Functional and Radiological Outcomes of Locking Compression Plate Osteosynthesis in Closed SCHATZKER Type V and VI Tibial Plateau Fractures: A Prospective Observational Study

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ABSTRACT:

Background: Schatzker type V and VI tibial plateau fractures are complex bicondylar intra-articular injuries commonly resulting from high-energy trauma. Achieving anatomical reduction, stable fixation, and early mobilization remains challenging because of fracture comminution and associated soft-tissue compromise. Locking compression plate (LCP) fixation has emerged as an effective fixation strategy by providing angular stability and preserving biological fixation principles.

Aim: To evaluate the functional and radiological outcomes of locking compression plate osteosynthesis in patients with closed Schatzker type V and VI tibial plateau fractures without neurovascular injury.

Materials and Methods: This prospective observational study included 20 consecutive patients with closed Schatzker type V and VI tibial plateau fractures treated with open reduction and internal fixation using locking compression plates. Functional outcomes were assessed using the Knee Society Score (KSS), while radiological outcomes were evaluated using Rasmussen's radiological criteria. Fracture union, operative parameters, complications, and factors influencing outcomes were analyzed using SPSS version 26.0.

Results: The mean age of the study population was 44.85±12.3 years, and 70% were males. Schatzker type V fractures accounted for 60% of cases, whereas 40% were type VI fractures. The mean radiological union time was 17.4±3.2 weeks. The mean Knee Society Score was 83.6±9.7, with 75%

of patients achieving excellent-to-good functional outcomes. Radiological assessment demonstrated excellent or good outcomes in 75% of patients. A significant positive correlation was observed between radiological and functional outcomes (p=0.021). Type VI fractures required significantly longer operative time, greater blood loss, increased graft utilization, and prolonged union time. Postoperative complications occurred in 25% of patients, with no implant failure or non-union.

Conclusion: Locking compression plate osteosynthesis provides reliable fixation and satisfactory functional and radiological outcomes in closed Schatzker type V and VI tibial plateau fractures. Anatomical restoration of the articular surface and stable fixation are key determinants of successful clinical recovery.

Keywords: Tibial plateau fracture, Locking compression plate, Schatzker classification, Knee Society Score, Rasmussen criteria

Introduction

Tibial plateau fractures represent challenging intra-articular injuries involving the weight-bearing surface of the proximal tibia and account for approximately 1% of all fractures encountered in orthopaedic practice [1]. These fractures are clinically important because disruption of the articular surface may result in instability, malalignment, stiffness, chronic pain, and post-traumatic osteoarthritis if inadequately treated [2,3]. Recent epidemiological studies have reported an increasing incidence of tibial plateau fractures, particularly due to rising rates of road traffic accidents and an aging population susceptible to osteoporotic injuries [1,4].

The mechanism of injury varies according to patient demographics and bone quality. Younger patients commonly sustain high-energy injuries resulting in bicondylar fractures and metaphyseal comminution, whereas elderly individuals often develop depression-type fractures following low-energy falls [5,6]. Schatzker type V and VI fractures constitute the most severe injury patterns and are characterized by bicondylar involvement with or without metaphyseal-diaphyseal dissociation. These fracture types are frequently associated with extensive articular disruption, soft-tissue injury, and higher complication rates [7].

Accurate evaluation of fracture morphology is essential for treatment planning. While conventional radiographs provide initial assessment, computed tomography has become indispensable for defining fracture anatomy, identifying depression fragments, and planning fixation strategies [8,9]. Modern understanding of tibial plateau fracture biomechanics has further emphasized the importance of restoring joint congruity and stabilizing all involved columns to achieve optimal outcomes [10].

Management strategies have evolved considerably over the past two decades. Although conservative treatment may be suitable for minimally displaced fractures, operative fixation is currently considered the standard of care for displaced bicondylar fractures [2]. Open reduction and internal fixation using locking compression plates has gained widespread acceptance because of its ability to provide angular stability, preserve periosteal blood supply, and facilitate biological fixation [11]. Biomechanical studies have demonstrated superior construct stability with locking plate systems, particularly in comminuted fractures and osteoporotic bone [12,13].

Several investigators have reported satisfactory

outcomes following locking plate fixation of proximal tibial fractures [14–17]. However, considerable variability exists in the literature because of differences in fracture patterns, inclusion criteria, fixation techniques, rehabilitation protocols, and outcome measures. Furthermore, prospective studies focusing exclusively on closed Schatzker type V and VI fractures without neurovascular injury remain limited.

