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Original Research Article

A Study of Functional Outcomes of PCL Tibial Avulsion Fractures Treated with Minimally Invasive Technique

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Conflict of interest: Nil

Abstract

Background: Posterior cruciate ligament (PCL) tibial avulsion fractures are uncommon injuries that can result in persistent knee instability and functional impairment if not treated appropriately. Minimally invasive cannulated cancellous (CC) screw fixation has emerged as an effective alternative to conventional open techniques.

Methods: This prospective observational study included 30 adult patients with displaced PCL tibial avulsion fractures (Meyers–McKeever Type II/III) treated by minimally invasive CC screw fixation at a tertiary care teaching hospital between June 2024 and November 2025. Functional outcome was assessed using the Lysholm Knee Score at baseline, 2 weeks, 6 weeks, 12 weeks, and 6 months. Radiological union, posterior knee stability, and postoperative complications were also evaluated.

Results: The mean age of the patients was 37.4 ± 5.2 years, and 80% were males. The mean Lysholm Knee Score improved significantly from 27.9 ± 1.7 preoperatively to 81.1 ± 2.4 at 6 months ($p<0.001$). The mean fracture union time was 8.8 ± 1.2 weeks, with complete radiological union achieved in 86.7% of patients. Stable knees without residual laxity were observed in 96.7% of patients. The overall complication rate was 13.3%, with arthrofibrosis being the most common complication (10%). No postoperative infections or revision surgeries were reported.

Conclusion: Minimally invasive CC screw fixation provides excellent functional recovery, reliable fracture union, restoration of knee stability, and a low complication rate in displaced PCL tibial avulsion fractures. It is a safe, effective, and practical surgical option, particularly in resource-limited settings.

Keywords: Posterior cruciate ligament; Tibial avulsion fracture; Cannulated cancellous screw; Minimally invasive fixation; Lysholm Knee Score; Fracture union; Knee stability.

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Introduction

Posterior cruciate ligament (PCL) injuries account for a relatively small proportion of knee ligament injuries compared with anterior cruciate ligament (ACL) injuries but remain clinically significant because of their essential role in maintaining knee stability and biomechanics [1]. The PCL is the strongest intra-articular ligament of the knee and serves as the primary restraint against posterior translation of the tibia, while also contributing to rotational stability during weight-bearing activities. Untreated or inadequately managed PCL injuries may result in chronic instability, pain, impaired function, altered gait, and early osteoarthritis, emphasizing the importance of timely diagnosis and appropriate treatment.[1]PCL tibial avulsion fractures are characterized by avulsion of a bony fragment from the tibial attachment while the ligament itself remains intact. These injuries commonly occur following high-energy trauma such as dashboard injuries during road traffic accidents, sports injuries, or falls onto a flexed knee, predominantly affecting young and economically active individuals [2]. The reported incidence of PCL injuries ranges from 3% to 44% of acute knee ligament injuries depending on the study population and diagnostic methods. Because associated injuries often overshadow the clinical presentation, isolated PCL injuries are frequently

overlooked, leading to delayed diagnosis and persistent posterior laxity, reduced range of motion, muscle weakness, and progressive degenerative changes.[3]Anatomically, the PCL originates from the lateral surface of the medial femoral condyle and inserts onto the posterior aspect of the tibial plateau. It comprises anterolateral and posteromedial bundles that function synergistically throughout knee motion to maintain stability. Biomechanically, the PCL resists approximately 95% of posterior tibial translation at 90° of knee flexion and preserves normal tibiofemoral contact mechanics. Loss of PCL integrity alters joint loading, increases cartilage stress, and predisposes to meniscal injury and osteoarthritis, resulting in difficulty with stair climbing, squatting, kneeling, and other routine activities.[4,5]Management of PCL tibial avulsion fractures depends on fracture displacement and knee instability. Minimally displaced fractures are generally treated conservatively, whereas displaced fractures usually require surgical fixation to achieve anatomical reduction, restore ligament tension, and prevent chronic instability and nonunion.[6] Surgical options include open reduction and internal fixation (ORIF), arthroscopic fixation, and minimally invasive posterior approaches. Although open surgery provides reliable fixation, it is associated with greater soft tissue dissection and postoperative morbidity, whereas arthroscopic techniques require specialized equipment and considerable expertise.[7]Minimally invasive posterior approaches have emerged as an effective alternative by providing adequate visualization with minimal soft tissue disruption, reduced blood loss, shorter operative time, and faster rehabilitation[8]. Stable fixation using cannulated cancellous (CC) screws, with or without a toothed washer or plate, provides excellent compression, promotes fracture union, restores knee stability, and facilitates early mobilization. These techniques are particularly advantageous in resource-limited settings because they require relatively simple instrumentation while providing satisfactory clinical outcomes.[9,10]Despite encouraging results, evidence regarding functional recovery, radiological union, and complication rates following minimally invasive CC screw fixation remains limited, particularly in developing countries[11,12]. Therefore, the present study was undertaken to evaluate the functional and radiological outcomes of minimally invasive fixation of PCL tibial avulsion fractures using cannulated cancellous screw fixation, with emphasis on fracture union, knee stability, range of motion, functional recovery, and procedure-related complications.

