The Role of Isolated Lateral Extra-Articular Tenodesis in Managing Residual Pivot Shift After Primary Anterior Cruciate Ligament Reconstruction and a New Medial Meniscal Tear

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Background: Persistent mildly abnormal knee kinematics after anterior cruciate ligament (ACL) reconstruction (ACLR) is an ongoing clinical problem.

Purpose: To compare the clinical outcomes of revision ACLR (rACLR), rACLR and lateral extra-articular tenodesis (LET), or isolated LET in patients with a grade ≥2 pivot shift after ACLR with an intact or partially torn graft and a new, symptomatic medial meniscal tear.

Study Design: Cohort study; Level of evidence, 3.

Methods: A retrospective review of all patients with a new, symptomatic medial meniscal tear diagnosed after a primary ACLR was performed. Patients were included if they demonstrated a grade ≥2 pivot shift on physical examination with an intact or partially torn ACL graft. Exclusion criteria included complete graft rupture. The senior author's management evolved in a practice change design from rACLR to rACLR with LET, to isolated LET over the study period. The primary outcomes were the International Knee Documentation Committee (IKDC), Lysholm, and Tegner patient-reported outcomes (PROs) at 2 years postoperatively.

Results: A total of 47 patients, with 16 in the rACLR group, 12 in the rACLR and LET group, and 19 in the isolated LET group were included. Baseline characteristics between groups were similar. At 2 years, the rACLR group IKDC score was 86.1 ± 6.6 and was lower than the rACLR and LET group (91.9 ± 4.4; *P* = .009; 95% CI, –10.4 to –1.2) and the isolated LET group scores (91.7 ± 3.0; *P* = .004; 95% CI, –9.7 to –1.6). The Lysholm score was lower in the rACLR group (85.8 ± 6.3) when compared with the rACLR and LET group (91.8 ± 4.6; *P* = .03; 95% CI, –11.8 to –0.39). There was no difference in any Tegner scores at 2 years (*P* = .09).

Conclusion: In patients with grade ≥2 pivot shift after an ACLR with an intact or partially torn graft and a new, symptomatic medial meniscal tear, the addition of an LET with or without rACLR led to improved PROs compared with an isolated rACLR. An isolated LET in this patient population should be considered an acceptable treatment option.

Keywords: knee ligament; ACL; knee; meniscus; lateral extra-articular tenodesis; reconstruction

Anterior cruciate ligament (ACL) reconstruction (ACLR) is one of the most frequently performed orthopaedic surgical procedures in the United States, with an estimated 350,000 performed annually.[4,34] Although a common procedure, return to activity after ACLR remains a challenge. Prior literature suggests that the rate of return to competitive sports is as low as 33% at 1 year postoperatively and that graft ruptures occur in up to 18% of high-risk athletes.[2,37]

Persistently abnormal knee kinematics after ACLR may play a role in subjective instability, meniscal pathology, and graft rupture.[3,33] Specifically, the medial meniscus may be at risk in patients with a persistently positive pivot shift due to its role as a secondary stabilizer of the knee.[33] Reconstructive techniques of the anterolateral complex such as the lateral extra-articular tenodesis (LET) have

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become increasingly popular as an adjunct to ACLR to mitigate persistent postoperative grade ≥2 pivot shift and graft failure in high-risk patients.[9,11] Notably, Getgood et al[11] found that the addition of an LET to a single-bundle hamstring tendon autograft ACLR resulted in significantly lower postoperative pivot-shift grade and graft rupture at 2 years after surgery.

Acute medial meniscal tears after an ACLR with or without associated graft rupture may be related to subtle persistently abnormal knee kinematics.[17] A revision ACLR (rACLR) is indicated in patients with subjective instability in the setting of complete graft rupture. However, the management of a new postoperative medial meniscal tear with intact or partially torn graft and a grade ≥2 pivot-shift examination is unclear. The purpose of this study was to compare the outcomes of an rACLR, rACLR with LET (rACLR + LET), and isolated LET in the treatment of a postoperative grade ≥2 pivot-shift examination and a new, symptomatic medial meniscal tear with an intact or partially torn ACLR graft. We hypothesized that an isolated LET would have equivalent clinical outcomes at 2 years postoperatively compared with an rACLR or rACLR + LET in treating a postoperative grade ≥2 pivot-shift examination in the context of a new, symptomatic medial meniscal tear after primary ACLR with an intact or partially torn graft.

METHODS

Patient Selection, Treatment, and Outcome Measures

A retrospective review was performed between September 2013 and July 2023 for all patients with a new, symptomatic medial meniscal tear sustained during activity and a grade ≥2 pivot-shift examination after a primary ACLR. A fellowship-trained musculoskeletal radiologist assessed magnetic resonance imaging (MRI) of the knee to diagnose medial meniscal tears and evaluate graft integrity and tunnel position. Patients were included if the ACLR graft was intact or partially torn defined as >50% of the graft still in continuity, in the setting of a new, symptomatic medial meniscal tear. Patients with a pivot-shift grade ≥2 on physical examination in the outpatient clinic setting performed by the senior surgeon (K.J.E.) were included in the study. Patients with grade 3 manual Lachman examination with concomitant ACLR graft rupture or tunnel malposition were excluded and managed with rACLR. Patients <15 years of age, those without a grade ≥2 pivot-shift examination, previous rACLR, previous osteotomy, grade ≥3 chondromalacia, infection, multiligamentous injury or reconstruction, associated cartilage procedure, <2 years of follow-up, and those without outcomes of interest were also excluded.

Patient charts were retrospectively reviewed for outcomes of interest at 6, 12, and 24 months. These included demographic data, initial ACLR graft type, recurrent meniscal tear, pivot-shift grade on physical examination, recurrent ACLR graft tears as detected by MRI, Lysholm patient-reported outcome (PRO) score, International Knee Documentation Committee (IKDC) PRO score, Tegner PRO, and complications. Return-to-sport data including level of return were also collected in athletes.

