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Lateral Extra-articular Tenodesis Is Associated With Improved Rotational Stability but Not Superior Short-Term Patient-Reported Outcomes After Primary Anterior Cruciate Ligament Reconstruction in Non-Athletic Patients

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Abstract

Background:

Lateral extra-articular tenodesis (LET) is increasingly used to improve rotational stability after anterior cruciate ligament reconstruction (ACLR), but evidence in non-athletic patients is limited. This study compared postoperative stability, patient-reported outcomes, and complications between isolated hamstring autograft ACLR and ACLR combined with LET in morphometrically comparable non-athletic patients.

Methods:

We retrospectively reviewed 83 consecutive patients who underwent primary hamstring autograft ACLR between June 2023 and June 2024 with a minimum follow-up of 12 months. Forty-three patients underwent isolated ACLR and 40 underwent ACLR with LET. All procedures were performed by the same fellowship-trained surgeon using standardised surgical and rehabilitation protocols. Postoperative stability, patient-reported outcomes, and complications were compared between groups.

Results:

Negative pivot-shift testing was more frequent in the ACLR + LET group than in the isolated ACLR group (95.0% vs 34.9%; $p < 0.001$). Lachman testing, anterior drawer testing, and KT-1000 side-to-side differences were comparable between groups. Knee injury and Osteoarthritis Outcome Score, Anterior Cruciate Ligament–Return to Sport after Injury, Lysholm score, Forgotten Joint Score-12, return-to-work time, Patient Acceptable Symptom State achievement, and complication rates did not differ significantly.

Conclusion:

In non-athletic patients undergoing primary hamstring autograft ACLR, LET augmentation was associated with improved postoperative rotational stability but not superior short-term patient-reported outcomes or anterior stability. Given the retrospective design, limited sample size, and short-term follow-up, larger prospective studies are required to confirm these findings.

Level of evidence

III (retrospective comparative study).

Introduction

Anterior cruciate ligament reconstruction (ACLR) is widely accepted as the standard surgical treatment for symptomatic anterior cruciate ligament (ACL) rupture in active individuals (1). Although contemporary ACLR techniques reliably restore anterior tibial stability, persistent rotational laxity remains a clinically relevant concern (2). It has been reported that up to 25–30% of patients demonstrate residual rotational instability following ACLR, and approximately one in nine patients experience graft rupture or clinical failure (3). In recent years, increasing attention has been directed toward the anterolateral complex of the knee [4, 5]. Biomechanical investigations have demonstrated that this complex functions as a secondary restraint to internal tibial rotation and contributes substantially to overall rotational stability(4). In this context, lateral extra-articular tenodesis (LET) has re-emerged as an adjunctive procedure to ACLR. Randomized and comparative studies have suggested that LET augmentation may improve rotational stability and reduce graft failure rates, particularly in selected high-risk patients (5).Recent meta-analyses have further demonstrated that the addition of LET significantly reduces the incidence of postoperative residual pivot shift compared with isolated ACLR (6). However, although improved rotational control has been consistently reported, the impact of LET on patient-reported functional outcomes remains controversial. Nevertheless most of the currently available evidence regarding LET augmentation has been derived from studies involving young athletes, high-demand individuals, revision cases, or patients with high-grade rotational instability. In contrast, relatively limited data exist regarding the clinical relevance of LET in non-athletic patients undergoing primary ACLR in routine clinical practice. Nevertheless, a substantial proportion of patients treated with ACLR in daily practice consist of recreationally active or non-athletic individuals rather than elite pivoting athletes. In these patients, although improved rotational control may theoretically enhance knee stability, its influence on patient-reported outcomes and subjective functional recovery remains unclear.

Therefore, the aim of the present study was to compare rotational stability, patient-reported outcomes, and complication rates between isolated hamstring autograft ACLR and ACLR combined with LET in demographically and morphometrically comparable non-athletic patients with a minimum 12-month follow-up. We hypothesized that the addition of LET would improve postoperative rotational stability without improving short-term patient-reported outcomes.

