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Arthroscopic ACL Tibial Spine Avulsion Fixation Using Suture Pull-Through Double-Tunnel Technique

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Learning Point of the Article:

In this small single-Centre cohort, arthroscopic suture pull-through fixation through two tibial tunnels achieved fracture union and favorable early functional outcomes without intra-articular hardware; comparative and longer-term studies are required before superiority, durability, or a low complication rate can be established.

Abstract

Introduction: Avulsion fractures of the tibial spine are uncommon injuries that primarily affect children and adolescents but are increasingly recognized in adults after high-energy trauma. Displaced Meyers and McKeever Type II–IV fractures require fixation to restore anterior cruciate ligament (ACL) function, obtain anatomical reduction, and prevent residual knee instability. Arthroscopic suture pull-through fixation using a double-tibial-tunnel technique avoids intra-articular hardware while providing stable fixation.

Objectives: The objective of the study was to assess the radiological and clinical outcomes of arthroscopic ACL tibial spine avulsion fixation in skeletally mature patients using the suture pull-through double-tunnel technique.

Materials and Methods: This prospective observational study included 26 skeletally mature patients with displaced tibial spine avulsion fractures treated using the arthroscopic suture pull-through double-tunnel technique. Functional outcomes were assessed with the Lysholm Knee Score and Tegner Activity Scale, while radiological union, clinically assessed post-operative stability, complications, and return to pre-injury activity were recorded. The study had no control group, and the available follow-up was limited to the early post-operative period.

Results: All 26 patients completed the available follow-up and achieved radiological union by 3 months. The mean pre-operative Lysholm score derived from the patient-level table was 40.8 ± 2.2; the reported post-operative mean was 97, although individual post-operative Lysholm values were unavailable and a paired significance test could not be performed. The Tegner score improved from 2.88 ± 0.77 preoperatively to 5.96 ± 0.77 postoperatively ($P < 0.001$). Twenty-two patients (approximately 85%) returned to their pre-injury activity level within 4–6 months. Two patients developed a mild extension lag that resolved with supervised physiotherapy. No non-union, fixation failure, clinically significant residual instability, or revision surgery was reported; however, the sample was too small to determine the true incidence of uncommon complications.

Conclusion: In this small observational cohort, arthroscopic suture pull-through double-tunnel fixation was associated with radiological union and favorable early functional recovery while avoiding intra-articular hardware. Because the study was single-Centre, uncontrolled, short-term, and lacked instrumented stability and detailed imaging-based reduction measures, these findings should be interpreted as preliminary rather than evidence of superiority or long-term reliability.

Keywords: Tibial spine avulsion fracture, anterior cruciate ligament, arthroscopy, suture pull-through technique, double-tunnel fixation, Lysholm score, Tegner activity scale, knee instability.

Author's Photo Gallery

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Introduction

Despite being relatively rare, tibial spine avulsion fractures mostly affect skeletally immature patients between the ages of 8 and 14 due to hyperextension or rotational injuries, often related to sports or road-traffic trauma [1]. An increasing incidence among adults has been reported, particularly after high-energy trauma, where concomitant collateral ligament or meniscal injuries may occur [2]. Untreated or inadequately managed displaced fractures, particularly Type III and Type IV injuries, may lead to non-union, malunion, flexion deformity, and persistent knee instability [3].

Tibial spine avulsions were first described by Poncet in 1875 and were subsequently classified by Meyers and McKeever in 1959, with modification by Zaricznyj in 1987 [4]. Magnetic resonance imaging (MRI) provides detailed evaluation of associated ligamentous, meniscal, and chondral injuries [5]. Management depends on displacement and reducibility; conservative treatment is generally reserved for minimally displaced fractures, whereas displaced or unstable injuries require surgical fixation [6].

Traditional fixation options include cannulated screws, Herbert screws, K-wires, and suture anchors, each with specific advantages and limitations [7]. Suture pull-through techniques have gained popularity because they avoid implant prominence and hardware removal while allowing fixation through the anterior cruciate ligament (ACL) substance [7]. Published studies have reported favorable functional recovery and early mobilization with suture-based fixation [8]; however, the present study was not designed to compare fixation methods.