Materials and Methods

This prospective observational study was conducted in the Department of Orthopaedics, Basaveshwara Teaching and General Hospital, affiliated with Mahadevappa Rampure Medical College, Kalaburagi, and Karnataka. The study was carried out over a period of 18 months from June 1, 2024, to November 30, 2025. A total of 30 consecutive patients with displaced posterior cruciate ligament (PCL) tibial avulsion fractures who underwent minimally invasive cannulated cancellous (CC) screw fixation were included in the study. The study population comprised adult patients presenting with acute PCL tibial avulsion fractures who fulfilled the predefined eligibility criteria. Eligible patients were enrolled consecutively after obtaining written informed consent.

Inclusion Criteria

Patients were included in the study if they met the following criteria:

1. Posterior cruciate ligament injury confirmed clinically by a Grade II or higher posterior drawer test and radiologically by the presence of a tibial avulsion fracture.
2. Tibial avulsion fracture with displacement greater than 5 mm (Meyers–McKeever Type II or III).
3. Age 18 years or older.

Exclusion Criteria

Patients were excluded if they had:

1. Age below 18 years.
2. Knee osteoarthritis of Kellgren–Lawrence Grade II or higher.
3. Open fractures (Gustilo–Anderson Grade I or higher).
4. Associated fractures involving the proximal tibia or distal femur.

Study Procedure: After obtaining Institutional Ethics Committee approval and written informed consent, demographic details, mechanism of injury, clinical history, and findings of physical examination were recorded using a prestructured and validated case record proforma. Initial evaluation included assessment of posterior knee instability using the posterior drawer test and radiological evaluation with standard anteroposterior and lateral radiographs. Additional imaging was performed whenever required to confirm the diagnosis and assess fracture morphology. All patients underwent surgical fixation within two weeks of injury using a minimally invasive dorsal approach. Under appropriate anesthesia, a 3-cm posterior incision was made over the knee. After careful soft tissue dissection, the fracture hematoma was evacuated and the avulsed fragment was anatomically reduced

under fluoroscopic (C-arm) guidance. Stable fixation was achieved using a 4-mm cannulated cancellous screw supplemented with a toothed washer/plate wherever required. Wound closure was performed in layers, and a standardized postoperative rehabilitation protocol was followed for all patients.

Outcome Measures: The primary outcome was functional recovery assessed using the Lysholm Knee Scoring System at baseline (preoperatively), 2 weeks, 6 weeks, 12 weeks, and 6 months following surgery.

The secondary outcome measures included:

- Radiographic evidence of fracture union.
- Posterior tibial displacement (mm).
- Knee laxity grade assessed clinically.
- Postoperative complications, including infection, implant-related complications, delayed union, nonunion, and residual instability.

Follow-up Protocol: Patients were followed regularly according to a standardized schedule. Clinical evaluation was performed every 2 weeks during the first 6 weeks after surgery and subsequently once every month until completion of the 6-month follow-up period. Radiographic assessment was performed at 4 weeks, 12 weeks, 24 weeks, and 48 weeks to evaluate fracture healing, implant position, and maintenance of reduction.

