Clinical Sports Medicine Update

A Lateral Extra-articular Procedure Reduces the Failure Rate of Revision Anterior Cruciate Ligament Reconstruction Surgery Without Increasing Complications

A Systematic Review and Meta-analysis

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Background: Lateral extra-articular procedures are becoming increasingly popular in association with anterior cruciate ligament (ACL) reconstruction, especially in patients with persistent rotatory instability and in a high-risk population. However, few studies have investigated the outcomes of the lateral extra-articular procedure as an associated procedure in an ACL revision (R-ACLR) setting and its benefit with respect to isolated intra-articular reconstruction.

Hypothesis: Lateral extra-articular procedures reduce the failure rate of revision ACL reconstruction (R-ACLR).

Purpose: To compare subjective outcomes, knee stability, and failure and complication rates between patients who underwent ACL revision with and without an associated lateral extra-articular procedure.

Study Design: Systematic review and meta-analysis; Level of evidence, 3.

Methods: A systematic search of the PubMed, Cochrane, and OVID databases was performed on September 2022 in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Eligible studies were trials directly comparing patients who had isolated ACL revision with patients who had ACL revision associated with lateral extra-articular procedures at a minimum follow-up of 2 years. A meta-analysis was performed, and bias and the quality of the evidence were rated according to the Newcastle-Ottawa Scale. The meta-analysis was conducted according to the PRISMA guidelines.

Results: Eight studies were included: a total of 334 patients were treated with isolated revision (isolated (R-ACLR)) and 342 treated with combined revision and a lateral extra-articular procedure (combined (R-ACLR)). For the failure rate, the meta-analysis showed a significantly decreased relative risk reduction of 54% (*P* = .004) in patients with combined (R-ACLR) with respect to isolated R-ACL, whereas no difference in complication rate was observed. The combined (R-ACLR) group demonstrated a decreased risk ratio of 50% (*P* = .002) for having a positive pivot-shift test result and a relative risk reduction of 68% (*P* = .003) for having a grade 2-3 pivot shift when compared with the isolated (R-ACLR) group. Finally, no significant differences were observed among the lateral extra-articular procedures.

Conclusion: The addition of a lateral extra-articular procedure to revision ACL significantly reduced the failure rate and postoperative pivot shift without increasing the complication rate. Anterolateral ligament reconstruction and a lateral extra-articular procedure with iliotibial band were effective in improving the outcomes of revision ACL reconstruction. Further high-level studies could help to clarify which subgroup of patients could particularly benefit from an anterolateral procedure in the context of ACL revision.

Keywords: anterior cruciate ligament (ACL); revision; complication; meta-analysis; failure

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Management of anterior cruciate ligament (ACL) injury has evolved significantly in the past decades because of an increased awareness of knee anatomy and biomechanics. However, regardless of the surgical technique, poor subjective results, persistent instability, and graft reruptures are reported in a significant number of patients.[9,13,24]

In attempt to reduce and mitigate "anterolateral" knee instability,[14] lateral extra-articular tenodesis (LET)—such as the one described by Amirault et al,[2] Andrews and Sanders,[3] Ellison,[7] and others[16,19]—was often performed in the 1970s and 1980s as a stand-alone procedure. When ACL reconstruction became the standard of care for the treatment of ACL tear, those extra-articular procedures were initially performed in association with intra-articular reconstruction[17,19] and then gradually abandoned for increasing concerns regarding their biomechanics and a possible increase of stiffness, overconstraint, and a higher risk of lateral compartment osteoarthritis.[8,22]

In recent years, there has been a renewed interest in the anterolateral compartment of the knee because in vitro studies have found a significant effect of anterolateral procedures in controlling the pivot shift, reducing the tibial rotation, and decreasing the mechanical stress on the ACL graft.[3,16,23] Moreover, high-level studies have found a significant decrease in ACL graft failure when lateral extra-articular procedures are performed in combination with an intra-articular reconstruction in primary cases.[24]

According to recent systematic reviews and meta-analyses of high-level studies focused on primary ACL reconstruction, LET can improve knee stability by reducing the residual pivot shift, yield superior clinical results, and reduce the graft rerupture rate to less than one-third.[20,23]

Given this clinical evidence, some authors claimed that lateral procedures could be an appealing option in an ACL revision setting to reduce the failure rate and persistent rotatory instability.[3,16] However, there is limited literature available on the outcomes and complications of lateral procedures in the setting of ACL revision and their real benefit as compared with the isolated intra-articular reconstruction. In fact, ACL revision surgery requires the management of multiple challenges, including high-grade rotatory instability, tunnel widening, hardware malposition, previous suboptimal meniscal treatment, and initial cartilage degeneration, highlighting the importance of meticulous preoperative diagnostics and workup, as noted by the ESSKA (European Society of Sports Traumatology, Knee Surgery & Arthroscopy). Consensus on ACL revision.[26] Yet, there is a concern that performing a lateral extra-articular procedure could increase the complication rate and not result in clinically relevant improvement considering the complex scenarios and multiple challenges of the ACL revision setting.

The purpose of this study was thus to perform a systematic review of the literature to evaluate the outcome of revision ACL reconstructions performed in association with lateral extra-articular procedures as compared with isolated ACL revision. The hypotheses were as follows: (1) the combined procedures would result in better objective outcomes, especially in terms of residual rotatory laxity, clinical scores, and lower failure rates, and (2) an increased complication rate could be expected in the combined procedure group. The results of the present study are intended to evaluate the appropriateness of the indication to perform a lateral extra-articular procedure in the setting of ACL revision.

