

RESEARCH ARTICLE

Differences in Clinical Outcomes and Rotational Stability Between Anterolateral Ligament Reconstruction and Lemaire Lateral Tenodesis Following Primary Anterior Cruciate Ligament Reconstruction

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Received: 3 December 2024

Accepted: 22 January 2025

Abstract

Objectives: Residual instability following anterior cruciate ligament reconstruction (ACLR) is a common concern among young, active patients. Currently, two primary methods are used to address this matter: anterolateral ligament reconstruction (ALLR) using a graft and lateral extra-articular tenodesis (LET). This study aims to compare the Lemaire method for LET with ALLR in minimizing rotational instability after ACLR.

Methods: This retrospective cohort study included patients with ACL ruptures who underwent simultaneous arthroscopic ACLR and either Lemaire lateral tenodesis or ALL reconstruction between April 2013 and March 2021. Patients were re-examined approximately 24 months post-operatively. We evaluated rotational instability using the pivot shift test, and anterior stability with the KT-1000 test. Outcomes were measured using the Lysholm and International Knee Documentation Committee (IKDC) questionnaires.

Results: This study evaluated 53 patients who underwent ACLR using either the Lemaire method for LET (n=24) or ALLR technique (n=29). No substantial differences were observed in terms of age, sex, body mass index (BMI), number of physiotherapy sessions, time from injury to surgery, or the diameter of the ACL graft. Rotational stability was significantly better in the Lemaire group (16.7% vs. 82.8%, $P < 0.001$). Although functional outcomes were higher in the Lemaire group, these differences were not statistically significant. Multivariate logistic regression analysis revealed that the surgical technique was the only significant predictor of rotational instability, with patients undergoing ALLR being 18.8 times more likely to experience a positive pivot shift (OR: 18.78, 95% CI: 4.34–81.18, $P < 0.001$).

Conclusion: This retrospective cohort study suggests that Lemaire LET may be more effective than ALLR in minimizing rotational instability following arthroscopic ACLR. However, there was no superiority in functional scores between the groups.

Level of evidence: III

Keywords: Anterior cruciate ligament, Anterolateral ligament, Anterolateral ligament reconstruction, Lateral extra-articular tenodesis, Lemaire technique, Rotational instability

Introduction

Anterior cruciate ligament (ACL) injuries represent a substantial orthopedic burden globally with an increasing incidence and persistent complications despite advancements in standard treatment methods,

particularly ACL reconstruction (ACLR).^{1,2} Despite the introduction of novel graft types and techniques for ACLR, studies have shown that approximately 8-25% of patients face long-term complications, including instability and

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THE ONLINE VERSION OF THIS ARTICLE
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treatment failure.³⁻⁵ Particularly, graft failure and rotational instability in young, active individuals continue to represent a significant clinical issue.^{6,7}

Rotational instability following ACLR is often attributed to damage to the anterolateral extra-articular tissues. Research indicates that approximately 18% of patients experience some degree of rotational instability post-ACLR.⁸ Therefore, identifying the most effective treatment approach remains a significant challenge for orthopedic surgeons.⁹ Recent evidence suggests that the anterolateral corner plays a crucial role in the rotational stability of the knee.¹⁰⁻¹² However, it is not necessary to restore the anterolateral complex in all patients undergoing ACLR. Currently, ACLR revision, young patients demanding pivoting activities, increased tibial slope, and meniscal injury are indications for a stabilizing procedure for the anterolateral complex besides the routine ACLR.^{13,14}

Several procedures have been investigated to substitute the function of the anterolateral complex, with anterolateral ligament reconstruction (ALLR) using grafts and lateral extra-articular tenodesis (LET) techniques, such as the Lemaire technique, being widely practiced globally. Both techniques have demonstrated an ability to enhance the stability of the knee joint when combined with ACLR and theoretically decrease the load on the reconstructed ACL.¹⁵⁻¹⁸ Studies have shown that the incorporation of LET is associated with improved clinical outcomes and a diminished incidence of graft failure following ACLR.^{16,19,20}

Regardless of the precise technique and graft type, similar to LET, ALLR has been shown to improve knee stability, reduce the risk of ACL graft failure, and improve clinical outcomes in prospective studies.²¹

There is currently no consensus on the proper method for restoring the function of anterolateral complex. This study aims to compare the effectiveness of iliotibial band (ITB) lateral tenodesis using the Lemaire method against ALLR with a gracilis tendon graft in minimizing rotational instability of the knee following arthroscopic ACLR.