The senior author's (K.J.E.) preferred treatment for a grade ≥2 pivot-shift examination after ACLR with new medial meniscal pathology changed over the duration of the study. Initially, these cases were managed with rACLR. Throughout the study collection period, management evolved to include the addition of LET to rACLR, followed by isolated LET. As a result, this represented a consecutive series of patients.

Surgical Procedure

Examination under anesthesia and diagnostic arthroscopy were performed in all cases to confirm preoperative diagnosis and decision-making. In cases that involved rACLR, MRI was utilized to evaluate for tunnel widening. In cases that involved >12-mm tunnel diameter, a staged rACLR with initial bone grafting was planned, and the final decision was made during diagnostic arthroscopy. Graft choice was determined primarily by which autograft was available after the initial ACLR. The senior author's preference was to utilize all-soft tissue quadriceps or bone–patellar tendon–bone (BPTB) autograft depending on graft availability. If quadriceps autograft was used for rACLR, an all-inside fixation strategy was achieved with an adjustable loop suspensory system (TightRope; Arthrex) on the femoral side and an attachable button system (Arthrex) on the tibial side. If BPTB was used, adjustable loop suspensory system (Tightrope; Arthrex) was used on the femoral side and aperture fixation with an interference screw (Regenesorb; Smith+Nephew) on the tibial side. A 4.75-mm suture anchor (SwiveLock; Arthrex) was used for secondary fixation on the tibia in all cases.

The LET procedure was performed according to the modified Lemaire technique.[15] A 6-cm longitudinal incision

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was made 1 cm posterior to the lateral epicondyle toward the Gerdy tubercle with the knee in flexion. Dissection was carried down to the iliotibial band (ITB). A 1 cm–wide, 8 cm–long strip of the posterior half of the ITB was isolated and detached proximally. Care was taken not to disrupt the distal attachment onto the Gerdy tubercle. After releasing deep attachments of the vastus lateralis, the free end of the ITB was whipstitched with a nonabsorbable suture. Vertical capsular incisions were made on the anterior and posterior borders of the fibular collateral ligament (FCL) in preparation for ITB passage. The ITB was passed deep to the FCL from distal to proximal utilizing a right-angled clamp. The lateral femoral condylar metaphyseal flare was identified and cleared with electrocautery. With the graft taut but not overtensioned at 60° of knee flexion, fixation on the femoral side was achieved with a 4.75-mm suture anchor or 15-mm socket and 6-mm interference screw (Biosure Regenesorb; Smith & Nephew).

The medial meniscal tear pattern, size, location, chronicity, and tissue quality were assessed by the senior surgeon and considered along with patient characteristics to gauge whether the meniscus was repairable. Longitudinal tears were repaired with an all-inside technique using all-inside meniscal repair devices (FiberStitch; Arthrex), while radial tears were repaired with an outside-in, side-to-side technique, based on the senior surgeon's standard practice. If the tear was judged to be nonrepairable, a partial meniscectomy was performed with a combination of arthroscopic biters and an arthroscopic shaver, maintaining as many circumferential meniscal fibers intact as possible.

Postoperative Care

Patients were placed in a brace locked in extension postoperatively. Weightbearing as tolerated with crutches with the knee in extension was permitted for 2 weeks. At 2 weeks postoperatively, the patient was weaned off crutches and range of motion (ROM) as tolerated in a brace was permitted. Physical therapy was initiated at 2 weeks and focused on ROM and strengthening. Brace use was continued until 6 weeks postoperatively. There were no changes in the postoperative ROM or weightbearing status based on the presence or absence of a meniscal repair or LET. Athletes went through several tests before being cleared for return to sports, with identical protocols between groups. In addition to full ROM and no effusion, quadriceps and hamstring strength were required to be ≥90% of the nonoperative side. In addition, the single-hop and triple-crossover hop test for distance had to be ≤10% of the noninjured leg. Finally, the athlete completed lower extremity functional testing with his or her physical therapist. The patient then advanced to sports-specific training, increasing activities to full contact under athletic trainer supervision. Final clearance came from the senior surgeon when the patient returned to practice and displayed no hesitancy or compensatory strategies during cutting drills, especially deceleration at full effort.

Statistical Analysis

Statistical analysis was performed with computation software (SPSS Statistics, Version 23; IBM). Participant demographics and past surgical history were recorded. A chi-square test was performed to compare initial and rACLR graft type proportion in each group, pre- and postoperative meniscal status, pre- and postoperative physical examination and imaging findings, and postoperative complications between the rACLR, rACLR + LET, and isolated LET groups. A 1-way analysis of variance (ANOVA) with the Bonferroni correction was completed to compare follow-up period duration, IKDC, Lysholm, and Tegner scores preoperatively and at 6, 12, and 24 months postoperatively between groups. Significance was set at $P < .05$ with a 95% CI, and all data are presented as mean and standard deviation.

A post hoc power analysis to assess achieved power was completed using a sample size calculator (G*Power, Version 3.1; Universität Düsseldorf). A 1-way ANOVA analysis of 3 groups with a mean group size of 15, effect size of 0.5, and α of .05 achieved 85% statistical power.

RESULTS

Baseline Characteristics

In total, 1136 ACLRs were completed during the study collection dates. Of these, 76 consecutive medial meniscal tears after ACLR with residual rotational instability were assessed for study eligibility (Figure 1). Ultimately, 47 patients (female, n = 17) were included in the final analysis.

Baseline characteristics are summarized in Table 1. The mean follow-up period after revision surgery was 30 ± 7 months (range, 24-49 months) for the isolated LET group, 33.8 ± 8.4 months (range, 24-53 months) for the rACLR + LET group, and 36.6 ± 11.2 months (range, 24-64 months) for the rACLR group (P = .10). The mean duration between initial and revision surgery was 23.5 ± 11.8 months (range, 5-45 months) for the isolated LET group, 26.5 ± 18 months (range, 7-62 months) for the rACLR + LET group, and 23.4 ± 16 months (range, 5-62 months) for the rACLR group (P = .83).