Materials and Methods

Study Design

This retrospective comparative study was conducted at a single tertiary referral center between June 2023 and June 2024. Ethical approval for this study was obtained from the Ankara Bilkent City Hospital No. 2 Clinical Research Ethics Committee (approval no. E2-23-4339, 17 February 2023). The requirement for informed consent was waived because of the retrospective design. The study was designed to compare isolated hamstring autograft ACLR with ACLR combined with LET in a non-athletic patient population while minimizing major technical and anatomical confounders. To reduce surgical variability, all procedures were performed by the same senior surgeon, who had completed formal sports surgery

fellowship training, using standardized graft preparation, tunnel positioning, fixation methods, and postoperative rehabilitation protocols.

Patient Selection

Patients diagnosed with primary ACL rupture based on clinical examination and magnetic resonance imaging findings who underwent surgical treatment between June 2023 and June 2024 were retrospectively reviewed. Patients aged between 18 and 45 years with a minimum postoperative follow-up of 12 months and available preoperative MRI and radiographic imaging were considered eligible for inclusion. To obtain a more homogeneous non-athletic study population and minimize potential confounding factors affecting postoperative stability, only patients with non-contact injury mechanisms, body mass index < 30 kg/m², and isolated ACL injuries without associated ligamentous injury or periarticular fracture were included. For the purposes of this study, non-athletic patients were defined as individuals who did not participate in competitive sports or regular pivoting sports and whose routine physical activity was limited to recreational or occupational activities. Patients undergoing revision ACLR, those with previous knee surgery, concomitant ligament injury, contralateral ACL rupture, contact injury mechanism, follow-up shorter than 12 months, or patients not operated on by the senior surgeon were excluded from the study. Although the calculated sample size was 86 patients, 83 consecutive eligible patients met the inclusion criteria during the study period and were included in the final analysis, comprising 43 patients who underwent isolated ACLR and 40 patients who underwent ACLR combined with LET. Demographic variables including age, sex, body mass index, operated side, smoking status, time from injury to surgery, and follow-up duration were recorded. Treatment allocation is described in the “Indications for Lateral Extra-articular Tenodesis” subsectio.

Radiological Evaluation

The following morphometric parameters previously associated with rotational instability or ACLR outcomes were evaluated using preoperative MRI and standard radiographs: anterior tibial translation (ATT)[8], lateral femoral condylar ratio[9, 10], femorotibial rotation angle[11, 12], femoral intercondylar notch width[13, 14], posterior tibial slope[15, 16] and lateral femoral notch sign [17, 18]. Measurements were performed on sagittal, coronal, and axial MRI sequences as well as standard anteroposterior and lateral knee radiographs.

All measurements were independently performed by a sports medicine specialist with 4 years of experience (A.Y.) and an orthopaedic surgeon with 5 years of experience (B.A.). Both assessors were blinded to the patients' clinical data. The mean of both measurements was used for statistical analysis, and interobserver reliability was assessed using the intraclass correlation coefficient. Morphometric evaluation was performed to assess anatomical comparability between groups and minimize the potential influence of anatomical variability on postoperative stability outcomes.

Surgical Technique

ACL Reconstruction

All surgical procedures were performed under spinal anesthesia with the patient in the supine position using a pneumatic tourniquet. Anatomical single-bundle ACLR was performed in all patients using a standardized surgical technique [19]. A quadrupled hamstring autograft consisting of semitendinosus tendon with or without gracilis augmentation was prepared according to graft diameter requirements, and a graft diameter greater than 8 mm was targeted in all cases. Standard anteromedial and anterolateral arthroscopic portals were established. Following diagnostic arthroscopy, concomitant meniscal injuries were managed according to intraoperative findings. Repairable tears were treated with arthroscopic meniscal repair, whereas irreparable tears underwent partial meniscectomy. The distribution of concomitant meniscal procedures was recorded and compared between groups as a baseline characteristic. Femoral tunnel preparation was performed through the anteromedial portal with the knee in hyperflexion, while the tibial tunnel was created at the native ACL footprint using a complete tibial tunnel technique as previously described [19]. Both the femoral and tibial graft fixation were achieved using adjustable-loop cortical suspensory fixation devices. No supplementary fixation was used on either the femoral or tibial side. Final graft fixation was performed in full extension under posterior tibial reduction.