Materials and Methods

Patients, Design, and Setting

This retrospective cohort study evaluated the medical records of 61 patients who underwent simultaneous ACLR, using semitendinosus tendon graft (three or four layers) combined with anterolateral augmentation at our university hospital between April 2013 and March 2021. The patients were followed for a minimum of 24 months. Informed consent was retrieved prior to surgery. The patients were divided into two groups based on the surgical techniques employed to address anterolateral rotatory instability: One group underwent ALLR using the gracilis tendon, while the other group received LET via the Lemaire method. All procedures were performed by two knee surgeons (HRY and AT), with each surgeon operating on patients from both groups.

Inclusion and exclusion criteria Data Collection

18 to 50-year-old patients who underwent simultaneous ACLR using a semitendinosus tendon graft (three or four layers) and either Lemaire LET or ALLR using a gracilis tendon, with at least 2 years follow-up after surgery, were included in the study. Exclusion criteria were set as the presence of multiple ligament knee injuries, meniscal

injuries, the use of ACL grafts other than those specified, previous knee surgery, non-compliance with post-operative rehabilitation protocols, failed ACLR with anterior knee instability, and refusal to participate in the study.

Data Collection

Demographic data such as age, gender, smoking status, and body mass index (BMI), as well as clinical data including the time interval from injury to operation, the type of surgical technique (Lemaire or ALLR), and post-operative physiotherapy, were extracted from medical records using a standardized checklist. All patients who underwent surgery between April 2013 and March 2021 were called for a follow-up visit. During this visit, patients were examined by two knee surgery fellows-in-training, who were blinded to the type of procedure performed at the time of assessment. The surgical site and scars were covered prior to the examination by our knee surgery fellows-in-training to ensure adherence to the blinding protocol.

Anterior knee stability was assessed using KT-1000 measurements in cases of failed ACLR. A difference in tibial translation greater than 3 mm was considered indicative of an ACL injury.²² The rotational assessment was performed by the pivot shift test. A positive result is noted by a shift or "clunk" as the lateral tibial plateau reduces between 20 and 40 degrees of knee flexion, following subluxation in full extension. The test is graded from 0 (normal) to 3 (locked subluxation), with higher grades indicating more severe instability. In our study, rotational instability was defined as a grade of 1 or higher on the pivot shift test.^{23,24}

In cases of disagreement between the two assessors, a third researcher was brought in to resolve the discrepancies. The intraclass correlation coefficient (ICC) was employed to estimate inter-rater agreement.

Functionally, the patients were assessed using the Lysholm²⁵ and International Knee Documentation Committee (IKDC)²⁶ questionnaires. The validity and reliability of the IKDC²⁷ and Lysholm²⁸ questionnaires have been established for native Farsi-speaking patients.

Surgical Procedures

After performing a standard ACLR with a semitendinosus tendon graft (three or four layers), we planned for an anterolateral augmentation through either LET or ALLR:

1-The Lemaire's Lateral Extra-Articular Tenodesis (LET)

A skin incision was performed 6 cm posterior to the lateral epicondyle of the femur. A 1 cm-wide strip of the posterior portion of the ITB was harvested ensuring that the distal attachment remained intact. The graft was routed beneath the lateral collateral ligament (LCL) and secured to the supracondylar region of the lateral condyle of the femur using bioabsorbable screws, with the knee maintained at 60 degrees of flexion and in a neutral tibial rotation. [Figure 1].¹⁷

2-Anterolateral Ligament Reconstruction (ALLR)

The ALL originates from the femur on the posterosuperior aspect of the LCL and is inserted 1 cm below the tibial plateau, anterior to the head of the fibula. A standard harvest of the ipsilateral gracilis tendon was performed and a double layered gracilis tendon graft was prepared to a minimum

length of 80 mm. The reconstruction technique utilized small incisions to identify both attachment sites of the ALL, where half tunnels were drilled. The graft was passed beneath the

fascia lata into these tunnels, with fixation achieved using biotenodesis screws at both the tibia and femur [Figure 2].¹⁸



