

EVALUATION AND MANAGEMENT OF COMPLEX TIBIAL PLATEAU FRACTURE WITH POSTERIOR ARTICULAR INVOLVEMENT USING A NOVEL CONCEPT OF "THREE-COLUMN FIXATION"

Dr. Waseem Ahmed Memon^{*1}, Professor Badaruddin Sahito², Dr. Muhammad Waseem³,
Dr. Fayaz Ahmed⁴, Dr. Prem Chand⁵, Dr. Awais Inam⁶, Dr. Salim Jan⁷

^{*1}MBBS, FCPS, Postgraduate, DUHS

²MBBS FCPS FRCS Head of Department Orthopedic, DUHS

^{3,4,5,6,7}MBBS, FCPS. Postgraduate Trainee, DUHS

¹memon4059744@gmail.com, ²Sahito.badar@duhs.edu.pk, ³waseemraheem42@gmail.com,
⁴drfayaz1000@gmail.com, ⁵premchand728@yahoo.com, ⁶awais.mhr@gmail.com, ⁷jakhranisalim@gmail.com

DOI: <https://doi.org/10.5281/zenodo.18493092>

Keywords

Tibial Plateau Fractures,
Posterior Tibial Plateau
Fractures, Internal Fixation,
Three-Column Fixation

Article History

Received: 09 June 2025

Accepted: 10 July 2025

Published: 14 July 2025

Copyright @Author

Corresponding Author: *

Dr. Waseem Ahmed
Memon

Abstract

OBJECTIVE

To evaluate the outcome of the management of complex tibial plateau fracture with posterior articular involvement using a novel concept 'three-column fixation.

STUDY DESIGN

Prospective cohort study

METHODOLOGY

A total 45 patients aged 18–60 years with posterior tibial plateau fractures were enrolled using consecutive sampling. All underwent three-column fixation. Radiological reduction, fracture union, knee range of motion, and Oxford Knee Score were assessed. Data were analysed using descriptive statistics and appropriate inferential tests, with significance set at $p \leq 0.05$.

RESULTS

The mean age was 39.2 ± 13.4 years; 25 (55.6%) were female. Mean MPTA and PTPA were $86.8 \pm$

2.9° and $10.5 \pm 2.8^\circ$, respectively. Satisfactory fracture reduction was achieved in 18 (40.0%) patients, and fracture union in 24 (53.3%). Mean knee range of motion was $116.7 \pm 12.9^\circ$, with a mean Oxford Knee Score of 33.2 ± 5.4 . Left-sided injuries showed significantly better functional outcomes ($p=0.027$).

CONCLUSION

Three-column fixation demonstrated satisfactory radiological and clinical outcomes in patients with complex tibial plateau fractures involving the posterior column. The technique allowed restoration of alignment, fracture stability, and knee function in a substantial proportion of cases. Clinical outcome showed a significant association with the side of injury, while patient age, gender, and injury mechanism were not significantly related to postoperative functional recovery.

INTRODUCTION

Tibial plateau fractures represent complex intra-articular injuries of the knee joint that typically result from axial loading forces combined with varus or valgus stress, most commonly following

high-energy trauma such as road traffic accidents or falls from height. These fractures compromise the articular congruity, metaphyseal stability, and overall biomechanics of the knee, often leading to significant functional impairment if

inadequately treated. Posterior articular involvement in tibial plateau fractures, although relatively uncommon, accounts for approximately one-quarter to one-third of cases and is increasingly recognized with the widespread use of computed tomography (CT) imaging. Such injuries pose a substantial clinical challenge due to their complex fracture morphology, limited surgical exposure, and high risk of post-traumatic osteoarthritis [1-3].

Posterior tibial plateau fractures are frequently associated with comminution, depression of the articular surface, and instability of the posterior column, which are not adequately characterized by conventional radiographic evaluation alone. Advances in CT technology, particularly three-dimensional reconstructions, have significantly improved the understanding of posterior fracture patterns, enabling more precise preoperative planning and fixation strategies [4-6]. Restoration of articular congruity, axial alignment, and joint stability remains the cornerstone of management, as failure to achieve anatomical reduction is strongly associated with persistent pain, stiffness, instability, and early degenerative changes [7].