The present study evaluated arthroscopic ACL tibial spine avulsion fixation using a suture pull-through double-tunnel technique, with emphasis on functional outcomes, knee stability, radiological union, complications, and return to pre-injury activity.

Materials and Methods

Study design and setting

A prospective observational study was conducted in the Department of Orthopaedics, N.D. Desai Medical College, and included a consecutive sample of 26 eligible patients with tibial spine avulsion fractures.

Ethical approval: The manuscript records approval from Dr. N. D. Desai Faculty of Medical Science and Research Medical Centres, Nadiad (No. Dr NDDFMSR/IEC/2026/03/05; dated May 02, 2026). Written informed consent for participation and use of anonymized clinical/radiographic material should be confirmed in the final submitted version. The approval date must be reconciled with the verified study period before submission.

Patient selection

Inclusion criteria

- Skeletally mature patients aged 18–60 years
- Meyers and McKeever Type II, III, or IV fractures (modified by Zaricznyj)
- Closed injuries suitable for arthroscopic fixation.

Exclusion criteria

- Concomitant meniscal or chondral injury requiring additional treatment
- Associated proximal tibial fracture
- Previous surgery on the affected knee
- Inadequate muscle power or inability to comply with rehabilitation.

Four patients had Type II, 19 had Type III, and three had Type IV injuries. The mean interval from injury to fixation was approximately 1 week. All patients underwent arthroscopic suture pull-through double-tunnel fixation.

Surgical technique

All procedures were performed under spinal anesthesia with the patient supine. A thigh support and pneumatic tourniquet were used, and standard anteromedial and anterolateral arthroscopic portals were established.

Pre-operative preparation

- Plain radiographs confirmed the tibial spine avulsion fracture (Fig. 1)

Preoperative x-ray showing tibial spine avulsion

Figure 1: Pre-operative radiographs showing the tibial spine avulsion fracture.

Figure 2: Post-operative radiographs demonstrating reduction and the tibial tunnel fixation construct.

• MRI was used to define fracture morphology and screen for associated intra-articular injury

• The joint was irrigated with normal saline to clear the hemarthrosis and loose debris.

Fracture reduction and fixation

1. Diagnostic arthroscopy: A 30° 4-mm arthroscope was introduced to assess the fracture and intra-articular structures

2. Fracture reduction: The fragment was reduced with the knee at approximately 40° of flexion and maintained with a probe or temporary K-wire when required

3. Suture passage: A 45° suture lasso carrying a steel wire was passed through the anteromedial portal near the ACL tibial insertion. The shuttle wire was retrieved and used to pass a non-absorbable FiberTape loop through the ACL fibers

4. Tunnel creation: Through a 3-cm oblique anteromedial tibial incision, a tibial tunnel guide set at 55° was positioned. A 4-mm drill pin was used to create anteromedial and anterolateral tibial tunnels under arthroscopic guidance

5. Final fixation: A flexible wire loop was passed through each tunnel. The suture limbs were crossed through the opposite tunnels to create a crisscross construct; reduction was confirmed arthroscopically, and the sutures were tied over a 1-cm cortical bone bridge with the knee at approximately 30° of flexion.

Post-operative assessment and rehabilitation

• Fixation stability was confirmed by arthroscopic visualization and intraoperative fluoroscopy

• The knee was immobilized in an ACL brace in full extension for 3 weeks

• Weeks 1–3: Isometric quadriceps exercises, straight-leg raises, and non-weight bearing

• Weeks 4–6: Hinged brace, progressive range of motion, and gradual weight bearing

• Full weight bearing was permitted by 8 weeks according to clinical progress

• Radiographs at 3 months were used to assess union and alignment (Fig. 2).

