

RESEARCH ARTICLE

Arthroscopic Pull-Out Suture vs. Open Screw Fixation for ACL Tibial Avulsion Fractures: A Comparative Study

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Abstract

Objectives: To compare the clinical outcomes between the pull-out suture fixation and the open screw fixation techniques, with particular attention to range of motion (ROM), pain intensity, and Lysholm scores at six and twelve months postoperatively.

Methods: This retrospective cohort study was conducted at Shahid Chamran Hospital, affiliated with Shiraz University of Medical Sciences, between 2020 and 2024. A total of 50 patients were included and evenly divided into two groups (n = 25 each): one treated with pull-out suture fixation and the other with screw fixation. Clinical outcomes assessed at six and twelve months postoperatively included range of motion (ROM), pain intensity, and Lysholm scores.

Results: Statistically significant improvements in range of motion (ROM) and Lysholm scores were found in the pull-out suture fixation group compared with the screw fixation group at both six- and twelve-month follow-ups. In contrast, no significant difference in pain intensity was observed between the two groups.

Conclusion: Pull-out suture fixation was associated with superior clinical outcomes compared with screw fixation for the treatment of ACL tibial avulsion fractures. These findings may help inform surgical decision-making to optimize patient recovery.

Level of evidence: III

Keywords: ACL, ORIF, Pull-out suture, Screw Fixation, Tibial Spine Avulsion

Introduction

Anterior Cruciate Ligament (ACL) tibial avulsion fractures contribute significantly to knee instability, accounting for approximately 2% to 5% of all knee injuries.^{1,2} These injuries occur when a segment of the tibial spine is forcibly separated due to trauma. ACL avulsion fractures are more common in pediatric populations, where bone structures are weaker relative to ligament strength.³⁻⁵ In adults, ACL avulsions are increasing,⁶ and typically result from high-energy trauma, such as car accidents or intense physical activity.⁷⁻⁹

Additionally, females are reported to have a higher risk of ACL injuries, and post-reconstruction outcomes tend to be less favourable compared to those of males.^{10,11} ACL avulsion fractures can severely compromise knee function, primarily affecting anterior and rotational stability.^{5,12} Knee instability in the setting of ACL injuries can also occur due to medial meniscus ramp lesions.¹³

Several surgical techniques have been developed for the fixation of tibial avulsion fractures of the ACL. Among them, screw fixation provides strong mechanical stability but is

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associated with risks such as tibial bone damage and the potential need for hardware removal.¹⁴⁻¹⁶ In contrast, the pull-out suture technique reduces the risk of iatrogenic bone injury but requires greater surgical precision.¹⁵ However, previous studies have reported inconsistent findings regarding the comparative efficacy of these techniques [Figures 1 and 2].¹⁷⁻²⁰



Figure 1. Preoperative anteroposterior and lateral radiographs of the knee demonstrating tibial spine (A) and Postoperative radiographs showing screw fixation of the tibial spine avulsion fracture in lateral and anteroposterior views (B)



Figure 2. Preoperative anteroposterior and lateral radiographs of the knee demonstrating tibial spine (A) and Postoperative radiographs showing screw fixation of the tibial spine avulsion fracture in lateral and anteroposterior views (B).

This retrospective study aimed to compare the clinical and functional outcomes between pull-out suture fixation and screw fixation in patients with anterior cruciate ligament (ACL) tibial avulsion fractures. It was hypothesized that pull-out suture fixation would result in superior postoperative knee stability, range of motion (ROM), and patient satisfaction compared with screw fixation.

Materials and Methods

Study design and population

This retrospective cohort study was conducted at Shahid Chamran Hospital, an affiliated institution of Shiraz University of Medical Sciences. The objective was to evaluate the clinical and functional outcomes of pull-out suture fixation compared with screw fixation in the management of anterior cruciate ligament (ACL) tibial avulsion fractures. A total of 50 patients treated between

2020 and 2024 were selected through convenience sampling and evenly divided into two groups ($n = 25$ each): pull-out suture fixation and screw fixation. Clinical and functional outcomes were assessed at 6 months and 12 months postoperatively using validated evaluation tools.

