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Original Research Article

PROSPECTIVE EVALUATION OF KNEE FUNCTION AFTER SURGICAL FIXATION OF TIBIAL PLATEAU FRACTURES USING LOCKING COMPRESSION PLATES

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ABSTRACT

Background: Tibial plateau fractures are intra-articular injuries in which restoration of joint congruity, alignment and stability is essential to achieve good long-term knee function. Anatomical locking compression plates (LCP) provide fixed-angle stabilisation and may help maintain reduction while permitting early rehabilitation. **Objectives:** To evaluate the functional outcome of tibial plateau fractures treated surgically with an anatomical locking compression plate using the International Knee Documentation Committee (IKDC) subjective knee score and to document radiological outcomes and complications.

Materials and Methods: This prospective observational study included 40 adults (≥18 years) with acute tibial plateau fractures managed operatively using an anatomical LCP (lateral plating alone or dual plating when indicated). Fractures were classified by Schatzker system. Patients were followed at 6 weeks, 3 months, 6 months and 12 months. Primary outcome was IKDC subjective score recorded at each follow-up and categorised at final review (Excellent ≥80, Good 70–79, Fair 60–69, Poor <60). Secondary outcomes included time to radiological union, maintenance of reduction (articular step-off >2 mm, malalignment >5°) and complications.

Results: The mean age was 39.6 ± 12.8 years and 70% were male. Road traffic accident was the commonest mechanism (65%). Schatzker II was the most frequent pattern (25%); Schatzker V–VI comprised 37.5%. Median time to surgery was 4 (IQR 2–6) days; 75% underwent single lateral plating and 25% dual plating. Mean IKDC improved from 44.8 ± 9.5 at 6 weeks to 81.2 ± 9.7 at 12 months. At final follow-up, 80% achieved good–excellent outcome (Excellent 45%, Good 35%). Mean time to union was 15.0 ± 3.0 weeks; delayed union occurred in 5%. Articular step-off >2 mm was seen in 7.5% and malalignment >5° in 5%. Superficial infection occurred in 7.5%, deep infection in 2.5%, knee stiffness in 10%, implant failure/loss of reduction in 2.5% and reoperation in 2.5%.

Conclusion: Anatomical LCP fixation for operatively indicated tibial plateau fractures resulted in predominantly good-to-excellent knee function at 12 months, with timely union, acceptable maintenance of reduction and a low rate of major complications.

Keywords: Tibial plateau fracture; Locking compression plate; IKDC; Functional outcome; ORIF; Complications.

INTRODUCTION

Tibial plateau fractures are important peri-articular injuries because they disrupt the articular surface of the knee and compromise load transmission across the tibiofemoral joint.[1,2] These fractures are frequently associated with metaphyseal comminution, condylar widening and a variable

degree of soft-tissue injury and the overall pattern depends largely on the energy of trauma.[1] Since the injury involves a weight-bearing joint, the long-term result is influenced not only by fracture union but also by restoration of articular congruity, maintenance of mechanical axis and preservation of knee stability and motion.[2,3]

The main issue is not just fixing a fracture. It is restoring a weight-bearing joint. Even small residual depression, malalignment or instability can translate into persistent pain, restricted motion and later degenerative change.[2] Long follow-up studies have repeatedly shown that post-traumatic osteoarthritis is not rare after plateau fractures, even when union is achieved.[3-5] And functional recovery can remain "not fully normal" years after surgery, especially for higher-energy patterns.[5,6]

Operative strategies have evolved because conventional fixation struggled in comminution and osteoporotic metaphyseal bone. Locking constructs were introduced to improve stability by creating a fixed-angle device–bone relationship, helping maintain alignment and articular reduction until healing.[7,8] In complex bicondylar injuries, staged protocols, careful approach selection and dual-column support became common because single-incision or single-plate strategies had higher risks of malreduction and loss of fixation.[7,9] At the same time, complications remain real: deep infection and nonunion rates reported for high-energy bicondylar fractures are not trivial, especially when soft tissues are compromised.[10]

