

Primary ACL Repair and Reconstruction in Isolated ACL Ruptures

Forgotten Joint Scores and the Association Between Residual Laxity and Joint Awareness

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Background: Primary anterior cruciate ligament (ACL) repair has recently reemerged as a treatment option for carefully selected proximal ACL tears. However, evidence regarding patient-reported joint awareness and the relationship between postoperative laxity and joint awareness remains limited.

Purpose: To compare joint awareness, clinical outcomes, and postoperative laxity between primary ACL repair and hamstring tendon autograft reconstruction in carefully selected patients with isolated ACL rupture, and to explore the association between residual laxity and postoperative joint awareness.

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

Methods: This retrospective cohort study included 85 patients with isolated ACL rupture treated with either primary ACL repair ($n = 26$) or hamstring autograft reconstruction ($n = 59$), with a minimum follow-up of 24 months. Clinical outcomes, including visual analog scale score, Lysholm score, International Knee Documentation Committee (IKDC) score, Tegner activity scale score, postoperative knee laxity, return to sport, and rerupture rates, were evaluated. The authors also used the Forgotten Joint Score-12 (FJS-12), a measure of joint awareness, to evaluate patients. A higher score reflects lower joint awareness, suggesting function more similar to a native knee. Multivariable regression analyses were performed to evaluate variables associated with postoperative FJS-12 values.

Results: No differences were observed between groups in postoperative Lysholm, IKDC, and Tegner activity scale scores; Lachman- and pivot-shift-assessed postoperative laxity; and return-to-sport rates. However, postoperative FJS-12 values were significantly higher in the repair group compared with the reconstruction group (87.0 ± 15.0 vs 77.5 ± 14.2 ; mean difference, 9.5 points [95% CI, 2.8-16.3]; $P = .006$), corresponding to a moderate effect size (Cohen $d = 0.66$). Secondary exploratory regression analyses demonstrated that residual postoperative laxity was associated with lower postoperative FJS-12 values in both Lachman- and pivot-shift-based models ($R^2 = 0.649$ and 0.680 , respectively; $P < .001$ for both).

Conclusion: In carefully selected patients with proximal ACL tears and adequate tissue quality, no significant between-group differences were detected in conventional clinical outcomes, postoperative laxity, return-to-sport rates, or rerupture rates between primary ACL repair and reconstruction. Primary ACL repair was associated with higher postoperative FJS-12 values at short- to midterm follow-up, suggesting function more similar to that of a native knee. Residual postoperative laxity was associated with lower FJS-12 values in secondary exploratory analyses.

Keywords: anterior cruciate ligament; ACL repair; ACL reconstruction; joint awareness; FJS-12

Anterior cruciate ligament (ACL) reconstruction using autograft has remained the gold standard for the management of ACL rupture, consistently demonstrating reliable restoration of mechanical stability and high rates of return to sport.^{1,3} However, graft harvesting introduces inherent

donor site morbidity that can manifest as persistent anterior knee pain, sensory disturbances from saphenous nerve injury, and functional deficits, all of which may contribute to persistent awareness of the operated knee after reconstruction.^{6,8,10} Moreover, the creation of large bone tunnels and complete removal of native ligament tissue raise fundamental questions about whether complete ligament replacement is necessary in all cases, or whether tissue-preserving strategies might offer comparable outcomes with reduced surgical morbidity.^{15,18} Joint awareness after

ACL surgery is likely multifactorial. Donor site symptoms may contribute to persistent awareness of the operated knee after reconstruction,^{6,8,10} whereas preservation of native ligament tissue and proprioceptive factors may also be relevant in tissue-preserving ACL procedures.^{4,9} Therefore, both tissue preservation and residual postoperative laxity may be clinically relevant when evaluating patient-perceived joint awareness after ACL surgery.

These considerations have sparked renewed interest in primary ACL repair, a technique that was largely abandoned after early reports of high rerupture rates.¹⁸ Contemporary comparative studies have suggested that, when strict selection criteria are applied, primary ACL repair may achieve functional outcomes comparable to ACL reconstruction.^{11,17} Critically, these modern repair techniques are not applied indiscriminately but are reserved for carefully selected patients with proximal femoral-sided tears and adequate tissue quality.^{7,23}

Despite these advances, a fundamental gap remains in our understanding of patient-centered outcomes after ACL repair. While conventional metrics provide valuable functional data, they are frequently limited by ceiling effects and may fail to capture subtle differences in the patient's subjective experience.⁴ The Forgotten Joint Score-12 (FJS-12), validated for ACL surgery, assesses joint awareness during activities of daily living—the patient's ability to “forget” about their operated joint—with higher scores suggesting function more similar to that of a normal knee.⁴ This measure demonstrates superior discriminatory power compared to traditional outcome scores, with lower ceiling effects enabling detection of differences among high-performing patients.⁴ However, evidence evaluating joint awareness after ACL repair and reconstruction using the FJS-12 remains limited. A previous comparative study by Vermeijden et al²⁴ reported higher FJS-12 values after primary ACL repair compared to reconstruction at short- to midterm follow-up; however, the underlying determinants of joint awareness, particularly the role of postoperative mechanical stability, were not investigated.

The purpose of the present study was to compare joint awareness, functional outcomes, and postoperative laxity between primary ACL repair and hamstring tendon autograft reconstruction in patients with isolated ACL rupture treated according to tear pattern and tissue quality. In addition, the study aimed to explore the association between residual postoperative laxity and patient-reported joint awareness. We hypothesized that, in carefully selected proximal ACL tears with adequate tissue quality, primary ACL repair would demonstrate favorable functional outcomes, return-to-sport rates, rerupture rates, and Lachman- and pivot-shift-assessed postoperative

laxity, and that preservation of the native ACL tissue would be associated with higher FJS-12 values, reflecting less residual joint awareness during daily activities. The association between residual postoperative laxity and FJS-12 values was evaluated as a secondary exploratory analysis.

