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Anterior cruciate ligament reconstruction with lateral extra-articular tenodesis in patients at high risk of rotational instability

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ABSTRACT

Background: Despite advances in anterior cruciate ligament (ACL) reconstruction, residual rotational instability and graft failure remain concerns, particularly in high-risk patients. Lateral extra-articular tenodesis (LET) may improve rotational control and protect the ACL graft. To evaluate clinical outcomes of combined ACL reconstruction and LET using a modified Lemaire technique in patients at high risk of rotational instability.
Methods: This prospective observational study included 30 patients with primary ACL rupture and high-grade (grade 2 or 3) pivot shift treated at National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, from July 2022 to June 2025. All underwent arthroscopic ACL reconstruction combined with modified Lemaire LET. Functional outcomes were assessed using IKDC and Lysholm scores, while knee stability was evaluated by pivot-shift and Lachman tests. Preoperative and final follow-up outcomes were compared, with $p<0.05$ considered statistically significant.
Results: Mean age was 25.8±6.4 years and 66.7% were male. Mean IKDC score improved from 52.6±9.8 to 87.3±7.4 and Lysholm score from 58.9±10.6 to 91.2±6.8 (both $p<0.001$). At final follow-up, 86.7% had negative pivot-shift and 80.0% negative Lachman tests. Good-to-excellent outcomes were achieved in 86.7% by IKDC and 90.0% by Lysholm criteria. Overall, 83.3% returned to sports or previous activity and graft failure occurred in 3.3%.
Conclusions: Combined ACL reconstruction with modified Lemaire LET provided favorable functional recovery, improved knee stability and low graft failure, supporting its use in appropriately selected high-risk patients.

Keywords: Anterior cruciate ligament reconstruction, Lateral extra-articular tenodesis, Modified Lemaire technique, Pivot-shift test, Rotational instability

INTRODUCTION

Among traumatic knee injuries, anterior cruciate ligament (ACL) rupture is particularly important because it compromises anteroposterior and rotational stability, restricts athletic participation and may predispose patients to recurrent instability and subsequent intra-articular damage. Globally, the epidemiology varies by sport, sex and exposure pattern. Across contact sports, female athletes have been reported to sustain ACL injury at a higher rate than males, while high-impact rotational landing activities carry especially high risk.[1] In team-ball

sports, non-contact mechanisms account for approximately 55% of ACL injuries; pooled incidence is about 0.14 per 1,000 player-hours in females and 0.05 per 1,000 player-hours in males.[2] Biomechanical factors, including dynamic knee valgus, poor core control and landing mechanics, further contribute to injury susceptibility.[3] Within South Asia, including Bangladesh, robust population-based epidemiological estimates remain limited, leaving the regional burden incompletely characterized. For young, physically active patients with symptomatic instability, ACL reconstruction (ACLR) remains a major surgical strategy to restore knee stability and facilitate return to activity.

Despite improvements in graft selection, tunnel placement, fixation and rehabilitation, isolated ACLR does not always restore normal rotational control. Clinically, persistent pivot shift after reconstruction is particularly relevant because it reflects residual anterolateral rotatory laxity and is associated with poorer postoperative outcomes.[4] Consequently, increasing attention has focused on identifying patients in whom intra-articular ACLR alone may provide insufficient rotational restraint. To address this limitation, lateral extra-articular tenodesis (LET) has re-emerged as an adjunct to ACLR.

By reinforcing the anterolateral structures, the modified Lemaire LET is intended to limit excessive internal tibial rotation and reduce the load transmitted to the ACL graft.[5] Among high-risk patients, commonly including those with grade ≥2 pivot shift, young age, generalized ligamentous laxity, return to pivoting sports or other features associated with graft failure, additional lateral stabilization may be particularly relevant.[5,6]

In a secondary analysis of the STABILITY cohort, LET was associated with lower odds of asymmetric pivot shift (OR 0.56) and graft rupture OR 0.40, while high-grade preoperative laxity independently increased rupture risk.[6] Across pooled clinical evidence, the benefit of combined reconstruction is increasingly consistent. A meta-analysis of six randomized trials involving 1,010 patients found that ACLR plus LET reduced postoperative pivot shift (RR 0.56) and graft failure (RR 0.35), compared with isolated ACLR.[7] Broader meta-analyses have reported similar findings, with improved rotational stability and lower graft-failure rates after anterolateral augmentation.[8,9] More recent evidence has also shown favorable patient-reported outcomes and return-to-sport profiles after lateral extra-articular procedures.[10]

Among pediatric and adolescent high-risk populations, combined ACLR and LET has likewise been associated with markedly lower rerupture rates than isolated reconstruction.[11] Nevertheless, additional surgery may introduce concerns regarding stiffness, lateral pain, hardware irritation, over constraint and reoperation; a recent systematic review estimated an overall LET-related complication rate of approximately 4.2%.[12] Because most available evidence comes from outside South Asia, uncertainty remains about outcomes in Bangladeshi patients, where injury patterns, access to rehabilitation, activity demands and follow-up may differ. Accordingly, prospective local evaluation is needed to determine whether the reported gains in rotational control and graft protection translate into routine tertiary-care practice. Therefore, this study aimed to evaluate the clinical outcomes of combined ACLR and LET using a modified Lemaire technique.

