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Original Research

Lateral extra-articular tenodesis reduces graft failure without affecting functional outcomes after revision anterior cruciate ligament reconstruction: A retrospective comparative study with 6-year follow-up

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ABSTRACT

Introduction: Revision anterior cruciate ligament reconstruction (ACLR) is associated with a substantially higher risk of anterior cruciate ligament (ACL) graft failure than primary ACLR. Lateral extra-articular tenodesis (LET) has gained increasing attention as an adjunctive procedure to enhance rotatory stability and potentially reduce the rate of ACL graft failure. The purpose of this study was to compare clinical and functional outcomes between patients undergoing isolated revision ACLR and those undergoing revision ACLR with concomitant LET. We hypothesized that the addition of LET would reduce the incidence of ACL graft failure without compromising functional outcomes or return-to-sport rates.

Methods: This retrospective cohort study included skeletally mature patients who underwent first-time revision ACLR with a minimum follow-up of four years. Patients were divided into two groups according to surgical technique: isolated revision ACLR (n = 58) and revision ACLR with LET (n = 65). ACL graft failure was defined as clinically confirmed graft rupture based on a positive pivot-shift or Lachman test, magnetic resonance imaging, or the need for further revision ACLR. Demographic characteristics, surgical details, and patient-reported outcomes (International Knee Documentation Committee [IKDC] and Tegner activity scale) were compared between groups.

Results: A total of 123 patients were analyzed (mean age: 27.1 ± 8.0 years) with a mean follow-up of 6.0 years (range: 4.5–7.3 years). Functional outcomes were comparable between groups (IKDC score: 80.4 ± 9.2 vs 84.1 ± 8.8; p = 0.86; Tegner score: 6.6 ± 1.3 vs 6.7 ± 1.2; p = 0.92). ACL graft failure occurred in 11 patients (18.3%) in the isolated revision ACLR group and in 2 patients (3.3%) in the revision ACLR with LET group (p = 0.03; odds ratio: 0.15; 95% confidence interval: 0.03–0.72). Sixty percent of all patients (74/123) returned to sport, including 50 (40.6%) who reached their preinjury level, with no statistically significant differences between groups (p = 0.41).

Conclusion: The addition of an LET to revision ACLR significantly reduced the rate of ACL graft failure without adversely affecting functional recovery or return-to-sport rates. This procedure may serve as a valuable adjunct for selected high-risk patients undergoing revision ACLR.

Level of evidence: IV.

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What are the new findings?

- The addition of a lateral extra-articular tenodesis (LET) to revision anterior cruciate ligament reconstruction (ACLR) significantly reduced the rate of anterior cruciate ligament graft failure (3.3% vs 18.3%) compared with isolated revision ACLR at a median follow-up of more than six years.
- Functional outcomes, evaluated using the International Knee Documentation Committee and Tegner activity scores, were similar between isolated revision ACLR and revision ACLR with LET, indicating that the addition of the procedure did not adversely affect patient-reported recovery.
- Return-to-sport analysis showed that 60% of patients returned to sporting activity and that 40.6% resumed their preinjury level. Although the LET group exhibited slightly higher rates of return to sport, these differences were not statistically significant.

INTRODUCTION

Revision anterior cruciate ligament reconstruction (ACLR) is a complex procedure associated with inferior outcomes and a higher rate of anterior cruciate ligament (ACL) graft failure compared with primary ACLR [1,2]. Reported failure rates after revision ACLR range from 15% to 20%, whereas primary ACLR typically shows rates below 5% [3,4]. This difference highlights the biological and technical challenges inherent to revision settings, such as tunnel malposition, tunnel widening, limited graft options, and altered knee kinematics.

Residual rotatory instability following ACLR has been increasingly recognized as a key contributor to graft overload and subsequent ACL graft failure. One of the main causes of this instability is injury to the anterolateral structures of the knee, which plays a critical role in controlling internal tibial rotation [5–7]. In recent years, lateral extra-articular tenodesis (LET) has been reintroduced as an adjunctive procedure to improve rotatory stability and decrease the risk of ACL graft failure, particularly in high-risk populations such as those undergoing revision ACLR or presenting with high-grade pivot shift [8,9].