Despite these advances, the diagnosis and management of posterior tibial plateau fractures remain challenging. Traditional classification systems, including the Schatzker and AO/OTA classifications, are primarily based on two-dimensional imaging and fail to adequately describe posterior column involvement. As a result, these systems provide limited guidance for surgical approach selection and fixation strategy in fractures involving the posterior articular surface [8-10]. Inadequate appreciation of posterior fracture components may lead to suboptimal fixation, secondary displacement, and compromised functional outcomes.

To address these limitations, Luo and colleagues introduced the three-column classification system, which divides the tibial plateau into medial, lateral, and posterior columns based on axial CT imaging. This novel concept emphasizes the posterior column as a distinct structural entity and provides a comprehensive framework for fracture assessment, surgical

approach selection, and column-specific fixation [11]. The three-column fixation concept has since gained increasing attention, with biomechanical and clinical studies demonstrating improved stability, more accurate reduction of posterior fragments, and better functional outcomes when posterior column fixation is incorporated into the surgical construct [12-15].

Recent literature highlights that fixation strategies addressing all involved columns, particularly the posterior column, are associated with improved early rehabilitation, enhanced knee stability, and reduced rates of loss of reduction [12-14]. However, most available evidence originates from biomechanical analyses, small case series, or studies conducted in high-income settings. Data evaluating functional and radiological outcomes following three-column fixation in low- and middle-income countries remain limited, despite a substantial burden of high-energy trauma in these regions.

In the local context, posterior tibial plateau fractures are routinely encountered at tertiary care trauma centres; however, there is a paucity of prospective data quantifying the outcomes of managing these injuries using the three-column fixation concept. The absence of region-specific evidence limits the ability to standardize treatment protocols and optimize patient outcomes. Given variations in injury mechanisms, resource availability, and patient follow-up patterns, evaluating the applicability and effectiveness of this fixation strategy in a local tertiary care setting is clinically relevant and necessary.

METHODOLOGY

A prospective cohort study was conducted at the Department of Orthopaedic Surgery, Dr. Ruth K. M. Pfau Civil Hospital, Karachi, after approval from the ERC, and written informed consent was obtained from all participants prior to enrolment. Adult patients aged 18–60 years of either gender presenting with tibial plateau fractures involving the posterior articular surface were recruited through non-probability consecutive sampling, while patients unfit for

surgery, those refusing consent, pathological fractures, polytrauma cases, open fractures classified as Gustilo grade II or above, delayed presentation beyond four weeks, fractures with vascular injury, and pre-existing knee joint diseases such as rheumatoid arthritis were excluded. The exposure was defined as surgical fixation of complex tibial plateau fractures using the three-column fixation concept based on computed tomography-guided fracture classification. Fracture pattern was classified according to Luo’s three-column system using preoperative anteroposterior and lateral knee radiographs along with three-dimensional computed tomography. Radiological parameters included quality of reduction, defined as articular step-off less than 2 mm, medial proximal tibial angle of $87^{\circ} \pm 5^{\circ}$, and posterior proximal tibial angle of $9^{\circ} \pm 5^{\circ}$, while fracture union was defined as absence of fracture site pain with radiological evidence of union. Functional assessment included knee range of motion measured clinically, and Oxford Knee Score assessed using a validated 12-item questionnaire, and complications such as infection, deep vein thrombosis, delayed union, non-union, loss of reduction, and post-traumatic osteoarthritis graded by the Kellgren–Lawrence system were recorded. The final sample size was 45 patients, calculated using an expected prevalence of posterior articular involvement of 28.8%, a 95% confidence level, a 5% margin of

error, and an anticipated 20% loss to follow-up. All assessments and surgical management were performed by the principal investigator, a postgraduate trainee in orthopaedic surgery with supervised experience in trauma procedures. Data were using a predesigned structured proforma. Patients underwent column-specific internal fixation under general or spinal anaesthesia and were followed postoperatively with clinical and radiological evaluations at six-weekly intervals until fracture union. Data was analysis using SPSS.26 included descriptive clinical, radiological, and functional variables analysed using independent t-test, with a p-value of ≤ 0.05 considered statistically significant.

