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Original Article

Clinical and Radiological Outcomes Following Open Reduction and Screw Fixation via a Posterior Approach for Tibial PCL Avulsion Fractures

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ABSTRACT

Objective: Tibial avulsion fractures of the posterior cruciate ligament (PCL) are uncommon injuries that may lead to persistent posterior instability and functional limitations if not anatomically reduced and rigidly fixed. This study aimed to evaluate the clinical and radiological outcomes of open reduction and screw fixation of tibial PCL avulsion fractures performed through a posterior knee approach.

Materials and Methods: We retrospectively reviewed 33 patients who underwent open reduction and screw fixation for tibial PCL avulsion fractures via a posterior knee approach. The cohort included 29 males (87.9%) and 4 females (12.1%), with a mean age of 34.9±12.9 years (range, 14–65). The right knee was involved in 19 cases (57.6%) and the left knee in 14 (42.4%). The most common injury mechanisms were motorcycle accidents (45.5%) and falls (36.4%), followed by bicycle accidents (9.1%) and sports injuries (9.1%). In 25 patients (75.8%), the fracture was isolated, whereas 8 (24.2%) had associated periarticular fractures involving the patella, femur, tibia, or combinations of these structures. Radiological follow-up averaged 31.9±29.4 months (range, 12–120), and functional follow-up averaged 54.1±39.5 months (range, 12–120). Outcome measures included the Lysholm knee score, the IKDC score, range of motion, and the visual analog scale (VAS) for pain.

Results: At the final follow-up, the mean Lysholm score was 73.0±15.5 (range, 37–100), and the mean IKDC score was 70.6±16.1 (range, 32–98). The mean knee flexion deficit was 21.2°±15.0° (range, 0–45), and the mean extension lag was 10.0°±10.0° (range, 0–30). The mean VAS pain score was 2.2±1.5 (range, 0–6), indicating generally low pain levels during daily activities. All fractures united.

Conclusion: Open reduction and screw fixation through a posterior approach consistently achieved fracture union with low residual pain. However, functional outcomes were moderate, and residual range-of-motion deficits were observed, indicating that successful osseous healing does not necessarily translate into optimal clinical recovery in this heterogeneous trauma cohort.

Keywords: Fracture fixation, internal fixation, knee injuries, open reduction, posterior cruciate ligament, tibial fractures, treatment outcome.

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INTRODUCTION

The posterior cruciate ligament (PCL) is one of the key structures providing posterior stabilization to the knee joint and forms the primary resistance mechanism against posterior tibial displacement.[1] PCL injuries account for approximately 3–20% of acute knee ligament injuries. Tibial avulsion fractures represent a distinct clinical entity within this injury spectrum.[1,2]

Tibial avulsion fractures of the PCL typically result from high-energy trauma. Dashboard injuries, caused by a posteriorly directed force applied to the knee in flexion, and motorcycle accidents are among the most common injury mechanisms.[1,3] Concomitant intra-articular or periarticular pathologies have been reported in 20–30% of cases and may adversely influence postoperative functional outcomes.[1,3,4] Previous comparative studies have demonstrated that associated meniscal or ligamentous injuries may influence both surgical planning and rehabilitation protocols.[5]

Displaced PCL avulsion fractures, that are not anatomically reduced and adequately stabilized can lead to permanent posterior instability, impaired knee biomechanics, and early degenerative changes.[3,5] Persistent posterior laxity has also been shown to increase patellofemoral contact pressures and accelerate cartilage degeneration.[5,6] Although conservative treatment may be considered in cases with minimal displacement, anatomical reduction and stable internal fixation are recommended, especially in Meyers–McKeever type II and III fractures.[7]

Both open surgical techniques and arthroscopic methods have been described for the surgical treatment of tibial PCL avulsion fractures. Arthroscopic methods are advantageous because they are minimally invasive and allow for the simultaneous treatment of accompanying intra-articular lesions.[2] However, achieving adequate reduction in large fragments or comminuted fractures can be technically challenging. It has been reported that arthroscopy-assisted fixation may have a steep learning curve and requires specialized instrumentation, potentially limiting its applicability in certain centers.[8] Open posterior approaches, on the other hand, allow for direct visualization of the fracture bed, anatomical reduction, and rigid fixation with screws or plates.[7] Recent comparative series have shown that open posteromedial fixation techniques provide comparable union rates and functional outcomes to arthroscopic methods, with shorter operative times in some reports.[9]