Therefore, the present prospective observational study was undertaken to evaluate the functional and radiological outcomes of locking compression plate osteosynthesis in a homogeneous cohort of patients with closed Schatzker type V and VI tibial plateau fractures and to identify factors influencing recovery following surgical fixation.

Materials And Methods

Study Design and Setting

A prospective observational study was conducted in the Department of Orthopaedics, Sree Balaji Medical College and Hospital, Chennai, after obtaining approval from the Institutional Human Ethics Committee. Patients were enrolled consecutively and followed according to a standardized treatment and rehabilitation protocol.

Study Duration

The study included patients treated during the study period and followed for a mean duration of approximately 15 months, with follow-up ranging from 12 to 18 months.

Sample Size

Twenty patients with closed Schatzker type V and VI tibial plateau fractures were included in the study.

Inclusion Criteria

- Closed Schatzker type V tibial plateau fractures
- Closed Schatzker type VI tibial plateau fractures
- Age above 18 years
- Patients willing to participate and provide informed consent
- Absence of neurovascular injury

Exclusion Criteria

- Open fractures
- Associated neurovascular injuries
- Pathological fractures
- Previous ipsilateral knee surgery
- Patients unfit for surgery
- Patients unwilling to participate or comply with follow-up

Methodology

All patients underwent detailed clinical assessment and radiological evaluation. Fractures were classified according to the Schatzker classification system. Definitive fixation was performed using locking compression plates through open reduction and internal fixation techniques after adequate soft-tissue optimization.

Bone grafting was performed when metaphyseal defects were present following elevation of depressed articular fragments. Autologous iliac crest cancellous grafts or synthetic bone substitutes were used according to intraoperative requirements.

Postoperatively, patients received standardized rehabilitation protocols emphasizing early knee mobilization and progressive weight-bearing based on radiological evidence of healing.

Outcome Measures

Primary outcomes included:

- Functional outcome assessed using the Knee Society Score (KSS)
- Radiological outcome assessed using Rasmussen's radiological criteria

Secondary outcomes included:

- Operative duration
- Intraoperative blood loss
- Time to radiological union

- Bone graft requirement
- Postoperative complications
- Relationship between radiological and functional outcomes

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Independent Student's t-test, Chi-square test, and one-way analysis of variance (ANOVA) with Bonferroni post-hoc comparisons were applied as appropriate. A p-value less than 0.05 was considered statistically significant.

Results

Demographic Characteristics

The study included 20 patients with closed Schatzker type V and VI tibial plateau fractures managed using locking compression plate osteosynthesis. The mean age was 44.85±12.3 years, with most patients (60%) belonging to the 31–50-year age group. Males constituted 70% of the study population, reflecting the predominance of high-energy trauma among economically active individuals. Right-sided injuries were slightly more common (55%) than left-sided injuries, although this difference was not statistically significant (p=0.62).

Table 1. Demographic Profile of the Study Population

Parameter	Category	Frequency (n=20)	Percentage (%)	Mean ± SD	p value
Age (years)	21–30	3	15		
	31–50	12	60	44.85 ± 12.3	
	51–70	5	25		
Sex	Male	14	70		0.48
	Female	6	30		
Side affected	Right	11	55		0.62
	Left	9	45		

Chi-square test; SPSS version 26.0.

Fracture Pattern Distribution

Schatzker type V fractures represented the majority of cases (60%), while type VI fractures accounted for 40%. Type VI fractures were generally associated with higher-energy mechanisms of injury and greater fracture complexity. No statistically significant association was observed between fracture type and sex distribution (p=0.41).

Table 2. Distribution of Fracture Types

Fracture Type	Male (n=14)	Female (n=6)	Total (n=20)	Percentage (%)	p value
Type V (Bicondylar)	8	4	12	60	
Type VI (Bicondylar + Metaphyseal Dissociation)	6	2	8	40	0.41

Chi-square test.

Operative Characteristics

The mean interval between injury and definitive surgery was 5.2±2.4 days, with most patients undergoing fixation between 4 and 6 days after injury. The overall mean operative duration was 108.4±18.6 minutes and mean intraoperative blood loss was 312.5±78.3 mL. Patients with Schatzker type VI fractures required significantly longer operative time and experienced greater blood loss than those with type V fractures, reflecting the increased technical complexity of these injuries. Both differences reached statistical significance.