Lateral Extra-Articular Tenodesis (Modified Lemaire)

In the LET group, a modified Lemaire tenodesis procedure was performed prior to graft insertion. A strip of the iliotibial band approximately 10 cm in length was harvested while preserving its distal insertion at Gerdy’s tubercle. The graft was passed deep to the lateral collateral ligament and fixed proximal and posterior to the lateral epicondyle using a PEEK interference screw. Tunnel convergence with the ACL femoral tunnel was carefully evaluated arthroscopically during femoral fixation. Final LET fixation was performed with the knee positioned at 60° of flexion and neutral tibial rotation.

The principal surgical steps of ACLR and LET augmentation are illustrated in Fig. 1.

Indications for Lateral Extra-articular Tenodesis

During the study period, the senior surgeon progressively adopted LET augmentation as contemporary evidence expanded the indications for the procedure beyond traditional high-risk athletic populations. Although patients were evaluated according to these evolving concepts, LET was not performed according to a strict predefined indication algorithm. Rather, treatment allocation reflected the senior surgeon's contemporaneous clinical judgment based on the available evidence at the time of surgery

Postoperative Rehabilitation

All patients followed a standardized postoperative rehabilitation protocol. In patients who underwent concomitant meniscal repair, knee range of motion was initially restricted to protect the repair, after which they progressed through the same rehabilitation program as the remaining patients. Early quadriceps activation and weight bearing with crutch support were initiated as tolerated. Closed-chain strengthening and proprioceptive exercises were progressively advanced during follow-up. Light jogging and low-impact activities were permitted after the third postoperative month. Return to non-pivoting sports was generally allowed after 6 months, whereas return to pivoting and contact sports was permitted after 9–12 months according to muscle strength, functional recovery, and clinical assessment.

Clinical Evaluation

Postoperative evaluation was performed in all patients who completed a minimum follow-up of 12 months. Clinical knee stability was assessed using the Lachman test, anterior drawer test, and pivot-shift test, each graded according to standard clinical grading systems [20]. Objective anterior tibial translation was evaluated using a KT-1000 arthrometer (MEDmetric Corp., San Diego, CA, USA) at 134 N and compared with the contralateral knee. Measurements were performed with the patient in the supine position while using a virtual reality (VR) headset to facilitate relaxation and minimize external environmental distractions during the examination. All clinical examinations and KT-1000 measurements were performed by the same examiner under standardized testing conditions to minimize measurement variability (Fig. 2). Functional and psychological outcomes were assessed using validated patient-reported outcome measures, including the Knee Injury and Osteoarthritis Outcome Score (KOOS), ACL–Return to Sport after Injury (ACL-RSI) scale, Forgotten Joint Score-12 (FJS-12), Lysholm score, and Patient Acceptable Symptom State (PASS). Higher scores indicated better functional outcomes where applicable..

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 with a 95% confidence interval.

Normality was assessed using skewness and kurtosis values (± 3 accepted as normal). Parametric data were analyzed using independent sample t-tests, while non-parametric data were analyzed using the Mann–Whitney U test. Categorical variables were compared using chi-square tests. Interobserver reliability was evaluated using a two-way random-effects, absolute-agreement, single-measurement intraclass correlation coefficient.

Sample size calculation was performed using G*Power version 3.1.9.4 (Heinrich Heine University, Düsseldorf, Germany). In the absence of prior studies specifically evaluating morphometrically comparable non-athletic patients undergoing ACL reconstruction with or without LET, a large standardized effect size (Cohen's d = 0.80) was prespecified according to Cohen's recommendations to represent a clinically meaningful between-group difference. Assuming a two-sided α of 0.05, 95% power, and an allocation ratio of 0.75, the required sample size was calculated as 86 patients.