Figure 1. Intraoperative views. A) A strip of iliotibial band is harvested through lateral incision while distal insertion remains intact to the Gerdy's tubercle. B) The graft is fixed to the lateral femoral supracondylar area

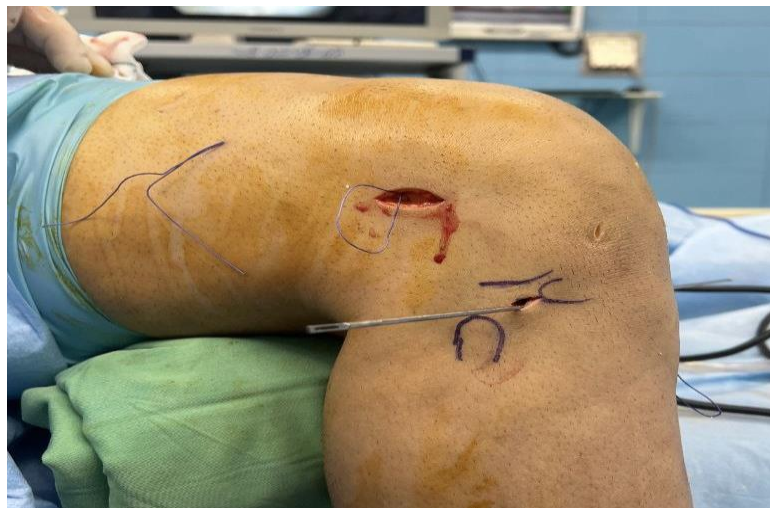


Figure 2. Intraoperative views A) Gracilis graft is passed through 2 separate minimal incisions under the fascia lata. Finally the graft is fixed at the original sites of anterolateral complex

Rehabilitation

The postoperative rehabilitation protocol was divided into six steps, each designed to address specific recovery goals:

Stage I: Immediate Postoperative Phase (0–2 Weeks)

The focus was on reducing swelling, minimizing pain, restoring patellar mobility, achieving full extension, and gradually improving flexion. Emphasis was placed on overcoming arthrogenic muscle inhibition, re-establishing quadriceps control, and regaining full active extension.

Stage II: Intermediate Postoperative Phase (3–5 Weeks)

Efforts were directed toward maintaining full extension and restoring flexion comparable to the contralateral side. Gait normalization was prioritized.

Stage III: Late Postoperative Phase (6–8 Weeks)

The goals included maintaining a full range of motion (ROM), safely progressing strengthening exercises, promoting proper movement patterns, and avoiding post-exercise pain or swelling. Activities that caused discomfort at the graft donor site were restricted.

Stage IV: Transitional Phase (9–12 Weeks)

This phase emphasized the safe progression of strength training and the ongoing promotion of proper movement patterns.

Stage V: Early Return to Sport (3–5 Months)

Strengthening exercises were advanced cautiously. Sport-specific training programs were initiated, while avoiding

activities that could cause pain at the graft donor site.

Stage VI: Unrestricted Activities (6+ Months)

Patients were cleared for unrestricted participation in sports after ensuring full recovery and strength.

Statistical Analysis

Quantitative variables were tested for normal distribution by the Shapiro-Wilk and Kolmogorov-Smirnov tests. Variables with normal distributions were described as means and standard deviations, while those with skewed distributions were noted as medians with interquartile ranges. Qualitative data were reported using descriptive statistics, including percentages and frequencies. Quantitative variables were compared using an independent t-test when the normality assumption was satisfied; otherwise, the non-parametric Mann-Whitney U test was applied. The chi-square test was utilized to compare qualitative variables between the two groups. A multivariate logistic regression analysis was performed to evaluate the effect of the two surgical procedures on rotational instability, adjusting for several confounding factors. A p-value of less than 0.05 was considered statistically significant. Stata version 17 (StataCorp, College Station, TX, USA) was used for the data analysis.