METHODS

Study Design and Patient Selection

This retrospective cohort study included patients who underwent surgical treatment for ACL rupture between January 2022 and January 2024. A total of 223 patients were screened for eligibility based on predefined inclusion and exclusion criteria. The study was approved by the Karabük University Non-Interventional Clinical Research Ethics Committee (Decision No. 2026/2844; April 7, 2026), and all procedures were conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants. Only patients with complete isolated ACL rupture confirmed by clinical examination and magnetic resonance imaging (MRI) who underwent isolated ACL surgery were included.

To isolate the effect of ACL surgery technique and minimize confounding related to concomitant procedures, patients who underwent any meniscal intervention (meniscal repair or meniscectomy; $n = 83$) were excluded from both groups. This approach ensures that observed differences in outcomes can be attributed to the ACL procedure itself rather than meniscal pathology or treatment. In addition, patients with multiligament knee injuries requiring surgical reconstruction ($n = 11$), partial ACL tears treated with repair ($n = 4$), concomitant advanced chondral pathology requiring cartilage procedures such as microfracture or matrix application ($n = 21$), or revision ACL surgery ($n = 19$) were excluded. All included patients had a minimum follow-up of 24 months. After application of all criteria, 85 patients were included in the final analysis.

Treatment allocation was based on intraoperative assessment of tear location and tissue quality. Primary ACL repair was performed in patients with proximal femoral-sided tears demonstrating adequate tissue quality, defined as continuous ligament substance with preserved fiber architecture and sufficient length to reach the anatomic footprint. ACL reconstruction was performed in patients with midsubstance or distal tears, or proximal tears with inadequate tissue quality (severe fiber disruption, extensive fraying, or insufficient length).

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Ethical approval was obtained from Karabük University Non-Interventional Clinical Research Ethics Committee (Decision No. 2026/2844; April 7, 2026).

Surgical Technique

All procedures were performed arthroscopically by a single experienced surgeon (Y.E.) using standardized techniques.

Primary ACL Repair. After diagnostic arthroscopy, the femoral ACL footprint was debrided to promote biological healing. A single double-loaded 5.0-mm titanium suture anchor (Tulpar Medical) was inserted at the anatomic femoral footprint. The anchor was preloaded with nonabsorbable USP No. 2 ultra-high-molecular-weight polyethylene sutures. One suture limb was passed through the proximal ACL remnant to restore its native insertion and achieve appropriate tension. The second suture limb was used to reinforce the repair by applying a running locking stitch configuration along the ligament substance, with approximately 5 passes distally and 5 passes proximally, creating a circumferential reinforcement. All sutures were tied arthroscopically, and final tension and stability were confirmed. No internal brace augmentation was used in any patient.

ACL Reconstruction. A hamstring tendon autograft, including the semitendinosus and gracilis tendons, was harvested from the ipsilateral limb and prepared as a quadrupled graft. After debridement of the native ACL, anatomic femoral and tibial tunnels were created using an anteromedial portal technique. The femoral tunnel was drilled at the native footprint with the knee in hyperflexion, and the tibial tunnel was positioned centrally within the native insertion site. The graft was passed through the tunnels and fixed using a suspensory fixation device (LoopFix T1; Tulpar Medical) on the femoral side and an interference screw (Bio Interfix; Tulpar Medical) on the tibial side, with the knee positioned at approximately 20° to 30° of flexion under appropriate tension. Final graft tension, stability, and range of motion were confirmed before completion of the procedure.

Postoperative Rehabilitation

A standardized rehabilitation protocol was applied to all patients, with no differences between the ACL repair and ACL reconstruction groups. Partial weightbearing with crutches was initiated immediately after surgery and progressively advanced to full weightbearing within 4 to 6 weeks. Early range of motion exercises and progressive quadriceps-strengthening exercises were encouraged under physical therapist supervision. Return to running activities was permitted after restoration of adequate muscle strength and neuromuscular control. Return to pivoting and cutting sports activities was allowed between 9 and 12 months postoperatively after clinical clearance. Clinical clearance was based on the absence of joint effusion, restoration of full range of motion, near-symmetrical quadriceps strength, and satisfactory functional performance as assessed by the treating surgical team.

Clinical Evaluation

Clinical and functional outcomes were assessed using validated scoring systems. Preoperatively, the visual analog

scale (VAS) score, Lysholm score, International Knee Documentation Committee (IKDC) subjective score, and preinjury Tegner activity scale score were recorded. At the 24-month follow-up, the VAS, Lysholm, IKDC, Tegner activity scale, and FJS-12 values were evaluated. All outcome measures were collected by an independent investigator (M.A.) who was not involved in the surgical procedures.

Return to sport was defined as achieving a postoperative Tegner activity level equal to or greater than the preinjury level at a minimum 24-month follow-up, indicating successful restoration of preinjury sports participation.

Patient Acceptable Symptom State

Patient Acceptable Symptom State (PASS) analyses were performed for IKDC and Lysholm scores using previously established thresholds. The PASS was defined as a postoperative IKDC score ≥ 75.9 and a Lysholm score ≥ 85 , based on established thresholds for ACL reconstruction.^{14,16}

Assessment of Knee Laxity

Postoperative knee laxity was evaluated at the 24-month follow-up using Lachman and pivot-shift tests. All examinations were performed by a single experienced orthopaedic surgeon (U.D.) who was not involved in the surgical procedures and was blinded to treatment allocation. Test results were graded and recorded for analysis.