Results

Patient Characteristics

A total of 83 patients were included in the final analysis, including 43 (51.8%) who underwent isolated ACLR and 40 (48.2%) who underwent ACLR combined with LET. The mean follow-up duration was 18.04 ± 5.79 months (range, 12–38 months). The two groups were comparable with respect to age, sex distribution, operative side, smoking status, body mass index, type of concomitant meniscal surgery, time from injury to surgery, and follow-up duration, with no statistically significant differences in any baseline characteristic (all $p > 0.05$) (Table 1).

Table 1
Demographic and baseline characteristics

Variable	Isolated ACLR (n = 43)	ACLR + LET (n = 40)	p value
Age (years)	27.51 ± 8.27	27.55 ± 8.34	0.983
Male sex – n (%)	38 (88.4%)	35 (87.5%)	0.903
Right side – n (%)	19 (44.2%)	23 (57.5%)	0.321
Smoking – n (%)	26 (60.5%)	25 (62.5%)	1.000
BMI (kg/m²)	27.47 ± 2.61	26.53 ± 3.43	0.402
Meniscal repair – n (%)	13 (30.2%)	13 (32.5%)	1.000
Partial meniscectomy – n (%)	2 (4.7%)	1 (2.5%)	1.000
Time to surgery (months)	15.86 ± 27.30	19.13 ± 40.75	0.952
Follow-up (months)	18.93 ± 6.77	17.08 ± 4.41	0.141

ACLR = anterior cruciate ligament reconstruction; LET = lateral extra-articular tenodesis; BMI = body mass index

Preoperative Morphometric Characteristics

ATT was classified as normal in 60.5% of patients in the isolated ACLR group and 67.5% in the ACLR + LET group ($p = 0.872$). The lateral femoral condylar ratio was similar between groups (0.62 ± 0.03 vs. 0.62 ± 0.06, $p = 0.827$). Normal femorotibial rotation angle was observed in 75.6% and 77.5% of patients, respectively ($p = 0.841$). Femoral intercondylar notch width classification did not differ significantly between groups ($p = 0.510$). Normal posterior tibial slope was observed in 90.7% of the isolated ACLR group and 97.5% of the ACLR + LET group ($p = 0.193$). The prevalence of a lateral femoral notch sign was comparable between groups (30.2% vs. 30.0%, $p = 0.982$). These findings confirmed that the isolated ACLR and ACLR + LET groups were morphometrically homogeneous, minimizing the potential influence of anatomical variability on postoperative outcomes. Interobserver reliability was excellent for all

continuous morphometric measurements, with intraclass correlation coefficients ranging from 0.82 to 0.94.

Postoperative Knee Stability

Postoperative knee stability outcomes are summarized in Table 2. The distribution of postoperative pivot-shift grades differed significantly between groups ($p < 0.001$). A negative pivot-shift test (Grade 0) was observed in 95.0% of patients in the ACLR + LET group compared with 34.9% in the isolated ACLR group, whereas Grade 2 and Grade 3 pivot-shift findings were observed only in the isolated ACLR group, indicating superior postoperative rotational stability after LET augmentation. However, no significant between-group differences were observed in the proportion of patients with a negative Lachman test (50.0% vs 48.8%, $p = 0.897$) or a negative anterior drawer test (47.5% vs 53.5%, $p = 0.745$). Similarly, the mean KT-1000 side-to-side difference was comparable between the ACLR + LET and isolated ACLR groups (3.08 ± 2.35 mm vs 3.56 ± 2.22 mm, $p = 0.338$), suggesting similar restoration of anterior knee stability