Table 3. Mean Operative Time and Blood Loss

Fracture Type	Mean Operative Time (min) ± SD	Mean Blood Loss (mL) ± SD	p value (Time)	p value (Blood Loss)
Type V	102.3 ± 16.7	278.4 ± 69.8		
Type VI	116.5 ± 19.3	355.6 ± 75.2	0.04	0.03
Overall Mean	108.4 ± 18.6	312.5 ± 78.3		

Independent Student's t-test.

Bone Grafting Requirement

Bone grafting was performed in 13 patients (65%) to restore metaphyseal defects created following elevation of depressed articular fragments. The need for graft augmentation was significantly higher in Schatzker type VI fractures than in type V fractures (87.5% vs. 50.0%, p=0.047). Autologous iliac crest cancellous graft remained the most commonly utilized grafting material.

Table 4. Bone Grafting Requirement According to Fracture Type

Fracture Type	Bone Graft Used	Frequency (n)	Percentage (%)	Graft Type	p value
Type V	Yes	6	50.0	3 Autograft / 3 Synthetic	
	No	6	50.0	–	
Type VI	Yes	7	87.5	4 Autograft / 3 Synthetic	
	No	1	12.5	–	0.047
Total	13	65.0		10 Autograft / 3 Synthetic	

Chi-square test.

Functional Outcome

At final follow-up, the mean Knee Society Score was 83.6±9.7, indicating overall good functional recovery. Excellent or good outcomes were achieved in 75% of patients. Although type V fractures demonstrated a greater proportion of excellent and good results than type VI fractures, the difference was not statistically significant (p=0.18). These findings suggest that satisfactory knee function can be achieved in most patients when stable fixation and structured rehabilitation are employed.

Table 5. Functional Outcome Based on Knee Society Score

Outcome Grade	KSS Range	Type V (n=12)	Type VI (n=8)	Total (n=20)	Percentage (%)	p value
Excellent	≥90	5	3	8	40.0	
Good	80–89	5	2	7	35.0	
Fair	70–79	2	2	4	20.0	
Poor	<70	0	1	1	5.0	0.18
Mean KSS ± SD		84.7 ± 8.9	81.9 ± 10.5	83.6 ± 9.7		

Chi-square test.

Radiological Outcome

Radiological assessment using Rasmussen's criteria demonstrated excellent or good outcomes in 75% of patients. The mean Rasmussen score was 16.9±2.8. Type V fractures tended to achieve superior radiological restoration compared with type VI fractures; however, this difference narrowly missed statistical significance (p=0.056). Overall, the findings indicate satisfactory restoration of alignment and articular congruity following LCP fixation.

Table 6. Radiological Outcome According to Rasmussen's Criteria

Outcome Grade	Score Range	Type V (n=12)	Type VI (n=8)	Total (n=20)	Percentage (%)	p value
Excellent	18–20	6	3	9	45.0	
Good	15–17	4	2	6	30.0	
Fair	12–14	2	2	4	20.0	
Poor	<12	0	1	1	5.0	0.056
Mean Score ± SD		17.3 ± 2.5	16.2 ± 3.1	16.9 ± 2.8		

Chi-square test.

Additional Findings

The mean radiological union time for the entire cohort was 17.4±3.2 weeks. Patients with Schatzker type VI fractures demonstrated significantly delayed union compared with those having type V fractures (19.1±3.4 weeks vs. 16.2±2.5 weeks; p=0.042). All fractures achieved radiological union by 24 weeks.

Postoperative complications occurred in 25% of patients. Knee stiffness and superficial wound infection each occurred in 10% of cases, while delayed union was observed in one patient (5%). No deep infection, implant failure, malalignment, or non-union was recorded. Although complications were more frequent among type VI fractures, the difference was not statistically significant (p=0.29).

A statistically significant association was observed between radiological and functional outcomes (p=0.021), with patients demonstrating

excellent radiological restoration more likely to achieve excellent or good functional recovery.

Age significantly influenced postoperative function. Younger patients achieved superior Knee Society Scores, while increasing age was associated with progressively poorer functional outcomes (p=0.031).