Prior Surgical Status

All participants except 2 underwent hamstring tendon or BPTB autograft for their initial ACLR, with no difference in initial graft type between groups (P = .87) (Table 2). A total of 24 (51%) participants underwent a concomitant meniscal repair with their initial ACLR, with no difference between groups (P = .60). While there was no difference in preoperative pivot-shift grade between groups (P = .74), the rACLR + LET group had more participants with a positive preoperative Lachman test compared to the other groups (P = .01). There was no difference in the

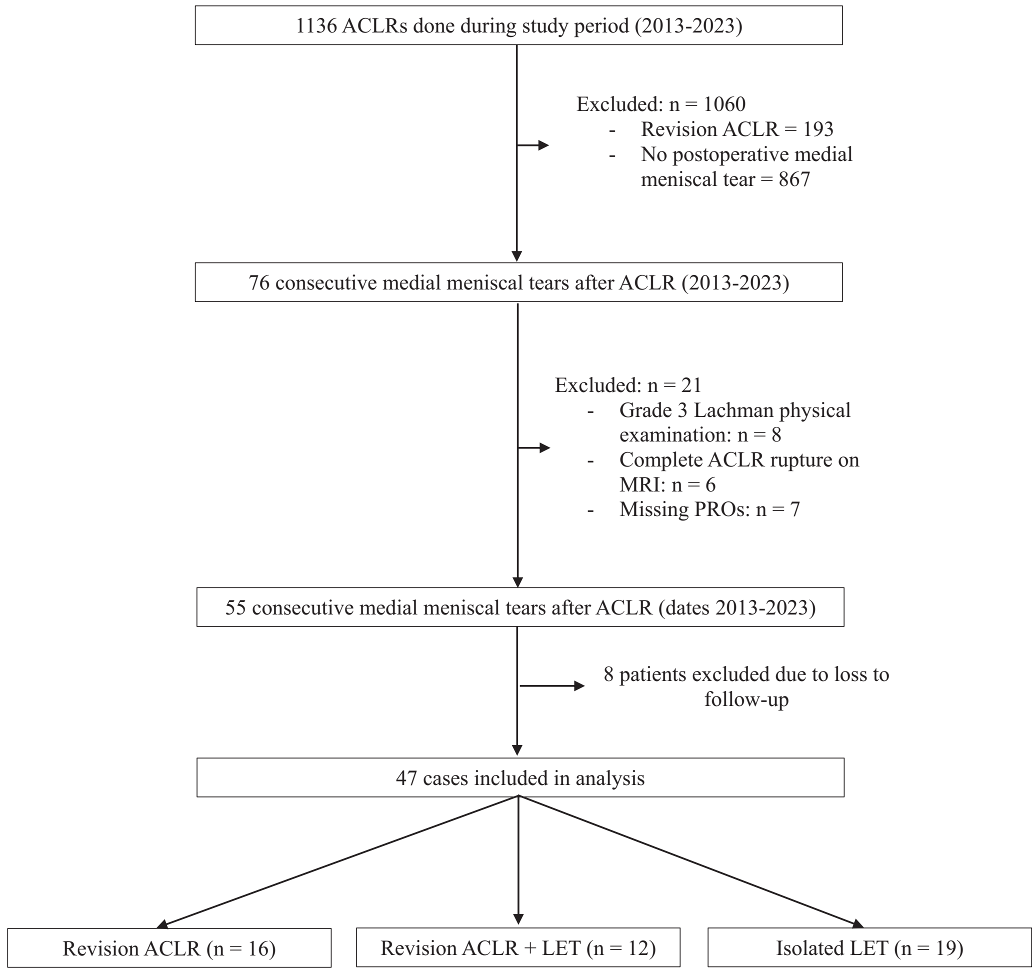

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow diagram. ACLR, anterior cruciate ligament reconstruction; LET, lateral extra-articular tenodesis; MRI, magnetic resonance imaging; PRO, patient-reported outcome.

preoperative Kellgren-Lawrence (KL) osteoarthritis grade (*P* = .39); 31 (66%) participants had evidence of a partial ACL graft injury on preoperative MRI, with no difference between groups (*P* = .75).

Clinical Outcomes

Preoperative IKDC and Lysholm scores were lower in the isolated LET group compared with the rACLR group (IKDC: *P* = .02 [95% CI, –15.9 to –1.0]; Lysholm: *P* = .01 [95% CI, –15.5 to –1.9]) (Figures 2 and 3). There was no difference in the preoperative Tegner scores between groups (*P* = .61) (Figure 4). At 6 months after revision surgery, the rACLR group had higher IKDC scores compared with the rACLR + LET group (*P* = .0001; 95% CI, 5 to 18.3) and higher Lysholm scores compared with both the rACLR + LET (*P* = .001; 95% CI, 4.4 to 18.4) and the isolated LET groups (*P* = .001; 95% CI, 1.2 to 13.7). At 1 year after revision surgery, there were no differences in IKDC scores between groups (*P* = .05), but the Lysholm score was lower in the rACLR group compared with both the isolated LET group (*P* = .017; 95% CI, –9.7 to –0.77) and the rACLR + LET groups (*P* = .002; 95% CI, –12.3 to –2.2). At 2 years after revision surgery, there were no differences in Tegner scores between groups (*P* = .09). The rACLR group had lower mean IKDC scores (86.1 ± 6.6) compared with the rACLR + LET group (mean 91.9 ± 4.4, *P* = .009; 95% CI, –10.4 to –1.2) and isolated LET group (mean 91.7 ± 3.0, *P* = .004; 95% CI, –9.7 to –1.6) and a lower Lysholm score (rACLR mean 85.8 ± 6.3) compared with the rACLR + LET group (91.8 ± 4.6, *P* = .03; 95% CI, –11.8 to –0.39) at 2 years after revision surgery. There was no difference in PROs between the isolated LET and rACLR + LET groups at 2 years after revision surgery ($P \geq .99$). There was no difference in the rate of return to sports (*P* = .10) or return to sports at the same level (*P* = .06) between groups.