For additional exploratory analyses, postoperative knee laxity was dichotomized separately for the Lachman and pivot-shift tests. For the Lachman test, grade 0 represented a negative examination or no increased anterior tibial translation compared with the contralateral knee, grade 1 indicated 1 to 5 mm of increased anterior tibial translation, grade 2 indicated 6 to 10 mm of increased translation, and grade 3 indicated ≥ 11 mm of increased translation. Lachman grades 0 and 1 were classified as no or minimal residual laxity (group 0), whereas grades 2 and 3 were classified as clinically significant residual laxity (group 1). For the pivot-shift test, grade 0 represented a negative examination, grade 1 a glide phenomenon, grade 2 a definite clunk, and grade 3 gross rotational instability with marked tibial subluxation. Pivot-shift grades 0 and 1 were classified as no or minimal residual laxity (group 0), whereas grades 2 and 3 were classified as clinically significant residual laxity (group 1). These dichotomized Lachman- and pivot-shift-based variables were used separately to evaluate the association between residual postoperative laxity and patient-reported outcomes.

The examiner (U.D.) performing postoperative laxity assessments was experienced in clinical knee examination and blinded to surgical treatment allocation. Instrumented laxity measurements such as KT-1000 arthrometer testing were not routinely available in the present cohort.

Complications

Postoperative complications, including infection, deep vein thrombosis, neurovascular injury, and graft rerupture,

were recorded from clinical records. Infection was defined as superficial or deep surgical site infection according to the Centers for Disease Control and Prevention criteria, confirmed by clinical findings and supported by laboratory and/or imaging data. Graft rerupture was defined as recurrent symptomatic instability with a positive Lachman and/or pivot-shift test result and was confirmed by MRI in all suspected cases. Donor site morbidity in the reconstruction group was assessed through direct patient questioning regarding pain, paresthesia, cramps, or functional limitations.

Statistical Analysis

Statistical analyses were performed using appropriate parametric or nonparametric tests based on data distribution. Data distribution was assessed using the Shapiro-Wilk test and visual inspection of histograms, box plots, and normal Q-Q plots. Only patients with complete clinical records and minimum follow-up data were included in the final analyses; therefore, no imputation method for missing data was required. Continuous variables are expressed as mean $\pm$ standard deviation, and categorical variables as frequency and percentage. Group comparisons were performed using the independent-samples *t* test or Mann-Whitney *U* test for continuous variables and chi-square or Fisher exact test for categorical variables. Changes over time were analyzed, and delta values were calculated for clinical scores. Patients were categorized as having achieved or not achieved the PASS, and rates were compared between groups using the chi-square or Fisher exact test, as appropriate.

Linear regression analyses were performed to evaluate variables associated with postoperative outcomes, including VAS, IKDC, Lysholm, and FJS-12 values. For postoperative VAS, IKDC, and Lysholm scores, variables entered into the models included group allocation, age, body mass index (BMI), and the corresponding preoperative score. For postoperative FJS-12 values, secondary exploratory models were constructed to evaluate the association between residual postoperative laxity and joint awareness. Because residual laxity is a postoperative variable and may lie on the causal pathway between surgical technique and postoperative joint awareness, these models were not intended to estimate an independent causal effect of treatment allocation and were interpreted as exploratory association analyses. No a priori power calculation was performed because of the retrospective design, and the sample size was determined by the number of eligible patients during the study period. Accordingly, nonsignificant between-group comparisons were interpreted as no detected differences rather than evidence of equivalence or noninferiority. A *P* value $<.05$ was considered statistically significant.

RESULTS

Patient Characteristics and Baseline Outcomes

A total of 85 patients were included in the final analysis: 26 patients (30.6%) in the repair group and 59 patients

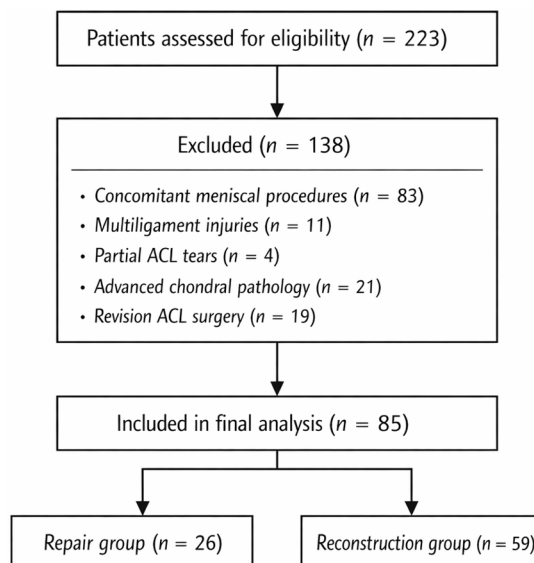


Figure 1. Flowchart of patient selection and study inclusion. A total of 223 patients were assessed for eligibility. After applying exclusion criteria, 85 patients were included in the final analysis: 26 patients in the primary anterior cruciate ligament (ACL) repair group and 59 patients in the reconstruction group.

(69.4%) in the reconstruction group (Figure 1). Baseline patient characteristics and preoperative patient-reported outcomes were comparable between groups, with the exception of preoperative VAS pain scores, which were significantly higher in the repair group (4.88 ± 1.21 vs 3.83 ± 1.23 ; $P = .001$). Detailed baseline characteristics are presented in Table 1.

Postoperative Functional Outcomes

At a minimum 24-month follow-up, no significant differences were observed between the repair and reconstruction groups in postoperative Lysholm, IKDC, or Tegner activity scale scores ($P > .05$ for all) (Figure 2, Table 2).

