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No Increased Risk of Cyclops Lesions or Extension Deficit After ACL Reconstruction: Analysis of Multiple Remnant-Preserving Techniques Compared to the Standard Approach

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Abstract

Purpose

To compare clinical outcomes, knee extension, return to sport, and cyclops lesion rates among different remnant-preserving anterior cruciate ligament (ACL) reconstruction techniques and a standard non–remnant-preserving technique.

Methods

We conducted a retrospective cohort study of 250 adults who underwent primary ACL reconstruction with semitendinosus grafts between 2015 and 2019 and had a minimum 24-month follow-up. Patients were allocated to five groups according to intraoperative management of the tibial remnant: stump-preserving (<50% remnant), remnant-threading (>50% remnant), selective-bundle reconstruction (augmentation), remnant retensioning (>50% remnant), and standard reconstruction with complete remnant debridement. The primary outcome was graft failure requiring revision surgery. Secondary outcomes included knee extension deficit, Lysholm and IKDC scores, Tegner activity level, time to return to sport, and cyclops lesions diagnosed on 12-month MRI. Group comparisons were performed using appropriate parametric or non-parametric tests for continuous variables and χ^2 or Fisher's exact tests for categorical variables.

Results

At a mean follow-up of 38.7 ± 9.9 months, graft failure occurred in 4 of 250 patients (1.6%), with no significant differences among the five groups. An extension deficit of 0–3° was observed in 8% of patients, and no deficits >3° were recorded, without relevant between-group differences. The mean time to return to sport was 9.1 ± 3.1 months, and Lysholm, IKDC, and Tegner scores were comparable across techniques. Cyclops lesions were detected on MRI in 16 patients (6.4%), and only 4 required arthroscopic debridement; cyclops rates were not associated with remnant preservation strategies.

Conclusions

Remnant-preserving ACL reconstruction is a safe surgical strategy that does not increase the risk of cyclops lesions or extension deficits. Given the comparable functional outcomes and the absence of deficits exceeding 3%, remnant preservation represents a reliable clinical approach that can be performed without compromising patient safety or postoperative range of motion.

Level of evidence III

Introduction

Anterior cruciate ligament (ACL) rupture or insufficiency and its association with sports participation are well established. Over at least the past 15 years, the pathophysiology of this injury, surgical

reconstruction methods, and rehabilitation protocols have been extensively investigated to improve postoperative clinical outcomes in a population largely composed of athletes; nevertheless, despite increased understanding and technical advances, rerupture rates remain high[15, 16].

Mechanoreceptors have been identified in the ACL, particularly near the tibial insertion[9]. Accordingly, using the tibial remnant as an adjunct during ACL reconstruction (ACLR) has been proposed to enhance postoperative graft revascularization[13], a finding demonstrated in cadaveric studies but not yet confirmed in humans. Some studies have suggested that remnant-preserving techniques may improve patient-reported outcomes, such as Lysholm scores, although recent systematic reviews have not consistently demonstrated superiority over standard techniques.

Uncertainty remains regarding the percentage of tibial remnant that is truly beneficial to achieve meaningful postoperative improvements. Moreover, prior MRI-based studies evaluating graft revascularization have not found significant differences among reconstruction techniques[12], and recent reviews do not conclude in favor of one ACLR technique over another[16].

The primary objective of this study was to compare graft failure, knee extension, and cyclops lesion rates among different remnant-preserving ACL reconstruction techniques and a standard non–remnant-preserving technique. Secondary objectives were to evaluate return to sport and patient-reported outcome measures (PROMs). We hypothesized that preservation of the tibial ACL remnant would not be associated with clinically meaningful or statistically significant differences in postoperative complications or validated PROMs compared with non–remnant-preserving techniques.