There was no difference in the number of meniscal repairs between groups at the time of revision surgery (*P* = .29). There was also no difference in graft type for rACLR (*P* = .35). At the latest follow-up, there was no difference in the KL grade between groups (*P* = .08), the number of retears of the meniscus (*P* = .08), the number of rACLR graft ruptures (*P* = .40) or other complications including

TABLE 1
Baseline Characteristics[a]

	Isolated LET (n = 19)	Revision ACLR + LET (n = 12)	Revision ACLR (n = 16)	95% CI	*P*
Sex					
Male	12 (63.2)	8 (66.7)	10 (62.5)		.06
Female	7 (36.8)	4 (33.3)	6 (37.5)		
Age, y, mean (SD)	23.8 (9.3)	24.6 (9.7)	23.5 (8.8)	–9.3 to 7.7[b] –7.5 to 8.1[c] –9.9 to 7.7[d]	.95
Side					
Left	11 (57.9)	7 (58.3)	7 (43.8)		
Right	8 (42.1)	5 (41.7)	9 (56.3)		
BMI, kg/m^2, mean (SD)	24.3 (4.3)	24.1 (3.4)	25.6 (3.5)	–3.3 to 3.8[b] –4.5 to 2.0[c] –2.2 to 5.1[d]	.53
Global ligamentous laxity	11 (57.9)	6 (50)	7 (43.8)		.91
Beighton score, /9, mean (SD)	2.3 (2.5)	2.9 (2.6)	2.6 (2.6)	–2.9 to 1.7[b] –2.4 to 1.8[c] –2.8 to 2.1[d]	.78
High school athlete	6 (31.6)	3 (25)	6 (37.5)		.78
College athlete	4 (21.1)	4 (33.3)	2 (12.5)		.41
Follow-up, mo, mean (SD)	30 (7.0)	33.8 (8.4)	36.6 (11.2)	–12.1 to 4.4[b] –14.2 to 1.0[c] –5.8 to 11.3[d]	.10
Time interval, mo, mean (SD)	23.5 (11.8)	26.5 (18.0)	23.4 (16.0)	–16.8 to 10.7[b] –12.6 to 12.7[c] –17.3 to 11.2[d]	.83

[a]Data are presented as n (%) unless otherwise indicated. ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; LET, lateral extra-articular tenodesis. Global ligamentous laxity is defined as Beighton Score ≥4.
[b]Confidence interval between isolated LET and revision ACLR + LET groups.
[c]Confidence interval between isolated LET and revision ACLR groups.
[d]Confidence interval between revision ACLR + LET and revision ACLR groups.

painful hardware (*P* = .17), hematoma (*P* = .25), or arthrofibrosis (*P* = .52) (Table 3). Last, a postoperative pivot-shift examination revealed a grade 1 result in 7 (44%) participants in the rACLR group, 1 (8%) participant in the rACLR + LET group and 2 (11%) participants in the isolated LET group (*P* = .03).

DISCUSSION

The most important finding from this study was that there was no difference in 2-year PROs after an isolated LET compared with rACLR + LET when treating a grade ≥2 pivot-shift examination with new, symptomatic medial meniscal tear after primary ACLR with an intact or partially ruptured graft. Additionally, rACLR resulted in significantly lower IKDC and Lysholm scores compared with an rACLR + LET at the 2-year follow-up. Persistent mild abnormality in knee kinematics after an ACLR is an ongoing clinical problem despite advancements in reconstruction techniques.[5,21] These findings suggest that an LET, whether in addition to rACLR or in isolation, leads to an improved pivot-shift examination and subjective outcomes for persistently abnormal knee kinematics after primary ACLR. If an isolated LET avoids the added morbidity of an rACLR including a higher reoperation rate and postoperative complications while achieving the same or better PROs, then it may be a practice-changing development.[20]

Lateral extra-articular procedures were originally described as an isolated treatment for an ACL-deficient knee but fell out of favor due to inferior outcomes and high rates of recurrent symptoms of instability.[23,28] However, the improved rotational control and lower rerupture rate after the addition of a modified Lemaire LET to an ACLR led to a renewed interest in the indications for an isolated LET.[6,11] Further, multiple studies showed equivalent or superior PROs after an ACLR combined with a lateral, extra-articular procedure compared with ACLR alone.[10,30,31] Perelli et al[27] showed improved kinematics and subjective stability after an isolated LET in ACL-deficient knees in patients aged >55 years. However, our study is the first to report improved PROs after an isolated LET in a young, athletic population with a residual grade ≥2 pivot-shift examination after ACLR. This is a potentially unique indication for an isolated LET, when the primary ACLR does not restore completely normal knee kinematics but it is intact on imaging and arthroscopy and may be at least partially functional.

ACL deficiency is a risk factor for subsequent medial meniscal tear due to the secondary stabilizer role of the

TABLE 2
Prior Surgical Status[a]

	Isolated LET (n = 19)	Revision ACLR + LET (n = 12)	Revision ACLR (n = 16)	P
Initial graft				
Hamstring tendon	10 (52.6)	6 (50)	9 (56.3)	.87
BPTB	8 (41.1)	5 (41.7)	7 (43.8)	
Quadriceps	1 (5.3)	1 (8.3)	0 (0)	
Previous meniscal repair	8 (42.1)	7 (58.3)	9 (56.3)	.60
Medial	3 (37.5)	2 (28.6)	4 (44.4)	
Lateral	5 (62.5)	5 (71.4)	5 (55.6)	
Preoperative pivot shift				
Normal	0 (0)	0 (0)	0 (0)	.74
1	0 (0)	0 (0)	0 (0)	
2	10 (52.6)	8 (66.7)	9 (56.3)	
3	9 (47.4)	4 (33.3)	7 (43.8)	
Preoperative Lachman				
Normal	9 (47.4)	0 (0)	5 (31.3)	.01[b]
0-5 mm	4 (21.1)	8 (66.7)	3 (18.8)	
6-10 mm	6 (31.6)	4 (33.3)	8 (50)	
>10 mm	0 (0)	0 (0)	0 (0)	
Preoperative Kellgren-Lawrence grade				
Normal	15 (78.9)	10 (83.3)	10 (62.5)	.39
Mild JSN	4 (21.1)	2 (16.7)	6 (37.5)	
Mild JSN with osteophytes	0 (0)	0 (0)	0 (0)	
JSN, osteophytes, sclerosis	0 (0)	0 (0)	0 (0)	
Endstage degeneration	0 (0)	0 (0)	0 (0)	
Preoperative partial ACL graft injury on MRI	12 (63.2)	9 (75)	10 (62.5)	.75