In contrast, postoperative FJS-12 values were significantly higher in the repair group compared with the reconstruction group (87.0 ± 15.0 vs 77.5 ± 14.2 ; mean difference, 9.5 points [95% CI, 2.8-16.3]; $P = .006$), indicating less joint awareness during activities of daily living. The magnitude of this difference was moderate (Cohen $d = 0.66$). Both groups demonstrated substantial improvement from baseline to final follow-up, and no detected between-group differences were observed in the magnitude of improvement in Lysholm or IKDC scores ($P > .05$). Although the improvement in VAS scores was significantly greater in the repair group compared with the reconstruction group ($P = .012$), this finding should be interpreted in the context of higher preoperative VAS scores in the repair group. Final postoperative VAS scores were similar between groups ($P = .799$).

TABLE 1
Baseline Patient Characteristics and Preoperative Scores^a

	Repair Group (n = 26)	Reconstruction Group (n = 59)	P Value
Age, y	29.7 ± 7.4	30.6 ± 7.9	.637
BMI, kg/m ²	25.1 ± 1.9	24.9 ± 2.3	.661
Follow-up duration, mo	36.6 ± 7.4	36.1 ± 5.6	.745
Preoperative VAS score	4.88 ± 1.21	3.83 ± 1.23	.001
Preoperative Lysholm score	59.7 ± 4.1	60.2 ± 4.0	.565
Preoperative IKDC score	50.5 ± 3.1	51.5 ± 2.9	.160
Preoperative Tegner score	6.77 ± 0.76	6.71 ± 0.77	.733

^aData are presented as mean ± SD. BMI, body mass index; IKDC, International Knee Documentation Committee; VAS, visual analog scale.

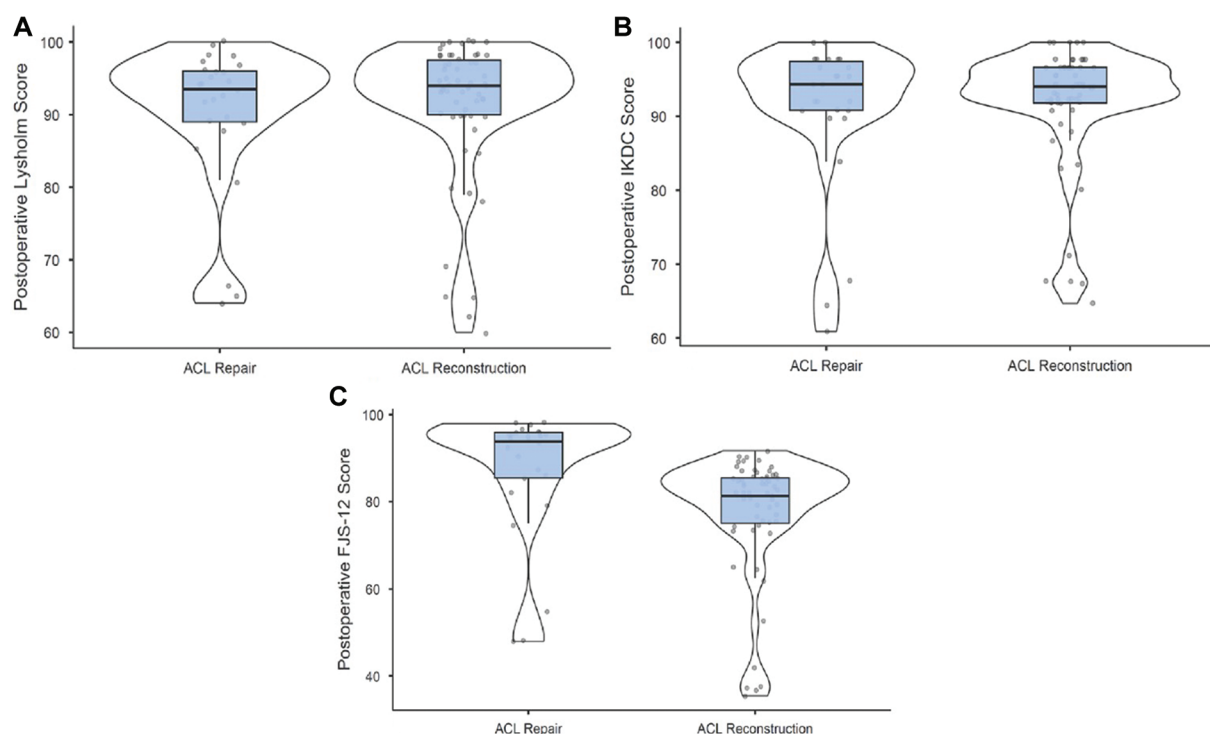


Figure 2. Distribution of postoperative (A) Lysholm, (B) International Knee Documentation Committee (IKDC), and (C) Forgotten Joint Score-12 (FJS-12) scores at the 24-month follow-up. Violin plots with overlaid box plots and jittered individual data points are shown for the anterior cruciate ligament (ACL) repair and ACL reconstruction groups. The width of each violin represents the density of observed scores within each group.

TABLE 2
Postoperative Functional Scores and Δ Values^a

	Repair Group (n = 26)	Reconstruction Group (n = 59)	P Value
Postoperative VAS score	0.88 ± 1.18	0.81 ± 1.11	.799
Postoperative Lysholm score	90.1 ± 10.3	91.2 ± 9.7	.544
Postoperative IKDC score	90.8 ± 10.5	91.7 ± 8.4	.928
Postoperative Tegner score	6.35 ± 1.26	6.36 ± 1.21	.967
Postoperative FJS-12	87.0 ± 15.0	77.5 ± 14.2	.006
Δ VAS score	-4.00 ± 1.55	-3.02 ± 1.42	.012
Δ Lysholm score	30.4 ± 10.8	31.0 ± 10.2	.996
Δ IKDC score	40.3 ± 10.9	40.2 ± 8.9	.347

^aData are presented as mean ± standard deviation. FJS-12, Forgotten Joint Score-12; IKDC, International Knee Documentation Committee; VAS, visual analog scale; Δ , change from baseline to final follow-up.