METHODS

No external funding was received for the initiation or completion of this study. A systematic search of the PubMed, Cochrane, and OVID databases was performed on September 2022 following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[18] guidelines to identify all studies related to ACL revision surgery with a concomitant lateral extra-articular procedure as compared with ACL revision surgery alone. A comprehensive systematic search was performed using the following medical keywords for initial screening: "(anterior cruciate ligament OR ACL) AND (anterolateral OR plasty OR lateral OR extraarticular OR tenodesis) AND (revision)." Gray literature was also searched by screening the website ClinicalTrials.gov for concluded or ongoing clinical trials related to the topic of the search.

The titles and abstracts were independently screened by the 2 reviewers (A.G. and R.A.O.H.), and the full text of the relevant articles was obtained.

The inclusion criteria were as follows:

- Prospective, retrospective, or randomized studies comparing patients who had revision ACL reconstruction with a lateral extra-articular procedure versus isolated revision ACL reconstruction
- Minimum mean follow-up of 2 years
- At least 1 of the following outcomes: Lysholm Knee Scoring Scale, Tegner Activity Scale, objective International Knee Documentation Committee (IKDC) classification, Knee injury and Osteoarthritis Outcome Score (KOOS), anteroposterior knee laxity measured using the KT-1000/2000 arthrometer or pivot-shift test, or failure rate
- English, Spanish, or French language.

No restrictions were imposed for graft choice, method of participant matching, or cartilage and meniscal treatment.

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Data Extraction

An electronic table for data extraction was created for the study using Excel (Microsoft). The following data were extracted: title, authors, year of publication, journal, type of study, population characteristics (age at surgery, sex, and time to follow-up), type of intervention (ACL revision surgery with or without lateral extra-articular procedure), the kind of lateral plasty, failure rate, other complications, and clinical and/or functional outcomes. Particular attention was used to identify the reason for the choice between the isolated or combined procedure, the inclusion criteria, and the preoperative laxity of the 2 groups. Surgical details were extracted when reported, including the graft used for revision reconstruction and the meniscal and/or cartilage status.

The mean values of the subjective clinical scores (Lysholm, Tegner, IKDC, and KOOS) were extracted. The objective clinical evaluation was performed by extracting the objective IKDC score, pivot-shift result, arthrometric evaluation, side-to-side difference in stress radiographs, and KT-1000/2000 arthrometer measurements.

The mean side-to-side difference and standard deviation measured in millimeters were extracted for knee laxity. In addition, the number of patients with pivot-shift and Lachman test results classified as normal (grade 0), nearly normal (grade 1), abnormal (grade 2), or severely abnormal (grade 3) were extracted. For statistical analysis and to optimize data extraction when the laxity grade was pooled, 2 separate analyses were performed considering the positive test (grade 1, 2, or 3) or grade 2 and 3 tests as the outcome.

Finally, complications and failures that occurred during the follow-up period were noted. Failures were identified according to the definition of every study as the cases of rerupture or persistent instability.

Quality appraisal of the studies was performed using the modified version of the Newcastle-Ottawa Scale[25] for nonrandomized studies.

Statistical Analysis

All data were presented in tables systematically and narratively. In the case that outcomes were reported in >2 studies, a formal meta-analysis was performed using RevMan (Version 5.4; Cochrane Collaboration). Continuous variables were extracted and analyzed as mean and standard deviation. The corresponding author was contacted and asked to provide the data if the standard deviation was not reported. In the event of no response, the standard deviation was calculated from the available data according to a previously validated formula: [(higher range value – lower range value) / 4] or (interquartile range / 1.35).[12] The highest standard deviation was used if the standard deviation could not be calculated using this approach. The mean difference (MD) and 95% CI were calculated for continuous variables. The risk ratio (RR) and risk difference (RD) were calculated for dichotomous variables. The RR was defined as the ratio of the risk of an event in the 2 groups. It ranges from 0 to infinity, with values of 1 indicating no differences in the risk between the groups; <1, a lower risk in the combined revision and lateral extra-articular procedure group (study group); and >1, a higher risk in the study group. The relative risk reduction was calculated as $(1 - RR) \times 100$. The RD was defined as the difference between the observed risk of the 2 groups (between –1 and +1 and also expressed as percentage).

We tested for heterogeneity using the χ^2 and Higgins I^2 tests; according to the Cochrane guidelines, moderate heterogeneity was considered in the case of $I^2 > 30\%$ or $P < .05$. We adopted a conservative statistical approach by applying a Mantel-Haenszel random-effects model in the presence of moderate heterogeneity and a fixed-effects model when the I^2 and P values were <30% and >.05, respectively. In addition, a sensitivity analysis was performed, removing the studies that included patients with high preoperative laxity. $P < .05$ was considered statistically significant in all analyses.

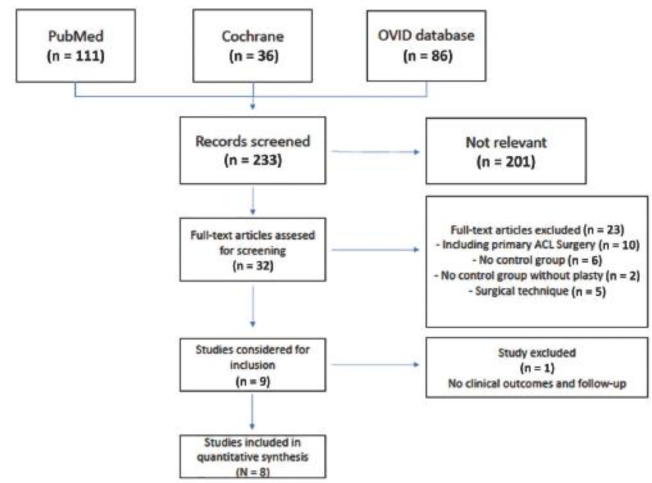


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for study inclusion. ACL, anterior cruciate ligament.