Functional outcome was assessed using the Lysholm Knee Score, while posterior knee stability was evaluated clinically at each follow-up visit. Both assessments were performed independently by two orthopedic surgeons to minimize observer bias.

Data Collection: Data collected included demographic characteristics, mechanism of injury, operative details, baseline clinical findings, serial Lysholm Knee Scores, radiographic union status, posterior tibial displacement, knee laxity grade, and postoperative complications. All data were recorded in a standardized proforma and entered into Microsoft Excel for analysis.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages.

Changes in Lysholm Knee Scores over successive follow-up visits were analyzed using repeated-measures analysis of variance (ANOVA) with appropriate post hoc comparisons. Categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant.

Results

A total of 30 patients with displaced posterior cruciate ligament (PCL) tibial avulsion fractures underwent minimally invasive cannulated cancellous (CC) screw fixation and completed the scheduled follow-up. The demographic profile, operative characteristics, functional outcomes, radiological healing, and postoperative complications are summarized in Tables 1–5 and Figures 1–2.The baseline demographic and clinical characteristics of the study population are presented in Table 1. The mean age of the patients was 37.4 ± 5.2 years, with a predominance of male patients (80.0%). Most patients were manual laborers (73.3%) and sustained injury following motorcycle accidents (66.7%). Right and left knee involvement was equally distributed. The mean interval between injury and surgery was 12.5 ± 2.1 days. Patients presented with severe pain (mean VAS 8.1 ± 0.7), while swelling and inability to walk immediately after injury were observed in 93.3% of cases (Table 1).The operative characteristics and preoperative investigations are summarized in Table 2 and Figure 1. Fixation using a toothed plate with a cannulated cancellous screw was performed in 73.3% of patients, whereas 26.7% underwent CC screw fixation alone. The mean operative time was 48.2 ± 4.1 minutes, and postoperative knee brace immobilization was maintained for a mean duration of 6.9 ± 0.9 weeks.

All patients received prophylactic cefoperazone–sulbactam. Preoperative laboratory investigations showed abnormal complete blood counts in 30.0%, abnormal liver function tests in 10.0%, and abnormal renal function tests in 6.7%, while all patients were seronegative for HIV and HBsAg (Table 2, Figure 1).Functional recovery following surgery demonstrated progressive improvement throughout the follow-up period (Table 3, Figure 2). The mean Lysholm Knee Score improved from 27.9 ± 1.7 at baseline to 34.7 ± 2.3 at 2 weeks, 55.5 ± 2.6 at 6 weeks, 69.8 ± 2.5 at 12 weeks, and 81.1 ± 2.4 at 6 months.

The overall mean improvement in Lysholm score was 53.2 ± 2.1 points, which was statistically highly significant ($p <0.001$) (Table 3, Figure 2).Radiological and clinical outcomes at the final follow-up are shown in Table 4. The mean fracture union time was 8.8 ± 1.2 weeks, and complete radiological union was achieved in 86.7% of patients. Delayed union or nonunion occurred in 13.3% of cases. Residual posterior displacement was minimal (0.32 ± 0.14 mm), and stable knees without residual laxity were observed in 96.7% of patients, while persistent posterior laxity was noted in only 3.3% (Table 4, Figure 3). Postoperative

complications and overall outcomes are summarized in Table 5. Arthrofibrosis was the most common complication, occurring in 10.0% of patients, whereas persistent posterior laxity was observed in 3.3%. No patient developed a surgical site infection or required revision surgery. The overall complication rate was 13.3%. Statistical analysis demonstrated highly significant improvements in functional outcome, fracture union, and posterior knee stability, with all comparisons showing p <0.001 (Table 5).