Table 2
Postoperative knee stability outcomes

Variable	Isolated ACLR	ACLR + LET	p value
Pivot-shift grade – n (%)			< 0.001
Grade 0 (negative)	15 (34.9%)	38 (95%)	
Grade 1 (+)	13 (30.2%)	2 (5.0%)	
Grade 2 (++)	14 (32.6%)	0 (0%)	
Grade 3 (+++)	1 (2.3%)	0 (0%)	
Negative Lachman – n (%)	21 (48.8%)	20 (50%)	0.897
Negative anterior drawer – n (%)	23 (53.5%)	19 (47.5%)	0.745
KT-1000 difference (mm)	3.56 ± 2.22	3.08 ± 2.35	0.338

ACLR = anterior cruciate ligament reconstruction; LET = lateral extra-articular tenodesis

Patient-Reported Outcomes

At the final follow-up, the mean follow-up duration was 18.93 ± 6.77 months in the isolated ACLR group and 17.08 ± 4.41 months in the ACLR + LET group ($p = 0.141$). Mean KOOS scores were 76.27 ± 17.44 and 76.68 ± 15.31, respectively ($p = 0.910$). Similarly, ACL-RSI scores were 42.14 ± 22.95 in the isolated ACLR group and 49.90 ± 21.69 in the ACLR + LET group ($p = 0.118$). Mean Lysholm scores were 79.65 ± 18.46 and 82.70 ± 13.61, respectively ($p = 0.688$), while Forgotten Joint Score-12 values were 65.31 ± 22.95 and 67.85 ± 23.43, respectively ($p = 0.619$). Return-to-work time was also comparable between groups (2.74 ± 1.30 months vs 3.30 ± 7.32 months, respectively; $p = 0.052$). PASS was achieved by 76.7%

of patients in the isolated ACLR group and 92.5% of patients in the ACLR + LET group; however, this difference did not reach statistical significance (p = 0.095).

Complications

Complications were observed in 11.6% of patients in the isolated ACLR group and 10.0% of patients in the ACLR + LET group, with no significant difference between groups (p = 0.812). In the isolated ACLR group, complications included two graft reruptures, two superficial postoperative infections, and one case of knee stiffness. Both graft reruptures occurred following traumatic reinjury at 14 and 16 months postoperatively, and both patients subsequently underwent revision ACLR. Both postoperative infections resolved with oral antibiotic therapy. The patient who developed postoperative knee stiffness was successfully treated with an intensive physiotherapy program without requiring surgical intervention. In the ACLR + LET group, one patient experienced lateral knee pain, one developed a postoperative hematoma, one had a superficial postoperative infection, and one reported a subjective catching sensation. The postoperative infection resolved with oral antibiotic therapy, and all remaining complications were managed successfully with conservative treatment without requiring reoperation. No significant between-group difference was identified regarding overall complication or graft failure rates.

Discussion

The principal finding of the present study was that LET augmentation significantly improved postoperative rotational stability after primary hamstring autograft ACLR in non-athletic patients, as demonstrated by a substantially higher rate of negative pivot-shift testing. In contrast, anterior stability measures, including Lachman test, anterior drawer test, and KT-1000 side-to-side difference, were comparable between groups. Similarly, short-term patient-reported outcomes and complication rates did not differ significantly between isolated ACLR and ACLR + LET. These findings suggest that, in this cohort, the principal clinical effect of LET augmentation was improved rotational control rather than measurable superiority in short-term patient-reported outcomes. This distinction is important because most previous evidence supporting LET augmentation has been derived from young, high-demand, athletic, or high-risk cohorts. By contrast, the present study evaluated a non-athletic population treated in routine clinical practice while minimizing technical and anatomical variability through single-surgeon procedures, hamstring autograft use, standardized rehabilitation, and preoperative morphometric comparability. Unlike previous studies focusing on predefined high-risk characteristics such as generalized ligamentous laxity or knee hyperextension, LET augmentation in the present cohort reflected the senior surgeon's evolving clinical practice rather than a strict indication algorithm. During the study period, the indications for LET progressively expanded in parallel with the emerging literature supporting its role in improving rotational stability and graft protection, and treatment decisions were therefore individualized according to the surgeon's contemporary clinical judgment.