TABLE 3
Knee Laxity Assessment at Final Follow-up^a

Laxity Test	Repair Group (n = 26)	Reconstruction Group (n = 59)	P Value
Lachman test			.891
Normal	16 (61.5)	35 (59.3)	
Mild	4 (15.4)	13 (22.0)	
Moderate	3 (11.5)	5 (8.5)	
Severe	3 (11.5)	6 (10.2)	
Pivot-shift test			.847
Normal	21 (80.8)	51 (86.4)	
Mild	2 (7.7)	4 (6.8)	
Moderate	1 (3.8)	2 (3.4)	
Severe	2 (7.7)	2 (3.4)	

^aData are presented as n (%). *P* values represent overall group comparison using the chi-square test. Original categorical stability data are presented for descriptive purposes; dichotomized variables (normal/mild vs moderate/severe) were used in regression analyses.

Knee Laxity

No significant between-group differences were detected in postoperative knee laxity as assessed by the Lachman and pivot-shift tests ($P > .05$). Detailed laxity assessment results are presented in Table 3. For the dichotomized Lachman classification used in the exploratory regression analyses, 20 patients (76.9%) in the repair group and 48 patients (81.4%) in the reconstruction group were classified as having no or low residual laxity, whereas 6 patients (23.1%) and 11 patients (18.6%), respectively, were classified as having clinically significant residual laxity. For the dichotomized pivot-shift classification, 23 patients (88.5%) in the repair group and 55 patients (93.2%) in the reconstruction group were classified as having no or low residual laxity, whereas 3 patients (11.5%) and 4 patients (6.8%), respectively, were classified as having clinically significant residual laxity.

Clinical Success Indicators

Rates of PASS achievement were high and comparable between groups for both IKDC (88.5% vs 91.5%; $P = .656$) and Lysholm (84.6% vs 86.4%; $P = .824$) scores.

Return to sport was achieved in 84.6% of patients in the repair group and 86.4% in the reconstruction group ($P = .824$), while rerupture rates were similar between groups (11.5% vs 13.6%; $P = .798$) (Table 4).

Factors Associated With Postoperative Outcomes

Multivariable linear regression analyses revealed no significant associations between the examined variables and postoperative VAS, IKDC, and Lysholm scores. Detailed results of the regression analyses are presented in Table 5. The models for postoperative VAS ($R^2 = 0.007$; $P =$

TABLE 4
Return to Sport, Rerupture, and PASS^a

	Repair Group (n = 26)	Reconstruction Group (n = 59)	P Value
Return to sport	22 (84.6)	51 (86.4)	.824
Rerupture	3 (11.5)	8 (13.6)	.798
Achieved PASS for IKDC score (≥ 75.9)	23 (88.5)	54 (91.5)	.656
Achieved PASS for Lysholm score (≥ 85)	22 (84.6)	51 (86.4)	.824

^aData are presented as n (%). IKDC, International Knee Documentation Committee; PASS, Patient Acceptable Symptom State. Return to sport is defined as achieving a postoperative Tegner activity level greater than or equal to the preinjury level at the minimum 24-month follow-up.

.968), IKDC ($R^2 = 0.008$; $P = .954$), and Lysholm ($R^2 = 0.010$; $P = .937$) scores were not statistically significant.

In contrast, secondary exploratory regression models incorporating postoperative laxity demonstrated significant associations with postoperative FJS-12 values. The model including Lachman-based stability classification explained a substantial proportion of variance in FJS-12 values ($R^2 = 0.649$; $P < .001$). Residual laxity showed a strong association with lower postoperative FJS-12 values ($B = -27.77$; $P < .001$).

Similarly, when pivot-shift-based stability classification was used, the model demonstrated higher explanatory power ($R^2 = 0.680$; $P < .001$), with residual instability showing a strong association with lower FJS-12 values ($B = -41.56$; $P < .001$). In contrast, age, BMI, and preoperative IKDC scores were not significantly associated with postoperative joint awareness.

The distribution of postoperative FJS-12 values according to dichotomized Lachman and pivot-shift categories, stratified by surgical group, is shown in Figure 3.

The unstandardized regression coefficients and 95% confidence intervals for both FJS-12 models are illustrated in Figure 4.

Complications

Postoperative complications differed between the groups (Table 6). In the repair group, no cases of infection, neurovascular injury, or other procedure-related complications were observed. As no graft harvesting was performed, donor site morbidity was not applicable in this group. In the reconstruction group, 1 patient developed a superficial donor site infection, which was successfully treated with local debridement and oral antibiotic therapy. Another patient required implant removal (U-staple) along with deep surgical debridement and intravenous antibiotic treatment due to deep infection. Thromboembolic complications occurred in 2 patients, including 1 case of deep vein thrombosis and 1 case of pulmonary embolism; both were managed successfully with medical therapy. In

TABLE 5
Multivariable Linear Regression Analysis for Factors Associated With Postoperative FJS-12 Values^a

	<i>B</i>	Standardized β	95% CI for <i>B</i>	<i>P</i> Value
Model 1: Including Lachman group ^b				
Group (reconstruction vs repair)	-11.233	-0.347	-15.592 to -6.874	<.001
BMI	-0.065	-0.009	-0.979 to 0.850	.888
Age	0.201	0.104	-0.059 to 0.461	.128
Preoperative IKDC score	0.315	0.062	-0.370 to 0.999	.363
Lachman group (0 vs 1)	-27.772	-0.744	-32.760 to -22.784	<.001
Model 2: Including pivot-shift group ^c				
Group (reconstruction vs repair)	-11.588	-0.358	-15.757 to -7.419	<.001
BMI	0.360	0.053	-0.509 to 1.229	.412
Age	0.045	0.023	-0.205 to 0.295	.719
Preoperative IKDC score	0.145	0.029	-0.509 to 0.799	.660
Pivot-shift group (0 vs 1)	-41.562	-0.766	-48.505 to -34.619	<.001

^aBMI, body mass index; FJS-12, Forgotten Joint Score-12; IKDC, International Knee Documentation Committee.