[a]Data are presented as number (%) unless otherwise indicated. ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BPTB, bone–patellar tendon–bone; JSN, joint space narrowing; LET, lateral extra-articular tenodesis; MRI, magnetic resonance imaging.
[b]Significant difference, $P < .05$.

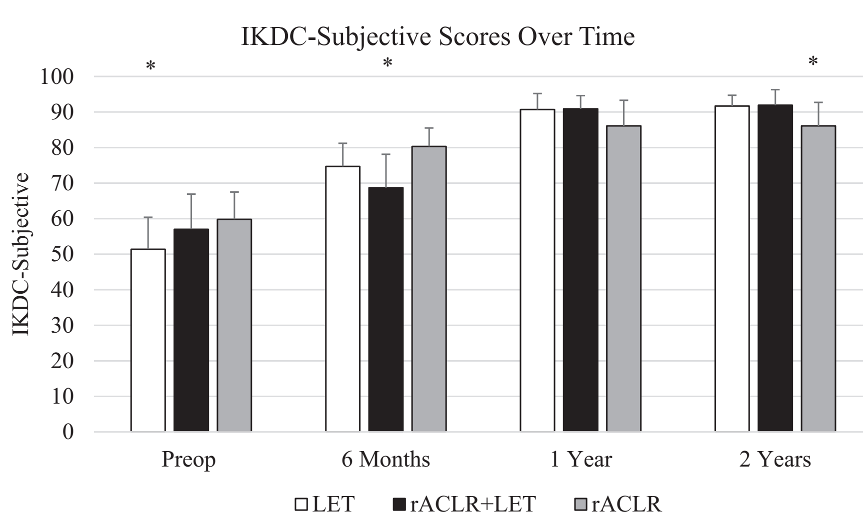

Figure 2. Change in IKDC subjective score over time. Preop: before revision surgery; 6 months, 1 year, and 2 years: postoperative time points; *Significant $P < .05$ compared with 1 other condition at time point. IKDC, International Knee Documentation Committee; LET, lateral extra-articular tenodesis; Preop, preoperative; rACLR, revision anterior cruciate ligament reconstruction.

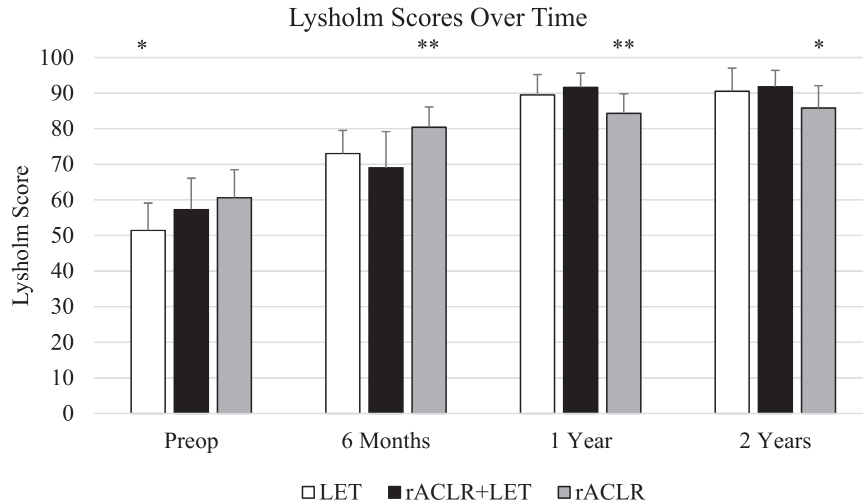

Figure 3. Change in Lysholm score over time. Preop: before revision surgery; 6 months, 1 year, and 2 years: postoperative time points; *Significant $P < .05$ compared with 1 other condition at time point; **Significant $P < .05$ compared with both other conditions at time point. IKDC, International Knee Documentation Committee; LET, lateral extra-articular tenodesis; Preop, preoperative; rACLR, revision anterior cruciate ligament reconstruction.

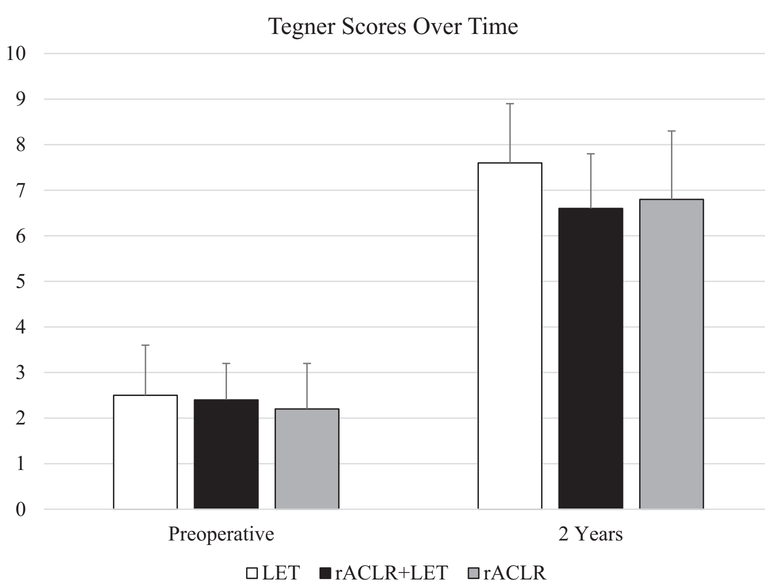

Figure 4. Change in Tegner score over time. Preop: before revision surgery; 2 years: postoperative time point. LET, lateral extra-articular tenodesis; rACLR, revision anterior cruciate ligament reconstruction.