Meta-analyses and comparative series have consistently demonstrated similar functional and radiological outcomes between open and arthroscopic fixation techniques. Despite the growing body of literature, the optimal surgical technique for displaced tibial PCL avulsion fractures remains controversial.[10] Moreover, there remains ongoing debate regarding the optimal fixation strategy for large or comminuted fragments, particularly in trauma settings.[2] Clinical practice is thus still influenced by research assessing the mid-term clinical results of practical and repeatable surgical procedures.

Despite existing studies on tibial PCL avulsion, most reports focus on relatively homogeneous cohorts or isolated injuries. In contrast, real-world clinical practice frequently involves heterogeneous trauma patterns, including cases with associated periarticular fractures. Therefore, evaluating outcomes in such heterogeneous populations remains clinically relevant.

The aim of this study was to evaluate the mid-term clinical and radiological outcomes of open reduction and screw fixation for tibial PCL avulsion fractures using a posterior knee approach.

MATERIALS AND METHODS

Study Design and Patient Population

This retrospective study evaluated patients who underwent open reduction and screw fixation through a posterior knee approach for tibial posterior cruciate ligament (PCL) avulsion fractures. Patients treated at our institution between January 2015 and December 2024 were retrospectively reviewed. Thirty-three consecutive patients who met the inclusion criteria were included in the final analysis.

The study protocol was approved by the Antalya Training and Research Hospital Scientific Research Ethics Committee (Approval No: 20/5; Date: November 27, 2025; Project No: 2025-437). The study was conducted in accordance with the principles of the Declaration of Helsinki. Due to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee. The inclusion criteria were patients aged 14 to 65 years with closed physes who underwent surgical fixation for a tibial PCL avulsion fracture, had a minimum follow-up of 6 months, and had complete clinical and radiological records available. The exclusion criteria were patients with multiligament knee injuries requiring primary ligament reconstruction, patients with open physes, and those with incomplete medical records or follow-up shorter than 6 months.

Surgical Technique

All patients underwent open reduction and internal fixation using a posterior knee approach. Patients were placed in the prone position under either spinal or general anesthesia. A posterior incision was made in the popliteal region, and the interval between the medial head of the gastrocnemius and the semimembranosus tendon was developed to expose the

posterior aspect of the proximal tibia while carefully protecting the neurovascular structures.

Following exposure of the fracture site, the avulsed fragment was identified and anatomically reduced under direct visualization. When required, temporary fixation was achieved using reduction clamps or Kirschner wires. Intraoperative fluoroscopy was used to confirm adequate fracture reduction and appropriate screw placement. Definitive fixation was performed using screws to achieve stable interfragmentary compression and restore the anatomic attachment of the posterior cruciate ligament. The number and type of screws were determined intraoperatively according to the operating surgeon's preference and based on fragment size, fracture morphology, and bone quality. Because the primary aim of this study was to evaluate the overall clinical and radiological outcomes of open posterior reduction and screw fixation, implant-specific comparisons were not performed.

The operations were performed by experienced orthopedic surgeons proficient in the posterior knee approach. In all cases, the same posteromedial interval between the medial head of the gastrocnemius muscle and the semimembranosus tendon was used.

Postoperative Rehabilitation

In the postoperative period, patients were treated using a standard rehabilitation protocol based on fracture stability and the presence of associated pathologies. An angle-adjustable knee brace was used in the early postoperative period. Range of motion was gradually increased under supervision, and rehabilitation exercises were initiated. Weight-bearing was gradually permitted according to clinical and radiological evaluations. Physiotherapy was performed to restore knee mobility and function.

Outcome Assessment

Clinical and radiological evaluations were performed during follow-up. Functional outcomes were assessed using the Lysholm Knee Score and the International Knee Documentation Committee (IKDC) score. Pain levels were evaluated using the visual analog scale (VAS). Knee range of motion was assessed clinically, and loss were recorded as flexion deficit and extension lag. Fracture healing and union were assessed using radiographic examinations. Full extension was defined as 0°, and maximal physiological flexion was defined as 135°.