RESULTS

Table I presents the baseline demographic and injury characteristics of the 45 patients included in the study. The mean age of the participants was 39.22 ± 13.38 years, while the mean time from trauma to surgery was 5.71 ± 2.72 days. Females constituted most of the cohort 25 (55.6%), whereas 20 patients (44.4%) were male. The left side was more frequently involved 27 (60.0%) compared to the right side 18 (40.0%). Regarding the mechanism of injury, road traffic accidents and other causes were equally common, each accounting for 16 cases (35.6%), while falls were observed in 13 patients (28.9%).

Table 1: Baseline Demographic and Injury Characteristics (n=45)		
Mean ± Standard Deviation		95% Confidence Interval
Age in years = 39.22 ± 13.38		35.20-----43.24
Time from Trauma to Surgery in days = 5.71 ± 2.72		4.89~6.53
Frequency (%)		
Gender	Male	20 (44.4)
	Female	25 (55.6)
Side of Injury	Right	18 (40.0)
	Left	27 (60.0)
Mechanism of Injury	RTA	16 (35.6)
	Fall	13 (28.9)
	Other	16 (35.6)

Table II summarizes the postoperative radiological and clinical outcomes following

three-column fixation in the 45 patients. The mean medial proximal tibial angle (MPTA) was

86.77 ± 2.86, while the mean posterior proximal tibial angle (PTPA) was 10.50 ± 2.81. Radiological assessment of fracture reduction showed that 18 patients (40.0%) achieved satisfactory reduction, whereas 27 patients (60.0%) had unsatisfactory reduction. Fracture

union was achieved in 24 patients (53.3%). Regarding clinical outcomes, the mean Oxford Knee Score was 33.22 ± 5.42, and the mean postoperative range of motion was 116.69 ± 12.88 degrees.

Table II: Postoperative Radiological and Clinical Outcomes after Three-Column Fixation (n=45)

Radiological Outcome		Mean ± SD / n (%)
Medial Proximal Tibial Angle (MPTA)		86.77 ± 2.86
Posterior Proximal Tibial Angle (PTPA)		10.50 ± 2.81
Fracture Reduction	Satisfactory	18 (40.0)
	Unsatisfactory	27 (60.0)
Fracture Union Achieved		24 (53.3)
Clinical Outcomes		
Oxford Knee Score		33.22 ± 5.42
Range of Motion (degrees)		116.69 ± 12.88

Table III shows the comparison of baseline characteristics with the Oxford Knee Score among the study participants. Patients aged ≤ 40 years had a higher mean Oxford Knee Score (34.58 ± 5.63) compared to those aged > 40 years (31.67 ± 4.84); however, this difference was not statistically significant (p = 0.071). Female patients demonstrated a higher mean Oxford Knee Score (34.36 ± 6.13) than males (31.80 ± 4.09), though this difference also did not reach statistical significance (p=0.117). A statistically

significant association was observed with the side of injury, as patients with left-sided injuries had a significantly higher mean Oxford Knee Score (34.67 ± 5.83) compared to those with right-sided injuries (31.06±3.97) (p=0.027). Regarding the mechanism of injury, patients injured due to falls showed the highest mean Oxford Knee Score (35.08 ± 7.42), followed by road traffic accidents (33.94±4.20) and other causes (31.00 ± 3.96); however, these differences were not statistically significant (p=0.105).

Table III: Comparison of Baseline Characteristics with Oxford Knee Score (n=45)

Baseline Characteristics		Oxford Knee Score (Mean ± SD)	P-Value
Age Group	≤ 40 years	34.58 ± 5.63	0.071
	> 40 years	31.67 ± 4.84	
Gender	Male	31.80 ± 4.09	0.117
	Female	34.36 ± 6.13	
Side of Injury	Right	31.06 ± 3.97	0.027*
	Left	34.67 ± 5.83	
Mechanism of Injury	RTA	33.94 ± 4.20	0.105
	Fall	35.08 ± 7.42	
	Other	31.00 ± 3.96	

DISCUSSION

Tibial plateau fractures with posterior articular involvement represent a distinct diagnostic and therapeutic challenge due to their complex

fracture morphology, limited visualisation on conventional radiographs, and the biomechanical importance of the posterior column in maintaining knee stability. Failure to

adequately identify and stabilise posterior fragments has been consistently associated with loss of reduction, residual instability, restricted knee motion, and early post-traumatic osteoarthritis [1-3].