Inclusion and exclusion criteria

Eligible participants were patients aged 15 to 47 years of both sexes who were diagnosed with isolated anterior cruciate ligament (ACL) tibial avulsion fractures and underwent surgical treatment using either pull-out suture fixation or screw fixation. Participants were eligible for inclusion only if they had complete clinical records and could participate in long-term follow-up assessments. Patients were excluded if they presented with concomitant fractures involving the knee joint (e.g., tibial plateau or distal femoral fractures), multi-ligamentous knee injuries, or incomplete medical documentation.

Sampling method and data collection procedure

Data were collected retrospectively using standardized checklists derived from patients' medical records. The collected data were categorized into two main groups: (1) Demographic characteristics, including age, sex, and cause of injury; and (2) Treatment outcomes, including return to work, pain level, range of motion (ROM), and patient satisfaction.

These outcomes were assessed at 6 months and 12 months postoperatively. Patients were also contacted for long-term follow-up and invited for clinical re-examination. Patient satisfaction and functional outcomes were evaluated using the Lysholm Knee Scoring System, a widely used tool for assessing knee function after ACL surgery. Based on the Lysholm score, knee function was categorized as poor (<60), moderate (60–81), good (82–94), or excellent (>94).

Pull-out surgical technique

For pull-out suture fixation, two 2.7-mm diameter bone tunnels were created medial and lateral to the displaced fracture fragment, extending into the anteromedial cortex of the proximal tibia using a guide pin. The distal exits of the tunnels were spaced by more than 10 mm. Two No. 2 Ethibond sutures were passed through the anterior cruciate ligament (ACL) just proximal to the fracture fragment, positioned anterior and posterior to the tunnels. Each pair of sutures was then passed through the respective bone tunnels using an appropriate gauge wire loop. The fracture bed was prepared using a curette, and the double sutures were tensioned and secured with five knots over the tibial bridge between the tunnels. Although No. 5 Ethibond sutures are thicker and generally preferred, No. 2 Ethibond sutures were selected in this study because they have been more frequently utilized in previous reports.^{21,22} Postoperatively, the knee was immobilized with a splint for two weeks, after which gradual range-of-motion exercises were initiated every two weeks.

Knee stability was clinically evaluated using the Lachman and anterior drawer tests. For the Lachman test, the patient was positioned supine with the knee flexed approximately 20–30°. The examiner stabilized the distal femur with one hand while applying an anteriorly directed force to the proximal tibia with the other hand. An intact, firm endpoint without excessive anterior translation of the tibia relative to the femur was interpreted as a negative test result. In contrast, increased anterior displacement compared with the contralateral knee was considered a positive finding.

For the anterior drawer test, the patient was placed supine with the knee flexed to 90°. The examiner stabilized the foot and applied an anterior force to the proximal tibia. The amount of anterior translation was quantified in millimetres and compared with the contralateral side. Ensuring hamstring relaxation during the test was essential for accuracy. A firm endpoint and minimal anterior translation were regarded as normal findings.

Statistical analysis

Statistical analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). A p-value < 0.05 was considered statistically significant. The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Descriptive statistics were presented as mean $\pm$ standard deviation (SD) and illustrated using tables and graphical representations. Between-group comparisons for categorical and continuous variables were conducted using Chi-square and independent-sample t-tests, respectively. Within-group (longitudinal) comparisons of outcomes—including pain intensity, knee range of motion (ROM), and patient satisfaction—were evaluated using paired t-tests comparing preoperative and postoperative values at 6 and 12 months postoperatively.

Results

Study population and baseline comparisons

A total of 50 patients with anterior cruciate ligament (ACL) tibial avulsion fractures were included in the analysis. Among them, 25 patients underwent pull-out suture fixation and 25 underwent screw fixation. The overall mean age of the cohort was 25.9 ± 8.8 years (range, 15–47 years). There were no statistically significant differences between the two groups in terms of age or sex [Table 1].