RESULTS

The systematic search generated 111 abstracts from PubMed, 36 from Cochrane, and 86 from OVID, with an additional article identified via the gray literature search (Figure 1). A total of 201 abstracts were excluded by title and abstract screen; 32 articles were obtained in full text; and the selection criteria were applied. Twenty-three articles were excluded, as they were based on primary surgery, did not have a control group, or were surgical technique articles. One study[5] did not have clinical outcomes and follow-up and was thus excluded. One ongoing randomized controlled trial was found on ClinicalTrials.gov (NCT02680821); however, no outcomes were reported yet, and thus it was not included in this review. Finally, 8 studies[1,6,13,15,21,27-29] were included in the systematic review.

TABLE 1
Characteristics of the Included Studies[a]

Study	Journal	Treatment Choice	R-ACL Group	Laxity	Follow-up, mo: Minimum; Mean ± SD	No.	Age, y		Sex	
							Mean	SD	Male	Female
Alm (2020)[1]	*Knee*	Surgeon choice	Isolated	High	24; 26.4 ± 3.3	14	29.3	10.3	8	6
			Combined	High		59	31.4	10.5	31	28
Eggeling (2022)[6]	*Arch Orthop Trauma Surg*	Temporal criteria	Isolated	Low	24; 28.7 ± 8.8	55	31.9	9.9	35	20
			Combined	Low		23	33.3	12.3	13	10
Helito (2023)[13]	*Arthroscopy*	Surgeon choice	Isolated	Mixed	24; 35.3 ± 12.9	88	31.0	5.2	77	11
			Combined	Mixed	24; 32.8 ± 9.1	86	29.8	8.3	66	20
Lee (2019)[15]	*Am J Sports Med*	Temporal criteria	Isolated	Mixed	36; 41.5 ± 8.2	45	27.3	7.6	34	11
			Combined	Mixed	36; 38.2 ± 6.9	42	26.8	6.1	33	9
Porter (2018)[21]	*Am J Sports Med*	Laxity	Isolated	High	24	20	22.6	2.4	9	11
			Combined	High		18	28.2	7.2	9	9
Trojani (2012)[27]	*Knee Surg Sports Traumatol Arthrosc*	Surgeon choice	Isolated	Mixed	24	79	NA	NA	NA	NA
			Combined	Mixed		84	NA	NA	NA	NA
Ventura (2021)[28]	*Orthop Traumatol Surg Res*	Surgeon choice	Isolated	Mixed	24; 54	12	29.3	9.5	9	3
			Combined	Mixed		12	31.4	10.3	10	2
Yoon (2021)[29]	*J Knee Surg*	Temporal criteria	Isolate	High	24	21	29.6	10.2	17	4
			Combined	High		18	32.9	10.8	16	2

[a]NA, not assessed; R-ACLR, revision anterior cruciate ligament.

Study Design and Patient Characteristics

None of the 8 studies were formal randomized controlled trials; the treatment allocation was based on surgeon preference in 4 studies, temporal reason in 3, and intraoperative laxity assessment in 1. Despite the nonrandomized nature of the studies, the approach was considered conservative regarding the assessment of the role of lateral extra-articular procedures, with no risk of overestimating its effect because the trend of the studies was to apply the combined procedure in the high-risk cases with higher laxity. Regarding the pattern of preoperative laxity, 3 studies included only patients with high-grade pivot shift (2, 3); 1 study, only patients with low-grade pivot shift (0, 1); and 4 studies, patients with mixed preoperative laxity. Overall, 334 patients received isolated revision (isolated (R-ACLR)), and 342 received revision and a lateral extra-articular procedure (combined (R-ACLR)). Specifically, a LET with iliotibial band (ITB) was used in 5 studies[1,6,21,27,28]; an anterolateral ligament (ALL) reconstruction, in 2 studies[15,29]; and both techniques[13], in 1 study. Preoperative patient characteristics were similar between the isolated and combined R-ACL groups (Tables 1 and 2).

Meta-analysis of Subjective Outcomes

The Lysholm score, assessed in 6 studies[1,6,13,15,28,29], did not show a significant difference in the MD between the isolated and combined R-ACLR groups (P = .13). A similar trend was reported for the IKDC (P = .16), which was assessed in 6 studies[1,6,13,15,28,29], and for the Tegner score (P = .60), which was assessed in 6 studies[1,6,15,21,28,29] (Table 3, Figure 2). Of the 2 studies that assessed the KOOS, 1 reported significantly better values in patients with combined R-ACLR for 3 subscales (Symptoms, Activities of Daily Living, and Sport/Recreation)[1].

Meta-analysis of Laxity

The Lachman test, assessed in 4 studies, did not show significant differences between the isolated and combined R-ACL groups considering patients with positive Lachman (RD, P = .30; RR, P = .32) and patients with grade 2-3 Lachman (RD, P = .81; RR, P = .64) (Table 4, Figure 3).

Within the 6 studies that assessed anteroposterior laxity with instruments, a significantly lower MD of 0.68 mm was found in patients of the combined R-ACL group when compared with the isolated R-ACL group (P = .003).[1,6,13,15,28,29]

Regarding the pivot-shift test, which was assessed in all 8 studies, a significantly lower risk of having either a positive pivot shift (RD = −0.18, P = .002; RR = 0.50, P = .0001) or a grade 2-3 pivot shift (RD = −0.08, P = .002; RR = 0.32, P = .003) was reported in patients with combined R-ACLR with respect to patients with isolated R-ACL (Table 4).