Previous biomechanical and clinical studies have demonstrated that the addition of an LET reduces anterolateral translation and pivot-shift grades without increasing complication rates [7]. However, most of the available literature focuses on primary ACLR, with limited data addressing revision cases. The evidence regarding mid-to long-term outcomes after revision ACLR combined with an LET procedure remains scarce.

The present study was designed to address this knowledge gap. The purpose was to compare clinical and functional outcomes between patients undergoing isolated revision ACLR and those undergoing revision ACLR supplemented with an LET. The hypothesis was that the addition of the LET procedure would significantly reduce the rate of ACL graft failure without adversely affecting functional recovery or return-to-sport outcomes.

METHODS

Ethical review was undertaken by the Health and Disability Ethics Committee of our institution (approval number: 2013–01). Given the retrospective nature of the study, informed consent was obtained from all patients at the time of surgery for the prospective collection of clinical and functional outcomes, and patients were subsequently contacted and consented again for the use of anonymized data in this investigation.

This retrospective cohort study included skeletally mature patients who underwent first-time revision ACLR between 2014 and 2020, with a minimum follow-up of four years. Patients with less than four years of follow-up, incomplete medical records, or those lost to follow-up were excluded.

Exclusion criteria included neurovascular injuries, tibial plateau fractures, generalized joint laxity, advanced osteoarthritis (Kellgren-Lawrence grade $\geq$3), multiligament reconstructions, cartilage transplantation, meniscus transplantation, and previous osteotomy procedures. Patients requiring staged reconstruction with bone grafting or tunnel filling were also excluded to ensure homogeneity of surgical technique.

Surgical technique

All procedures were performed by four senior knee surgeons with more than 10 years of experience, under general anesthesia with a thigh-high tourniquet. All diagnoses were first checked clinically and with magnetic resonance imaging (MRI); diagnostic arthroscopy was conducted to evaluate the remnant fibers and confirm the diagnosis. Graft selection was based on tunnel integrity and tissue availability and included bone-patellar tendon-bone (BTB), semitendinosus-gracilis (STG), or allografts.

For patients undergoing LET, a modified Lemaire technique was performed using a strip of ipsilateral iliotibial band (8 $\times$ 1 cm) left attached distally at Gerdy's tubercle. The graft was passed deep to the lateral collateral ligament and fixed proximally just posterior and proximal to the lateral femoral epicondyle, with the knee at 60–90° of flexion in neutral rotation. Fixation was achieved using either a staple or an anchor, per surgeon preference.

This angle of fixation was selected to reproduce physiological tension in extension while avoiding over-constraint, consistent with previously described techniques [10].

Patients typically stayed one night in the hospital and completed at least one physiotherapy session before discharge. Patients who underwent meniscal repair were immobilized with a range-of-motion (ROM) brace and had weight-bearing restrictions for six weeks, after which full ROM was allowed.

Postoperative rehabilitation protocol

The rehabilitation protocol focused on pain and edema management, joint range of movement, and quadriceps activation in the early weeks. As rehabilitation progressed, functional, proprioceptive, and core-strengthening exercises were introduced according to the recovery phase [11,12]. Impact and plyometric exercises began no earlier than the third or fourth month, depending on the patient's condition [13].

Postoperative follow-ups were conducted at 2, 4, and 6 weeks and at 3, 6, and 12 months by the treating surgeon. After completing the rehabilitation protocol, patients underwent MRI to assess graft ligamentization.

Return-to-sport activities were not permitted before 9 months postoperatively and required physician clearance based on functional testing.

All patients were included in the postoperative patient-reported outcome analysis, including those who sustained ACL graft failure and those who subsequently underwent re-revision ACLR. These individuals

completed the same International Knee Documentation Committee (IKDC) and Tegner evaluations at the final follow-up, and their scores were analyzed together with the rest of the cohort.

Although standard follow-up visits extended to 12 months postoperatively, all patients were contacted between September and December 2024 for a review. This was accomplished through clinic visits or structured telephone interviews, during which patient-reported outcome measures were obtained.