Several clinical and biomechanical studies have investigated the effect of LET when added to hamstring autograft ACLR, with varying results regarding rotational stability, anterior laxity, and functional outcomes. Accordingly, unlike the STABILITY trial, LET augmentation in the present study was not

applied according to predefined high-risk criteria but reflected the gradual evolution of the senior surgeon's clinical practice as evidence supporting lateral augmentation accumulated. Getgood et al., in the STABILITY randomized trial, reported that the addition of LET significantly reduced graft rupture and persistent rotatory instability compared with isolated ACLR, particularly in young and high-risk patients [21]. Meta-analyses by Mao et al. and Hewison et al. confirmed that LET augmentation significantly decreases residual pivot shift but does not consistently improve anterior laxity measurements or functional scores [7, 22]. Onggo et al. also reported lower graft failure rates and improved rotational control with combined ACLR and LET, while KT-1000 measurements and clinical anterior stability tests were comparable between groups [23]. In another systematic review, Migliorini et al. concluded that LET improves rotational stability but may not always translate into superior clinical outcome scores, especially in non-selected patient populations [6]. Biomechanical studies have supported these findings, demonstrating that LET primarily reduces rotational laxity and graft loading under pivoting forces, with limited effect on pure anterior tibial translation [24, 25]. However, not all studies have reported similar findings. Some authors have demonstrated that the addition of LET may lead to improved clinical and functional outcomes in selected patient groups. Cavaignac et al. reported that combined ACLR and LET resulted in better rotational stability and improved functional scores in patients with high-grade pivot shift [26]. Likewise, Devitt et al. found that extra-articular augmentation may improve subjective outcomes in high-risk patients [27]. In contrast, other studies have suggested that the benefit of LET may depend on patient selection, activity level, and baseline rotational laxity. These discrepancies in the literature indicate that the clinical effect of LET on patient-reported outcomes remains controversial. Consistent with these reports, our findings support the concept that LET augmentation primarily influences rotational control rather than anterior tibial translation or short-term subjective functional recovery. Patients treated with ACLR combined with LET demonstrated substantially improved postoperative rotational stability, whereas anterior stability measurements, complication rates, and short-term patient-reported outcomes remained comparable between groups. This may be explained by the fact that patient-reported outcome measures are multifactorial and may not be sensitive enough to detect differences in rotational control, particularly in non-athletic populations and at short-term follow-up. Although two traumatic graft reruptures were observed only in the isolated ACLR group, the difference was not statistically significant because of the limited sample size. Therefore, no definitive conclusion regarding the protective effect of LET on graft survival can be drawn from the present study. Nevertheless, the observed trend is consistent with previous studies reporting lower graft failure rates after LET augmentation [21, 23]. Likewise, no significant difference was observed in return-to-work time between the groups. Return to work was not restricted according to a predefined protocol or delayed at the discretion of the senior surgeon. Instead, patients were allowed to resume work after achieving satisfactory clinical recovery, with the timing primarily determined by the physical demands of their occupation, workplace requirements, and individual preferences rather than by the surgical procedure itself. This likely explains the relatively wide variability in return-to-work times observed, particularly in the ACLR + LET group.

Several methodological aspects strengthen the findings of the present study, including the use of a single fellowship-trained surgeon, standardized surgical and rehabilitation protocols, exclusive use of hamstring autografts, and preoperative morphometric evaluation to minimize anatomical confounding. In addition, the inclusion of a predominantly non-athletic population may provide clinically relevant insight into the role of LET augmentation in routine primary ACLR outside high-demand athletic cohorts. From a clinical perspective, the present findings suggest that LET augmentation may represent a safe adjunctive procedure for improving rotational control without increasing short-term complications or negatively affecting patient-reported outcomes.