METHODS

This prospective observational study was conducted at the National Institute of Traumatology and Orthopaedic Rehabilitation, NITOR, Dhaka, Bangladesh, from July 2022 to June 2025. Authors enrolled 30 patients with ACL injury and a high risk of rotational instability using purposive sampling. Patients with a primary ACL rupture, clinical evidence of high-grade pivot shift grade 2 or 3 and suitability for combined ACL reconstruction (ACLR) with lateral extra-articular tenodesis (LET) were included. We excluded patients undergoing revision ACL reconstruction, those with major concomitant ligament injuries requiring separate reconstruction, advanced knee osteoarthritis, active infection or previous major surgery on the affected knee.

After obtaining informed consent, we recorded demographic and clinical information, including age, sex, affected side, mechanism of injury, time from injury to surgery and associated meniscal injury. Preoperative knee function and stability were evaluated using the International Knee Documentation Committee (IKDC) subjective score, Lysholm score, pivot-shift test and Lachman test.

All patients underwent arthroscopic ACL reconstruction followed by LET using a modified Lemaire technique. We managed associated meniscal pathology arthroscopically when indicated. We followed a standardized postoperative rehabilitation protocol, including progressive range-of-motion exercises, muscle strengthening, gradual weight bearing and a staged return to sports or usual activities.

Clinical follow-up included assessment of functional recovery, knee stability, return to activity, patient satisfaction, graft failure, recurrent instability and postoperative complications. We reassessed functional outcomes using the IKDC subjective and Lysholm scores and evaluated objective stability using the pivot-shift and Lachman tests at final follow-up.

Data were analyzed using SPSS (V. 26.0). Continuous variables were expressed as mean±standard deviation, while categorical variables were presented as frequency and percentage. Preoperative and postoperative continuous outcomes were compared using paired statistical tests, while categorical stability outcomes were compared using appropriate tests for paired proportions. A p value of <0.05 was considered statistically significant.

RESULTS

Among the 30 patients undergoing combined ACLR and LET, the mean age was 25.8±6.4 years, with more than half (53.3%) aged 21–30 years. Males predominated, accounting for 66.7% of participants. Sports-related injury was the most common mechanism (60.0%) and the right knee was affected in 56.7%. Preoperatively, 63.3% had grade-2 and 36.7% had grade-3 pivot shift and 56.7% had associated meniscal injury (Table 1).

After combined ACLR and LET, both functional outcome scores improved substantially. The mean IKDC subjective score increased from 52.6±9.8 preoperatively to 87.3±7.4 at final follow-up, representing a mean improvement of 34.7 points. Similarly, the mean Lysholm score improved from 58.9±10.6 to 91.2±6.8, with an improvement of 32.3 points. Both changes were statistically significant ($p<0.001$) (Table 2). At final follow-up, objective knee stability improved markedly.

Although all patients initially had high-grade rotational instability, 86.7% had a negative pivot-shift test after surgery, 13.3% had residual grade-1 pivot shift and none had grade-2 or grade-3 instability. Similarly, 80.0% had a negative Lachman test and 20.0% had only grade-1 laxity at final follow-up. Improvements in both pivot-shift and Lachman findings were statistically significant ($p<0.001$) (Table 3).

At final follow-up, most patients achieved favorable functional outcomes. By IKDC subjective score, 46.7% achieved excellent and 40.0% achieved good outcomes, for a combined good-to-excellent rate of 86.7%. Based on the Lysholm score, 36.7% had excellent and 53.3% had good outcomes, giving an overall good-to-excellent rate of 90.0%. Only a small proportion had fair or poor functional outcomes (Table 4).

Regarding postoperative recovery and return to activity, 83.3% of patients returned to sports or their previous activities, while 66.7% regained the same pre-injury activity level. The mean time to return to activity was 8.7±2.3 months. In addition, 90.0% of patients reported being satisfied or very satisfied with the surgical outcome, indicating a generally favorable patient-reported recovery following combined ACLR and LET (Table 5).

Postoperative complications and treatment failure were relatively uncommon. Graft failure or re-rupture occurred in 3.3% and recurrent symptomatic instability occurred in 3.3% of patients.

