

Original Research Article

A morphology-based classification system and management strategy for postero-medial tibial plateau fractures

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ABSTRACT

Background: Posteromedial tibial plateau fractures represent a distinct subset of proximal tibial injuries, characterized by coronal-plane fracture orientation and complex fragment morphology that may be overlooked on standard radiographs. Earlier classification systems such as the Schatzker and pre-2018 AO/OTA schemes did not adequately describe posterior or posteromedial fracture patterns, limiting their usefulness in surgical planning. However, the revised 2018 AO/OTA classification introduced axial-plane modifiers to specifically identify posteromedial involvement. Despite this advancement, considerable heterogeneity remains in fracture morphology and intraoperative behavior, highlighting the need for a dedicated morphology-based classification that more directly correlates fracture pattern with fixation strategy and clinical outcome.

Methods: Forty adult patients with postero-medial tibial plateau fractures were prospectively studied. Fractures were classified by sagittal position of fracture line (L1-L3), apex orientation on AP view (A1-A2), and displacement on CT (Da <2 mm, Db >2 mm). Surgical approach and fixation strategy were selected accordingly, and intraoperative stability was assessed under fluoroscopy. Outcomes were evaluated with radiographs, range of motion, and Knee Society Score (KSS) at 6 months.

Results: Of 40 patients (mean age 41 years), 24 fractures involved L1, 11 L2, and 5 L3 regions; 27 had medial apex (A1) and 13 lateral apex (A2). L1Db and L2 fractures showed marked instability, while L3Da patterns remained stable through flexion. All unstable patterns required buttress plating, with surgical approach dictated by apex orientation. Radiological union occurred in all cases at a mean of 14 weeks. At 6 months, 85% of patients achieved excellent or good outcomes; complications included stiffness in three cases and ACL laxity in one.

Conclusions: This morphology-based classification reliably correlates fracture patterns with stability, surgical approach, and rehabilitation needs. It offers a practical framework for individualized management of posteromedial tibial plateau fractures and may improve functional outcomes. Further multicenter validation is recommended.

Keywords: Novel classification for posteromedial tibial plateau fractures, Posteromedial tibial plateau fracture, Proximal tibia fracture classification,

INTRODUCTION

Tibial plateau fractures are complex injuries involving the proximal articular surface of tibia. They are frequently caused by high-energy trauma such as car crashes or falls

from a height or low-energy injuries in osteoporotic bone.¹ If not managed appropriately, these fractures can result in substantial morbidity, including chronic pain, malalignment, instability, stiffness, and the development of post-traumatic osteoarthritis (PTOA). The reported

incidence of PTOA after tibial plateau fractures ranges from 23% to 44% at mid- to long-term follow-up, even after anatomically restored joint surfaces. Restoration of joint congruity and stability is therefore critical to minimize the risk of progressive degenerative joint disease.² They are classified using standard systems such as the Schatzker and AO/OTA classifications, which are based on the location and pattern of the fracture.³ Restoring articular congruity, limb alignment, and joint stability is the goal of management as this more often calls for surgery, especially in cases of displaced or comminuted fractures.⁴

Additionally, the thin soft tissue envelope around the proximal tibia increases the risk of wound complications and infection following surgical intervention. Choosing the appropriate surgical approach and fixation strategy—whether lateral locked plating, dual plating, or minimally invasive techniques—must be tailored to fracture morphology and soft tissue condition. Early mobilization is crucial for functional recovery but must be balanced against the risk of fixation failure or loss of reduction, especially in osteoporotic bone or highly unstable patterns.⁵ Thus, optimal management of tibial plateau fractures requires careful preoperative planning, advanced surgical skill, and a patient-specific rehabilitation protocol to minimize complications and ensure satisfactory outcomes.

Postero-medial tibial plateau fractures constitute a complex subset of proximal tibial injuries that are frequently underdiagnosed on initial plain radiographs due to their unique coronal fracture orientation. Conventional classification systems often fail to delineate these injuries with adequate specificity, thereby limiting their utility in guiding appropriate surgical management. While these fractures may appear in isolation, they are more commonly encountered as components of bicondylar tibial plateau fractures and have significant implications for joint stability and long-term functional outcome.