Several limitations should also be acknowledged. First, the retrospective design may have introduced inherent selection bias despite attempts to minimize technical and anatomical confounding through standardized surgical protocols and preoperative morphometric comparability. Second, although an a priori power analysis was performed, the relatively limited sample size may have reduced the ability to detect smaller differences in patient-reported outcomes between groups. Third, the mean follow-up duration of approximately 18 months reflects only short-term outcomes and does not permit evaluation of long-term graft survival, degenerative progression, or late functional differences. Furthermore, all surgical procedures were performed by a single fellowship-trained surgeon. Although this approach reduced technical variability and strengthened internal validity, it may limit the external validity and generalizability of the present findings. In addition, the absence of preoperative patient-reported outcome measures prevented assessment of postoperative change scores. Postoperative rotational stability was evaluated using the conventional clinical pivot-shift test rather than instrumented quantitative methods. Although all examinations were performed by the same examiner under standardized testing conditions, the pivot-shift test remains examiner-dependent, relies on subjective clinical grading, and may therefore affect the reproducibility of the findings. Generalized ligamentous laxity and knee hyperextension were not systematically recorded and could not be evaluated as potential confounders. Finally, actual return-to-sport rates were not evaluated because the study population consisted predominantly of non-athletic individuals, for whom return to competitive or pivoting sports was not a predefined treatment objective.

Conclusion

In non-athletic patients undergoing primary hamstring autograft ACLR, LET augmentation was associated with improved postoperative rotational stability without increasing short-term complication rates. However, improved rotational control did not translate into superior short-term patient-reported outcomes or anterior stability measurements. Given the retrospective design, relatively small sample size, and short-term follow-up, these findings should be interpreted with caution, and larger prospective studies are warranted to confirm the role of LET augmentation in this patient population.

Abbreviations

ACLR

anterior cruciate ligament reconstruction
ACL
anterior cruciate ligament
LET
lateral extra-articular tenodesis
ATT
anterior tibial translation
ITB
iliotibial band

Declarations

Ethics approval and consent to participate:

Ethical approval for this study was obtained from the Ankara Bilkent City Hospital No. 2 Clinical Research Ethics Committee (approval no. E2-23-4339, 17 February 2023). The study was conducted in accordance with the Declaration of Helsinki. Owing to the retrospective design of the study, the requirement for informed consent was waived by the Ankara Bilkent City Hospital No. 2 Clinical Research Ethics Committee.

Clinical trial number:

Not applicable.

Consent for publication:

Written informed consent was obtained from the participant whose image appears in Figure 2 for the publication of the image and associated clinical details. The image was additionally anonymized by blurring identifiable facial features.

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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No funding was received for this study.

Authors' Contribution:

BA contributed to the conception and design of the study, data collection, radiological and clinical assessments, statistical analysis, interpretation of the data, drafting of the manuscript, and critical revision of the manuscript.

AY contributed to study design, radiological assessments, data interpretation, and critical revision of the manuscript for important intellectual content.

ME contributed to data collection, clinical assessments, data interpretation, and critical revision of the manuscript.

CÇ contributed to radiological assessments, data acquisition, and critical revision of the manuscript.

MU contributed to patient recruitment, clinical evaluation, data collection, and critical revision of the manuscript.

MD contributed to data analysis, interpretation of the findings, and critical revision of the manuscript.

SA conceived and supervised the study, performed all surgical procedures, contributed to study design and data interpretation, critically revised the manuscript for important intellectual content, and approved the final version of the manuscript.