Statistical Analysis

Statistical analyses were performed using SPSS software (IBM SPSS Statistics, version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean±standard deviation and range, while categorical variables were expressed as numbers and percentages.

RESULTS

A total of 33 patients were included in the study. The cohort consisted of 29 males (87.9%) and 4 females (12.1%), with a mean age of 34.9±12.9 years (range, 14–65). The right knee was involved in 19 patients (57.6%), whereas 14 patients (42.4%) had injuries of the left knee. The most common injury mechanisms were motorcycle accidents (45.5%), followed by falls (36.4%), bicycle accidents (9.1%), and sports injuries (9.1%). Fractures were isolated in 25 patients (75.8%), while 8 patients (24.2%) had associated periarticular fractures involving the patella, femur, tibia, or combined femoral and tibial injuries. The mean time from injury to surgery was 4.1±3.4 days (range, 1–20). Demographic characteristics are summarized in Table 1. Representative preoperative computed tomography images demonstrating a tibial PCL avulsion fracture are shown in Figure 1.

Table 1. Demographic and clinical characteristics of the study population

Variables	Data
Age (years±SD)	34.9±12.9 (14-65)
Sex (n, %)	
Female	4 (12.1%)
Male	29 (87.9%)
Side (n, %)	
Right	19 (57.6%)
Left	14 (42.4%)
Weight (kg±SD)	79.7±13.4 (47-108)
Height (cm±SD)	174.6±6.0 (162-186)
BMI (kg/m2±SD)	26.1±4.5 (15.6-38.1)
Mechanism of Injury	
Motorcycle accident	15 (45.5%)
Fall	12 (36.4%)
Bicycle Accident	3 (9.1%)
Sports Injury	3 (9.1%)
Isolated fractures (n, %)	25 (75.8%)
Associated fractures (n, %)	8 (24.2%)
Time to surgery (days±SD)	4.1±3.4 (1-20)
Accompanying fractures (n, %)	
None	25 (75.8%)
Patella	3 (9.1%)
Femur	3 (9.1%)
Tibia	1 (3.0%)
Femur + Tibia	1 (3.0%)

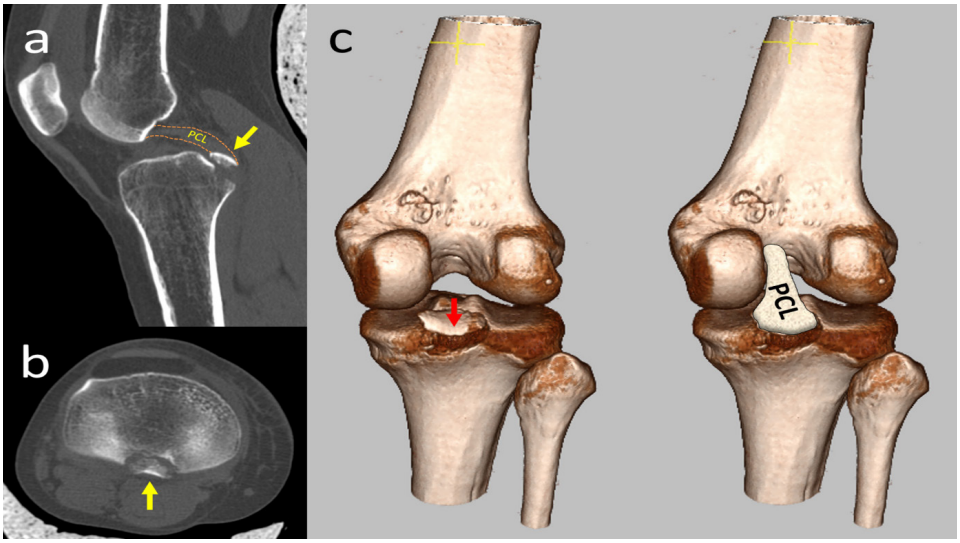

Figure 1. Typical preoperative CT scans showing an avulsion fracture of the tibial posterior cruciate ligament (PCL).