Materials and methods

Study Design

We conducted a retrospective cohort study based on a manual review of the electronic health record (EHR) for all patients who underwent primary anterior cruciate ligament (ACL) reconstruction between January 2015 and December 2019. Only cases with a minimum follow-up of 24 months were included. This retrospective study was approved by our institution's institutional review board, which waived the requirement for written informed consent owing to the use of de-identified data obtained from routine clinical care. All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Patients ≥ 18 years who underwent ACL reconstruction using a semitendinosus graft were eligible. Exclusion criteria were: multiligament knee injuries (involving more than two ligaments in the same traumatic event), prior ACL surgery, concomitant osteotomy performed at the time of the reconstruction,

concomitant meniscal repair for bucket-handle or radial tears, and reconstructions performed with alternative grafts (quadriceps tendon, bone–patellar tendon-bone (BTB), or cadaveric allograft).

Study Groups

Patients were stratified into five groups according to the ACL reconstruction (ACLR) technique and the percentage of remnant preserved: Group A comprised cases with < 50% tibial remnant treated with a stump-preserving approach; Group B included cases with > 50% remnant undergoing a remnant-threading (suture-weaving) technique integrating the remnant with the neograft; Group C consisted of selective-bundle (augmentation) reconstructions in which one native ACL bundle was preserved; Group D encompassed remnant-retensioning procedures in patients with > 50% residual ACL tissue; and Group E comprised standard ACLR with complete remnant debridement. Figure 1 illustrates each technique. Graft failure was defined as any episode of knee instability, traumatic or atraumatic, necessitating surgical reintervention with revision ACL reconstruction.

Variables and Outcomes

All patients had a minimum 24-month follow-up. Outcome variables included postoperative knee extension deficit, functional scores (Lysholm and IKDC), and time to return to sport, with activity level quantified using the Tegner Activity Scale. Immediate postoperative radiographs were obtained to assess femoral and tibial tunnel positioning, and magnetic resonance imaging at the final follow-up was performed to evaluate graft status.

The primary endpoint was graft failure, defined as any episode of subjective instability requiring revision ACL reconstruction. Secondary endpoints included postoperative knee extension deficit, Lysholm and IKDC scores, Tegner activity level, time to return to sport, and the presence of cyclops lesions on 12-month postoperative MRI.

Statistical Analysis

Continuous variables were summarized as mean (standard deviation) when approximately normally distributed and as median (interquartile range, 25–75) otherwise. Categorical variables were reported as absolute and relative frequencies (n, %). The primary endpoint, graft rerupture rate, was compared among surgical techniques using the χ^2 test or Fisher's exact test, as appropriate.

For secondary outcomes (Lysholm and IKDC scores), given their typically non-normal distribution, the Kruskal–Wallis test was used for comparisons across the five groups. Time to return to sport (months) was compared among groups using one-way analysis of variance or the Kruskal–Wallis test according to the observed distribution, and return-to-sport rates and major complication rates were compared using the χ^2 test or Fisher's exact test, as appropriate. Two-sided p-values < 0.05 were considered statistically significant. All analyses were performed using Stata version 13 (StataCorp, College Station, TX, USA).

Results

A total of 250 patients were included in the final analysis. The cohort was distributed into five groups based on the remnant management technique. Mean follow-up for the entire cohort was 38.7 ± 9.9 months, with no statistically significant differences among groups (p = 0.19). Demographic and follow-up data are summarized in Table 1.

Table 1
Demographic characteristics and follow-up by surgical technique

Group	Surgical technique	Number of patients (n)	Average follow-up (months ± SD)
A	Stump-preserving	63	42.0 ± 8.6
B	Remnant-threading	14	25.5 ± 1.4
C	Selective-bundle reconstruction	92	39.4 ± 8.8
D	Remnant retensioning	38	31.2 ± 3.1
E	Standard technique	42	42.6 ± 12.8
Total		250	38.7 ± 9.9

Complications and Imaging

The overall graft failure rate was 1.6% (4 of 250 patients), with no significant differences among the surgical techniques (p = 0.609). Specifically, failures occurred in Group A (n = 2) and Group C (n = 2), while no failures were recorded in Group B, D or E.

Postoperative MRI was obtained for 185 patients (74%) at the 12-month mark. Cyclops lesions were identified in 16 patients (6.4%). There were no significant between-group differences in the presence of cyclops lesions or surgical failure (p = 0.739 and p = 0.609, respectively). Table 2 summarizes MRI-detected cyclops lesions and symptomatic cases requiring surgery for anterior fibrosis.