Outcome measures and statistical analysis

The Lysholm Knee Score, Tegner Activity Scale, radiological union, return to activity, extension deficit, residual instability, fixation failure, and revision surgery were recorded. Continuous variables are presented as mean ± standard deviation and categorical variables as number and percentage. Patient-level pre-operative and post-operative Tegner scores were compared using the paired Wilcoxon signed-rank test. A two-sided $P < 0.05$ was considered statistically significant. Individual post-operative Lysholm scores were not available; therefore, a paired statistical test for Lysholm improvement could not be calculated. Post-operative knee stability was not quantified with KT-1000/KT-2000 arthrometry or another instrumented laxity measure, and standardized pivot-shift grading was not available. Radiographic assessment documented union and alignment, but quantitative measurements of residual displacement, articular step-off, or tunnel position were not available. Post-operative MRI assessment of ACL continuity or tension was not performed.

Results

The study included 26 patients (18 males and eight females)

Table 1: Patient demographics and fracture characteristics

Parameter	Value
Total patients	26
Male patients	18
Female patients	8
Mean age	30 years (range 18–60)
Injury mechanism	Sports: 10; motorcycle accidents: 16
Fracture type	Type II: 4; type III: 19; type IV: 3

Table 2: Functional and radiological outcomes			
Outcome	**Pre-operative**	**Post-operative/ follow-up**	***P*-value**
Lysholm knee score	40.8±2.2	97	Not calculated: Individual post-operative Lysholm scores were unavailable
Tegner activity scale	2.88±0.77	5.96±0.77	<0.001
Fracture union at 3 months	—	26/26 (100%)	—
Return to pre-injury activity	—	22/26 (approximately 85%) within 4–6 months	—

with a mean age of 30 years (range 18–60 years). Sports-related trauma accounted for 10 injuries and motorcycle accidents for 16 injuries (Table 1).

Fracture distribution was Type II in four patients, Type III in 19 patients, and Type IV in three patients (Table 1).

The patient-level pre-operative Lysholm score averaged 40.8 ± 2.2, while the reported post-operative mean was 97. Because individual post-operative Lysholm values were unavailable, the magnitude and statistical significance of paired Lysholm improvement could not be independently calculated. The Tegner score improved from 2.88 ± 0.77 to 5.96 ± 0.77 (Wilcoxon $P < 0.001$) (Tables 2 and 3).

All patients achieved radiological union by 3 months. Twenty-two of 26 patients (approximately 85%) were recorded as having returned to their pre-injury activity level within 4–6 months (Table 2). A validated return-to-sport or return-to-activity testing battery and prespecified objective criteria for successful return were not available; accordingly, this outcome should be interpreted descriptively.

Two patients developed a mild post-operative extension lag, which resolved with supervised physiotherapy. No patient required revision surgery, and no non-union, fixation failure, or clinically significant residual knee instability was reported during the available follow-up. Given the cohort size of 26 patients and the short follow-up, these observations do not exclude uncommon complications or later instability/reinjury.

Discussion

Tibial spine avulsion injuries, traditionally associated with adolescents, are increasingly recognised in adults after high-energy motor-vehicle and sports trauma [9]. Stable fixation is intended to restore knee stability and minimise functional deficit. Suture fixation has the practical advantage of avoiding implant prominence and possible secondary hardware removal, but the present uncontrolled study cannot establish superiority or equivalence compared with screw fixation, suture-anchor fixation, or other techniques [7].

Several fixation methods, including K-wires, screws, staples, suture anchors, and transosseous sutures, have been described. Suture-based methods have produced favorable outcomes in published series [10]. In the present cohort, all fractures united by 3 months, the reported post-operative Lysholm score was 97, and the Tegner Activity Scale improved significantly. These early findings are broadly consistent with reports of favorable functional recovery after suture fixation [11]. However, the lack of individual post-operative Lysholm values prevents paired statistical assessment of that score,

Table 3: Patient-level pre-operative Lysholm and Tegner activity scale scores			
Patient No.	**Pre-operative Lysholm score**	**Pre-operative Tegner score**	**Post-operative Tegner score**
1	40	3	6
2	45	2	7
3	42	3	6
4	39	2	5
5	41	4	7
6	43	3	6
7	38	2	5
8	42	3	6
9	37	2	5
10	44	4	7
11	40	3	6
12	39	2	5
13	41	3	6
14	42	4	7
15	43	3	6
16	40	2	5
17	37	3	6
18	39	2	5
19	42	4	7
20	38	3	6
21	44	2	5
22	40	3	6
23	41	4	7
24	39	3	6
25	42	2	5
26	43	4	7
Mean±SD	40.81±2.19	2.88±0.77	5.96±0.77

SD: Standard deviation

and the absence of a comparator precludes conclusions about relative efficacy.