At the final follow-up, fracture union was achieved in all patients (100%). Figure 2 displays representative postoperative radiographs demonstrating various screw fixation techniques. Functional evaluation revealed a mean Lysholm Knee Score of 73.0±15.5 (range, 37–100) and a mean IKDC score of 70.6±16.1 (range, 32–98). Pain levels were generally low, with a mean VAS score of 2.2±1.5 (range, 0–6). Regarding knee range of motion, the mean flexion deficit was 21.2°±15.0° (range, 0–45), and the mean extension deficit was 10.0°±10.0° (range, 0–30). The mean radiological follow-up period was 31.9±29.4 months (range, 12–120), while the mean clinical follow-up duration was 54.1±39.5 months (range, 12–120). Functional outcomes are summarized in Table 2. Descriptive subgroup comparison showed broadly similar functional scores and range-of-motion deficits between the isolated and associated injury groups.

No major complications, such as nonunion, deep infection, neurovascular injury, or revision surgery, were observed. Despite complete fracture union, residual motion deficits were observed in a substantial proportion of patients, indicating that full functional recovery was not consistently achieved across the cohort.

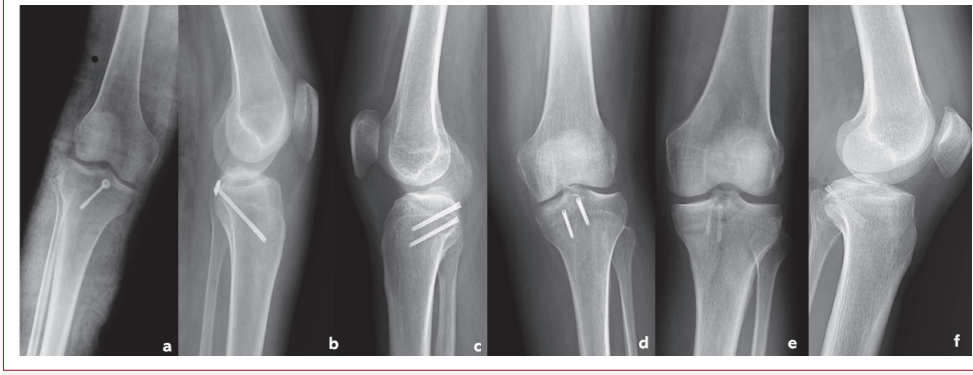

Figure 2. Tibial posterior cruciate ligament avulsion fractures treated with open reduction and internal fixation with various screw types are shown in representative postoperative radiographs. **(a,b)** Anteroposterior and lateral views of cannulated screw fixation. **(c,d)** Anteroposterior and lateral views of headless compression screw fixation. **(e,f)** Anteroposterior and lateral images of magnesium screw fixation.

Table 2. Clinical and radiological outcomes of the overall cohort and descriptive subgroup comparison by injury pattern

Variables	Overall (n=33)	Isolated (n=25)	Associated (n=8)
Lysholm knee score	73.0±15.5	73.2±13.6	72.1±20.5
IKDC	70.6±16.1	71±14.6	69.1±20.4
VAS (postop)	2.2±1.5	2.1±1.4	2.5±2.1
Knee flexion deficit (°)	21.2±15.0	23.0±14.1	15.6±15.9
Knee extension deficit (°)	10.0±10.0	10±10.4	10.0±9.3
Union (n, %)	33 (100%)	25 (100%)	8 (100%)

IKDC: International Knee Documentation Committee; VAS: Visual Analogue Scale

DISCUSSION

The tibial PCL avulsion fractures are uncommon but clinically important injuries, as untreated or inadequately reduced lesions may lead to residual posterior instability, pain, and functional impairment. Current evidence supports surgical treatment as the preferred management strategy for displaced fractures. Nevertheless, in selected acute and isolated cases with minimal displacement, nonoperative treatment may still be considered; Yoon et al. reported that conservative treatment may be feasible in acute isolated PCL avulsion fractures with displacement of less than 6.7 mm.[11] In the present series, all patients underwent surgical fixation, indicating that the injuries were displaced and required operative management. The achievement of fracture union in all cases further supports the appropriateness of this treatment approach.