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population (n = 30)

Parameter	Value
Age (years), mean ± SD	37.4 ± 5.2
Male, n (%)	24 (80.0)
Female, n (%)	6 (20.0)
Manual labor occupation, n (%)	22 (73.3)
Motorcycle accident, n (%)	20 (66.7)
Right knee involvement, n (%)	15 (50.0)
Left knee involvement, n (%)	15 (50.0)
Duration from injury to surgery (days), mean ± SD	12.5 ± 2.1
Pain score (VAS), mean ± SD	8.1 ± 0.7
Swelling present, n (%)	28 (93.3)
Unable to walk immediately after injury, n (%)	28 (93.3)

Table 2: Operative Characteristics and Preoperative Investigations (n = 30)

Parameter	Value
Toothed plate + CC screw fixation, n (%)	22 (73.3)
CC screw fixation alone, n (%)	8 (26.7)
Duration of surgery (minutes), mean ± SD	48.2 ± 4.1
Knee brace immobilization (weeks), mean ± SD	6.9 ± 0.9
Cefoperazone + Sulbactam prophylaxis, n (%)	30 (100)
Abnormal CBC, n (%)	9 (30.0)
Abnormal liver function tests, n (%)	3 (10.0)
Abnormal renal function tests, n (%)	2 (6.7)
HIV/HBsAg positive, n (%)	0 (0.0)

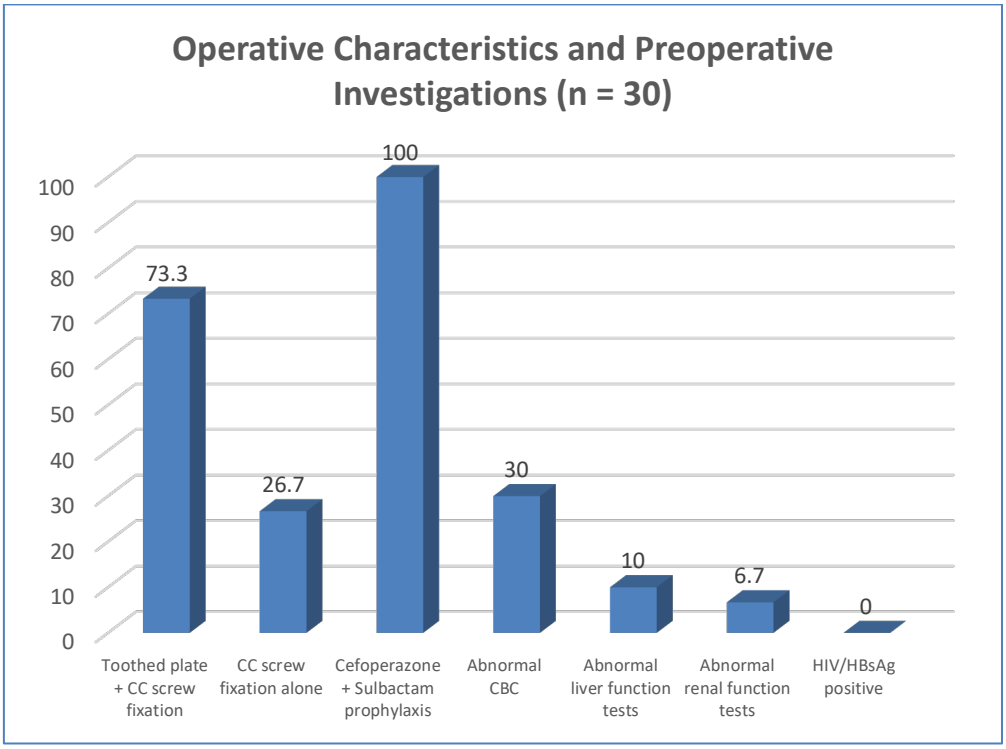

Figure 1: Operative Characteristics and Preoperative Investigations (n = 30)