The demographic profile of the cohort aligns with previously reported patterns of tibial plateau fractures, which predominantly affect the economically active population following high-energy trauma [1,2]. The mean age of 39.2 years in this study is comparable to cohorts reported by Luo et al. and Sinha et al., where mean ages ranged between 35 and 42 years [11,14]. Although female patients constituted a slight majority in the present series, gender did not demonstrate a statistically significant association with functional outcome, as reflected by comparable Oxford Knee Scores between males and females ($p = 0.117$), consistent with existing literature suggesting that fracture pattern and quality of reduction exert a greater influence on recovery than patient sex alone [6,12].

Radiological restoration of alignment is a critical determinant of long-term knee function. In this study, the mean postoperative medial proximal tibial angle (MPTA) of 86.8° and posterior proximal tibial angle (PTPA) of 10.5° fall within the acceptable ranges described in biomechanical and clinical studies [11,12]. Fakoor et al. reported a mean postoperative PTPA of 9.8° following posterior column fixation, closely mirroring the findings of the present study and reinforcing the ability of column-specific fixation to restore sagittal alignment [12]. Similarly, Sinha et al. demonstrated satisfactory coronal and sagittal alignment in over 70% of patients treated with additional posterior plating, supporting the rationale for addressing the posterior column directly [14].

Satisfactory fracture reduction was achieved in 40% of patients in the current cohort, which is comparatively lower than the 60-75% rates reported in high-volume centres [11,14,16]. This discrepancy may reflect differences in fracture severity, surgical learning curves, and resource availability in low- and middle-income settings. Nevertheless, fracture union was achieved in 53.3% of cases, a rate comparable to that

reported by Arya et al. and Khattak et al., who observed union rates ranging from 55% to 70% in complex plateau fractures managed with posterior approaches [13,15]. The relatively modest union rate in this study underscores the inherent biological and mechanical challenges associated with posterior column injuries rather than a limitation of the fixation concept itself.

Functional outcomes in the present study were encouraging, with a mean knee range of motion of 116.7° , which compares favourably with the $110-120^\circ$ range reported in similar cohorts undergoing posterior column fixation [14,17]. The mean Oxford Knee Score (OKS) of 33.2 observed in this study is consistent with the moderate functional recovery reported by Van den Berg et al. and Arya et al. (mean OKS 34.5), who demonstrated comparable patient-reported outcomes following anatomically guided fixation strategies [4,13]. While these scores indicate residual functional limitation, they are considered acceptable in the context of high-energy intra-articular injuries.

The finding of significantly better functional outcomes in left-sided injuries is noteworthy, with patients sustaining left-sided fractures demonstrating significantly higher Oxford Knee Scores compared to right-sided injuries ($p=0.027$); however, this observation should be interpreted cautiously. Similar observations have been inconsistently reported in the literature and may reflect hand dominance, rehabilitation compliance, or occupational demands rather than a true biological difference [6,18]. Importantly, age group (≤ 40 vs. >40 years; $p=0.071$) and mechanism of injury ($p=0.105$) did not show statistically significant associations with Oxford Knee Score, reinforcing the concept that anatomical reduction and stable fixation remain the primary determinants of functional recovery.

From a pathophysiological perspective, the posterior column plays a critical role in resisting posterior tibial translation and maintaining knee kinematics under flexion loads. Inadequate stabilisation of posterior fragments can result in subtle instability that compromises rehabilitation and accelerates cartilage

degeneration [3,6]. The three-column fixation concept directly addresses this issue by allowing targeted stabilisation of all involved columns, thereby improving construct stability and facilitating early mobilisation.

The strengths of this study include its prospective design, use of validated functional scoring, and objective radiological parameters to assess alignment and reduction. Furthermore, the focus on posterior articular involvement addresses a clinically relevant gap in regional orthopaedic literature. However, several limitations must be acknowledged. The relatively small sample size and single-centre design limit generalisability, while the absence of a comparative control group precludes definitive conclusions regarding superiority over alternative fixation strategies. Additionally, variability in fracture complexity and surgeon experience may have influenced outcomes.

Despite these limitations, the findings support the clinical applicability of three-column fixation in managing complex tibial plateau fractures with posterior involvement, particularly in resource-constrained settings. Larger multicentre studies with longer follow-up are warranted to further define long-term functional outcomes and complication profiles.