In the present study, open reduction and screw fixation through a posterior approach resulted in a 100% fracture union rate and low pain levels, consistent with the existing literature. Fracture union was achieved in all cases, and the mean VAS score of 2.2 indicated that pain during daily activities was generally limited. However, the mean Lysholm score (73.0±15.5) and mean IKDC score (70.6±16.1) were lower than those reported in many published series of isolated injuries. Open surgical series involving isolated tibial PCL avulsion fractures have generally reported more favorable functional outcomes; for example, Joshi et al. reported a mean Lysholm score of 97±7.6 and a mean knee flexion of 121.7°±9.2°, whereas Khalifa et al. reported a mean Lysholm score of 93.4±3.9 and a mean flexion of 120.7°±4.3.[12,13] Similarly, Schmidt-Hebbel et al. reported a mean Lysholm score of 85.17 after open screw fixation.[14] The relatively moderate IKDC and Lysholm scores observed in our cohort indicate that satisfactory fracture healing does not necessarily translate into optimal functional recovery, a finding that has also been reported in other knee surgical contexts.[15]

The moderate functional outcomes observed in this study may be related to multiple factors, including injury severity, high-energy trauma mechanisms, and the presence of associated injuries. However, the exact contribution of these factors could not be determined due to the descriptive design of the study. In our study, 24.2% of patients had associated periarticular fractures, and a substantial proportion of injuries resulted from high-energy trauma, both of which may have adversely affected patient-perceived knee function. This interpretation is supported by previous studies, such as the study by Xiong et al.; however, it could not be directly evaluated in the present cohort due to the descriptive nature of the study.[4] In addition, the mean flexion loss of 21.2° and the mean extension lag of 10° observed in our series suggest that, despite successful osseous healing, functional recovery may remain limited in terms of range of motion. Considering that maximal flexion was defined as 135° and full extension as 0° in our study, the observed deficits correspond to an average knee flexion of approximately 114°. Importantly, IKDC and Lysholm scores do not merely reflect fracture union but rather represent multidimensional outcome measures encompassing knee motion, daily function, and activity level. Therefore, the lower functional scores and restricted range of motion observed in our cohort may be attributed to the combined effects of high-energy trauma, associated osseous and soft-tissue injuries, and a tendency toward postoperative stiffness.

The timing of surgery may also influence the clinical outcomes of tibial PCL avulsion fractures. In the present study, the mean interval from injury to surgery was relatively short, at 4.1±3.4 days. Early surgical intervention may facilitate fracture reduction and help prevent scar formation and soft-tissue contracture around the avulsed fragment. Previous studies have suggested that delayed treatment may be associated with poorer functional outcomes. For instance, Xiong et al.[4] reported that patients undergoing delayed surgery for tibial PCL avulsion fractures had significantly worse functional scores than those treated earlier. Therefore, although the functional

outcomes in our cohort may have been adversely influenced by the severity and heterogeneity of injury mechanisms, the relatively early timing of surgery may have contributed to the high union rate observed in this series, which is consistent with previous reports suggesting that delayed surgery may adversely affect outcomes.[4]

With regard to the surgical approach, the current literature has not demonstrated a clear superiority of the open posterior technique over arthroscopic methods. Systematic reviews by Hooper et al.[10] and Song et al.[16] have shown that open posterior fixation and arthroscopic fixation generally provide comparable clinical outcomes, union rates, and restoration of stability. Likewise, in the comparative study by Sabat et al.,[17] no substantial differences were observed between the open posterior approach and arthroscopic single-tunnel suture fixation in short-term outcomes. However, in a more recent retrospective study, Li et al.[18] reported that, after matching, the arthroscopic group achieved better Lysholm, IKDC, and KT-1000 results than the open group. Nevertheless, one of the most recent meta-analyses, by Rajnish et al.[19] in 2025, concluded that arthroscopic and open techniques are broadly comparable in terms of outcomes and complications. Taken together, the current evidence suggests that the choice of approach should not be based solely on whether the procedure is open or arthroscopic but rather on factors such as fragment morphology, associated intra-articular pathology, surgeon experience, and institutional technical resources. Although fracture union was consistently achieved, functional recovery was moderate, and motion deficits remained. These findings indicate that anatomic healing alone does not guarantee optimal functional outcomes.