Table 2
Cyclops lesions, surgery for anterior fibrosis, and graft failures by group

Group	Patients with cyclops n (%)	Surgery for cyclops	Surgical failures (revision)
A	5 (7.9%)	2 (3.2%)	2 (3.2%)
B	1 (7.1%)	0	0
C	5 (5.4%)	0	2 (2.2%)
D	1 (2.6%)	0	0
E	4 (9.5%)	2 (4.8)	0
Total	16 (6.4%)	4 (1.6%)	4 (1.6%)

Terminal Knee Extension

Across all groups, 8% of patients exhibited an extension deficit of 0–3°, and no deficits > 3° were observed. In Group A, 6 patients had a loss of extension of 0–3°, including 2 with a 3° deficit. In Groups B, C, D, and E, 1, 8, 2, and 3 patients, respectively, had a 0–3° deficit. Statistical analysis revealed no relevant between-group differences regarding terminal extension loss.

Return to Sport and Functional Evaluation

The mean time to return to sport was 9.1 ± 3.1 months with no significant between-group differences ($p > 0.5$). By group, the mean (± SD) time was 9.1 ± 1.6 months for Groups A and B, 8.9 ± 2.9 months for Group C, 8.8 ± 1.5 months for Group D, and 9.2 ± 3.4 months for Group E.

Regarding patient-reported outcome measures (PROMs), Lysholm and IKDC scores were comparable across all groups, with no statistically significant differences identified. On the Tegner Activity Scale, a decrease in pre-injury activity levels was observed in a small subset of patients: 7 in Group A, 3 in Group C, 4 in Group D, and 2 in Group E.

DISCUSSION

The most significant finding of this study is that we observed no significant differences in the incidence of cyclops lesions or terminal knee extension deficits among the various remnant-preserving ACL reconstruction (ACLR) techniques compared with a standard debridement approach. These results suggest that the theoretical risk of mechanical block or increased fibrosis associated with preserving native ACL tissue may be overestimated.

In our cohort, an extension loss of 0–3° occurred in 8% of patients, with no deficits exceeding 3° recorded. This is notably lower than the 15.9% prevalence reported by Scholes et al. in a recent meta-analysis, although they utilized a more stringent threshold of ≥ 5° to define deficit[14]. While Nakayama

et al. previously noted a greater loss of extension in patients undergoing remnant preservation[11], our data align more closely with the findings of Delaloye et al., who identified early postoperative extension loss, rather than the surgical technique itself, as the primary risk factor for developing cyclops syndrome[5]. Our results reinforce the principle that early rehabilitation and correct tunnel placement are the most critical factors in preventing fibrovascular nodules.

The mean time to return to sport was 9.1 months, with no significant differences between groups in the present series. While Bierke et al[2] observed a higher 1-year return-to-sport rate in remnant-preserving procedures (79% vs 68%), our findings support the conclusions of several meta-analyses indicating that remnant preservation does not meaningfully accelerate the return to high-level athletic activity[6, 17].

Likewise, we found no between-group differences in Lysholm or IKDC scores; some decrease was seen in Tegner scores in select groups. This consistency matches the results of Masuda et al. and Iwaasa et al., who reported comparable outcomes in anatomic double-bundle reconstructions regardless of tissue preservation[7, 10]. Although some studies, such as those by Ahn et al. and Bosco et al., have shown superior PROMs with remnant preservation, the lack of consensus in recent meta-analyses suggests that any functional benefit may be marginal or population-specific [1, 3, 6, 17].

The overall incidence of MRI-detected cyclops lesions was 6.4%, with only four cases requiring surgical intervention. The relationship between preservation and cyclops formation remains controversial in the literature. For instance Hishimura et al. reported a lower cyclops rate with remnant preservation (13.3% vs 29.1%)[6], whereas Cha et al.[4] and Ahn et al.[1] found no significant association. Importantly, Delaloye et al. identified early postoperative extension loss as a significant risk factor for cyclops syndrome[5]; limited early extension appears to play a central role in the development of this complication regardless of surgical technique[5, 8]. Our study adds robust evidence to the latter, suggesting that preserving the tibial remnant does not inherently predispose patients to anterior fibrosis.