meniscus in anterior knee translation.[5,33] ACLR within 6 months of injury decreases the risk of subsequent meniscal tear but does not eliminate it completely.[13] Our study identified and focused on the group of individuals with a subsequent, symptomatic medial meniscal tear after ACLR suggestive of persistently mildly abnormal knee kinematics. Medial meniscal repair improves anterior tibial translation compared with tear resection.[12] In our study, there was no difference in the number of meniscal repairs between groups at the time of revision surgery (P = .29) and no difference in the number of retears of the meniscus (P = .08) after revision surgery. These findings suggest that an isolated LET after ACLR with a grade ≥2 pivot-shift examination is sufficient to restore rotational stability and avoid further meniscal injury while maintaining equal or superior rates of return to sports.

A persistent pivot shift is associated with symptomatic instability after ACLR.[19,29,35,36] Risk factors for a persistent pivot shift include high-grade preoperative pivot shift under anesthesia and knee hyperextension.[36] There was no difference in preoperative pivot shift between groups in our study, but notably all patients included in this study

TABLE 3
Revision Surgery and Outcomes[a]

	Isolated LET (n = 19)	Revision ACLR + LET (n = 12)	Revision ACLR (n = 16)	P
Revision ACLR graft				
Hamstring tendon		0 (0)	0 (0)	.35
BPTB		3 (25)	6 (37.5)	
Quadriceps		6 (50)	9 (56.3)	
Allograft		3 (25)	1 (6.3)	
Medial meniscal surgery				
Repair	17 (89.5)	10 (83.3)	11 (68.8)	.29
Partial meniscectomy	2 (10.5)	2 (16.7)	5 (31.2)	
Recurrent meniscal tear after revision	1 (5.3)	1 (8.3)	5 (31.3)	.08
Recurrent ACL graft tear	1 (5.3)	0 (0)	2 (12.5)	.40
Postoperative pivot shift				
Normal	17 (89.5)	11 (91.7)	9 (56.3)	.03[b]
1	2 (10.5)	1 (8.3)	7 (43.8)	
2	0 (0)	0 (0)	0 (0)	
3	0 (0)	0 (0)	0 (0)	
Postoperative hematoma	3 (15.8)	1 (8.3)	0 (0)	.25
Postoperative arthrofibrosis	2 (10.5)	2 (16.7)	4 (25)	.52
Painful hardware	1 (5.3)	0 (0)	3 (18.8)	.17
Postoperative Kellgren-Lawrence grade				
Normal	13 (68.4)	10 (83.3)	8 (50)	.08
Mild JSN	3 (15.8)	1 (8.3)	3 (18.8)	
Mild JSN with osteophytes	3 (15.8)	1 (8.3)	5 (31.3)	
JSN, osteophytes, sclerosis	0 (0)	0 (0)	0 (0)	
End-stage degeneration	0 (0)	0 (0)	0 (0)	
Preoperative partial ACL graft injury on MRI	12 (63.2)	9 (75)	10 (62.5)	.75
Return to sports	10 (52.6)	5 (41.7)	6 (37.5)	0.10
Return to sports at same level	9 (47.4)	4 (33.3)	4 (25.0)	0.06

[a]Data are presented as n (%) unless otherwise indicated. ACL, anterior cruciate ligament; ACLR, ACL reconstruction; BPTB, bone–patellar tendon–bone; JSN, joint space narrowing; LET, lateral extra-articular tenodesis; MRI, magnetic resonance imaging.
[b]Significant difference, $P < .05$.

had at least a grade 2 examination. Although the pivot shift is examiner dependent and its accuracy in the context of partial ACL tears is only 68%,[18] the senior author completed all examinations to improve consistency and reliability. We found a greater rate of postoperative grade 1 pivot shift in the rACLR group (7 patients; 44%) compared with 1 patient (8%) after rACLR + LET and 2 patients (11%) after isolated LET, respectively. Our data suggest that the addition of an LET to a previous ACLR, or concomitantly with rACLR, improves the postoperative pivot shift. This is in line with previous findings that showed decreased tibial internal rotation after an LET in clinical and laboratory-based settings.[1,22,24,32] While the LET seemed to be the common factor to improve the pivot-shift examination, it was not the primary outcome of interest and deserves further study.

Abnormal pivot-shift examination after ACLR is associated with reduced athletic career length, inferior Lysholm scores, and higher risk of rACLR.[3,14] Ten (52.6%) of the patients in the isolated LET group returned to sports compared with 5 (41.7%) and 6 (37.5%) in the rACLR + LET and rACLR groups, respectively (P = .10) Similarly, 9 (47.4%) patients in the isolated LET group returned to sports at the same level compared with 4 in the rACLR + LET (33.3%) and rACLR (25.0%) groups, respectively (P = .06). Improved outcomes after an isolated LET may be attributed to the limited morbidity of this procedure compared with an rACLR. Since the majority of ACL reinjuries after ACLR occur early after return to sports and within 2 years of operative intervention, our findings provide insight regarding a high-risk period for reinjury after ACLR.[25] Given these findings, we hypothesized that the addition of an LET would improve the return to sports rate and career longevity among athletes with persistent mildly abnormal knee kinematics after primary ACLR.