From the standpoint of fixation method, screw fixation is particularly suitable for large, single-fragment avulsions amenable to compression, as it allows direct visualization, anatomic reduction, and stable interfragmentary compression. In contrast, hook plates, pin-hook constructs, or suture-based techniques may offer advantages in small or comminuted fragments. Qi et al.,[19] for example, compared hook plate fixation with hollow lag screw plus gasket fixation and reported favorable results with both techniques, while suggesting that hook plates may provide potential advantages in selected cases.[7] Similarly, Liu et al.[5] reported comparably satisfactory outcomes using a hook plate through an inverted L posteromedial approach and arthroscopic Endobutton fixation. By contrast, Schmidt-Hebbel et al.,[14] in a series treated with a posterior approach and cannulated screws, reported fracture union in all cases, a mean side-to-side posterior translation difference of 2.6 mm, and a mean range of motion of 1°–118°. Likewise, in our series, fracture union was achieved in all patients treated with screw fixation, supporting the effectiveness of this method when fragment morphology is appropriate. In the present study, the primary objective was not to compare implant-specific performance but to evaluate the overall clinical outcomes of this surgical strategy in routine clinical practice. Therefore, the heterogeneity in screw types should be interpreted as a reflection of intraoperative decision-making rather than a variable specifically investigated in this analysis. However, our functional scores and range-of-motion findings also indicate that union alone does not necessarily guarantee an optimal clinical outcome.

This study has several limitations. A major limitation is the absence of a standardized objective postoperative stability assessment, such as stress radiographs or arthrometric evaluation. First, the retrospective design and lack of a control group preclude definitive conclusions regarding the superiority of posterior open screw fixation over arthroscopic or alternative open techniques. Second, the inclusion of both isolated cases and cases with associated periarticular fractures resulted in a heterogeneous cohort. Third, objective methods for quantifying residual instability, such as stress radiographs, KT-1000 arthrometry, or similar quantitative assessments, were not used. This represents an important limitation, since objective assessments of posterior stability, such as stress radiographs, have been used in previous studies to quantify postoperative posterior translation.[14] Future prospective comparative studies incorporating standardized rehabilitation protocols are needed to better clarify the effects of associated fractures, surgical delay, and postoperative stiffness on outcomes. Another limitation is that postoperative rehabilitation protocols were not analyzed in a standardized manner. Because this was a retrospective outcome study, the focus was placed on the final clinical and radiological results of the surgical treatment rather than on the comparative effects of rehabilitation strategies. Variations in postoperative management may therefore have influenced functional recovery and range-of-motion outcomes. The wide range of follow-up durations may have introduced additional heterogeneity in outcome assessment. The difference between radiological and clinical follow-up durations reflects the retrospective nature of the study and the variability in long-term patient follow-up.

CONCLUSION

In conclusion, open reduction and screw fixation through a posterior approach achieved reliable fracture union with low residual pain in patients with tibial PCL avulsion fractures. However, the presence of flexion loss, extension lag, and relatively lower Lysholm and IKDC scores indicates that successful osseous healing does not necessarily translate into optimal functional recovery. These findings suggest that, beyond stable fixation, preservation of knee range of

motion and appropriate postoperative rehabilitation remain important determinants of overall clinical recovery.

DECLARATIONS

Ethics Committee Approval: This study was approved by the Antalya Training and Research Hospital Scientific Research Ethics Committee (Approval No: 20/5; Date: 27 November 2025; Project No: 2025-437). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Not applicable.

Conflict of Interest: The authors declared no conflict of interest.

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Peer-review: Externally peer-reviewed.

ABBREVIATIONS

PCL: Posterior Cruciate Ligament
IKDC: International Knee Documentation Committee
VAS: Visual Analogue Scale
ROM: Range of Motion
ORIF: Open Reduction and Internal Fixation
SD: Standard Deviation
CT: Computed Tomography
SPSS: Statistical Package for the Social Sciences

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