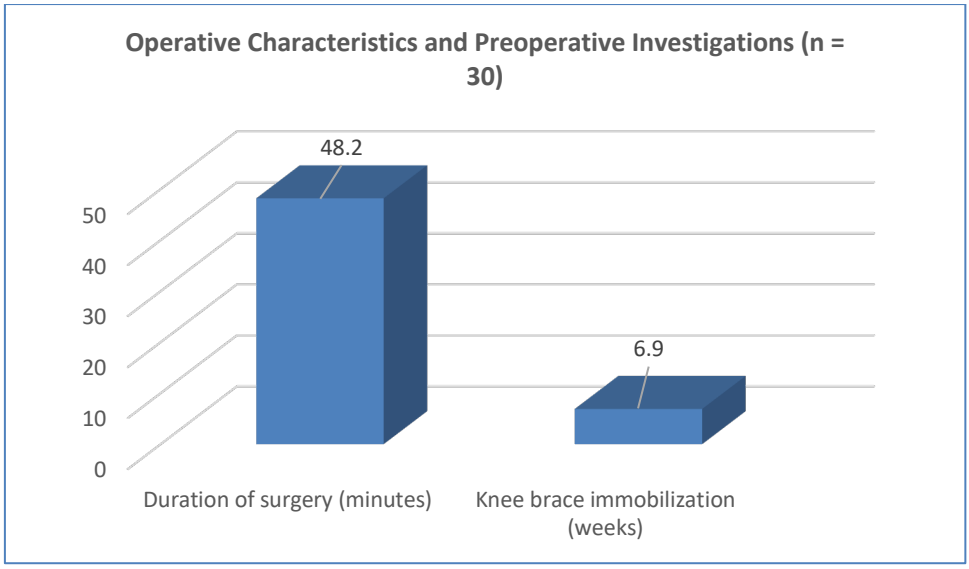

Figure 2: Operative Characteristics and Preoperative Investigations (n = 30)

Table 3: Functional Outcome Following Minimally Invasive CC Screw Fixation (n = 30)

Follow-up	Lysholm Knee Score (Mean ± SD)
Baseline	27.9 ± 1.7
2 weeks	34.7 ± 2.3
6 weeks	55.5 ± 2.6
12 weeks	69.8 ± 2.5
6 months	81.1 ± 2.4
Overall improvement	53.2 ± 2.1
p-value	<0.001

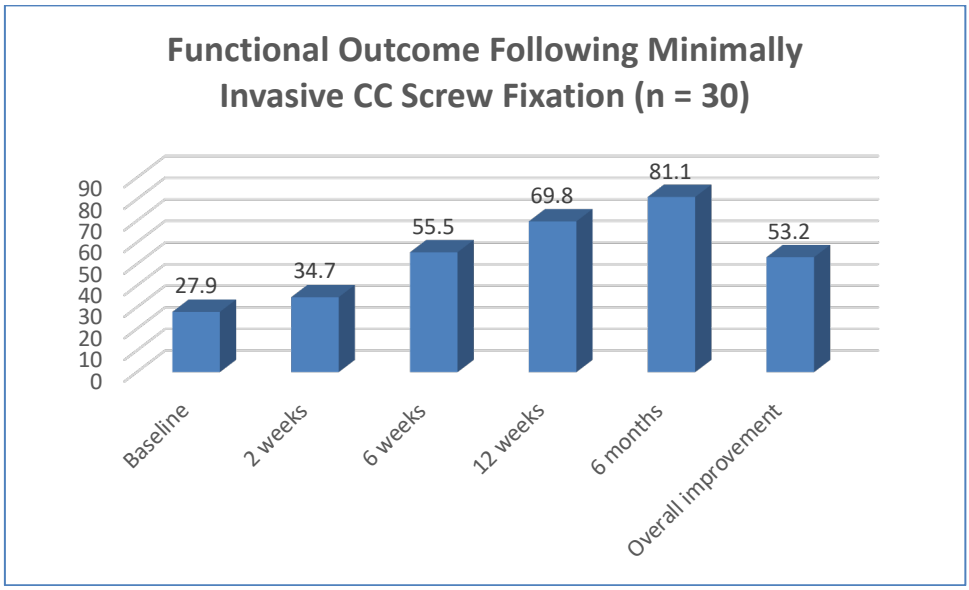

Figure 3: Functional Outcome Following Minimally Invasive CC Screw Fixation (n = 30)

Table 4: Radiological and Clinical Outcomes at Final Follow-up (n = 30)

Parameter	Value
Fracture union time (weeks), mean ± SD	8.8 ± 1.2
Complete radiological union, n (%)	26 (86.7)
Delayed union/Nonunion, n (%)	4 (13.3)
Residual posterior displacement (mm), mean ± SD	0.32 ± 0.14
Stable knee without residual laxity, n (%)	29 (96.7)
Persistent posterior laxity, n (%)	1 (3.3)