Limitations

The retrospective nature, small cohort size, and involvement of a single surgeon limited the statistical strength and external validity of this study. While we found no difference in the initial or rACLR graft type between groups, both variables included multiple graft sources, which may have introduced confounding. It is well documented that allograft has a 4 times–higher rerupture rate than autograft for ACLR, and although only 1 participant in the rACLR group and 3 in the rACLR + LET group underwent an allograft rACLR, it is possible that this affected the study outcomes.[16] Additionally, results of a subgroup analysis to compare the initial ACLR graft type in each group of this study would be underpowered and unreliable. The medial meniscal tear patterns were not recorded and could have differed between groups. Although no 2 meniscal tears are the same, it is likely that tear pattern, size, location, tissue quality, and chronicity all play a role in the amount of stability lost when a meniscal tear is present. Additionally, 9 patients underwent a medial meniscal repair during the initial ACLR, and it is possible that some of these patients presented with failure of meniscal healing rather than a new meniscal tear. However, there was no difference in the number of patients who underwent a medial meniscal repair during the initial ACLR between the 3 groups. Another limitation was that the follow-up period was only 2 years; therefore, we could not make conclusions about the long-term outcomes or robustness of an isolated LET to maintain an improved pivot-shift examination or PROs after an initial ACLR with persistent mildly abnormal knee kinematics and a new medial meniscal tear. Since no time to return to sports was recorded for participants, we could not make definitive conclusions about why at 6 months postoperatively the rACLR group demonstrated the best PROs, but at 1- and 2-year follow-up points the results flipped and the rACLR group demonstrated the worst PROs. However, it is possible that the isolated LET group was cleared for return to sports earlier than the other 2 groups, which resulted in a small initial increase in pain and swelling associated with increased activity in the isolated LET group at that time. Finally, the subjective nature and moderate interrater reliability (IRR) of the Lachman and pivot-shift physical examination maneuvers (IRR, 0.45 and 0.53, respectively this is preexisting evidence, not findings of the current study) limits the reliability of these outcomes.[7,26] Further, since the senior author was not blinded to the treatment during postoperative physical examination, there was a risk of confirmation bias for the associated outcomes. Future analysis may benefit from computer navigation or accelerometer use for kinematic and stability assessment to increase the objectivity and reliability of the results.[8,21]

Future Directions

A prospective, multicenter randomized controlled trial with an adequately powered sample and long-term, objective outcomes such as reinjury rate that compares rACLR, rACLR + LET, and isolated LET to treat a grade $\geq$2 pivot-shift examination after a primary ACLR with a new, symptomatic meniscal tear and intact or partially torn graft would guide future surgeon practice patterns. Additionally, an adequately powered subgroup analysis to compare the initial ACLR graft types would provide insight as to whether the initial graft type affects PROs or postoperative graft failure in this clinical scenario. In the meantime, surgeons must use the evidence available in combination with the specific clinical scenario and their clinical acumen to decide when an LET is indicated in the revision setting after ACLR with residual rotational instability and a possible meniscal tear.

CONCLUSION

In patients with a grade $\geq$2 pivot-shift examination after an ACLR with an intact or partially torn graft and a new, symptomatic medial meniscal tear, the addition of an LET with or without rACLR led to improved PROs compared with an isolated rACLR. An isolated LET in this patient population should be considered an acceptable treatment option.

REFERENCES

1. Ahsan ZS, Berube EE, Frondorf BJ, et al. Role of lateral extra-articular tenodesis in restraining internal tibial rotation: in vitro biomechanical assessment of lateral tissue engagement. *Am J Sports Med*. 2024;52(1):87-95.
2. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to the preinjury level of competitive sport after anterior cruciate ligament reconstruction surgery: two-thirds of patients have not returned by 12 months after surgery. *Am J Sports Med*. 2011;39(3):538-543.
3. Ayeni OR, Chahal M, Tran MN, Sprague S. Pivot shift as an outcome measure for ACL reconstruction: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(4):767-777.
4. Buller LT, Best MJ, Baraga MG, Kaplan LD. Trends in anterior cruciate ligament reconstruction in the United States. *Orthop J Sports Med*. 2015;3(1):2325967114563664.
5. Cristiani R, Rönnblad E, Engström B, Forssblad M, Stålman A. Medial meniscus resection increases and medial meniscus repair preserves anterior knee laxity: a cohort study of 4497 patients with primary anterior cruciate ligament reconstruction. *Am J Sports Med*. 2018;46(2):357-362.
6. Devitt BM, Bell SW, Ardern CL, et al. The role of lateral extra-articular tenodesis in primary anterior cruciate ligament reconstruction: a systematic review with meta-analysis and best-evidence synthesis. *Orthop J Sports Med*. 2017;5(10):2325967117731767.
7. Elasy TA, Gaddy G. Measuring subjective outcomes rethinking reliability and validity. *J Gen Intern Med*. 1998;13:757-761.
8. Figueroa F, Figueroa D, Guiloff R, Putnis S, Fritsch B, Itriago M. Navigation in anterior cruciate ligament reconstruction: state of the art. *J ISAKOS*. 2023;8(1):47-53.
9. Geeslin AG, Moatshe G, Chahla J, et al. Anterolateral knee extra-articular stabilizers: a robotic study comparing anterolateral ligament reconstruction and modified Lemaire lateral extra-articular tenodesis. *Am J Sports Med*. 2018;46(3):607-616.
10. Getgood A, Hewison C, Bryant D, et al; Stability Study Group. No difference in functional outcomes when lateral extra-articular tenodesis is added to anterior cruciate ligament reconstruction in young active patients: the Stability Study. *Arthroscopy*. 2020;36(6):1690-1701.
11. Getgood AMJ, Bryant DM, Litchfield R, et al; STABILITY Study Group. Lateral extra-articular tenodesis reduces failure of hamstring tendon autograft anterior cruciate ligament reconstruction: 2-year outcomes from the STABILITY study randomized clinical trial. *Am J Sports Med*. 2020;48(2):285-297.
12. Grassi A, Dal Fabbro G, Di Paolo S, et al. Medial and lateral meniscus have a different role in kinematics of the ACL-deficient knee: a systematic review. *J ISAKOS*. 2019;4(5):233-241.
13. Hagmeijer MH, Hevesi M, Desai VS, et al. Secondary meniscal tears in patients with anterior cruciate ligament injury: relationship among operative management, osteoarthritis, and arthroplasty at 18-year mean follow-up. *Am J Sports Med*. 2019;47(7):1583-1590.
14. Jackson GR, Lee J, Tuthill T, et al. Higher rates of residual postoperative instability after anterior cruciate ligament reconstruction in