TABLE 2
Characteristics of the Studies[a]

Study: ACL Failure Characteristics	ACL: Femoral Tunnel	ACL: Graft	Lateral Extra-articular Procedure: Technique	Lateral Extra-articular Procedure: Graft	Meniscal Lesion
Alm (2020)[1]	AM portal				
NA		14 autograft (HT, BPTB, QT)	NA	NA	NA
NA		59 autograft (HT, BPTB, QT)	LET (modified Lemaire)	59 autograft (ITB)	NA
Eggeling (2022)[6]	AL portal				
T: 35		55 autograft (HT, BPTB, QT)	NA	NA	24 medial, 12 lateral
T: 10		23 autograft (HT, BPTB, QT)	LET (modified Lemaire)	23 autograft (ITB)	11 medial, 4 lateral
Helito (2023)[13]	Outside-in				
Td: 10; Ti: 78		75 autograft (HT, BPTB, QT) 13 allograft	NA	NA	23 medial, 16 lateral
Td: 14; Ti: 72		67 autograft (HT, BPTB, QT) 19 allograft	41 ALL-R 45 LET (modified Lemaire)	41 HT or allograft 45 autograft (ITB)	29 medial, 16 lateral
Lee (2019)[15]	All-inside				
T: 36		45 allograft (anterior tibialis)	NA	NA	15 medial, 9 lateral
T: 37		42 allograft (anterior tibialis)	ALL-R	42 allograft (gracilis)	14 medial, 11 lateral
Porter (2018)[21]	NA				
NA		20 autograft (contralateral HT)	NA	NA	NA
NA		18 autograft (contralateral HT)	LET (modified Lemaire)	18 autograft (ITB)	NA
Trojani (2012)[27]	NA				
NA		79 autograft (HT, BPTB, QT)	NA	NA	NA
NA		84 autograft (HT, BPTB, QT)	LET (modified Lemaire)	84 autograft (ITB)	NA
Ventura (2021)[28]	TT or AM portal				
NA		12 autograft (contralateral HT)	NA	NA	NA
NA		12 autograft (contralateral HT)	LET (modified MacIntosh)	12 autograft (ITB)	NA
Yoon (2021)[29]	AM portal				
T: 12		4 autograft, 15 allograft, 2 mixed	NA	NA	10 medial, 2 lateral
T: 13		2 autograft, 16 allograft, 0 mixed	ALL-R	18 allograft (tibialis)	4 medial, 3 lateral

[a]ACL, anterior cruciate ligament; AL, anterolateral; ALL-R, anterolateral ligament reconstruction; AM, anteromedial; BPTB, bone–patellar tendon–bone; HT, hamstring tendon; ITB, iliotibial band; LET, lateral extra-articular tenodesis; NA, not assessed; QT, quadriceps tendon; T, traumatic; Td, traumatic direct; Ti, traumatic indirect; TT, transtibial.

TABLE 3
Meta-analysis of Continuous Variables[a]

		R-ACLR, No. of Patients		Mean Difference Meta-analysis			
	No. of Studies	Combined	Isolated	Model	Mean Difference (95% CI)	*P* Value	Heterogeneity, %
IKDC	6	240	235	RE	2.67 (–1.06 to 6.40)	.16	51
Lysholm	6	240	235	RE	3.46 (–0.97 to 7.89)	.13	63
Tegner	6	172	167	FE	0.06 (–0.17 to 0.30)	.60	13
AP laxity, mm	6	240	235	RE	–0.68 (–1.13 to −0.23)	**.003**	55

[a]Bold indicates $P < .05$. AP, anteroposterior; FE, fixed effect; IKDC, International Knee Documentation Committee; R-ACL, revision anterior cruciate ligament; RE, random effect.

Considering a mean risk of 20.1% for a positive pivot shift in combined R-ACLR and 39.2% in isolated R-ACL, a significant relative risk reduction of 50% was calculated. Similarly, for a mean risk of 3.3% of grade 2-3 pivot shift in combined R-ACL and 11.1% in isolated R-ACL, a significant relative risk reduction of 68% was calculated.

Meta-analysis of Complications and Failures

Complications were assessed in 7 studies; no significant differences were reported between the isolated and combined R-ACL groups (RD, $P = .24$; RR, $P = .19$).[1,6,13,15,21,28,29] However, a significantly lower failure risk was reported in patients with combined R-ACLR when compared with isolated R-ACLR (RD = −0.07, $P = .004$; RR = 0.46, $P = .004$) (Table 4, Figure 3). Considering a mean failure rate of 5.6% in combined R-ACL and 11.7% in isolated R-ACL, a significant relative risk reduction of 54% was calculated.

Subgroups and Sensitivity Analysis

A subgroup analysis was performed by the type of lateral extra-articular procedure (LET vs ALL reconstruction). The analysis performed for the pivot shift and failure rate showed similar results when the isolated revision ACL was compared with combined revision + ALL reconstruction or LET, with no subgroup differences ($P < .05$). In addition, the RD and relative risk of failure between isolated ACL revision and combined ACL revision + ALL reconstruction were similar to those obtained from the analysis of the LET group (Table 5).