Discussion

The present prospective observational study evaluated the functional and radiological outcomes of locking compression plate osteosynthesis in patients with closed Schatzker type V and VI tibial plateau fractures. Complex bicondylar tibial plateau fractures remain among the most challenging periarticular injuries because of extensive articular involvement, metaphyseal comminution, and the risk of long-term functional impairment. The findings of the present study demonstrate that LCP fixation provides reliable stabilization, satisfactory fracture union, and favorable functional recovery in the majority of patients.

The mean age of the study population was 44.85±12.3 years, with 60% of patients belonging to the 31–50-year age group. A clear male predominance (70%) was observed. These findings are consistent with the epidemiological observations reported by Elsoe et al. and Court-Brown and Caesar, who demonstrated that tibial plateau fractures commonly occur in economically productive males exposed to high-energy trauma such as road traffic accidents and occupational injuries [1,2]. Similar demographic patterns have also been reported in contemporary series evaluating bicondylar tibial plateau fractures [3].

In the present study, Schatzker type V fractures accounted for 60% of cases whereas type VI fractures constituted 40%. Although both fracture patterns represent severe bicondylar injuries, type VI fractures are generally associated with metaphyseal-diaphyseal dissociation and greater soft-tissue damage. Luo et al. emphasized that increasing fracture complexity directly influences surgical difficulty and postoperative recovery [4]. The higher operative complexity observed in type VI fractures in the current study supports this biomechanical concept.

The mean interval between injury and surgery was 5.2±2.4 days. Most patients underwent definitive fixation after soft-tissue stabilization had been achieved. Similar staged treatment strategies have been advocated by Egol et al., who demonstrated improved outcomes and reduced wound complications when high-energy tibial plateau fractures were managed after adequate soft-tissue recovery [5]. The absence of any significant association between fracture type and timing of surgery in the present study suggests that operative timing should primarily be guided by soft-tissue status rather than fracture morphology alone.

Operative duration and blood loss were significantly greater among patients with Schatzker type VI fractures. The mean operative time increased from 102.3 minutes in type V fractures to 116.5 minutes in type VI fractures, while mean blood loss increased from 278.4 mL to 355.6 mL. These findings reflect the greater technical demands of achieving reduction and stabilization in fractures associated with metaphyseal comminution and dissociation. Similar observations were reported by Raj et al., who found that increasing fracture complexity was associated with prolonged surgery and increased intraoperative blood loss irrespective of the fixation strategy employed [6].

Bone grafting was required in 65% of patients and was significantly more common among type VI fractures. The higher graft utilization observed in the present study is likely attributable to extensive metaphyseal voids following elevation of depressed articular fragments. Autologous iliac crest cancellous grafts remained the most frequently used grafting material. Previous investigators have similarly emphasized the importance of graft augmentation in restoring metaphyseal support and preventing secondary collapse in complex plateau fractures [7]. The findings of the current study reinforce the continued relevance of bone grafting in managing severe articular depression.

Radiological union was achieved in all patients, with a mean healing time of 17.4±3.2 weeks. Type VI fractures required significantly longer union times than type V fractures. The delayed healing observed in more severe fractures is biologically plausible because of greater comminution, disruption of local vascularity, and higher-energy injury mechanisms. Venkatakrishnaiah et al. reported a mean union time of approximately 14.4 weeks following LCP fixation, while Egol et al. reported union rates within a similar timeframe among surgically managed proximal tibial fractures [3,5]. Although union occurred slightly later in the present study, all fractures united successfully without progression to non-union.

Functional recovery was encouraging, with a mean Knee Society Score of 83.6±9.7. Excellent or good outcomes were achieved in 75% of patients. Type V fractures demonstrated a higher proportion of favorable outcomes than type VI fractures, although the difference did not reach statistical significance. Comparable functional results have been reported in previous studies evaluating locking plate fixation. Venkatakrishnaiah et al. documented predominantly excellent and good outcomes using Rasmussen-based assessments, while several earlier studies have reported favorable functional outcomes in 60–80% of patients following modern fixation techniques [3,5,8]. The present findings therefore support the effectiveness of LCP fixation in restoring knee function following severe bicondylar fractures.

Radiological outcomes were similarly favorable, with 75% of patients achieving excellent or good Rasmussen radiological grades. The mean Rasmussen score was 16.9±2.8. Although type V fractures demonstrated marginally better radiological restoration than type VI fractures, the difference approached but did not achieve statistical significance. Dobelle et al. reported improved radiographic alignment in bicondylar fractures treated using comprehensive fixation strategies and highlighted the importance of maintaining mechanical alignment throughout healing [9]. The radiological outcomes observed in the current study compare favorably with these contemporary reports.