Demographic data, surgical details, and associated injuries were recorded from electronic health records. Functional outcomes were evaluated using the IKDC subjective score and the Tegner activity scale, both of which have been validated for ACLR.

ACL graft failure was defined as a confirmed ACL graft rupture, diagnosed through clinical instability on examination (positive Lachman or pivot-shift test), MRI, or the need for additional revision surgery. A "positive" Lachman test was defined as grade 1+ or greater, and a "positive" pivot-shift test was defined as grade 2+ or greater under anesthesia, in accordance with the standard 0–3+ grading scales [14, 15]. These thresholds were applied consistently throughout the study period to determine clinical ACL graft failure.

Return to sport was defined as the ability to resume any sporting activity, whereas return to the preinjury level was recorded separately.

Statistical methods

Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed variables were reported as mean ± standard deviation, while non-normally distributed variables were reported as median and interquartile range (IQR). Categorical variables were expressed as absolute frequencies and percentages.

Comparisons between groups were performed using the Student's t-test for normally distributed continuous variables, Mann-Whitney U-test for non-parametric variables, and χ^2 or Fisher's exact test for categorical variables. The Wilcoxon signed-rank test was used for preoperative and postoperative comparisons of ordinal clinical tests (Lachman, anterior drawer, and pivot shift).

Statistical significance was set at a p value < 0.05. For statistically significant differences, effect sizes with 95% confidence intervals were reported. Analyses were performed using STATA v.18.5.

RESULTS

A total of 147 patients underwent revision ACLR during the study period. Of these, 24 were excluded (12 due to less than 4 years of follow-up, 7 due to incomplete records, and 5 lost to follow-up), leaving 123 patients available for analysis (58 in the isolated revision ACLR group and 65 in the revision ACLR with LET group).

The two groups were comparable in demographic characteristics. The proportion of male patients was similar between the isolated revision ACLR group (68.9%) and the revision ACLR with LET group (69.2%); the mean body mass index was 24.9 ± 3.5 kg/m^2 and 23.2 ± 3.2 kg/m^2, respectively ($p > 0.05$). The mean age at the time of surgery was 29.2 ± 9.7 years in the isolated revision ACLR group and 25.1 ± 5.9 years in the group of revision ACLR with LET ($p = 0.09$). The median follow-up was 6.6 years (IQR: 5.9–7.3) in the isolated revision ACLR group and 5.5 years (IQR: 4.5–6.5) in the group of revision ACLR with LET (Table 1).

Previous graft types included bone-patellar tendon-bone, STG, and allografts. The current revision grafts consisted of bone-patellar tendon-bone in 23 cases, STG in 98 cases, and allograft in 2 cases, with no significant difference in distribution between groups (Table 1).

Meniscal injuries were frequent in both groups. Medial meniscal tears were observed in 42 patients in the isolated revision ACLR group and 38 in the revision ACLR with LET group, while lateral meniscal tears were more common in the isolated revision ACLR group (16 versus 6).

Table 1
Demographic characteristics.

Characteristics	Isolated revision ACLR N = 58	Revision ACLR with LET N = 65
% Men	68.9	69.2
Mean age (years) (SD)	29.2 (9.7)	25.1 (5.9)
Mean BMI (kg/m^2) (SD)	24.9 (3.5)	23.2 (3.2)
Median follow-up (years) (IQR)	6.6 (5.9–7.3)	5.5 (4.5–6.5)
Revision ACLR graft		
BTB	9	14
STG	48	50
Allograft	1	1
Right knee (%)	47	50
Sports-related injuries (%)	94.8	92.3
Non–sports-related injuries (%)	5.2	7.7

Abbreviations: N = number; SD = standard deviation; IQR = interquartile range; BTB = bone-tendon-bone; ACLR = anterior cruciate ligament reconstruction; LET = lateral extra-articular tenodesis; BMI = body mass index; STG = semitendinosus and gracilis.

Chondral lesions were present in both groups without significant differences (Table 2).