All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figures

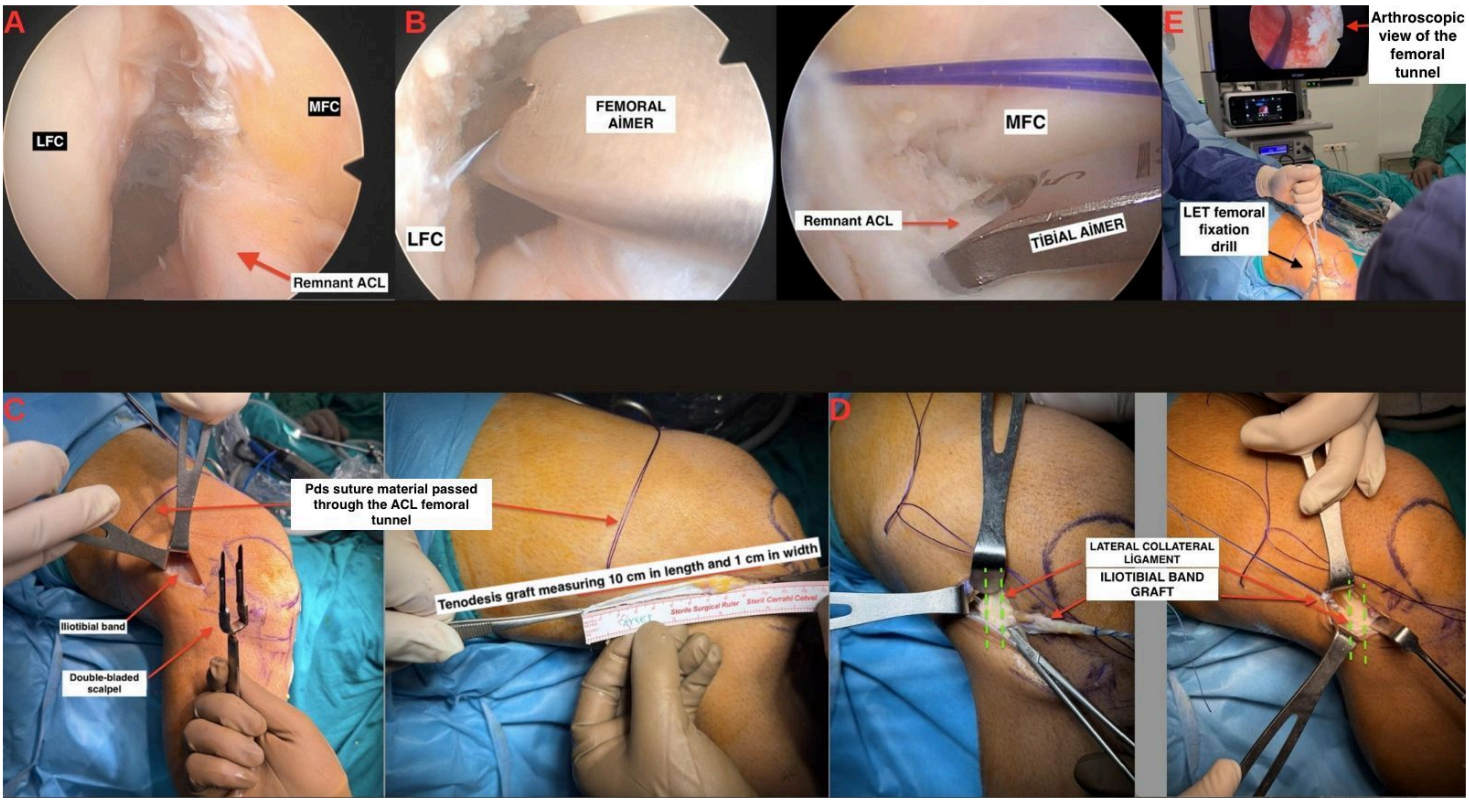


Figure 1

Principal surgical steps of ACLR combined with LET.

(A). Arthroscopic view of a ruptured ACL

(B). Preparation of the femoral and tibial Tunnels.

(C). Harvesting of the tenodesis graft using a double-bladed scalpel

(D). Graft preparation and passage beneath the lateral collateral ligament

(E). Simultaneous ACL femoral tunnel control during LET tunnel drilling.



Figure 2

KT-1000 arthrometer evaluation performed under standardized testing conditions. A virtual reality headset was used during the examination to facilitate patient relaxation and minimize external environmental distractions.