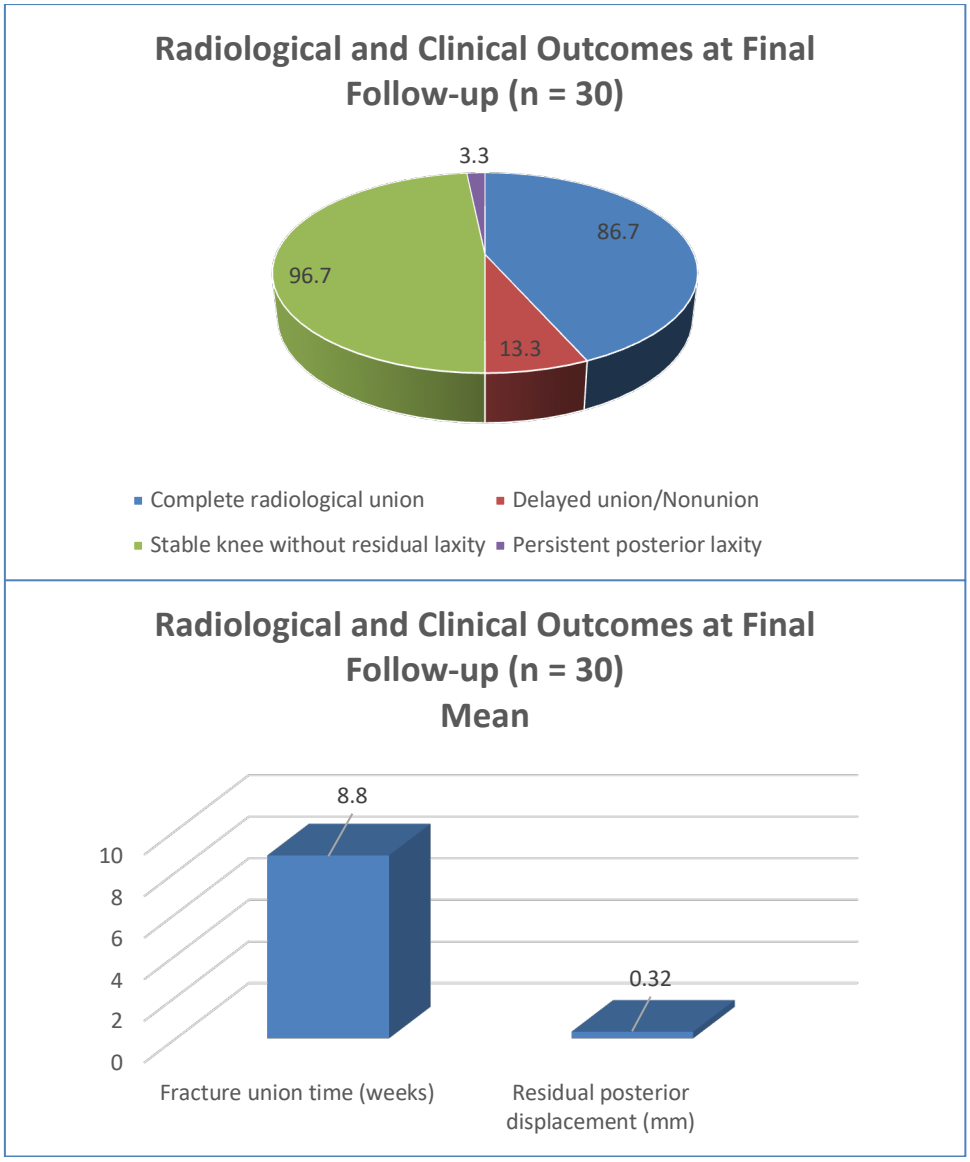

Figure 4: Radiological and Clinical Outcomes at Final Follow-up (n = 30)

Table 5: Postoperative Complications and Overall Outcome (n = 30)

Parameter	Value
Arthrofibrosis, n (%)	3 (10.0)
Persistent posterior laxity, n (%)	1 (3.3)
Surgical site infection, n (%)	0 (0.0)
Revision surgery required, n (%)	0 (0.0)
Overall complication rate, n (%)	4 (13.3)

Discussion

The present study included 30 patients with a mean age of 37.4 ± 5.2 years, of whom 80% were males and 73.3% were manual laborers. Motorcycle accidents accounted for 60% of injuries, indicating that PCL tibial avulsion fractures predominantly affect young, economically active males following high-energy trauma. Similar demographic characteristics were reported by Hooper et al. [13], whose systematic review of 1,440 patients demonstrated a mean age of 32.6 ± 5.7 years with 75.2% male predominance. Likewise, Guo et al. [1] reported a mean age of 32.1 years with a predominance of male patients undergoing minimally invasive fixation. Clinically, patients presented with severe symptoms, including a mean pain score of 8.1 ± 0.7, swelling in 93.3%, inability to walk in 93.3%, and a mean injury duration of 12.5 ± 2.1 days before surgery.