^b $R^2 = 0.649$; adjusted $R^2 = 0.627$; $F = 29.265$; $P < .001$.

^c $R^2 = 0.680$; adjusted $R^2 = 0.660$; $F = 33.543$; $P < .001$.

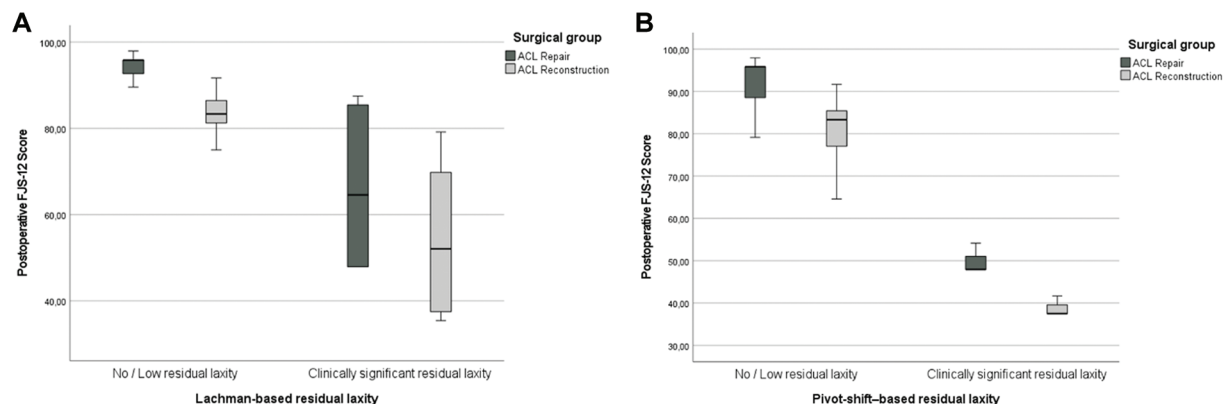


Figure 3. Association between residual postoperative laxity and postoperative Forgotten Joint Score-12 (FJS-12) values. Box plots demonstrate postoperative FJS-12 values according to dichotomized (A) Lachman and (B) pivot-shift categories, stratified by surgical group. ACL, anterior cruciate ligament.

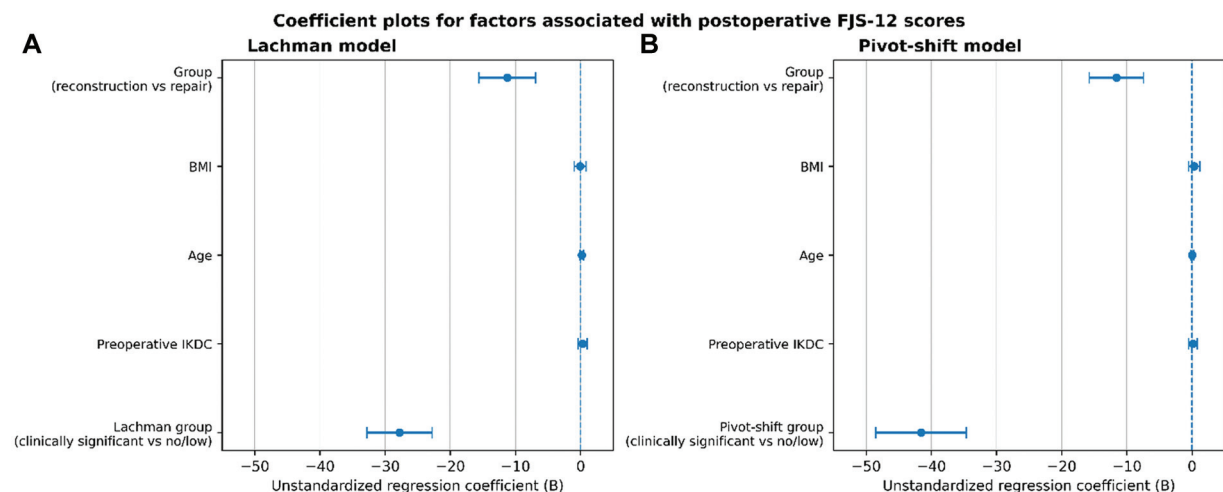


Figure 4. Coefficient plots for factors associated with postoperative Forgotten Joint Score-12 (FJS-12) values. Unstandardized regression coefficients with 95% confidence intervals are shown for the (A) Lachman-based model and (B) pivot-shift-based model. The vertical dashed line represents no association. BMI, body mass index; IKDC, International Knee Documentation Committee.