CT-based understanding also changed planning. Posterior and posteromedial fragments are easily underappreciated on plain radiographs and targeted approaches and antiglide buttress fixation have been described for better control of these fragments.[9] The "three-column" concept pushed this further, arguing that stability in complex plateau fractures often requires addressing lateral, medial and posterior columns with column-specific fixation.[11] The point is simple. If the fracture is three-dimensional, the fixation plan should stop being two-dimensional.[9,11] Minimally invasive plate osteosynthesis and biological fixation ideas were also adopted to reduce soft-tissue insult while still achieving stable fixation, with acceptable radiological and clinical outcomes reported in clinical series.[12] Yet across techniques, the end target stays the same: congruent joint surface, stable knee, correct alignment and early functional rehabilitation, because stiffness becomes its own long-term complication.[2,5,6]

For outcome measurement, patient-reported functional scoring matters because radiographs alone do not capture symptoms and activity limitation. The International Knee Documentation Committee (IKDC) subjective knee form was developed and validated as a reliable knee-specific measure across a variety of knee conditions, making it a pragmatic tool for functional assessment after periarticular injuries.[13]

In this context, the present prospective study was conducted to evaluate the functional outcome of tibial plateau fractures managed surgically with an anatomical locking compression plate. Functional outcome was assessed using the IKDC subjective score and clinicoradiological variables were analysed to understand recovery patterns in the treated cohort.[13]

MATERIALS AND METHODS

Study design and setting

This was a prospective observational study conducted in a tertiary care orthopaedic trauma unit. A total of 40 consecutive patients with tibial plateau fractures who underwent surgical fixation with an anatomical locking compression plate (LCP) were included. The study protocol was approved by the Institutional Ethics Committee and written informed consent was obtained from all participants prior to enrolment.

Participants

Patients presenting with tibial plateau fractures were screened in the emergency and outpatient services and recruited as per eligibility criteria.

Inclusion Criteria

Adults aged ≥18 years with an acute tibial plateau fracture requiring operative fixation were included. Only patients treated with an anatomical locking compression plate (LCP)—either lateral plating alone or dual plating when indicated—were enrolled. Participants were required to be willing to complete follow-up up to 12 months.

Exclusion Criteria

Pathological and periprosthetic tibial plateau fractures were excluded. Patients with polytrauma or head injury preventing standard rehabilitation or serial functional assessment were not included. Those with prior ipsilateral knee surgery or pre-existing disabling knee pathology were excluded to avoid confounding. Patients lost to follow-up before final assessment were excluded from outcome analysis.

Preoperative evaluation and fracture classification

All patients were assessed clinically for soft-tissue status, neurovascular integrity and associated injuries. AP and lateral radiographs were obtained in all cases and CT scan was performed when needed for fracture mapping and operative planning. Fractures were classified using the Schatzker system.[1] Open fractures, if present, were graded by Gustilo–Anderson classification.[14]

Surgical technique

Surgery was performed under regional or general anaesthesia with prophylactic antibiotics as per protocol. The approach and fixation plan were based on fracture morphology and soft-tissue condition. An anterolateral approach was used for most lateral plateau fractures, with an additional medial/posteromedial approach when a separate medial or posterior fragment required direct

reduction and buttress support. The objectives were articular restoration, correction of condylar widening and maintenance of alignment. Depressed fragments were elevated under fluoroscopy; temporary fixation was used as required. Subchondral rafting screws supported the reduced joint surface and bone graft/substitute was used selectively for metaphyseal voids. Definitive fixation was achieved with an anatomical LCP, using lateral plating alone for simpler patterns and dual plating for bicondylar or medial instability fractures.

Postoperative protocol and rehabilitation

Postoperatively, patients received elevation, analgesia and thromboprophylaxis as per institutional policy. Early knee mobilisation was started as tolerated, with focus on quadriceps strengthening and gradual range-of-motion gain. Weight bearing was advanced in a staged manner according to fracture stability and radiological healing, typically progressing from non/partial weight bearing to full weight bearing once union was evident.

Outcome measures

The primary outcome was functional recovery measured using the International Knee Documentation Committee (IKDC) subjective knee score.[13] IKDC scoring was recorded at predefined follow-up visits and used to categorise final functional outcome (Excellent/Good/Fair/Poor) using prespecified cut-offs.