Ethical Statement

This research received ethical approval from the Ethics Committee of Iran University of Medical Sciences, under the reference code IRIUMS.FMD.REC.1401.678. The study was

conducted in accordance with the principles outlined in the Declaration of Helsinki and adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.^{29,30}

Results

Overall, 61 patients were evaluated during follow-up, which 8 had a failed ACLR as determined by the KT-1000 test and were subsequently excluded from further study. The remaining 53 patients were assessed for rotational instability, with 24 in the Lemaire group and 29 in the ALLR group.

Patient Demographics

The patients had an average age of 29.09 ± 7.02 years, with ages ranging from 18 to 41 years. The majority of the patients (98.1%) were male. Sports injuries accounted for the injuries in 45 patients (84.9%). The mean BMI was 25.2 ± 2.1 kg/m². The mean duration from injury to surgery was 10.71 ± 8.7 months, with an interquartile range (IQR) of 6 to 15 months. The two groups were broadly similar in terms of age, gender distribution, BMI, and time from injury to surgery, with no statistically significant differences observed in these variables. One notable difference was in smoking status, with the ALLR group exhibiting a significantly higher proportion of smokers compared to the Lemaire group ($P = 0.043$). The use of physiotherapy, both before and after surgery, was similar between the two groups. These results are demonstrated in [Table 1].

Table 1. Comparison of demographic and clinical characteristics in two groups

Variable	Treatment Groups		P value
	Lemaire (N:24)	ALLR (N:29)	
Age (Year) (Median [IQR])	30.5 [25-34]	28 [22-36]	0.641 ^a
Sex (male)	24 (100%)	28 (96.6%)	0.886 ^b
BMI (Kg/m ²) (Mean± SD)	24.9± 2.2	25.4± 1.9	0.440 ^a
Smoker (n, %)	2 (8.33%)	9 (31.03%)	0.043^b
Physiotherapy			0.880 ^b
• Before surgery	14 (58.3%)	17 (58.6%)	
• Before & after surgery	8 (33.3%)	13 (44.8%)	
Time from injury to surgery (Months) (Median [IQR])	3.5 [3-12]	5 [3-12]	0.576 ^a
Graft diameter	8.21±0.5	8.32±0.4	0.717 ^a

^a Mann-Whitney U Test

^b Chi-squared test

Bold values indicate a statistically significant P

Surgical Outcomes

The ICC was 0.93, indicating excellent agreement within the range of 0.90 to 0.97. A notable disparity in knee rotational instability was observed between the two groups. A considerably lower percentage of patients in the Lemaire group exhibited a positive pivot shift test compared to the ALLR group (16.7% vs. 82.8%, $P < 0.001$), indicating superior rotational stability in the Lemaire group.

Functional outcomes were higher in the Lemaire group; however these differences did not reach statistical significance. The average Lysholm score in the Lemaire group was 85.2, compared to 76.8 in the ALL group. Similarly, the IKDC scores were 77.3 and 71.5, respectively, showing a trend toward improved knee function in the Lemaire group, although this difference was not statistically significant. The surgical outcome results are summarized in [Table 2].

Table 2. Comparison of outcomes in two surgical procedures

Variable	Treatment Groups		P value
	Lemaire (N:24)	ALLR (N:29)	
Positive pivot shift test (n, %)	4 (16.67%)	24 (82.76%)	<0.001^b
• Grade 1	4 (16.7%)	16 (55.2%)	
• Grade 2	0 (0.00%)	8 (27.6%)	
Lysholm Score (Mean± SD)	85.2± 12.1	76.8± 13.1	0.140 ^a
IKDC Score (Mean± SD)	77.3± 11.9	71.52± 13.4	0.157 ^a

^a Mann-Whitney U Test^b Chi-squared test

Bold values indicate a statistically significant P

Multivariate Logistic Regression

A multivariate logistic regression model was conducted to evaluate the elements affecting instability, as indicated by a positive pivot shift test. The type of surgical technique (ALLR vs. Lemaire) was found to be the only statistically significant factor in predicting rotational instability. Patients in the ALLR group were 18.8 times more likely to experience a positive pivot shift compared to those who underwent the Lemaire procedure (OR: 18.79, 95% CI: 4.34–81.18, $P < 0.001$). This finding indicates that the Lemaire technique

provides significantly better rotational stability.