TABLE 6
Postoperative Complications^a

Complication	Repair Group (n = 26)	Reconstruction Group (n = 59)
Infection		
Superficial	0 (0)	1 (1.7)
Deep	0 (0)	1 (1.7)
Thromboembolic complications		
Deep vein thrombosis	0 (0)	1 (1.7)
Pulmonary embolism	0 (0)	1 (1.7)
Nerve injury (saphenous paresthesia)	0 (0)	4 (6.8)
Other neurovascular injury	0 (0)	0 (0)
Total complications	0 (0)	8 (13.6)

^aData are presented as n (%). No graft harvesting was performed in the repair group; therefore, donor site morbidity was not applicable.

addition, 4 patients experienced paresthesia related to injury of the infrapatellar branch of the saphenous nerve during graft harvesting.

DISCUSSION

The most important finding of the present study is that primary ACL repair performed in carefully selected proximal tears with adequate tissue quality was associated with higher postoperative FJS-12 values than hamstring autograft reconstruction, while no significant between-group differences were detected in conventional clinical outcomes, postoperative laxity, return-to-sport rates, or rerupture rates at a minimum 24-month follow-up. No significant differences were observed between groups in postoperative pain, functional scores (Lysholm, IKDC, and Tegner), knee laxity, return-to-sport rates, or rerupture rates, suggesting that both techniques can achieve similar short- to midterm functional restoration in selected patients. However, patients treated with primary repair demonstrated significantly higher FJS-12 values compared with those undergoing reconstruction (87.0 ± 15.0 vs 77.5 ± 14.2 ; mean difference, 9.5 points [95% CI, 2.8-16.3]; $P = .006$), corresponding to a moderate effect size (Cohen $d = 0.66$), indicating lower awareness of the operated knee during daily activities. Additional exploratory analyses demonstrated that residual postoperative laxity was associated with lower FJS-12 values. Given the observational and cross-sectional nature of these analyses, these findings should be interpreted as associations rather than evidence of a causal mechanistic relationship. It is possible that the higher FJS-12 values observed after primary repair may partially relate to differences in postoperative laxity and preservation of native tissue characteristics; however, this interpretation remains speculative. In addition, although no procedure-related complications were observed in the repair group, the relatively limited sample size precludes definitive conclusions

regarding comparative safety profiles. Taken together, these findings suggest that primary ACL repair, when performed in appropriately selected proximal tears with adequate tissue quality, may be associated with higher FJS-12 values; however, these findings should be interpreted cautiously given the retrospective design, limited sample size, and nonrandomized treatment allocation.

The findings of the present study are in line with the limited but emerging body of literature on joint awareness after ACL surgery.^{13,24,26} Vermeijden et al²⁴ reported significantly higher FJS-12 values after primary ACL repair compared with reconstruction at short- to midterm follow-up, indicating reduced joint awareness with tissue-preserving techniques. However, that study was primarily limited to outcome comparison and did not investigate the underlying mechanistic factors influencing joint awareness. In contrast, the present study extends these findings by exploring the association between postoperative residual laxity and patient-reported joint awareness. The additional analyses demonstrated that greater residual laxity was associated with lower postoperative FJS-12 values. However, given the observational and cross-sectional design of the present study, these findings should be interpreted as exploratory associations rather than evidence of a mechanistic or causal relationship.

Recent literature has increasingly revisited primary ACL repair as a viable treatment option in carefully selected patients, particularly those with proximal femoral-sided tears and adequate tissue quality.^{18,19,22} Although ACL reconstruction remains the current gold standard, several contemporary studies, including randomized and matched comparative analyses, have demonstrated that primary repair can achieve comparable short- to midterm functional outcomes, knee laxity, and patient-reported results when strict selection criteria are applied.^{11,20,21} In line with these findings, the present study demonstrated no significant differences between the repair and reconstruction groups in terms of postoperative functional scores, knee laxity, return to sport, or overall clinical success. One of the main concerns highlighted in earlier literature is the potentially higher rerupture rate associated with repair; however, more recent evidence suggests that rerupture rates may be comparable to those of reconstruction when repair is limited to proximal tears with good tissue quality.^{11,19,22} Our results support this evolving concept, as rerupture rates were similar between groups, indicating that appropriate patient selection and surgical technique may mitigate previously reported risks.

Joint awareness, as quantified by the FJS-12, has emerged as a sensitive outcome measure that captures aspects of knee function not fully reflected by conventional scores such as the IKDC or Lysholm score.^{13,26} In ACL reconstruction cohorts, previous studies have reported mean postoperative FJS-12 values of approximately 71.4 ± 22.9 , while matched comparative analyses, including the study by Vermeijden et al,²⁴ have demonstrated mean values of 74.2 ± 21.7 after reconstruction and 82.0 ± 15.1 after primary repair at midterm follow-up.¹³ In this context, the significantly higher FJS-12 values

observed in our repair group compared to reconstruction (87.0 ± 15.0 vs 77.5 ± 14.2 ; $P = .006$) represent not only a statistically significant difference but also a moderate effect size (Cohen $d = 0.66$), suggesting a potentially clinically relevant difference in joint awareness. A plausible explanation for this difference is the preservation of native ligament tissue in primary repair.¹⁸ By maintaining intrinsic mechanoreceptors and anatomic insertion sites, repair may better preserve proprioceptive function and neuromuscular control.⁹ In contrast, ACL reconstruction depends on graft ligamentization, a process in which restoration of native neurosensory function may be incomplete or delayed.⁵ Furthermore, avoiding graft harvest eliminates donor site morbidity, which may contribute to persistent awareness of the operated knee after reconstruction.⁸ Taken together, these findings support the concept that tissue-preserving approaches may facilitate a more physiological restoration of knee function. Nevertheless, the clinical relevance of the observed between-group difference should be interpreted cautiously. The absolute difference in FJS-12 values between groups was 9.5 points, which is lower than the 16.5-point minimal clinically important difference previously reported in arthroplasty populations. Although this threshold may not be directly transferable to ACL surgery populations, it provides important context regarding interpretation of the magnitude of the observed difference.