Secondary outcomes included

Radiological union, assessed on serial radiographs; union was defined as bridging callus/trabeculation across fracture lines with absence of local tenderness on clinical examination.

Maintenance of reduction (articular step-off and alignment), assessed on follow-up radiographs.

Complications: superficial/deep infection, wound problems, knee stiffness, delayed union/nonunion, implant failure, loss of reduction and reoperation.

Follow-up schedule

Patients were followed up at 6 weeks, 3 months, 6 months and 12 months. At each visit, clinical examination (pain, swelling, range of motion, stability) and radiographs were obtained and IKDC was documented as per protocol.[13]

Statistical Analysis

Data were entered into a structured proforma and analysed using standard statistical software. Continuous variables were summarised as mean ± SD or median (IQR) depending on distribution; categorical variables were expressed as frequency and percentage. Change in IKDC over time was analysed using repeated measures testing (repeated measures ANOVA for normally distributed data or Friedman test for non-normal data). Association of functional outcome with fracture severity (e.g., lower vs higher Schatzker types), fixation construct (single vs dual plating) and complications was assessed using appropriate comparative tests, with $p < 0.05$ considered statistically significant.

RESULTS

Table 1: Baseline characteristics and fracture profile

Variable	Value
Age (years), mean ± SD	39.6 ± 12.8
Male, n (%)	28 (70.0)
Right side, n (%)	22 (55.0)
Mechanism: RTA / Fall / Sports, n (%)	26 (65.0) / 12 (30.0) / 2 (5.0)
Closed / Open, n (%)	36 (90.0) / 4 (10.0)
Schatzker I, n (%)	5 (12.5)
Schatzker II, n (%)	10 (25.0)
Schatzker III, n (%)	4 (10.0)
Schatzker IV, n (%)	6 (15.0)
Schatzker V, n (%)	8 (20.0)
Schatzker VI, n (%)	7 (17.5)

Forty patients were analysed with a mean age of 39.6 ± 12.8 years and male predominance (70%). Injuries were mainly due to RTA (65%), with 90% closed fractures. Schatzker type II was the commonest (25%), while type V–VI together formed 37.5% of fractures.

Table 2: Operative and perioperative details

Variable	Value
Time to surgery (days), median (IQR)	4 (2–6)
Surgical approach: Anterolateral / Posteromedial / Dual, n (%)	26 (65.0) / 6 (15.0) / 8 (20.0)
Fixation: Single lateral anatomical LCP / Dual plating, n (%)	30 (75.0) / 10 (25.0)
Bone graft/substitute used, n (%)	9 (22.5)
Operative time (min), mean ± SD	95 ± 18
Hospital stay (days), median (IQR)	6 (5–8)
Start of partial weight bearing (weeks), mean ± SD	6.5 ± 1.8

Median time to surgery was 4 days (IQR 2–6). The anterolateral approach was used most frequently (65%) and single lateral anatomical LCP fixation was performed in 75%, with dual plating in 25%. Bone graft/substitute was used in 22.5%. Mean operative time was 95 ± 18 minutes, median hospital stay 6

days (IQR 5–8) and partial weight bearing began at 6.5 ± 1.8 weeks.

Table 3: IKDC (Subjective) score progression with 95% CI (n = 40)

Follow-up	Mean ± SD	95% CI of mean	Mean change vs 6 weeks
6 weeks	44.8 ± 9.5	41.8 to 47.8	Reference
3 months	59.9 ± 10.2	56.6 to 63.2	+15.1
6 months	72.0 ± 11.0	68.5 to 75.5	+27.2
12 months	81.2 ± 9.7	78.1 to 84.3	+36.4

Mean IKDC improved progressively from 44.8 ± 9.5 at 6 weeks to 59.9 ± 10.2 at 3 months, 72.0 ± 11.0 at 6 months and 81.2 ± 9.7 at 12 months, showing a net mean improvement of +36.4 points from 6 weeks to 12 months.