Residual pivot shift of grade ≥1 was present in 13.3%, while knee stiffness and LET-related lateral knee discomfort occurred in 6.7% each. Superficial surgical-site infection and reoperation were recorded in 3.3% each, with no deep infection or neurovascular complications observed (Table 6).

Table 1: Baseline demographic and clinical characteristics of the study participants (n=30).

Variables	Category	N (%) / Mean±SD
Age (in years)	≤20	7 (23.3)
	21–30	16 (53.3)
	>30	7 (23.3)
	25.8±6.4	
Sex	Male	20 (66.7)
	Female	10 (33.3)
BMI (kg/m²)	24.3±2.8	
Affected knee	Right	17 (56.7)
	Left	13 (43.3)
Mechanism of injury	Sports-related injury	18 (60.0)
	Road traffic accident	8 (26.7)
	Other trauma	4 (13.3)
	Time from injury to surgery (months)	7.2±4.1
Preoperative pivot-shift grade	Grade 2	19 (63.3)
	Grade 3	11 (36.7)
	Associated meniscal injury	17 (56.7)

Table 2: Functional outcomes before and after combined ACLR and LET.

Outcome measure	Preoperative (Mean±SD)	Final follow-up (Mean±SD)	Mean improvement	P value
IKDC subjective score	52.6±9.8	87.3±7.4	34.7	<0.001
Lysholm score	58.9±10.6	91.2±6.8	32.3	<0.001

Table 3: Objective knee stability before and after combined ACLR and LET.

Clinical tests	Preoperative N (%)	Final follow-up N (%)	P value
Pivot-shift test			
Grade 0	0 (0.0)	26 (86.7)	<0.001
Grade 1	0 (0.0)	4 (13.3)	
Grade 2	19 (63.3)	0 (0.0)	
Grade 3	11 (36.7)	0 (0.0)	
Lachman test			
Grade 0	0 (0.0)	24 (80.0)	<0.001
Grade 1	5 (16.7)	6 (20.0)	
Grade 2	17 (56.7)	0 (0.0)	
Grade 3	8 (26.7)	0 (0.0)	

Table 4: Categorized functional outcomes at final follow-up.

Outcomes	Category	n (%)
IKDC subjective outcome	Excellent (≥90)	14 (46.7)
	Good (80–89)	12 (40.0)
	Fair (70–79)	3 (10.0)
	Poor (<70)	1 (3.3)
Lysholm outcome	Excellent (95–100)	11 (36.7)
	Good (84–94)	16 (53.3)
	Fair (65–83)	3 (10.0)
	Poor (<65)	0 (0.0)

Table 5: Return to activity and patient-reported recovery following combined ACLR and LET.

Variables	N (%)/Mean±SD
Returned to sports or previous activity	25 (83.3)
Returned to same pre-injury activity level	20 (66.7)
Returned at a lower activity level	5 (16.7)
Unable to return to previous activity	5 (16.7)
Mean time to return to activity (months)	8.7±2.3
Satisfied or very satisfied with outcome	27 (90.0)

Table 6: Postoperative complications and treatment failures.

Outcomes	N (%)
Graft failure/re-rupture	1 (3.3)
Recurrent symptomatic instability	1 (3.3)
Residual pivot shift (grade ≥1)	4 (13.3)
Knee stiffness	2 (6.7)
Superficial surgical-site infection	1 (3.3)
LET-related lateral knee discomfort	2 (6.7)
Reoperation	1 (3.3)
Deep infection	0 (0.0)
Neurovascular complication	0 (0.0)

DISCUSSION

In this prospective study, combined ACL reconstruction and lateral extra-articular tenodesis using a modified Lemaire technique substantially improved functional outcomes and objective knee stability in patients at high risk of rotational instability. At final follow-up, the mean IKDC subjective score increased from 52.6±9.8 to 87.3±7.4, while the Lysholm score improved from 58.9±10.6 to 91.2±6.8, both with p<0.001. Furthermore, 86.7% of patients had a negative pivot-shift test, 80.0% had a negative Lachman test, 83.3% returned to sports or

previous activities and graft failure occurred in only 3.3%. Collectively, these findings support LET augmentation as an effective strategy for improving stability in ACL-deficient knees with substantial preoperative rotational laxity.

Regarding rotational stability, the postoperative negative pivot-shift rate of 86.7% represents a major improvement because all patients had grade-2 or grade-3 pivot shift before surgery. In the stability randomized trial, adding LET reduced clinical failure from 40% to 25% and graft rupture from 11% to 4%, demonstrating that additional anterolateral restraint can protect reconstructed knees in high-risk patients.[13] Consistently, subsequent analysis of the stability cohort showed that LET reduced the odds of asymmetric pivot shift by 44% (OR 0.56) and graft rupture by 60% (OR 0.40).[6] Similarly, the recent meta-analysis involving 1,327 patients reported significantly lower positive postoperative pivot shift and graft failure following ACLR with a lateral extra-articular procedure.[14] These findings closely support the 13.3% residual grade-1 pivot shift and 3.3% graft failure observed in the present study.