High-energy tibial plateau fractures often involve severe articular comminution, meta-diaphyseal dissociation, and soft tissue compromise, making both diagnosis and treatment challenging. The presence of a posteromedial fragment has been documented in several reports. While Moore originally described the characteristic instability of posteromedial fragments, subsequent literature has primarily focused on posterior column fixation strategies, and detailed correlations between fracture morphology, intraoperative stability, and rehabilitation protocols remain incompletely defined. The lack of a dedicated classification system capturing the full spectrum of postero-medial fracture morphologies limits the surgeon's ability to predict fragment behavior, select an optimal surgical approach, or tailor postoperative rehabilitation protocols. Contemporary fixation strategies increasingly employ arthroscopy-assisted reduction and internal fixation (ARIF), which allows direct visualization of

articular reduction while minimizing soft-tissue disruption.

This study aimed to fill this gap by proposing a morphology-based classification system derived from the assessment of 40 patients with postero-medial tibial plateau fractures. Although sagittal fracture position can be identified on lateral radiographs, CT sagittal reconstructions were used to improve measurement accuracy and interobserver consistency. Through radiographic and computed tomography (CT) analysis, coupled with intraoperative observations and postoperative outcomes, this system offers a practical, reproducible framework that correlates fracture morphology with clinical behavior.

METHODS

This prospective observational study was conducted over a period of 3 years in department of orthopedics, Narayana health city, Bangalore, India (formerly Sparsh hospital), a tertiary care orthopedic trauma center. A total of 40 adult patients diagnosed with postero-medial tibial plateau fractures were included.

Patients were selected based on specific inclusion criteria: age above 18 years, radiologically confirmed postero-medial tibial plateau fracture either isolated or part of a bicondylar pattern, and willingness to undergo surgical management with postoperative follow-up. Patients with open fractures, pathological fractures, or polytrauma involving the ipsilateral lower limb were excluded from the study.

Ethical approval

The study protocol was reviewed and approved by the institutional ethics committee of Sparsh hospital (approval number ECR/520/Inst/KA/2014/RR-54). Written informed consent was obtained from all participants prior to enrolment. The study was conducted in accordance with the Declaration of Helsinki.

All consecutive eligible patients presenting with posteromedial tibial plateau fractures during the study period who fulfilled the inclusion criteria were recruited. Hence, consecutive sampling was employed. All patients underwent initial trauma resuscitation and stabilization as per advanced trauma life support (ATLS) protocols. Following clinical assessment, standard anteroposterior (AP) and lateral radiographs of the knee were obtained. Detailed fracture assessment was then performed using high-resolution computed tomography (CT) scans with sagittal, coronal, and 3D reconstructions to delineate fracture lines, displacement, and orientation of fracture fragments.

Each fracture was analysed and categorized based on three morphological parameters:

Sagittal position of fracture line (L)

Evaluated on lateral radiographs and CT sagittal images and classified as: L1: Fracture line located in the anterior third of the tibial plateau. L2: Fracture line crossing the middle third. L3: Fracture line extending into the posterior third (Figure 1).



Figure 1: Classification based on sagittal positions of the fracture line.

Frontal apex orientation (A)

Determined on AP radiographs and coronal CT scans: A1: Apex directed medially. A2: Apex directed laterally (Figure 2).



Figure 2: Classification based frontal apex orientation.

Vertical displacement (D)

Measured on CT sagittal reformation: Da: Undisplaced (<2 mm displacement). Db: Displaced (>2 mm displacement).