Table 1. Demographic data in treatment groups

Surgery Variable	Screw Fixation		Pull-Out	P-value
	Male	Female		
Age	25.52 $\pm$ 9.29		26.20 $\pm$ 8.41	0.78
Gender	Male	21	20	0.71
	Female	4	5	

Comparison of pain levels, knee mobility, and patient satisfaction after 6 months

At 6 months postoperatively, the pull-out suture fixation group showed significantly greater knee joint mobility compared with the screw fixation group (mean ROM: 143.49° vs. 140.24°, $P = 0.027$). Furthermore, patient satisfaction was significantly higher in the suture fixation group (mean satisfaction score: 85.32 vs. 81.12, $P = 0.003$).

Although mean pain scores were lower in the suture fixation group than in the screw fixation group (1.92 vs. 2.32), the difference was not statistically significant ($P = 0.12$) [Table 2].

Table 2. Progression of clinical outcomes, 6 months after surgery

Surgery Variable	Screw Fixation		Pull-Out		P-value
	Average	SD	Average	SD	
Range of Motion	143.49	4.24	140.24	5.74	0.027
Satisfaction (Lysholm)	85.32	3.44	81.12	5.6	0.003
Pain (VAS)	1.92	0.86	2.32	0.94	0.12

Progression from 6 to 12 months post-surgery

Between 6 and 12 months postoperatively, both groups demonstrated continued improvements in range of motion (ROM), knee stability, and patient satisfaction. However, these improvements were more pronounced in the pull-out suture fixation group [Table 3]. Range of motion significantly increased in both groups ($P < 0.001$). Patient satisfaction also continued to improve, showing a statistically significant difference in favor of the suture fixation group (mean satisfaction score at 12 months: 90.60 vs. 84.88, $P < 0.001$). Pain levels decreased in both groups; however, the intergroup difference remained statistically insignificant ($P = 0.19$).

Table 3. Progression of clinical outcomes, 12 months after surgery

Surgery Variable	Screw Fixation		Pull-Out		P-value
	Average	SD	Average	SD	
Range of Motion	149.6	4.996	141.92	5.38	<0.001
Satisfaction (Lysholm)	90.6	2.23	84.88	5.66	<0.001
Pain (VAS)	0.44	0.58	0.72	0.89	0.19

Longitudinal changes within each treatment group

Within-group analyses demonstrated significant improvements in all measured outcomes between the 6- and 12-month follow-ups [Table 4].

Table 4. Comparison of clinical outcomes (range of motion, patient satisfaction, pain, and knee stability) at six and twelve months following suture fixation and screw fixation for ACL tibial avulsion fractures

	Suture Fixation - 6 mo	Suture Fixation - 12 mo	P value	Screw Fixation - 6 mo	Screw Fixation - 12 mo	P value
ROM	143.49	149.6	<0.001	140.24	141.92	<0.001
Satisfaction (Lysholm)	85.32	90.6	<0.001	81.12	84.88	0.002
Pain Score	1.92	0.44	<0.001	2.32	0.72	<0.001
Knee Stability	2.08	1.38	<0.001	2.56	2.05	<0.001

Range of Motion (ROM):

Knee mobility increased in both groups as recovery progressed. In the pull-out suture fixation group, mean ROM improved from 143.5° at 6 months to 150.0° at 12 months ($P < 0.001$). The screw fixation group also showed a significant, though smaller, increase from 140.2° to 141.9° ($P < 0.001$).

These findings are consistent with a meta-analysis of 822 patients,²³ which represents the most comprehensive study to date comparing arthroscopic and open surgical techniques, including one randomized controlled trial. The analysis demonstrated that patients in the arthroscopic group experienced shorter fracture-healing times, lower complication rates, and higher postoperative excellent outcome rates and Lysholm scores. Arthroscopic surgery was also associated with shorter operative and hospitalization times.

Patient Satisfaction:

Satisfaction scores improved over time in both groups. The suture fixation group increased from 85.3 at 6 months to 90.6 at 12 months ($P < 0.001$), whereas the screw fixation group improved from 81.1 to 84.9 ($P = 0.002$). These findings indicate consistently higher satisfaction levels among patients treated with suture fixation.

Pain Levels:

Both groups experienced significant reductions in pain. Mean pain scores decreased from 1.9 to 0.4 ($P < 0.001$) in the suture fixation group and from 2.3 to 0.7 ($P < 0.001$) in the screw fixation group, reflecting marked postoperative pain relief.