One of the most important findings of this study was the significant positive correlation between radiological and functional outcomes ($p=0.021$). Patients who achieved superior radiological restoration were substantially more likely to achieve excellent or good functional recovery. This observation supports the fundamental orthopaedic principle that anatomical reduction of the articular surface contributes directly to improved joint biomechanics and clinical function. Marsh et al. previously demonstrated that residual articular incongruity adversely affects knee mechanics and predisposes patients to long-term functional deterioration [10]. The present findings provide further clinical evidence supporting meticulous articular reconstruction during surgery.

Age emerged as another significant determinant of outcome. Younger patients achieved superior Knee Society Scores, whereas advancing age was associated with progressively poorer functional recovery. Similar observations have been reported by Jensen et al., who found that age-related factors including reduced bone quality, slower healing, and diminished rehabilitation potential negatively influence postoperative outcomes [11]. These findings highlight the need for individualized rehabilitation strategies, particularly in elderly patients.

Postoperative complications occurred in 25% of patients. Knee stiffness and superficial wound infection were the most common complications, each occurring in 10% of cases. Delayed union occurred in one patient, whereas no deep infection, implant failure, malalignment, or non-union was encountered. Papagelopoulos et al. reported comparable complication rates in high-energy tibial plateau fractures and emphasized the importance of early mobilization in minimizing postoperative stiffness [12]. Similarly, Colman et al. demonstrated that prolonged operative duration increases infection risk, particularly in complex injuries [13]. The absence of deep infection and implant failure in the

present study reflects the benefits of careful surgical technique, soft-tissue preservation, and structured postoperative rehabilitation.

The strengths of the present study include its prospective design, homogeneous patient population, standardized surgical protocol, and simultaneous assessment of both functional and radiological outcomes. However, several limitations should be acknowledged. The sample size was relatively small, the study was conducted at a single institution, and follow-up duration was insufficient to evaluate long-term degenerative changes or post-traumatic osteoarthritis. Additionally, the absence of a control group limits direct comparison with alternative fixation methods. Larger multicentric studies with longer follow-up are warranted to validate these findings.

Overall, the results of the present study support locking compression plate osteosynthesis as an effective treatment modality for closed Schatzker type V and VI tibial plateau fractures. Stable fixation, anatomical reduction, and early rehabilitation collectively contribute to satisfactory clinical and radiological outcomes.

Conclusion

This prospective observational study demonstrated that locking compression plate osteosynthesis is a safe, reliable, and effective treatment modality for closed Schatzker type V and VI tibial plateau fractures. The technique provided stable fixation, facilitated fracture union, and resulted in satisfactory functional and radiological outcomes in the majority of patients.

The mean Knee Society Score indicated overall good functional recovery, while Rasmussen radiological assessment confirmed successful restoration of alignment and articular congruity in most cases. Although Schatzker type VI fractures were associated with greater operative complexity, increased blood loss, higher bone graft requirements, prolonged union time, and a higher incidence of complications, favorable outcomes were still achieved through meticulous surgical technique and structured rehabilitation.

A significant positive correlation between radiological restoration and functional recovery highlights the importance of achieving anatomical reduction during surgery. Furthermore, younger age was associated with superior postoperative function, emphasizing the influence of patient-related factors on recovery.

Based on these findings, locking compression plate fixation may be considered an effective fixation strategy for complex bicondylar tibial plateau fractures. Careful preoperative planning, preservation of soft tissues, restoration of articular congruity, and early rehabilitation remain essential for optimizing outcomes and minimizing complications.

Declarations

Ethics Approval:

The study was approved by the Institutional Human Ethics Committee, Sree Balaji Medical College and Hospital, Chennai.

Consent to Participate:

Written informed consent was obtained from all participants prior to enrollment.

Consent for Publication:

Obtained from all participants.

Funding:

No external funding was received.

Conflict of Interest:

The authors declare no conflict of interest.

Data Availability:

Data are available from the corresponding author upon reasonable request.

Author Contributions:

All authors contributed to study conception, data collection, analysis, manuscript preparation, and final approval.

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AI Disclosure Statement:

Artificial intelligence-assisted language editing tools were used solely for linguistic refinement and manuscript formatting. All scientific content, data interpretation, and conclusions were verified by the authors and derived from the original study data.

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