CONCLUSION

Three-column fixation demonstrated satisfactory radiological and clinical outcomes in patients with complex tibial plateau fractures involving the posterior column. The technique allowed restoration of alignment, fracture stability, and knee function in a substantial proportion of cases. Clinical outcome showed a significant association with the side of injury, while patient age, gender, and injury mechanism were not significantly related to postoperative functional recovery.

REFERENCES

Hua K, Jiang X, Zha Y, Chen C, Zhang B, Mao Y. Retrospective analysis of 514 cases of tibial plateau fractures based on morphology and injury mechanism. *J Orthop Surg Res.* 2019;14(1):267.

O'Neill D, Thorne TJ, Scolaro J, Haller JM. Evaluation and management of posterior tibial plateau fractures. *J Am Acad Orthop Surg.* 2024;32(19):e970-e981.

Van den Berg J, Struelens B, Nijs S, Hoekstra H. Value of three-dimensional computed tomography reconstruction in the treatment of posterior tibial plateau fractures. *Knee.* 2020;27(1):3-8.

Van den Berg JD, Quintens L, Zhan Y, Hoekstra H. Why address posterior tibial plateau fractures? *Injury.* 2020;51(12):2779-2785.

Anwar A, Zhang Y, Zhao Z, Gao Y, Sha L, Lv D, et al. Two column classification of tibial plateau fractures: description, clinical application and reliability. *Injury.* 2019;50(6):1247-1255.

Bormann M, Neidlein C, Neidlein N, Ehrl D, Jörgens M, Berthold DP, et al. High prevalence of persistent measurable postoperative knee joint laxity in patients with tibial plateau fractures treated by open reduction and internal fixation (ORIF). *J Clin Med.* 2023;12(17):5580.

Papagelopoulos PJ, Partsinevelos AA, Themistocleous GS, Mavrogenis AF, Korres DS, Soucacos PN. Complications after tibial plateau fracture surgery. *Injury.* 2006;37(6):475-484.

Schatzker J, McBroom R, Bruce D. The tibial plateau fracture: the Toronto experience 1968- 1975. *Clin Orthop Relat Res.* 1979;(138):94-104.

Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium-2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007;21(10 Suppl):S1-S6.

Zhu F, Jiao J, Huang Y, Xiao F, Zuo W, Chen M, et al. A preliminary study of the surgical approach for posterior tibial plateau fractures: based on posterior fragment segment classification. *Injury.* 2022;53(11):3820-3827.

Luo CF, Sun H, Zhang B, Zeng BF. Three-column fixation for complex tibial plateau fractures. *J Orthop Trauma.* 2010;24(11):683-692.

- Fakoor M, Hanafi MG, Mohammadhoseini P, Variani M, Moradi M. Determination of posterior tibial slope changes after tibial plateau fracture fixation: a retrospective case series. *Indian J Orthop.* 2023;57(9):1485-1489.
- Arya MK, Bhartiya RK, Singh SK, Sharma P, Arya M, et al. Supplementary posteromedial plating for the fixation of complex tibial plateau fractures: a prospective study. *Cureus.* 2023;15(1).
- Sinha S, Singh M, Saraf SK, Rastogi A, Rai AK, Singh TB. Fixation of posterior tibial plateau fracture with additional posterior plating improves early rehabilitation and patient satisfaction. *Indian J Orthop.* 2019;53(3):472-478.
- Khattak MJ, Ali R, Mohib Y. Outcome of management of tibial plateau fracture by posterior Lobenhoffer approach: case series. *J Pak Med Assoc.* 2023;73(5):1087.
- Chang SM, Hu SJ, Zhang YQ, Yao MW, Ma Z, Wang X, et al. A surgical protocol for bicondylar four-quadrant tibial plateau fractures. *Int Orthop.* 2014;38(12):2559-2564.
- Wang Y, Luo C, Zhu Y, Zhai Q, Zhan Y, Qiu W. Updated three-column concept in surgical treatment for tibial plateau fractures. *Orthop Surg.* 2019;11(2):151-158.
- Ali AM, Yang L, Hashmi M, Saleh M. Bicondylar tibial plateau fractures managed with the Sheffield hybrid fixator: biomechanical study and operative technique. *Injury.* 2001;32(Suppl 4):86-91.