Two patients developed a transient extension lag that responded to supervised physiotherapy. Mild post-operative range-of-motion deficits have been reported after tibial spine fixation [12]. Prolonged immobilization and delayed rehabilitation may increase the risk of stiffness [1]. Although a rehabilitation schedule was prescribed in this study, adherence, physiotherapy intensity, and patient compliance were not objectively monitored; these factors may have influenced functional recovery.

Residual laxity, non-union, reinjury, and arthrofibrosis remain clinically relevant concerns [13]. Comparative reports have described favorable functional outcomes after suture fixation relative to screw fixation [14, 15], but the current study did not include a comparator and did not measure instrumented post-operative laxity, standardized pivot-shift grade, MRI-based ACL integrity, or quantitative radiographic reduction parameters. Therefore, the absence of clinically significant residual instability in this series should not be interpreted as proof of restored ACL biomechanics or long-term functional continuity.

Study limitations

This study has several important limitations. First, the sample size was small (26 patients), reducing statistical power and limiting the ability to identify uncommon complications or perform reliable subgroup analyses. Second, the single-Centre design restricts external validity. Third, there was no control or comparator group using screw fixation, suture anchors, or another established method; consequently, superiority, equivalence, or comparative safety of the double-tunnel technique cannot be inferred. Fourth, follow-up was limited to approximately 3–6 months, which is insufficient to evaluate recurrent instability, reinjury, late fixation-related problems, long-term ACL function, or post-traumatic osteoarthritis. Fifth, the manuscript contains a major chronology discrepancy between the stated study period and the documented 2026 ethics approval; this must be verified against institutional records before submission. Sixth, individual post-operative Lysholm scores were unavailable, preventing paired analysis of Lysholm improvement. Seventh, post-operative stability was not quantified using KT-1000/KT-2000 arthrometry or another instrumented laxity test, and standardized objective pivot-shift grading was not available. Eighth, post-operative imaging confirmed union and alignment but did not include quantitative measures of fragment displacement, articular step-off, or tibial tunnel position. Ninth, return to pre-injury activity was insufficiently defined and was not based on a validated objective return-to-sport testing protocol; moreover, only 22 of 26 patients returned to their previous activity level. Tenth, exclusion of patients with concomitant meniscal or chondral injuries requiring treatment creates selection bias and may underestimate functional limitations and complications encountered in routine practice. Eleventh, Meyers and McKeever Types II, III, and IV fractures were pooled without fracture-type-specific outcome analysis, despite the possibility that displaced and comminuted patterns respond differently. Twelfth, rehabilitation adherence, physiotherapy intensity, and patient compliance were not objectively monitored. Thirteenth, the cohort was underpowered to establish a low complication rate for uncommon events such as fixation failure, non-union, or significant instability. Fourteenth, post-operative MRI or another objective assessment of ACL continuity, tension, or healing was not performed. Finally, the observational design, short-term follow-up, and limited objective stability assessment mean that the clinical relevance should be interpreted cautiously. Larger multicenter comparative studies with longer follow-up, standardized imaging, instrumented laxity testing, fracture-type stratification, and validated return-to-activity criteria are required.

Conclusion

In this 26-patient single-Centre observational cohort, arthroscopic suture pull-through double-tunnel fixation was associated with radiological union and favorable early functional outcomes, and most patients returned to their recorded pre-injury activity level. These findings are preliminary because the study lacked a comparator, had short follow-up, and did not include instrumented laxity testing, quantitative imaging-based reduction assessment, or post-operative MRI evaluation of ACL integrity. Larger prospective comparative studies are required before the technique can be considered demonstrably superior, reliably low-risk, or durable over the long term.

Clinical Message

For displaced ACL tibial spine avulsion fractures in skeletally mature patients, the double-tunnel suture pull-through technique is a hardware-free fixation option that showed favorable early outcomes in this small cohort; its comparative efficacy and long-term stability remain to be established.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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