Other variables, including age, time from injury to surgery, smoking status, and physiotherapy regimen, were not significant predictors of rotational instability in this model. The odds ratios for these factors were all approximately 1, and their confidence intervals crossed the null value. The logistic regression model demonstrated statistical significance ($P < 0.001$), confirming that the surgical technique was a crucial determinant of rotational stability in this cohort. The results are shown in [Table 3].

Table 3. Multivariate logistic regression of factors influencing rotational instability (positive pivot shift test)

	Odds ratio	Standard error	z	95% confidence interval	P-value
ALLR vs Lemaire	18.78	14.02	3.93	4.34-81.18	<0.001
Age	0.98	0.03	-0.59	0.91-1.04	0.553
Time from injury to surgery (Months)	1.02	0.03	0.67	0.95-1.08	0.506
Non-smoker vs smoker	0.27	0.26	-1.34	0.04-1.81	0.181
Physiotherapy before and after surgery vs physiotherapy before surgery	0.82	0.62	-0.25	0.19-3.59	0.801

Discussion

In this study, we retrospectively assessed 53 patients who underwent successful ACLR and had a simultaneous procedure performed for anterolateral augmentation. Comparing both Lemaire and ALLR with gracilis tendon groups revealed no significant differences in functional outcomes as evaluated by the Lysholm and IKDC scores. However, physical examination using the pivot shift test revealed that the Lemaire group exhibited significantly lower rates of rotational instability (16.7% vs. 82.8%, $P < 0.001$).

Rotational instability and reconstruction failure are among the most challenging issues following ACLR. Both the Lemaire modification of ITB tenodesis and ALLR have been suggested to improve the rotational stability and reduce the load on the ACLR graft. However, the superiority of one technique over the other remains questionable.⁸⁹

In a robotic study conducted by Gleeslin et al. on fresh frozen cadaveric knees, it was shown that both the LET and the ALLR, when combined with ACLR, are effective in improving

rotational instability. However, the LET group exhibited significantly better rotational stability and pivot shift test outcomes compared to the ALLR group.³¹ Consistent with our findings, another study by Inderhaug et al. compared the outcomes of ACLR with and without the ALLR and LET techniques on 12 cadaveric knees that underwent ACLR. They found that the Lemaire method produced normal laxity at all degrees of knee flexion, whereas the ALLR method resulted in normal laxity only when the tendon was fixed in full knee extension.³² These findings emphasize that the outcomes of these techniques are dependent on the surgeon's experience, and results of ALL augmentation surgeries can vary across different centers.

Multiple studies have evaluated the effectiveness of ALLR and LET in managing rotational instability following ACLR. Recent clinical studies have highlighted the importance of anterolateral augmentation in ACLR for enhancing stability.^{19,33,34} Evidence suggests that both procedures effectively restore stability. However, meta-analyses

comparing the LES and ALLR techniques found no significant differences in functional or mechanical outcomes. Both ALLR and LET improve pivot shift test scores compared to isolated ACL reconstruction, without significant differences in knee functional scores. This indicates that both procedures are viable options for enhancing stability without compromising functional recovery.³⁵⁻³⁹

A recent 2024 meta-analysis by Bosco et al. comparing ACLR with and without anterolateral augmentation procedures showed significantly lower rates of graft failure and rotational instability in patients who underwent either ALLR or LET. However, the authors found no significant difference between the two anterolateral augmentation techniques.³⁷ Furthermore, specific studies have highlighted differences in re-rupture rates between the two techniques. Agrawal et al. reported that ALLR had a lower ACL re-rupture rate (1.14%) compared to LET (4.03%), suggesting a more favorable long-term outcome with ALLR.³⁸ In our single-center study, we maintained consistency in technique; however, the meta-analysis included various centers including different techniques. The outcomes of the Lemaire technique, which we practice, may differ from those of other lateral extra-articular techniques performed at other centers. This variation may have contributed to the differences in our results.