Knee Stability:

Joint stability improved significantly in both groups. The suture fixation group improved from 2.1 at 6 months to 1.4 at 12 months ($P < 0.001$), while the screw fixation group improved from 2.6 to 2.1 ($P < 0.001$). Although both techniques enhanced knee stability over time, the suture fixation group demonstrated greater overall improvement.

Discussion

This study compared the surgical outcomes of anterior cruciate ligament (ACL) tibial avulsion fractures treated

with pull-out suture fixation and screw fixation. In the pull-out technique, sutures are passed through the ACL and secured over a tibial bridge. In contrast, screw fixation typically involves open reduction and internal fixation (ORIF) through a medial parapatellar incision.

The results demonstrated that pull-out suture fixation achieved significantly superior outcomes at both 6 and 12 months postoperatively, as reflected in range of motion (ROM) and Lysholm scores, indicating better knee function and patient satisfaction. No significant difference in postoperative pain was observed between the two groups.

A recent randomized comparative study conducted in Egypt on 26 patients with ACL tibial avulsion fractures²⁴ did not show significant differences between arthroscopic reduction and internal fixation (ARIF) and open reduction and internal fixation (ORIF) in terms of clinical outcomes, functional results, or complication rates. However, a higher incidence of postoperative stiffness and a longer time to regain a full range of motion were observed in the ORIF group. Similarly, Callanan et al.¹⁶ reported no significant differences between the two groups regarding postoperative arthrofibrosis, ACL reconstruction, meniscal procedures, instability, range of motion, return to sport, or time to return to sport in 67 patients. However, the screw fixation group demonstrated a 2.9-fold higher odds ratio for reoperation compared with the suture fixation group. It should be noted that both studies^{16,24} were conducted in populations with a mean age approximately 10 years younger than that of the present cohort.

Recently, Ayati Firoozabadi et al.²⁵ reported an arthroscopic technique for ACL avulsion fixation using an adjustable-loop cortical Endobutton. This approach allows secure fixation through a single tibial tunnel, enabling intraoperative re-tensioning of the construct, which may enhance stability in comminuted or small fracture fragments where screw fixation is less reliable. Early mobilization and weight-bearing are encouraged, potentially shortening recovery time compared with traditional fixation methods. Compared with the findings of the present study, both techniques highlight the advantages of suture-based fixation over screw fixation. In our cohort, pull-out suture fixation demonstrated superior outcomes in range of motion (ROM) and patient satisfaction at 6 and 12

months postoperatively, while pain scores remained comparable between groups. The Endobutton technique offers adjustable tensioning and eliminates the need for implant removal, though it requires specialized implants and advanced arthroscopic expertise. Taken together, these findings suggest that contemporary arthroscopic suture-based fixation methods—whether using pull-out sutures or adjustable-loop button constructs—may offer improved functional recovery and patient-reported outcomes compared with screw fixation.

While this study demonstrated a broad age distribution among patients and employed comprehensive outcome measures assessed at 6 and 12 months postoperatively, it has several limitations that should be acknowledged. These include its retrospective design and single-center setting. Future research with a larger sample size (e.g., > 50 patients) and a longer follow-up duration (> 1 year) would provide more robust evidence. In addition, incorporating detailed radiologic evaluations may offer a more comprehensive basis for comparison and enhance the accuracy of outcome assessment.

Conclusion

The findings of this retrospective cohort study indicate that pull-out suture fixation resulted in significantly better outcomes in knee range of motion and patient satisfaction, as measured by the Lysholm score, compared with open screw fixation at both 6 and 12 months postoperatively. No significant differences in postoperative pain levels were observed between the two groups.

Although these results are consistent with previous studies supporting arthroscopic and suture-based techniques for ACL tibial avulsion fractures, several limitations—including the small sample size, retrospective design, and single-center setting—should be acknowledged. Future prospective multicenter studies with larger cohorts and longer follow-up durations are recommended to validate these findings and further optimize surgical strategies for

ACL tibial avulsion management.

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Authors Contribution:

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