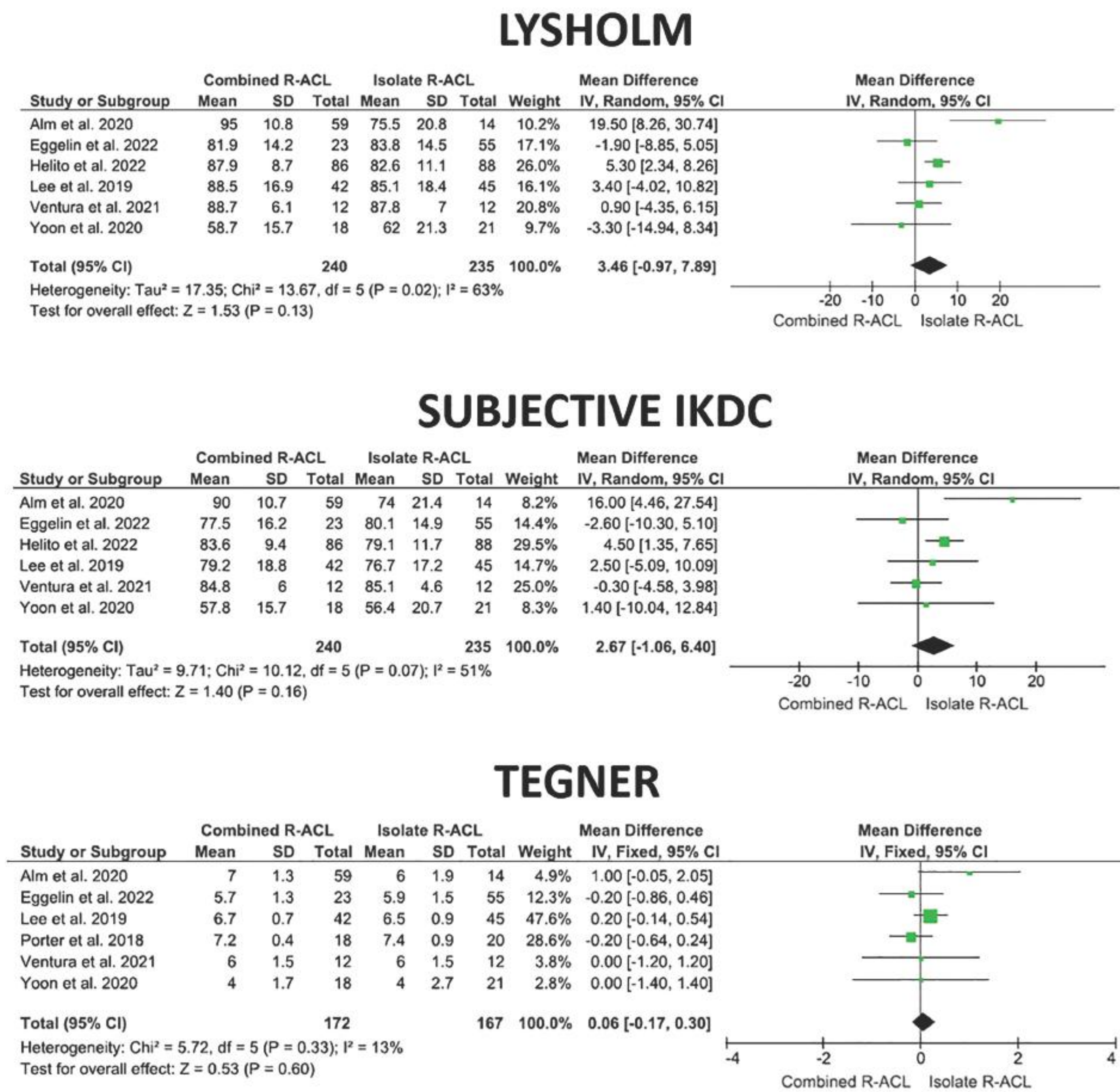


Figure 2. Meta-analysis of subjective outcomes. IV, inverse variance; R-ACL, revision anterior cruciate ligament; IKDC, International Knee Documentation Committee.

TABLE 4
Meta-analysis of Categorical Variables[a]

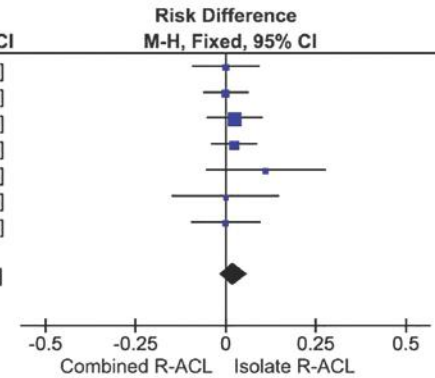
		Combined R-ACL		Isolated R-ACL		Risk Difference Meta-analysis				Risk Ratio Meta-analysis			
Parameter	No. of Studies	No. of Patients	Positive Outcome, %	No. of Patients	Positive Outcome, %	Model	Risk Difference (95% CI)	*P* Value	Heterogeneity, %	Model	Risk Ratio (95% CI)	*P* Value	Heterogeneity, %
Lachman													
1, 2, 3	4	112	25.9	102	32.4	RE	−0.07 (−0.21 to 0.07)	.30	41	FE	0.83 (0.58 to 1.20)	.32	0
2, 3	4	112	7.1	102	13.7	RE	−0.02 (−0.15 to 0.12)	.81	53	RE	0.74 (0.21 to 2.56)	.64	40
Pivot shift													
1, 2, 3	8	342	20.1	334	39.2	RE	−018 (−0.30 to −0.07)	**.002**	72	RE	0.50 (0.35 to 0.71)	**.0001**	40
2, 3	6	246	3.3	243	11.1	FE	−0.08 (−0.13 to −0.03)	**.002**	4	FE	0.32 (0.15 to 0.78)	**.003**	0
Complications	7	258	3.9	255	2.0	FE	0.02 (−0.02 to 0.06)		0	FE	1.91 (0.73 to 5.00)	.19	0
Failures	8	342	5.6	334	11.7	FE	−0.07 (−0.11 to 0.02)	**.004**	0	FE	0.46 (0.27 to 0.78)	**.004**	0

[a]Bold indicates $P < .05$. FE, fixed effect; R-ACL, revision anterior cruciate ligament; RE, random effect.