Regarding functional recovery, the final mean IKDC score of 87.3 and Lysholm score of 91.2 indicate good postoperative knee function. A similar improvement was documented in the systematic review by Migliorini et al where both IKDC and Lysholm scores improved significantly following ACLR with lateral augmentation, $p<0.01$.[10] Likewise, among high-risk patients, Brinkman et al, reported better early IKDC and Lysholm scores with hamstring ACLR plus LET than isolated hamstring ACLR, although the proportions achieving clinically important improvement were comparable.[15]

In revision surgery, Zanna et al observed an IKDC increase from 71.4 to 92.0, while Lysholm improved from 58.3 to 66.8 following reconstruction with LET.[16] The somewhat greater Lysholm improvement in the current study may reflect its primary reconstruction population, younger demographic profile and absence of previous reconstruction-related tissue damage. Despite these substantial within-patient improvements, available evidence indicates that LET does not invariably produce markedly higher patient-reported scores than isolated ACLR. In the STABILITY trial, groups did not differ clinically in patient-reported outcomes at later follow-up.[13]

Similarly, the meta-analysis by Macciacchera et al found improvement favoring lateral augmentation for Lysholm scores, but no significant difference in IKDC scores ($p=0.138$).[14] An earlier synthesis by Sonnery-Cottet et al also showed more consistent improvement in residual pivot shift than in subjective functional scores.[17] Therefore, the strong IKDC and Lysholm gains in this cohort probably reflect successful ACL reconstruction and rehabilitation overall, while LET may contribute principally through improved rotational control and graft protection. Regarding return to activity, 83.3% returned to sports or previous activities, although only 66.7% regained their pre-injury activity level. In the multicenter STABILITY analysis, return-to-sport rates were comparable between the ACLR and ACLR+LET groups, while graft rupture remained substantially lower with LET (4.1% versus 11.2%).[18] Similarly, Perelli et al documented return to the same competitive level in 90.6% after ACLR+LET compared with 82.4% following isolated reconstruction, although the difference was not statistically significant.[19] Among female soccer players, return-to-sport rates were 90.7% with LET and 85.6% without LET.[20] In contrast, only 58.8% returned to their desired sporting level in Zanna et al's revision cohort.[18] Differences across studies likely reflect age, competitive activity, revision status, rehabilitation protocols, psychological readiness and definitions of successful return to sport.

Concerning failure and complications, the 3.3% graft failure rate observed here is comparable with the 4% reported for ACLR+LET in the STABILITY trial.[13] and the 4.3% reported by Brinkman et al.[15] Among skeletally immature patients, failure was 6.3% with modified Lemaire LET versus 14.7% with isolated ACLR.[19] Evidence from revision populations has also generally demonstrated failure rates of 0–13% with lateral augmentation compared with 4.4–21.4% after isolated revision ACLR.[21] Nevertheless, not all evidence demonstrates superiority. In a revision cohort using quadriceps or patellar tendon grafts, failure rates were similar between isolated reconstruction and LET augmentation (12.8% versus 11.4%).[22] Such discrepancies suggest that the magnitude of LET benefit depends on baseline risk, graft selection, primary versus revision surgery and patient activity.

Clinically, these results reinforce selective LET augmentation for patients with high-grade pivot shift and substantial rotational instability, rather than indiscriminate use in all ACL reconstructions. Favorable stability has also been reported with allograft revision ACLR plus LET long-term hamstring revision ACLR plus extra-articular tenodesis and modified Lemaire augmentation in prospective revision surgery.[23-25] Given the marked reduction in rotational laxity, high functional scores, good return to activity and low graft failure observed in this cohort, combined ACLR and LET appears particularly valuable when conventional intra-articular reconstruction alone may leave an unacceptable risk of persistent rotational instability or reinjury.

Limitations

The study was limited by its small sample size, single-center design, lack of an isolated ACL reconstruction control group and relatively short follow-up. These factors may limit the generalizability of the findings and the ability to assess long-term graft survival and complications.

CONCLUSION

Combined ACL reconstruction with lateral extra-articular tenodesis using the modified Lemaire technique provided favorable functional and stability outcomes in patients at high risk of rotational instability. Patients showed marked improvements in IKDC and Lysholm scores, substantial reductions in pivot-shift and Lachman laxity, high return-to-activity rates and a low incidence of graft failure. These findings support LET as a useful adjunct to ACL reconstruction in appropriately selected high-risk patients.

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