Our study showed that fewer patients who underwent surgery with the Lemaire technique exhibited positive pivot shift tests compared to those who received a gracilis graft. These findings are significant, as they suggest that the incorporation of an anterolateral procedure may positively influence the internal rotation of the tibia, potentially enhancing rotational stability and benefiting patients undergoing ACLR. Lutz et al. provided a theoretical explanation for this observation, noting that the connection point of the ITB on the lateral tibia is wider than that of the reconstructed ALL, which has a narrower attachment in the tibial region. This anatomical difference may account for the superior pivot shift test results in patients treated with the Lemaire method compared to those who underwent ALL reconstruction using the gracilis tendon.⁴⁰

However, the choice between ALLR and LET should also consider individual patient needs and activity levels. A 2024 study conducted by Borque et al. involving 125 ACLR procedures in professional rugby players demonstrated that LET offers significant benefits, including enhanced rotational control and reduced re-rupture rates. This makes it a recommended adjunctive procedure in these cases. These findings suggest that patient-specific factors, including activity level and type of sport, are critical in determining the optimal adjunctive procedure.⁴¹

On the other hand, while LET is effective in providing rotational control and reducing re-rupture rates, it has been associated with over-constraining the knee at various flexion angles, which may lead to complications such as early osteoarthritis.⁴²⁻⁴⁵ Although biomechanical studies suggest that LET could lead to overconstraint compared to ALLR, systematic reviews have shown that this does not correlate with an increased risk of osteoarthritis.⁴⁶ The literature

indicates that applying a minimum force of 20 N is adequate to prevent overconstraint and to re-establish acceptable knee kinematics.⁴⁷

Our study has certain limitations that should be taken into account. First, due to its retrospective design, patients were not randomly assigned to surgical procedures. This non-random allocation may have influenced the study's outcomes. Although we adjusted the results based on demographic characteristics, there is a possibility of remaining confounding factors that were not accounted for due to the study's design. One significant limitation of this study is the relatively small sample size of the analyzed population. A limited sample may reduce the statistical power and generalizability of the findings, potentially affecting the ability to draw robust conclusions. Future studies with larger populations are needed to confirm these results and enhance their applicability across broader clinical settings. Despite these limitations, a major strength of this study lies in its comparative analysis of anterolateral augmentation using the Lemaire method versus ALLR using the gracilis tendon in reducing knee rotational instability in a large cohort of patients undergoing simultaneous ACLR performed at a single center. This focus enhances the generalizability and relevance of our findings.

Conclusion

Our retrospective study of 53 patients showed that for those with ACL injuries requiring augmentation of the anterolateral corner, the Lemaire method outperformed the ALLR in mechanical and rotational stability. However, no notable variations were detected among the groups regarding functional performance. Based on these findings, anterolateral augmentation using the Lemaire method can be recommended as an effective approach for enhancing knee stability in patients with ACL injuries. Nevertheless, further research with extended follow-up durations would provide more accurate estimates.

List of Abbreviations

Anterior cruciate ligament reconstruction (ACLR); Iliotibial band (ITB); Anterolateral ligament (ALL); International Knee Documentation Committee (IKDC); Anterior cruciate ligament (ACL); lateral extra-articular tenodesis (LET); Anterolateral ligament reconstruction (ALLR); Intraclass correlation coefficient (ICC); The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE).

Acknowledgement

N/A

Authors Contribution: Authors who conceived and designed the analysis: HRY & AT/ Authors who collected the data: MG, AMK, NL, HRY, AT/ Authors who contributed data or analysis tools: SHA, AMK, SAM, AF/ Authors who performed the analysis: SHA, AMK/ Authors who wrote the paper: SAM, SHA, AMK, AF, MG, NL, AT, HRY

Declaration of Conflict of Interest: The authors do NOT

have any potential conflicts of interest for this manuscript.

Declaration of Funding: The authors received NO financial support for the preparation, research, authorship, and publication of this manuscript.

Declaration of Ethical Approval for Study: This study was approved by the ethics committee of Iran University of Medical Sciences with code IR.IUMS.FMD.REC.1401.678. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the World Medical Association Declaration of Helsinki were adhered to in this study.

Declaration of Informed Consent: Informed consent was obtained from the patients regarding publishing their data and photographs for scientific purposes.

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