Importantly, the additional analyses performed in this study provide further insight into the determinants of joint awareness. While previous studies have primarily focused on functional outcomes and rerupture rates, the relationship between objective knee laxity and joint awareness has been insufficiently explored. In this context, our findings provide novel insight that joint awareness may be not only determined by surgical technique or biological factors, but also influenced by the degree of residual instability. Although residual laxity was associated with lower FJS-12 values, postoperative laxity did not differ significantly between treatment groups, and group allocation remained associated with FJS-12 after adjustment. Therefore, residual laxity should not be interpreted as explaining the between-group difference in FJS-12 values. Rather, these findings suggest that both surgical group and postoperative residual laxity may be associated with patient-perceived joint awareness.

Return-to-sport and rerupture rates remain among the most clinically relevant outcomes after ACL surgery.¹¹ In the present study, return to sport was achieved in 84.6% of patients in the repair group and 86.4% in the reconstruction group, with no significant difference between groups. Similarly, rerupture rates were comparable (11.5% and 13.6%, respectively). These findings are consistent with previous literature reporting return-to-sport rates ranging from 65% to 85% after ACL reconstruction, with higher rates observed in selected populations.^{2,12} Studies focusing on primary repair in carefully selected proximal tears have reported comparable return-to-sport rates in the range of 70% to 90%.²⁵ With respect to rerupture, earlier studies reported higher rerupture rates after ACL repair, particularly in heterogeneous patient populations.^{18,19} However,

more recent matched and contemporary series have demonstrated comparable rerupture rates between repair and reconstruction, generally reported in the range of 7% to 15% when strict selection criteria are applied.^{11,19,22} Return-to-sport rates in the present cohort were within the range reported in contemporary ACL repair and reconstruction literature. However, although rerupture rates did not differ significantly between groups, the absolute rerupture rates of 11.5% after repair and 13.6% after reconstruction are on the higher end compared with some recent contemporary ACL reconstruction series. This may be partly related to the relatively young and active cohort, the small sample size, and the high proportion of patients returning to sport. Therefore, these rerupture rates should be interpreted cautiously and require confirmation in larger cohorts with longer follow-up.

This study has several limitations that should be considered when interpreting the findings. First, the retrospective observational design introduces the potential for selection bias and confounding by indication, as treatment allocation was based on intraoperative assessment of tear location and tissue quality rather than randomization. Consequently, the treatment groups were inherently different from a biological and surgical indication standpoint, since primary repair was performed only in carefully selected proximal tears with adequate tissue quality, whereas reconstruction was used for less favorable tear patterns. Therefore, the present findings should not be interpreted as evidence of generalized superiority of repair over reconstruction. In addition, the exact interval between injury and surgery was not consistently available in the retrospective records and therefore could not be reliably analyzed. This may represent an additional source of residual confounding, particularly because injury chronicity may influence tissue quality and eligibility for primary ACL repair. Second, although the multivariable analyses demonstrated statistically significant associations between residual postoperative laxity and joint awareness, the relatively limited sample size and uneven group sizes—particularly in the smaller repair group—may reduce the stability and generalizability of the simplified statistical analyses and regression models, and these analyses should therefore be considered exploratory in nature. In addition, because postoperative stability and FJS-12 values were assessed at the same follow-up time point, the observed relationships should be interpreted as cross-sectional associations rather than evidence of a causal or mechanistic relationship. Third, postoperative laxity assessment relied on clinical Lachman and pivot-shift examinations without instrumented laxity measurements such as KT-1000 arthrometer testing. Furthermore, interobserver and intraobserver reliability analyses were not performed, and examiner-dependent variability may therefore have influenced the laxity findings. Fourth, although a minimum follow-up of 24 months was ensured, longer-term outcomes remain unknown, particularly with respect to durability and rerupture risk after ACL repair. Fifth, although a statistically significant difference in joint awareness was observed between groups, the clinical relevance of this difference should be interpreted cautiously, as

currently available minimal clinically important difference thresholds for FJS-12 are primarily derived from arthroplasty populations and may not be directly transferable to ACL surgery. Finally, important potentially influential variables including lower limb alignment, muscle strength, objective proprioceptive function, psychological readiness for return to sport, and detailed neuromuscular assessments were not evaluated. In addition, exclusion of patients undergoing concomitant meniscal procedures improved internal validity but may have reduced the generalizability of the findings to routine ACL practice, where associated meniscal pathology is common.

Despite these limitations, the present study provides exploratory evidence suggesting that primary ACL repair may be a reasonable treatment option in carefully selected proximal ACL tears with adequate tissue quality. The findings also highlight the potential value of joint awareness as an outcome measure beyond traditional functional scores. Moreover, the observed association between postoperative laxity and FJS-12 values suggests that residual laxity may be relevant to patient-perceived joint awareness after ACL surgery. Future prospective randomized studies with larger cohorts and longer follow-up are warranted to confirm these findings and further clarify the relationship between laxity, surgical technique, and patient-reported outcomes.

CONCLUSION

In this retrospective exploratory cohort study of carefully selected patients with isolated ACL rupture, no detected between-group differences were observed in conventional clinical outcomes, postoperative laxity, return-to-sport rates, or rerupture rates between primary ACL repair and hamstring autograft reconstruction. Primary ACL repair was associated with higher postoperative FJS-12 values at short- to midterm follow-up. Secondary exploratory analyses showed an association between residual postoperative laxity and lower FJS-12 values. Given the retrospective design, limited sample size, and nonrandomized treatment allocation, these findings should be interpreted cautiously and should not be considered evidence of equivalence or superiority.

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