Table 4: Final outcome at 12 months (IKDC category + union + complications)

Domain	Result
Functional outcome (IKDC), n (%)	
Excellent (≥80)	18 (45.0)
Good (70–79)	14 (35.0)
Fair (60–69)	6 (15.0)
Poor (<60)	2 (5.0)
Good + Excellent combined, n (%) [95% CI]	32 (80.0) [65.2–89.5]
Radiological outcome	
Time to union (weeks), mean ± SD	15.0 ± 3.0
Delayed union, n (%)	2 (5.0)
Articular step-off >2 mm, n (%)	3 (7.5)
Malalignment >5° (varus/valgus), n (%)	2 (5.0)
Complications, n (%)	
Superficial infection	3 (7.5)
Deep infection	1 (2.5)
Knee stiffness (ROM <90° at 3 months)	4 (10.0)
Implant failure / loss of reduction	1 (2.5)
Reoperation	1 (2.5)

At 12 months, IKDC outcome was excellent in 45% and good in 35%, giving 80% good–excellent overall. Mean time to union was 15.0 ± 3.0 weeks, with 5% delayed union. Residual step-off >2 mm occurred in 7.5% and malalignment >5° in 5%. Complications included superficial infection 7.5%, deep infection 2.5%, knee stiffness 10%, while implant failure/loss of reduction and reoperation were each 2.5%.

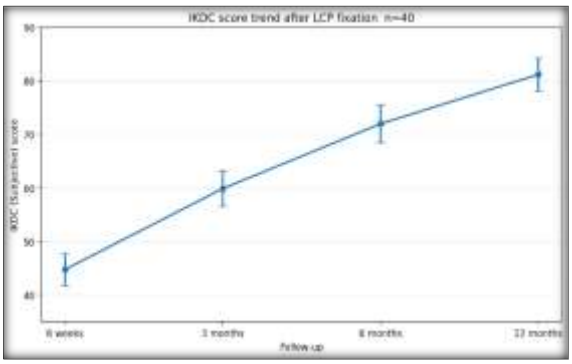

Figure 1: Knee function improves after LCP fixation IKDC trend and final events

DISCUSSION

This study evaluated knee function after surgical fixation of tibial plateau fractures using an anatomical locking compression plate, with IKDC as the primary outcome. Functional recovery in our study showed a consistent improvement pattern across follow-up, with mean IKDC rising from early postoperative limitation at 6 weeks to a substantially better level by 12 months. At final follow-up, good–excellent outcome was achieved in 80% of patients. This pattern suggested that when stable fixation was achieved and reduction was maintained, patient-reported knee function improved progressively through the first postoperative year, which was in line with long-term functional trends described by Manidakis et al. and Timmers et al., where recovery remained strongly linked to restoration of joint congruity and avoidance of complications.[5,6]

The baseline profile in our study (Table 1) showed male predominance and road traffic accidents as the commonest mechanism, which was consistent with the classic epidemiologic and injury-pattern observations reported by Schatzker et al. in their foundational series.[1] Although our cohort included a meaningful proportion of higher-grade fractures (Schatzker V–VI), the open fracture rate remained low (10%). This combination likely influenced outcomes because complex fracture morphology and soft-tissue injury burden had been repeatedly linked to increased complications and poorer function in higher-energy plateau injuries.[15,16] In addition, evidence from long follow-up cohorts (Rademakers et al.) had shown that even with union, long-term outcome could still be affected by residual articular incongruity and malalignment.[4] Therefore, the case-mix in our study likely contributed to the favourable functional distribution observed at 12 months.

Operative characteristics in our study (Table 2) suggested that fixation strategy was selected according to fracture morphology and soft-tissue condition. The median time to surgery of 4 days implied that definitive fixation was commonly performed after initial soft-tissue optimisation rather than immediate fixation in a swollen limb, consistent with principles described by Egol et al. in staged/soft-tissue–respecting management of high-energy proximal tibial injuries.[14] Most patients underwent single lateral plating, while dual plating was applied selectively (25%), which aligned with the concept that bicondylar or medial/posteromedial instability patterns required additional column support to prevent varus collapse and loss of reduction. This approach was supported by outcome series such as Barei et al., where dual-incision medial and lateral plate stabilisation was used for severe bicondylar fractures with acceptable functional results.[7] In our study, selective bone graft/substitute use (22.5%) also fit the typical logic of split-depression injuries, where void filling after elevation was used to support the subchondral surface and reduce the likelihood of late settling.