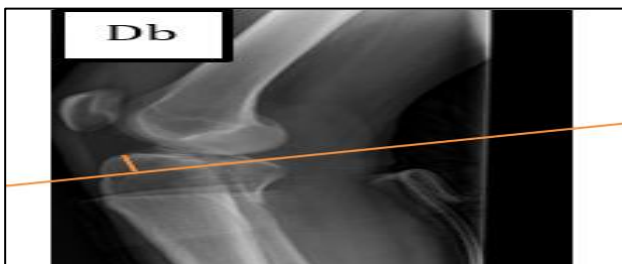


Figure 3: Vertical displacement of >2 mm (Db).

Based on these three parameters, a classification system was formulated to group fractures by morphological behaviour and likely biomechanical stability.

Classification

Group I: A1L1, A2L1 Da- Undisplaced, Db- Displaced. Group II: A1L2, A2L2. Group III: A1L3, A2L3 Da- Undisplaced, Db- Displaced.

Group I Da (Undisplaced highly unstable)

Fracture line in anterior 1/3rd of plateau, caused by axial loading on varus knee in 0-30° flexion. Ligamentotaxis keeps fragment undisplaced in extension but it is highly unstable. Requires floppy supine (A1) or prone (A2) approach and buttress plate fixation. Post-op: 4-6 weeks immobilization, gradual ROM, weight bearing after 3 months.

Group I Db (displaced highly unstable)

Similar to Da but with added internal rotation torque, causing vertical displacement even in extension. Direct reduction required using modified Lobenhoffer (A1) or posterior midline (A2). Post-op rehab same as Da but with caution during ROM to prevent varus failure.

Group II (moderately unstable)

Fracture line at mid-1/3rd of plateau, produced by axial load on a flexed knee. Always displaced vertically, but early flexion does not compromise stability. Needs direct reduction and fixation via modified Lobenhoffer (A1) or midline prone (A2). Early ROM possible after rigid fixation.

Group III Da (undisplaced stable)

Rare avulsion of semimembranosus insertion, often with ACL injury.⁶ Produced by complex external rotation/varus forces in flexion. Stable after fixation, managed with anti-glides buttress plate using Lobenhoffer approach. Early ROM is safe, functional outcomes usually excellent.

Group III Db (displaced unstable)

Similar to III Da but with displacement. Requires direct reduction and buttress plating, approach depending on apex position. Early controlled ROM possible, outcomes depend on associated soft tissue injury

All surgeries were performed under spinal or general anesthesia with the patient positioned appropriately depending on apex orientation. For A1 (medial apex) types, a modified Lobenhoffer approach in floppy lateral or supine position was used. For A2 (lateral apex) types, a posterior midline approach in prone position was employed. In cases involving bicondylar fractures, dual incisions were made to facilitate adequate exposure and

reduction. Intraoperative stability was systematically assessed by taking the knee through flexion under fluoroscopy after provisional fixation. Observed displacement patterns were recorded and correlated with fracture morphology, forming the basis for postoperative immobilization and rehabilitation recommendations.

Fracture fragments were anatomically reduced under fluoroscopic guidance. Fixation was achieved using non-locking or locking T- or L-shaped buttress plates as per fragment size and bone quality. After definitive buttress plate fixation, reduction stability was reassessed fluoroscopically through 30°-120° of knee flexion to detect loss of reduction. Collateral ligament integrity was simultaneously evaluated under varus-valgus stress, and cruciate ligament instability was screened using anterior drawer and posterior sag maneuvers under anesthesia

Postoperative management was carried out based on the fracture configuration and intraoperative stability. Stable fractures were permitted early range-of-motion (ROM) exercises within pain limits, while unstable patterns were immobilized in extension for 4-6 weeks, followed by gradual progression to passive and then active ROM. Full weight-bearing was delayed until radiological signs of union were observed, typically around 12 weeks postoperatively.

Patients were followed clinically and radiographically at 4-weeks, 8-weeks, 12-weeks, 6-month and 1-year intervals. Outcome parameters included radiological union, maintenance of reduction, knee range of motion, and complications such as implant failure or post-traumatic arthritis. One year follow-up was sufficient for functional outcome assessment but insufficient for evaluation of post-traumatic osteoarthritis. Long-term radiographic follow-up is ongoing and will be reported separately. Statistical analysis was performed using SPSS version XX (IBM Corp., Armonk, NY).