COMPLICATIONS

Study or Subgroup	Combined R-ACL Events	Combined R-ACL Total	Isolate R-ACL Events	Isolate R-ACL Total	Weight	Risk Difference M-H, Fixed, 95% CI
Alm et al. 2020	0	59	0	14	9.6%	0.00 [-0.09, 0.09]
Eggelin et al. 2022	0	23	0	55	13.8%	0.00 [-0.06, 0.06]
Helito et al. 2022	7	86	5	88	36.9%	0.02 [-0.05, 0.10]
Lee et al. 2019	1	42	0	45	18.4%	0.02 [-0.04, 0.09]
Porter et al. 2018	2	18	0	20	8.0%	0.11 [-0.05, 0.28]
Ventura et al. 2021	0	12	0	12	5.1%	0.00 [-0.15, 0.15]
Yoon et al. 2020	0	18	0	21	8.2%	0.00 [-0.10, 0.10]
Total (95% CI)		**258**		**255**	**100.0%**	**0.02 [-0.02, 0.06]**
Total events	10		5			

Heterogeneity: Chi² = 2.13, df = 6 (P = 0.91); I² = 0%
Test for overall effect: Z = 1.17 (P = 0.24)



FAILURES

Study or Subgroup	Combined R-ACL Events	Combined R-ACL Total	Isolate R-ACL Events	Isolate R-ACL Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Alm et al. 2020	3	59	3	14	12.5%	0.24 [0.05, 1.05]
Eggelin et al. 2022	3	23	6	55	9.1%	1.20 [0.33, 4.38]
Helito et al. 2022	4	86	13	88	33.1%	0.31 [0.11, 0.93]
Lee et al. 2019	0	42	2	45	6.2%	0.21 [0.01, 4.33]
Porter et al. 2018	0	18	0	20		Not estimable
Trojani et al. 2012	6	84	12	79	31.9%	0.47 [0.19, 1.19]
Ventura et al. 2021	0	12	0	12		Not estimable
Yoon et al. 2020	2	18	3	21	7.1%	0.78 [0.15, 4.15]
Total (95% CI)		**342**		**334**	**100.0%**	**0.46 [0.27, 0.78]**
Total events	18		39			

Heterogeneity: Chi² = 3.94, df = 5 (P = 0.56); I² = 0%
Test for overall effect: Z = 2.91 (P = 0.004)

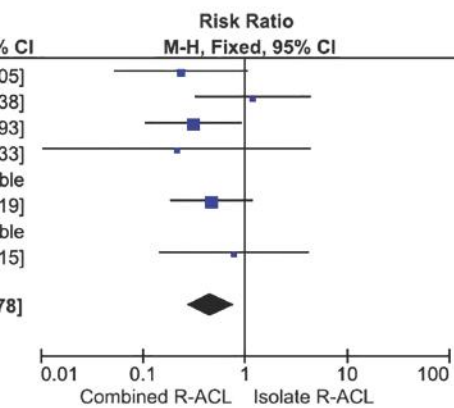


Figure 3. Meta-analysis of complications and failures. R-ACLR, revision anterior cruciate ligament; M-H, Mantel-Haenszel.

Considering the study design and inclusion criteria of each study, a secondary meta-analysis was performed only for the studies involving patients with low or mixed preoperative laxity data. For this reason, 3 studies where the patients presented high preoperative laxity were excluded from this analysis. Thus, 5 studies were included in this sensitivity analysis, which showed consistent results with respect to the main primary meta-analysis (Table 6, Figure 4).[6,13,15,27,28]

Quality Appraisal

All but 2 studies included patients with similar baseline characteristics. Trojani et al[27] performed a multicentric and multisurgeon study, and Porter et al[21] performed the lateral extra-articular procedure only in patients with residual laxity after intra-articular ACL reconstruction. All studies had attrition that did not differ across the groups (0%); the studies also used valid measurement of exposure and had a valid measurement of outcomes. Finally, all studies except 2 disclosed obvious potential conflicts of interest (Table 7).[13,27]

DISCUSSION

The most important finding of the present systematic review and meta-analysis was that adding a lateral extra-articular procedure to revision ACL reconstruction reduced the failure rate and the rotatory laxity of nearly 50% of cases with respect to the isolated intra-articular reconstruction; however, clinical subjective outcomes were similar. Thus, the first hypothesis was partially confirmed. Yet, the second hypothesis was not confirmed because the complication rate was similar between the isolated and combined procedures.

Those results partially align with the literature investigating the outcomes of combined LET procedures in the setting of primary ACL reconstruction.[20] A recent meta-analysis and systematic review similarly found a 3-times reduced risk of graft failure and a 40% diminished risk of

TABLE 5
Subgroup Analysis Based on Type of Lateral Extra-articular Procedure[a]

Parameter	No. of Studies	Combined R-ACLR: No. of Patients	Combined R-ACLR: Positive Outcome, %	Isolated R-ACLR: No. of Patients	Isolated R-ACLR: Positive Outcome, %	Risk Difference Meta-analysis: Model	Risk Difference (95% CI)	*P* Value	Heterogeneity, %	Risk Ratio Meta-analysis: Model	Risk Ratio (95% CI)	*P* Value	Heterogeneity, %
Pivot shift: 1, 2, 3													
LET	6	241	15.8	268	34.0	RE	−0.12 (−0.22 to −0.11)	**.03**	58	FE	0.55 (0.40 to 0.76)	**.0003**	0
ALL reconstruction	3	101	27.7	154	54.6	RE	−0.28 (−0.45 to −0.12)	**.001**	52	FE	0.50 (0.28 to 0.90)	**.02**	65
Subgroup difference								.10	63			.77	0
Pivot shift: 2, 3													
LET	4	145	12.4	177	30.5	RE	−0.12 (−0.21 to −0.03)	**.01**	65	FE	0.58 (0.37 to 0.91)	**.02**	0
ALL reconstruction	3	101	16.8	154	36.4	FE	−0.14 (−0.24 to −0.04)	**.008**	0	FE	0.59 (0.38 to 0.91)	**.02**	29
Subgroup difference								.80	0			.97	0
Failures													
LET	6	241	5.4	268	12.7	FE	−0.8 (−0.13 to −0.02)	**.006**	24	FE	0.42 (0.23 to 0.79)	**.007**	27
ALL reconstruction	3	101	5.0	154	11.7	FE	−0.6 (−0.12 to 0.01)	.10	0	FE	0.50 (0.20 to 1.26)	.14	0
Subgroup difference								.67	0			.76	0

[a]Bold indicates *P* < .05. ALL, anterolateral ligament; FE, fixed effect; LET, lateral extra-articular tenodesis; R-ACLR, revision anterior cruciate ligament; RE, random effect.

