>9</sup> and unnecessarily overconstraining an already well-preserved anterolateral side of the knee. Due to the inclusion of patients with lower-grade pivot shift preoperatively, the beneficial effects of the extra-articular augmentation may have been underestimated and may provide an alternative explanation for the similar results in most of the PROMs when all studies were analyzed.<sup>9</sup>

Graft choice may have potentially confounded the results of the present study. However, of the 5 studies in which different graft types were used, 4 showed no differences between the groups,<sup>9,18,56,61</sup> thereby enabling comparability. Data were lacking in the final study,<sup>2</sup> but the remaining 5 studies used the same graft construct for all patients. A recent meta-analysis has shown no difference between BPTB and hamstring grafts for ACL revision, although hamstring grafts are the preferred option because of lower donor-site morbidity.<sup>52</sup> In the revision setting, graft standardization is generally not feasible. This is due to the multifactorial nature of revision ACLR surgery taking into account the previous harvested grafts, the type of primary reconstruction used, the size and position of existing tunnels, tunnel widening, and multiple patient factors. The strength of this study includes being the first systematic review to specifically compare the clinical outcomes of revision surgery of the ACL with or without an extra-articular augmentation.

There are some limitations in this study. First, selection bias due to the retrospective, nonrandomized design of the majority of studies may have influenced the results. To date, no prospective randomized study has been performed addressing this question. Only 1 study<sup>56</sup> evaluated degenerative changes with radiographic follow-up. The mean follow-up of 35 months is not long enough to comment on any association with osteoarthritis or the concern that anterolateral augmentation may lead to over constraint and degenerative changes. The wide age range included in the studies may influence the correlation between the study findings and all population groups, including the pediatric and adolescent cohorts. Only 1 study used equipment to enable objective measurement of the pivot shift.<sup>48</sup> The fixation angle and tension of the augmented graft should be adapted according to the amount of rotatory laxity and the type of augmentation procedure performed.<sup>22</sup> This will provide better accuracy in the ability to correct the residual pivot shift and restore function to normal without overconstraining the knee. We recommend the use of equipment that can objectively assess pivot shift in future research on this topic.

Although there were differences in rehabilitation between studies, all studies included a postoperative regimen that was identical between both constructs, limiting its potential as a confounder.

Many factors need to be considered before revision. This includes preoperative factors such as radiographic evaluation, bone tunnel defects, previous femoral tunnel malposition, and graft diameter. Potentially important intraoperative findings and patient-related factors that could affect the outcomes of surgery were compared, although they were not consistent throughout the studies. In the majority of studies, there was no significant difference between the 2 cohorts, enabling comparability between the groups. One potential confounder was the graft positioning during the revision ACLR, particularly if placed in a nonanatomic position. Three studies positioned the graft anatomically,<sup>48,58,61</sup> three nonanatomic,<sup>18,27,28</sup> and the rest did not provide sufficient details.<sup>2,9,25,56</sup> Despite few complications, graft positioning was unreported in 6 studies.<sup>2,9,14,56,58,61</sup> It is important for future research to delve further into this to ensure that morbidity postaugmentation is kept minimal.

## CONCLUSION

Despite the limitations, this meta-analysis provides useful information for clinicians. Lateral extra-articular augmentation to a revision ACLR improved subjective IKDC scores, rotational stability, and reduced failure rates compared with isolated ACLR revision. Although there remains controversy on the necessity of augmenting all revision ACLRs, the present meta-analysis advocates adding a lateral extra-articular procedure in those with a higher-grade pivot shift.

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