The primary strength of this study is the analysis of a sizable cohort (n = 250) with no loss to follow-up and a high rate of 12-month postoperative MRI (74%). However, several limitations must be acknowledged. First, the retrospective design introduces inherent selection bias. Second, there is substantial heterogeneity in group sizes, such as the smaller sample in Group B (n = 14) compared to Group C (n = 92), which may reduce statistical power for certain sub-analyses. This disparity reflects the real world variability of ACL remnant morphology encountered intraoperatively, where the surgeon choice of technique is dictated by the quality and volume of the remaining tissue. Despite these differences, the consistency of the functional and imaging results across all groups provides valuable clinical insight into the safety of these techniques.

Conclusion

In this retrospective cohort, various remnant-preserving ACL reconstruction techniques showed no clinically meaningful differences in knee extension, cyclops lesion rates, or functional outcomes compared with standard debridement. Our findings demonstrate that preserving native ACL tissue is a

safe surgical option that does not predispose patients to anterior fibrosis or mechanical blocks. We believe there might be a role in proprioception and graft integration when preserving the patient's native ACL fibers. Consequently, the decision to preserve the tibial remnant should be individualized based on intraoperative findings, prioritizing precise anatomical tunnel placement to ensure optimal clinical results.

Declarations

Ethical approval:

The local ethics committee approved the study protocol (Protocol No. 6143 – IRB '00010193'). The requirement for written informed consent to participate was waived by the IRB due to the retrospective nature of the research and the use of de-identified data obtained from routine clinical care.

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Conflict of interest:

The authors declare no conflicts of interest related to this work.

Author Contribution

NLV: Conceptualized the study and formulated the research objectives. He performed the data analysis and drafted the original manuscript. FA: Conducted the manual review of electronic health records and oversaw data collection. He participated in the critical revision of the intellectual content.IGM: Performed data collection and retrospective cohort follow up. He contributed to the final revision of the manuscript. CHY: Supervised the statistical analysis. He critically reviewed the manuscript to ensure thecnical and surgical rigor.MCP: Critical revision of the discussion and conclusions. He provided final approval of the version to be published. JPZ: Designated the study protocol and coordinated the research team. He participated in drafting, results interpretation and overall project supervision.

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Figures

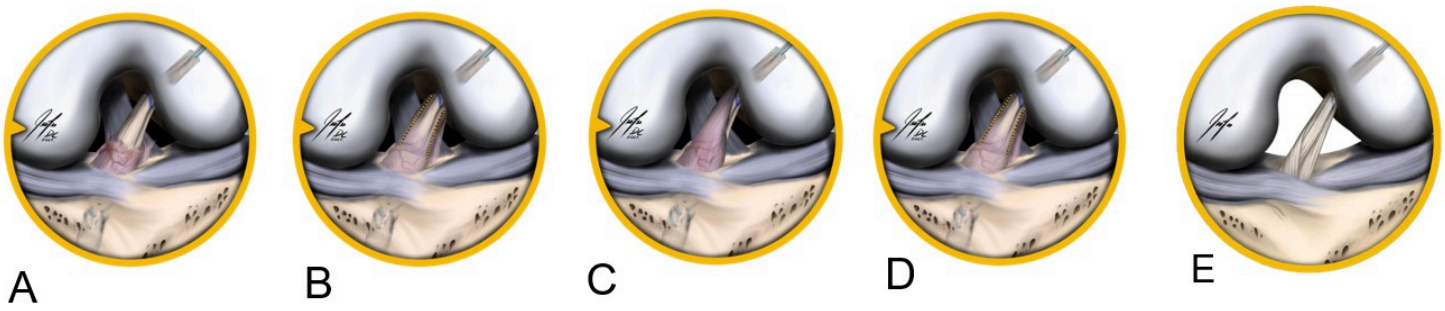


Figure 1

Schematic representation of the five ACL reconstruction techniques according to tibial remnant management: (A) stump-preserving, (B) remnant-threading, (C) selective-bundle reconstruction, (D) remnant retensioning, (E) Standard technique.