ACL graft failure occurred in 13 patients (10.6%); overall, there were 11 cases (18.3%) in the isolated revision ACLR group and 2 cases (3.3%) in the revision ACLR with LET group. This difference was statistically significant ($p = 0.03$; odds ratio: 0.15; 95% confidence interval: 0.03–0.72) (Table 3).

Among the failed ACLR, nine patients required re-revision ACLR and four were treated non-operatively. The mean time to ACL graft failure was 3.4 ± 1.1 years after the index procedure. No significant association was found between graft type and failure within each group ($p = 0.49$).

At the final follow-up, both groups showed satisfactory functional recovery. The mean IKDC score was 80.4 ± 9.2 in the isolated revision ACLR group and 84.1 ± 8.8 in the revision ACLR with LET group ($p = 0.86$); the mean Tegner activity score was 6.6 ± 1.3 and 6.7 ± 1.2, respectively ($p = 0.92$).

Overall, 74 patients (60.1%) returned to sporting activity at or above their preinjury level. Fifty patients (40.6%) resumed the same level of sport participation achieved before the primary injury. Although a higher proportion of patients in the revision ACLR with LET group returned to sport, the difference was not statistically significant ($p = 0.41$).

The mean time to return to sport was 11.4 ± 2.7 months, with no differences between groups ($p = 0.59$). No sex-based differences were observed in the rate of return to sport ($p = 0.64$).

There were no major complications such as deep infection, neurovascular injury, or arthrofibrosis in either group. Two patients (1.6%) required secondary procedures for symptomatic hardware removal, both in the isolated revision ACLR group. Four patients (3.3%) experienced late complications: two cyclops lesions requiring arthroscopic resection and two cases of donor site paresthesia. No cases of over-

Table 2
Associated injuries.

Associated injuries	Isolated revision ACLR	Revision ACLR with LET
Medial meniscal tear (N)	42	38
Lateral meniscal tear (N)	16	6
Medial femoral chondropathy (N)	4	3
Lateral femoral chondropathy (N)	5	7
Patellofemoral chondropathy (N)	1	2

Abbreviations: ACLR = anterior cruciate ligament reconstruction; LET = lateral extra-articular tenodesis; N = number.

Table 3
Surgery and associated outcomes.

Associated outcomes	Isolated revision ACLR	Revision ACLR with LET	p value
IKDC	80.4	84.1	0.86
Tegner	6.6	6.7	0.92
Re-rupture rate (%)	18.3	3.3	0.03*

Legend: (*) denotes statistical significance ($p < 0.05$). Abbreviations: ACLR = anterior cruciate ligament reconstruction; IKDC = International Knee Documentation Committee; LET = lateral extra-articular tenodesis.

constraint or excessive stiffness were recorded following the addition of the LET.

DISCUSSION

This study compared the outcomes of isolated revision ACLR and revision ACLR supplemented with an LET. The main finding was that the addition of the extra-articular procedure was associated with a significantly lower rate of ACL graft failure (3.3% versus 18.3%) at a mean follow-up of 6 years. Importantly, this difference was achieved without compromising functional outcomes or return-to-sport rates.

The results of the present study are consistent with growing biomechanical and clinical evidence indicating that the addition of an LET procedure can reduce anterolateral translation and control rotatory laxity [5–7]. These findings support the role of LET as a protective adjunct in the revision setting, consistent with previous reports [16–18]. Revision ACLR is a technically demanding procedure compared with primary ACLR, often exhibiting inferior results and higher failure rates due, in part, to biological, mechanical, and technical factors [19–21]. Recently, there has been renewed interest in reinforced intra-articular ACLR utilizing LET as an adjunct to address residual rotatory instability and decrease the rate of ACL graft failure.

Alm et al. reported a lower ACL graft failure rate in patients undergoing revision ACLR with LET than in those with isolated revision ACLR (5% versus 21%) [22,23]. This finding has clinical relevance and suggests that LET may biomechanically support the integrity of revision grafts by increasing resistance to anterolateral rotatory forces and reducing the stress transmitted across the intra-articular graft.