RESULTS

The baseline demographic and clinical characteristics are shown in Table 1. Most patients were males (72.5%), with a mean age of 41 years.

Table 1: Demographic characteristics.

Variables	Values
Number of patients	40
Mean age in years	41±SD
Male (%)	29 (72.5)
Female (%)	11 (27.5)

Fracture patterns were categorized based on the position of the fracture line on lateral radiographs (sagittal view): L1 (Anterior third): 24 cases, of which 20 were displaced (Db) and 4 were undisplaced (Da); L2 (Middle third): 11 cases,

all of which were displaced (Db); L3 (Posterior third): 5 cases, all undisplaced (Da).

Apex orientation on anteroposterior views showed: A1 (Medial apex): 27 patients; A2 (Lateral apex): 13 patients.

The fracture morphology according to the proposed classification is summarized in Table 2.

Table 2: Fracture morphology.

Variables	N (%)
L1	24 (60)
L2	11 (27.5)
L3	5 (12.5)
A1	27 (67.5)
A2	13 (32.5)
Da	9 (22.5)
Db	31 (77.5)

All L2 and L3 fractures were managed with direct reduction and buttress plating. In medial apex (A1) patterns, a modified Lobenhoffer posteromedial approach provided direct access for antiglide buttress plate placement. In lateral apex (A2) patterns, a prone posterior midline approach enabled perpendicular screw placement and optimal buttress effect. Fractures with lateral apex (A2) required deeper dissection and prone positioning for optimal exposure and fixation. The average surgical time was 120 minutes (range 90-145 minutes), and no intraoperative neurovascular complications were reported.

Intraoperative stability assessment showed that all L1Db and L2 fractures exhibited significant vertical instability during knee flexion beyond 60 degrees. In contrast, L3Da fractures maintained reduction even up to 120 degrees of passive motion. These observations were used to tailor the postoperative rehabilitation protocol, with L1 and L2 patterns requiring extended immobilization.

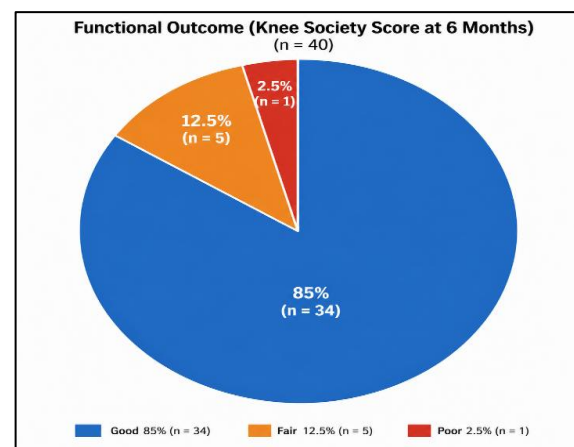


Figure 4: Functional outcomes.

Radiological union was achieved in all patients within an average of 14 weeks (range 12-18 weeks). Functional

outcomes were assessed using the Knee Society Score (KSS) at 6 months. Good outcomes were achieved in 34 patients (85%), fair in 5 patients, and poor in 1 patient who had limited ROM and residual varus deformity due to early weight-bearing and noncompliance.

Three patients had postoperative stiffness requiring manipulation under anesthesia. One patient with a posteromedial L3Da pattern exhibited clinical ACL laxity diagnosed by positive Lachman test under anesthesia which was managed conservatively; arthrometer assessment was not performed. No cases of implant failure or deep infection were recorded.

Table 3: Complications.

Complication	N (%)
No complications	90
Stiffness	7.5
ACL laxity	2.5
Implant failure	0
Infection	0

Overall, the proposed classification system correlated well with intraoperative behaviour and helped in selecting surgical approaches, fixation strategies, and rehabilitation protocols that led to favourable clinical outcomes.