TABLE 6
Sensitivity Analysis After Excluding Patients With Low Laxity[a]

Parameter	No. of Studies	Combined R-ACLR: No. of Patients	Combined R-ACLR: Positive Outcome, %	Isolated R-ACLR: No. of Patients	Isolated R-ACLR: Positive Outcome, %	Risk Difference Meta-analysis: Model	Risk Difference (95% CI)	*P* Value	Heterogeneity, %	Risk Ratio Meta-analysis: Model	Risk Ratio (95% CI)	*P* Value	Heterogeneity, %
Pivot shift													
1, 2, 3	5	247	23.1	279	38.7	RE	−0.18 (−0.28 to −0.08)	**.0006**	44	RE	0.54 (0.36 to 0.82)	**.004**	38
2, 3	3	151	2.7	188	11.7	FE	−0.09 (−0.14 to −0.03)	**.002**	13	FE	0.27 (0.11 to 0.70)	**.007**	29
Failures	5	265	5.2	279	11.8	FE	−0.06 (−0.11 to −0.02)	**.01**	0	FE	0.47 (0.26 to 0.85)	**.01**	0

[a]Bold indicates *P* < .05. FE, fixed effect; R-ACLR, revision anterior cruciate ligament; RE, random effect.

persistent positive pivot shift when LET was performed in addition to an intra-articular ACL reconstruction. However, different from our results, patients with primary ACL and LET also showed significantly higher Lysholm and IKDC scores.[20]

Because LET was usually recommended only in high-risk patients, controversies remain regarding its possible role in an ACL revision setting with low preoperative laxity.[1,4] A German research group demonstrated a reduction of failures from 21% to 5% after adding a lateral tenodesis to ACL revision in patients with high preoperative laxity,[1] whereas a similar study did not demonstrate such a benefit when low-laxity cases were evaluated.[6] Of note, the study population of the latter study was limited to 23 patients, which could have not been enough to detect a significant difference in the failure rate.

Apart from reconstruction failures, the present meta-analysis reports a significant reduction of postoperative positive or high-grade pivot shift (see Table 4). This confirmed the clinical efficacy in reducing rotatory laxity suggested in biomechanical studies.[10,20] Furthermore, a reduction of anteroposterior laxity was reported, even though the value of 0.68 mm could be considered irrelevant from a clinical point of view.

Interestingly, complications were not increased despite an additional combined procedure. When patients are counseled before a combined procedure, the only relevant issue could be represented by postoperative lateral-side pain. In fact, Helito et al[13] reported higher pain at the surgical site (72.1% vs 15.9%), which tended to last longer (3.2 vs 1.2 months) when a lateral procedure was performed. In the STABILITY trial, a similar increase in pain on the LET procedure surgical site was noted up to 6 months after surgery when this procedure was combined with primary ACL reconstruction, and a slightly larger number of patients required a second operation for hardware removal.[11] However, because additional cartilage and meniscal surgery could result in increasing pain on the surgical side, this difference in pain perception may be related to additional procedures performed at the time of ACL revision.

Another interesting finding of the present meta-analysis was that no gold standard technique for the lateral extra-articular procedure was identified between the tenodesis with ITB and ALL reconstruction, because both techniques were performed equally (Table 5). These results align with the only comparative study available,[13] which compared 88 isolated ACL revisions with 86 ACL revisions combined with lateral extra-articular procedures, including 41 ALL reconstructions and 45 ITB tenodeses. The authors demonstrated a similar reduction of the failure rate with respect to isolated revision (14.7%), using either ALL reconstruction (7.3%) or ITB tenodesis (2.2%). The relevant differences between the 2 lateral extra-articular procedures were a 2-point improvement of Lysholm score in