Another study that has recently been published on this topic is the 2024 systematic review by Grassi et al. [24]. After synthesizing data from eight studies comprising 334 patients with isolated revision ACLR and 342 patients with revision ACLR combined with an LET, the authors found a 54%clinically significant reduction in the risk of ACL graft failure when an LET was performed. More importantly, no statistically significant differences were observed in the complication rate, further supporting the relative safety of these procedures.

When discussing surgery with patients, an important consideration is that the addition of an extra-articular procedure may increase the risk of transient lateral knee pain. This finding was also reported by Helito et al. who observed lateral-sided pain in 72.1% of patients who underwent an LET and in only 15.9% of those who did not [25]. This laterality in pain perception, however, tended to resolve within approximately three months.

The second finding of our study was that patients in the LET group were younger (25.1 years versus 29.2 years), with nearly identical proportions of men (69.2% versus 68.9%). Although not statistically analyzed in the present study, younger age has been associated with higher activity levels and an increased risk of re-injury [26,27], representing a potential bias toward a greater failure rate in the younger cohort. No such trend was observed in this study, which further supports the potential protective effect of LET in high-risk populations.

The third finding of our study was that functional outcomes, assessed using the IKDC and Tegner activity scores, were similar between groups, with no statistically significant differences (IKDC score: 84.1 versus 80.4; Tegner score: 6.7 versus 6.6). This suggests that mid-term functional recovery or patient satisfaction is not adversely affected by the addition of an LET. These results are in line with previous literature [28].

In a multicenter retrospective study, Trojani et al. found that the addition of an LET was not associated with higher IKDC scores but was associated with a decreased risk of both pivot shift and ACL graft failure (7% in the LET group versus 15% in the isolated ACLR group) in a subgroup of 163 patients who underwent revision ACLR, with an LET performed in 51% of them [29]. These results are consistent with our findings as we also found no statistically significant improvement in patient-reported functional outcomes but a significant reduction in ACL graft failure risk. Moreover, according to Porter et al. the addition of an LET to a revision ACLR significantly limits anterior tibial translation compared with an isolated intra-articular reconstruction [30].

In our series, approximately 60% of patients returned to sport after revision ACLR and fewer than half were able to resume their preinjury level. Although the LET group showed a higher percentage of return to sport (63% versus 57%) and preinjury-level recovery (45% versus 36%), these differences were not statistically significant. These findings are consistent with previous reports by Wiggins et al. [26] and the systematic review by Grassi et al. [8], which demonstrated that return-to-sport rates after revision ACLR remain substantially lower than those observed after primary ACLR, with only 40–55%of patients regaining their preinjury level of activity. While LET supplementation appears to provide a protective effect against ACL graft failure, its influence on return-to-sport outcomes remains less clear, suggesting that factors beyond biomechanical stability—such as psychological readiness, rehabilitation quality, and sport-specific demands—play critical roles in achieving a successful return to play.

This study has several limitations. First, its retrospective design carries an inherent risk of selection bias, particularly regarding the decision to perform an LET, which depended on surgeon preference and evolving institutional practice. Second, we did not assess posterior tibial slope or generalized joint laxity, both recognized contributors to ACL graft failure. Third, patient-reported outcomes were limited to IKDC and Tegner scores; additional validated instruments could have provided a more comprehensive assessment. Finally, return to sport was self-reported and may not fully reflect sport-specific performance demands.

CONCLUSION

In this retrospective cohort with mid-to long-term follow-up, the addition of LET to revision ACLR was associated with a significantly lower rate of ACL graft failure than was isolated revision ACLR, without compromising functional outcomes or return-to-sport rates. These findings support the use of LET as a protective adjunct in selected patients undergoing revision ACLR. However, due to the retrospective design and limited sample size, the results should be interpreted with caution. Larger prospective, multicenter studies are needed to confirm these observations and to further define the indications, technical nuances, and long-term impact of LET in the revision setting.

Author contributions

All the authors contributed to the design, analyses and reporting for this manuscript. Both authors read and approved the final submitted manuscript.

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Declaration of competing interest

We have no conflicts of interest relevant to the content of this review.

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