DISCUSSION

Posteromedial proximal tibial fractures are biomechanically significant due to their contribution to posterior stability of the knee. Unlike typical split-depression patterns, these injuries are frequently oblique in orientation and may involve shear forces acting along the posterior slope of the tibia. Accurate detection often requires advanced imaging, as standard radiographs may fail to reveal the full extent of the fracture. Clinically, failure to recognize and adequately stabilize these fragments can lead to persistent instability, malalignment, and early degenerative changes. Surgical treatment often necessitates posterior or posteromedial approaches with carefully planned fixation using buttress plating to counteract the posterior shear forces. Given their unique morphology and mechanical implications, posteromedial fractures demand a tailored surgical strategy and precise preoperative planning to achieve optimal outcomes.

To classify tibial plateau fractures, multiple systems have been established, each with recognized advantages and limitations. The Schatzker and AO/OTA classification systems remain the most widely used frameworks for tibial plateau fractures. Earlier versions of these systems were based primarily on plain radiographs and did not adequately capture posterior or posteromedial fracture components. However, the revised AO/OTA Fracture and Dislocation Classification Compendium (2018) introduced axial-plane modifiers that allow specific identification of posterior and posteromedial involvement. Similarly, Schatzker and Kfuri have proposed updated

treatment-oriented algorithms that incorporate fracture location, including postero-medial patterns, into surgical decision-making.³ They established four quadrants by adding anterior and posterior divisions. To aid in determining the best course for plate and screw placement, they also proposed the idea of the “main fracture plane”, which is based on the exit locations of the wedge fragment from the articular and metaphyseal cortex.

Despite these advances, current classification systems remain primarily location-based and do not account for the orientation of the fracture line in the coronal plane, the three-dimensional morphology of the fragment, or its dynamic behavior under knee motion.^{7,8} Moreover, they do not directly correlate fracture pattern with intraoperative stability, fixation strategy, or postoperative rehabilitation protocols. As a result, there remains a need for a morphology-based classification that integrates fracture geometry, biomechanical behavior, and surgical implications to guide individualized management of posteromedial tibial plateau fractures.

One of the earliest systems, the Hohl and Moore classification, included tibial plateau dislocations and classified tibial plateau fractures according to the mechanism of injury. Moore first specifically described posteromedial fracture-dislocations of the tibial plateau (Moore type I), noting their characteristic coronal-plane fracture line. On the lateral view, the fracture line runs posteroinferiorly at 30°-45° to the long axis of the tibia and lies in the coronal rather than sagittal plane. The posterior fragment typically contains approximately half of the articular surface and is inherently unstable, displacing distally with knee flexion and allowing posterior subluxation of the medial femoral condyle.⁹ However, because of its limited applicability to CT-based imaging and its lack of detail on injuries in the posterior and coronal planes, it is currently regarded as outdated. More recent systems like the three-column or ten-segment classifications use CT imaging to capture the three-dimensional nature of these injuries, providing better insight into fracture morphology. Nonetheless, these systems may be cumbersome to apply in routine practice.¹⁰

The concept of medial, lateral, and posterior columns based on CT was first proposed by Luo et al.¹¹ The posterior column was separated by Chen et al into posterolateral (PL) and posteromedial (PM) columns based on different fracture morphologies.¹² Recent authors have proposed treatment-oriented algorithms incorporating main deformity direction and approach selection in complex tibial plateau fractures. Boluda-Mengod et al developed the SOTA decision-making algorithm for fixation of complex tibial plateau fractures, integrating fracture morphology with surgical approach selection. More recently, the modified oblique Lobenhoffer (MOL) approach has been anatomically validated for combined posterolateral and posteromedial column access. Similarly, there are numerous classification systems based on different parameters viz

morphology, mechanism of injury, posterolateral column as a separate entity, cartilage degeneration, soft tissue injuries etc.¹³ But currently, no widely accepted classification system exists that specifically and comprehensively addresses the unique morphology, mechanisms, and surgical considerations of posteromedial tibial plateau fractures which indicates that there is a great deal of room to propose a specialized classification system. High-resolution CT and 3D reconstruction could be incorporated into a novel method to quantify displacement and precisely identify fracture morphology, including fragment size, displacement, orientation and principle deformity direction which would help guide the safest and most effective surgical approaches. It should also include injury mechanism analysis, as varus-flexion and other loading patterns have distinct implications for fixation strategy which we tried to cover in our proposed classification.