The progressive IKDC improvement in our study (Table 3) was clinically expected for intra-articular knee trauma, where early limitations were driven by pain, swelling, quadriceps inhibition and guarded motion and later improvement reflected rehabilitation progression and staged weight bearing. Because IKDC captured patient-reported symptoms and activity limitation, it served as a relevant measure of functional recovery in this setting.[13] Importantly, the improvement curve in our study looked clinically consistent with published observations that most measurable recovery after plateau fixation occurred within the first year, while late limitations were commonly linked to stiffness, complications or residual incongruity.[5,6]

Final outcomes at 12 months (Table 4) showed internal consistency between function, radiological parameters and complication burden. The high good–excellent rate corresponded with low frequencies of step-off >2 mm and malalignment >5° and implant failure/loss of reduction was uncommon. This relationship remained clinically meaningful because residual incongruity and malalignment altered tibiofemoral loading and had been linked with long-term pain and post-traumatic degeneration in several long-term cohorts.[3-5] In addition, the low loss-of-reduction rate in our study was notable because reduction loss in bicondylar patterns had been specifically associated with CT-defined morphology and fixation choice. Weaver et al. reported that fracture pattern and fixation strategy were related to loss of reduction in bicondylar tibial plateau fractures and Kim et al. highlighted posterior coronal fragments as predictors of reduction loss.[17,18] The low reduction loss in our study therefore suggested that construct selection and fragment support (including rafting screws and selective grafting) were generally adequate for the treated patterns, particularly when medial/posteromedial support was added where needed.

Complications in our study were acceptable for an operatively treated plateau cohort. Superficial infection was limited and deep infection was infrequent, while early stiffness occurred in a minority (Table 4). Stiffness remained an expected concern after tibial plateau fractures because swelling, pain, protected weight bearing and variable rehabilitation adherence could delay motion recovery; even with union, stiffness could strongly influence patient-perceived outcome.[5,6] The low reoperation rate in our study further suggested that major mechanical failure or uncontrolled infection was uncommon.

Two contradictory areas in the literature helped frame interpretation. Vaartjes et al. reported that in minimally displaced fractures managed nonoperatively, CT step-off/gap up to 4 mm could still yield good function, suggesting the 2-mm threshold was not universal.[19] In our operatively indicated cohort with greater displacement/instability, aiming for near-anatomic reduction remained appropriate.[2-5] The need for routine dual plating in bicondylar patterns also remained debated: Barei et al. supported dual-column fixation in severe injuries,[7] whereas Gosling et al. showed selected bicondylar fractures could be treated with single lateral locked plating when soft tissues were a concern.[20] Our selective dual plating rate (25%) reflected this morphology-based approach. Finally, Ruffolo et al. reported higher deep infection and nonunion in high-energy bicondylar fractures, particularly with open wounds or fasciotomy, which likely explained why our lower open-fracture burden showed fewer major infective/nonunion events and limited generalisability to severely compromised soft tissues.[10]

However, few limitations of the study were that this study had a relatively small sample size from a single centre and the follow-up period of 12 months may not have captured late degenerative changes or longer-term functional plateauing.

Overall our study supported that anatomical LCP fixation for tibial plateau fractures produced stable fixation, timely union and predominantly good-to-excellent patient-reported knee function at one year, when fracture-specific fixation principles, reduction maintenance and structured rehabilitation were followed.

CONCLUSION

In this study, surgical fixation of tibial plateau fractures using an anatomical locking compression plate produced progressive improvement in knee function over follow-up, with IKDC scores increasing consistently from 6 weeks to 12 months. At one year, good-to-excellent functional outcome was achieved in the majority of patients, along with timely radiological union and maintenance of

alignment and articular congruity in most cases. Complications were infrequent and largely manageable, with low rates of deep infection, loss of reduction, implant failure and reoperation. Overall anatomical LCP fixation provided a stable construct that supported early rehabilitation and satisfactory functional recovery in operatively indicated tibial plateau fractures, while outcomes in severe soft-tissue compromise or high-energy open injuries should be interpreted cautiously.

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