female patients: a systematic review of level II studies. *Arthrosc Sports Med Rehabil*. 2023;5(5):100772.
15. Jesani S, Getgood A. Modified Lemaire lateral extra-articular tenodesis augmentation of anterior cruciate ligament reconstruction. *JBJS Essent Surg Tech*. 2019;9(4):e41.1-e41.7.
16. Kaeding CC, Aros B, Pedroza A, et al. Allograft versus autograft anterior cruciate ligament reconstruction: predictors of failure from a MOON prospective longitudinal cohort. *Sports Health*. 2011;3(1): 73-81.
17. Kobayashi K, Nakayama Y, Shirai Y, Narita T, Mori A. Meniscal tears after anterior cruciate ligament reconstruction. *J Nippon Med Sch*. 2001;68(1):24-28.
18. Leblanc MC, Kowalczuk M, Andruszkiewicz N, et al. Diagnostic accuracy of physical examination for anterior knee instability: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10): 2805-2813.
19. Lie DTT, Bull AMJ, Amis AA. Persistence of the mini pivot shift after anatomically placed anterior cruciate ligament reconstruction. *Clin Orthop Relat Res*. 2007;457:203-209.
20. Marx JS, Plantz MA, Gerlach EB, et al. Revision ACL reconstruction has higher incidence of 30-day hospital readmission, reoperation, and surgical complications relative to primary procedures. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(5):1605-1610.
21. Napier RJ, Feller JA, Devitt BM, et al. Is the KiRA device useful in quantifying the pivot shift in anterior cruciate ligament–deficient knees? *Orthop J Sports Med*. 2021;9(1):2325967120977869.
22. Nazzal EM, Keeling LE, Ryan PM, Herman ZJ, Hughes JD. The role of lateral extra-articular tenodesis in anterior cruciate ligament reconstruction and treatment of rotatory knee instability: a scoping review. *Curr Rev Musculoskelet Med*. 2023;16(6):235-245.
23. Neyret P, Palomo JR, Donell ST, Dejour H. Extra-articular tenodesis for anterior cruciate ligament rupture in amateur skiers. *Br J Sports Med*. 1994;28(1):31-34.
24. Özbek EA, Runer A, Dadoo S, et al. The effect of lateral extra-articular tenodesis in an ACL-reconstructed knee with partial medial meniscectomy: a biomechanical study. *Am J Sports Med*. 2023; 51(13):3473-3479.
25. Paterno MV, Rauh MJ, Schmitt LC, Ford KR, Hewett TE. Incidence of second ACL injuries 2 years after primary ACL reconstruction and return to sport. *Am J Sports Med*. 2014;42(7):1567-1573.
26. Peeler J, Leiter J, Macdonald P. Accuracy and reliability of anterior cruciate ligament clinical examination in a multidisciplinary sports medicine setting. *Clin J Sport Med*. 2010;20:80-85.
27. Perelli S, Gelber PE, Morales-Avalos R, et al. Isolated lateral extra-articular tenodesis in ACL-deficient knees: in vivo knee kinematics and clinical outcomes. *Knee Surg Sports Traumatol Arthrosc*. 2023;31(8):3212-3220.
28. Reid J, Hanks G, Kalenak A, Kottmeier S, Aronoff V. The Ellison iliotibial-band transfer for a torn anterior cruciate ligament of the knee. Long-term follow-up. *J Bone Joint Surg Am*. 1992;74(9): 1392-1402.
29. Ristanis S, Stergiou N, Patras K, Vasiliadis HS, Giakas G, Georgoulis AD. Excessive tibial rotation during high-demand activities is not restored by anterior cruciate ligament reconstruction. *Arthroscopy*. 2005;21(11):1323-1329.
30. Rowan FE, Huq SS, Haddad FS. Lateral extra-articular tenodesis with ACL reconstruction demonstrates better patient-reported outcomes compared to ACL reconstruction alone at 2 years minimum follow-up. *Arch Orthop Trauma Surg*. 2019;139(10):1425-1433.
31. Saithna A, Monaco E, Carrozzo A, et al. Anterior cruciate ligament revision plus lateral extra-articular procedure results in superior stability and lower failure rates than does isolated anterior cruciate ligament revision but shows no difference in patient-reported outcomes or return to sports. *Arthroscopy*. 2023;39(4):1088-1098.
32. Slette EL, Mikula JD, Schon JM, et al. Biomechanical results of lateral extra-articular tenodesis procedures of the knee: a systematic review. *Arthroscopy*. 2016;32(12):2592-2611.
33. Sommerfeldt M, Raheem A, Whittaker J, Hui C, Otto D. Recurrent instability episodes and meniscal or cartilage damage after anterior cruciate ligament injury: a systematic review. *Orthop J Sports Med*. 2018;6(7):2325967118786507.
34. Sugimoto D, LeBlanc JC, Wooley SE, Micheli LJ, Kramer DE. The effectiveness of a functional knee brace on joint-position sense in anterior cruciate ligament–reconstructed individuals. *J Sport Rehabil*. 2016;25(2):190-194.
35. Tashman S, Collon D, Anderson K, Kolowich P, Anderst W. Abnormal rotational knee motion during running after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2004;32(4):975-983.
36. Ueki H, Nakagawa Y, Ohara T, et al. Risk factors for residual pivot shift after anterior cruciate ligament reconstruction: data from the MAKS group. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(12): 3724-3730.
37. Webster KE, Feller JA. Exploring the high reinjury rate in younger patients undergoing anterior cruciate ligament reconstruction. *Am J Sports Med*. 2016;44(11):2827-2832.