Our analysis provides several key insights into the biomechanics and clinical behaviour of postero-medial tibial plateau fractures:

Knee flexion at injury

Determines sagittal position of the fracture. Increased flexion correlates with more posterior fracture lines.

Internal rotation torque

Affects apex orientation. Lateral apex fractures are biomechanically more stable but surgically more demanding.

Anterior third fractures (L1)

Most prone to displacement and require immobilization in extension postoperatively.

Surgical approach

Apex orientation guides incision placement and plate positioning.

The chief advantage of this new classification system lies in its ability to comprehensively describe the morphologic variations of postero-medial tibial plateau fractures, which were previously under-represented in existing systems. By better understanding the position of the fracture line, the apex orientation, and the degree of displacement, this classification allows the surgeon to anticipate the inherent stability or instability of the fragment, predict intra-operative challenges, and choose the most suitable surgical approach. Another strength of this system is that primary classification parameters can be identified on standard radiographs, while CT with sagittal and coronal reconstructions provides necessary refinement for displacement assessment and surgical planning, thus making it practical for routine clinical use. Unlike older classifications that group all such patterns together, this

system highlights how minor changes in fracture morphology directly influence stability, reduction technique, implant choice, and post-operative rehabilitation. It therefore bridges the gap between radiologic appearance and surgical decision-making, providing a pathway from pre-operative assessment to post-operative protocol formulation. Overall, the main advantage of this classification is that it offers a detailed, clinically meaningful framework that can guide individualized management strategies and optimize functional outcomes for patients.

Comparison with cadaveric studies, including Vanessa et al, confirms that fragment stability varies with knee motion and is dependent on fragment size and orientation.¹⁴ They came to the conclusion that the size and relationship of this fragment to the femur during regular range-of-motion activities determine how important it is to correct. It's possible that some postero-medial fragment sizes are naturally stable over a specific arc of motion. The results of this biomechanical analysis support the idea of specific fixation of the typical postero-medial fracture fragment in tibial plateau fractures and help us understand the inherent instability of this fragment outside of full extension. It is evident that regardless of tibiofemoral contact, the tibial-femoral relationship during progressive flexion is altered, which could result in displacement if this fragment is not specifically addressed surgically, even though it may initially appear non-displaced following injury and during surgical planning.

Comparing various fixation types and the associated fragment stability has been the subject of more recent research. Clinical evidence indicates that only lateral locking plating of bicondylar tibial plateau fractures may result in loss of reduction and severe mal-reduction, which causes medial collapse and varus deformity later on.¹⁵ The biomechanical literature supports dual plating in bicondylar fractures to reduce collapse risk, and buttress plating remains the gold standard for isolated postero-medial fragments.^{5,16}

This study has several limitations. First, it was conducted at a single tertiary care centre with a relatively small sample size, limiting the generalizability of the findings. Second, interobserver and intraobserver reliability of the proposed classification system were not evaluated. Third, the follow-up duration was limited to one year, precluding assessment of long-term outcomes such as post-traumatic osteoarthritis. Finally, the absence of a comparison group using existing classification systems limits direct assessment of the superiority of the proposed classification. Larger multicentre studies with longer follow-up are required to validate the reproducibility and clinical applicability of this classification.

CONCLUSION

Postero-medial tibial plateau fractures display substantial morphological variability, which significantly influences

intraoperative behavior and fixation strategies. Our proposed classification, grounded in radiographic and intraoperative observations, provides a reproducible framework to guide surgical decision-making and optimize outcomes. Future multi-center studies are needed to validate its clinical applicability and reliability across diverse patient populations.

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