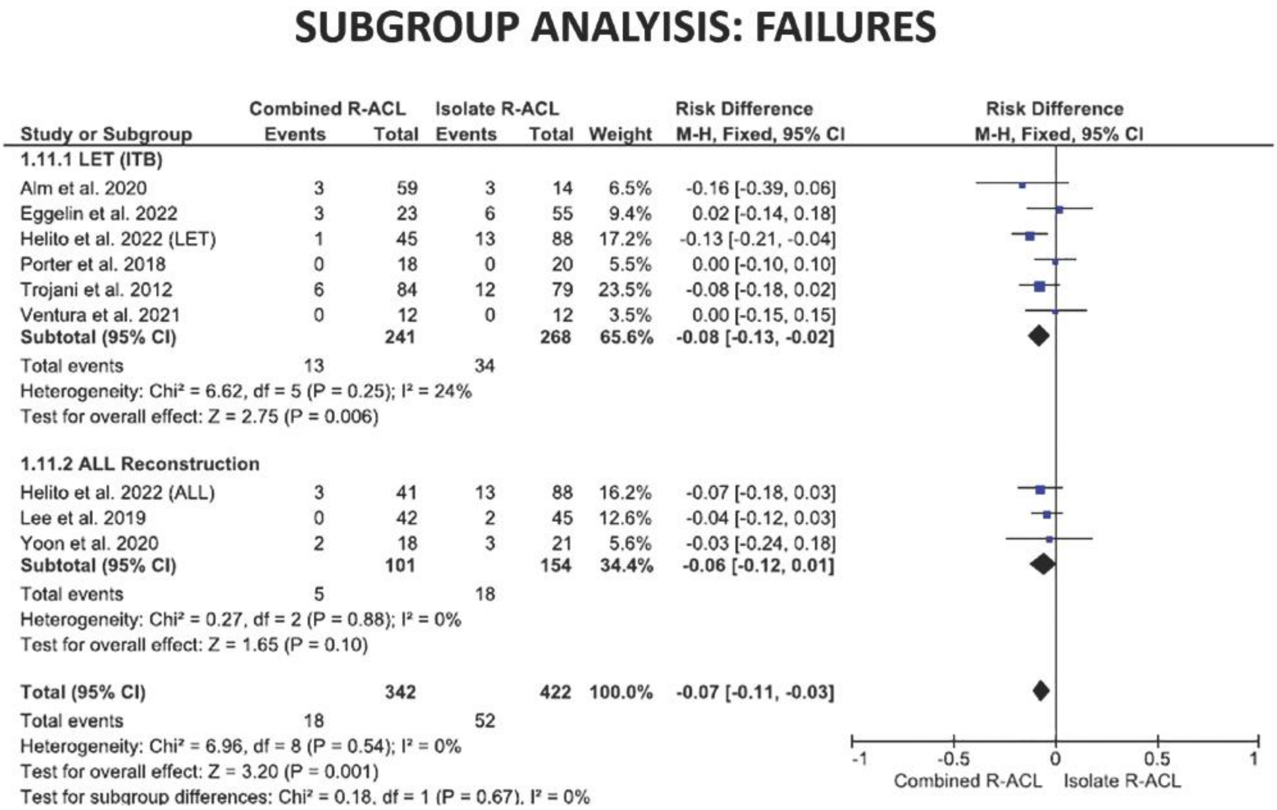


Figure 4. Subgroup analysis of failure rate, according to different surgical techniques of the lateral extra-articular procedure. ALL, anterolateral ligament; ITB, iliotibial band; LET, lateral extra-articular tenodesis; M-H, Mantel-Haenszel; R-ACLR, revision anterior cruciate ligament.

TABLE 7
Quality Appraisal of the Included Studies With the Modified Newcastle-Ottawa Scale[a]

Author	1	2	3	4	5	6	7	8
Lee[15]	Y	Y	Y	Y	N	N	N	Y
Alm[1]	Y	Y	Y	Y	N	N	N	Y
Eggeling[6]	Y	Y	Y	Y	N	N	N	Y
Trojani[27]	N	Y	Y	Y	N	N	N	N
Yoon[29]	Y	Y	Y	Y	N	N	N	Y
Porter[21]	N	Y	Y	Y	N	N	N	Y
Helito[13]	Y	Y	Y	Y	N	N	N	N
Ventura[28]	Y	Y	Y	Y	N	N	N	Y

[a]1: All study groups derived from similar source/reference populations? 2: Attrition not significantly different across study groups? 3: The measurement of exposure is valid? 4: The measurement of outcome is valid? 5: Investigators blinded to end point assessment? 6: Potential confounders identified (eg, comorbidities)? 7: Statistical adjustment for potential confounders made? 8: Funding sources disclosed and no obvious conflict of interests? N, no; Y, yes.

the ALL group and a longer period of postoperative lateral pain in the ITB tenodesis group.

The present study has several limitations. First, it included only nonrandomized comparative trials; unfortunately, randomized controlled studies were not available. Moreover, given the retrospective nature of most of the studies, it was not possible to systematically evaluate the effect on the outcomes of several aspects that should be considered while planning an ACL revision, such as the reason for failure, the meniscal treatment, hyperlaxity, the tibial slope, and the level of sport. Although randomization represents the most crucial characteristic for high-level evidence to avoid selection bias, some clarifications could justify the inclusion of nonrandomized comparative trials in this meta-analysis. In fact, the reason for performing isolated or combined revision ACL reconstruction was determined by surgical preference or temporal criteria in most of the studies and not because of a predefined clinically based algorithm.[6]

Another significant limitation was that only 8 studies with <700 patients were included in the present meta-analysis. Although this number of patients represents a decent sample size to compare the 2 main groups, it may reduce the statistical power for the analysis of several outcomes, especially in the subgroup analysis of the 2 lateral extra-articular procedures. In fact, just 3 studies were included when comparing isolated revision and combined revision + ALL reconstruction, which could have resulted in nonsignificant failure rate results. Yet, the RD and the relative risk were consistent with those obtained after the comparison between isolated revision and combined revision + LET but with larger confidence intervals, thus representing a possible beta error. Moreover, no significant differences were found in the subgroup comparison. Another limitation is related to the lack of a secondary statistical analysis between the groups of patients. Finally, another bias was present owing to the nonblinded patient evaluation and clinical outcomes and the subjective nature of the pivot-shift assessment. However, more objective and less biased outcomes, such as the failure rate, were included.

CONCLUSION

The addition of a lateral extra-articular procedure, either ALL reconstruction or ITB tenodesis, to an intra-articular revision ACL reconstruction was able to reduce the failure rate by nearly 50% and the postoperative pivot shift at short-term follow-up with respect to the isolated procedure, without increasing the number of complications. Outcomes were also better in the case of mixed preoperative laxity and not just in patients with high-grade laxity. ALL reconstruction and LET with ITB were effective in improving the outcomes of revision ACL reconstruction.

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