These findings reflect the severe instability associated with displaced PCL avulsion fractures. Guo et al. [1] similarly observed acute knee pain, instability, and displaced avulsion fractures requiring operative fixation within approximately 5

days of injury, supporting the clinical profile observed in the present study. Most patients (73.3%) underwent fixation using a toothed plate with a cannulated cancellous screw. The mean operative time was 48.2 ± 4.1 minutes, and postoperative immobilization averaged 6.9 ± 0.9 weeks, demonstrating that the minimally invasive technique is practical and reproducible. Comparable findings were reported by Guo et al. [1], who documented a mean operative time of 52.46 ± 7.64 minutes without neurovascular complications. Similarly, Abdallah et al. [14] reported an average operative time of 43 minutes using a mini-open posterior approach with minimal morbidity. Functional recovery was excellent, with the mean Lysholm Knee Score improving significantly from 27.9 ± 1.7 preoperatively to 81.1 ± 2.4 at 6 months, representing a mean improvement of 53.2 points ($p < 0.001$). These findings are consistent with Guo et al. [1], who reported improvement from 35.85 ± 1.22 to 94.12 ± 2.49 after one year. Wang et al. [15] also demonstrated Lysholm score improvement from 20.9 ± 7.0 to 97.1 ± 2.7 following arthroscopic suspensory fixation. Furthermore, the systematic review by Hooper et al. [13] reported mean improvements of 48.8 points after open surgery and 54.6 points after arthroscopic surgery, closely corresponding to the 53.2-point improvement observed in the present study. Radiological outcomes were equally encouraging.

Mean fracture union occurred at 8.8 ± 1.2 weeks, with 86.7% of patients achieving complete union by six months. Guo et al. [1] reported complete fracture union in all patients at a mean of 9.46 ± 1.33 weeks, while Abdallah et al. [14] observed union at approximately 5.6 weeks.

Similarly, Hooper et al. [13] demonstrated an overall fracture union rate of 99.1% following operative management, confirming the reliability of surgical fixation. The overall complication rate was low (13.3%), comprising arthrofibrosis (10%) and persistent laxity (3.3%), with no infections, neurovascular injuries, or revision surgeries.

Comparable safety profiles have been reported by Guo et al. [1], Wang et al. [15], and Abdallah et al. [14], all of whom documented minimal postoperative morbidity and excellent clinical outcomes. Overall, the present study supports minimally invasive posterior fixation as a safe and effective treatment for displaced PCL tibial avulsion fractures, providing excellent functional recovery, reliable fracture union, restoration of knee stability, and a low complication rate, consistent with the findings of Hooper et al. [13], Guo et al. [1], Abdallah et al. [14], and Wang et al. [15].

Conclusion

Minimally invasive cannulated cancellous screw fixation is a safe and effective treatment for displaced posterior cruciate ligament tibial avulsion fractures. The technique provides excellent functional recovery, early fracture union, restoration of posterior knee stability, and a low rate of postoperative complications. Its limited soft tissue dissection facilitates faster rehabilitation, satisfactory wound healing, and reduced surgical morbidity. Therefore, minimally invasive fixation represents a reliable and practical surgical option, particularly in centers with limited arthroscopic facilities.

Limitations

The present study was limited by its relatively small sample size and single-center design, which may affect the generalizability of the findings. The follow-up period of six months was insufficient to evaluate long-term outcomes such as post-traumatic osteoarthritis and implant-related complications. In addition, the absence of a comparison group undergoing open or arthroscopic fixation limited direct assessment of the relative effectiveness of the minimally invasive technique.

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