Bone and Arthrosurgery Science, 2025, Volume 3, Issue 6
http://ojs.bbwpublisher.com/index.php/BAS
Online ISSN: 2981-8222
Print ISSN: 3083-4856

Application of Joint Line Incision + Precise Pre-Bent Plate via Three-Dimensional Reconstruction of the Proximal Tibia *In Vitro* + Transparent Retractor in Tibial Plateau Fractures

Aixiang Pan, Zhenggui Qian, Weihua Liu

Dongtai Mei's Orthopedics and Traumatology Hospital, Yancheng 224200, Jiangsu, China

Abstract: *Objective:* To analyze the combined application effects of the joint line incision approach, precise pre-bent plates via three-dimensional reconstruction of the proximal tibia *in vitro*, and transparent retractors in the clinical treatment of Schatzker types III to VI tibial plateau fractures, and their impact on the functional recovery of the knee joint. *Methods:* A retrospective analysis was conducted on the surgical treatment outcomes of 28 patients with tibial plateau fractures admitted from January 2023 to January 2025. All patients underwent internal fixation surgery via the joint line incision approach after admission, with the combined use of precise pre-bent plates via three-dimensional reconstruction of the proximal tibia *in vitro* and transparent retractors for auxiliary treatment during surgery. Surgical treatment indicators, treatment outcomes, and the occurrence of complications were analyzed. Knee joint range of motion and knee joint function scores [New York Special Surgery Hospital Score (HSS), International Knee Documentation Committee Score (IKDC)] were compared before and after surgery. *Results:* At six months post-surgery, the overall excellent and good reduction rate of tibial plateau fractures in 28 patients was 89.29%. The overall incidence of surgical complications within six months post-surgery was 14.29%, with no cases of severe complications observed. The average surgical duration was 145.32 ± 15.07 minutes, the average intraoperative blood loss was 53.52 ± 6.71 ml, and the average time to fracture healing post-surgery was 14.65 ± 2.21 weeks. Compared to pre-surgery, the range of motion of the knee joint, as well as the HSS and IKDC scores of the knee joint, significantly increased at three and six months post-surgery, with statistically significant differences ($P < 0.05$). *Conclusion:* The application of three-dimensional reconstruction-based precise pre-bent plates for the proximal tibia and fluoroscopically visible retractors in internal fixation surgery via a joint line incision approach for patients with Schatzker type III–VI tibial plateau fractures can actively enhance surgical efficiency and the effectiveness of internal fixation. Additionally, it can assist in optimizing postoperative fracture reduction and the rehabilitation of knee joint function in patients.

Keywords: Tibial plateau fracture; Internal fixation surgery; Joint line approach; Three-dimensional reconstruction; Pre-bent plate; Fluoroscopically visible retractor

Online publication: December 31, 2025

1. Introduction

Tibial plateau fractures are a severe type of lower limb fracture, typically caused by high-energy stress injuries to the affected knee joint. These fractures can lead to swelling, pain, and mobility impairment of the knee joint. If not treated properly, they can further affect the weight-bearing and functional health of the knee joint, necessitating active treatment [1]. As the primary surgical treatment for tibial plateau fractures at the current stage, internal fixation can assist in promoting fracture reduction after the internal fixation plate is inserted through the incision, thereby maintaining the bone structure and functional health of the knee joint. However, upon analyzing traditional internal fixation plates and surgical outcomes, it has been found that factors such as inadequate pre-preparation of the plate, insufficient surgical precision, and poor fluoroscopic visibility of the retractor may fail to meet the precise surgical needs of some patients and affect the quality of postoperative functional rehabilitation of the knee joint. Therefore, surgical procedures should be improved in response to these factors [2,3]. Hence, to analyze the combined effects of the joint line incision approach, precise pre-bending of three-dimensional reconstructed plates for the proximal tibia *in vitro*, and fluoroscopically visible retractors in the clinical treatment of Schatzker type III–VI tibial plateau fractures, as well as their impact on the functional recovery of the knee joint, a therapeutic study was conducted. The details are as follows.

2. Data and methods

2.1. Clinical data

A retrospective analysis was conducted on the surgical treatment outcomes of 28 patients with tibial plateau fractures admitted from January 2023 to January 2025. Among the 28 patients, there were 17 males and 11 females, aged between 27 and 68 years (47.55 ± 4.98 years). The affected side was the left knee in 7 cases and the right knee in 21 cases. The causes of injury were traffic accidents in 21 cases, sports injuries in 4 cases, and falls from heights in 3 cases. According to the Schatzker classification, there were 5 cases of type III, 12 cases of type IV, 8 cases of type V, and 3 cases of type VI.

Inclusion criteria: (1) Closed tibial plateau fractures with a disease course of ≤ 7 days; (2) Preoperative imaging findings consistent with the diagnostic criteria for Schatzker type III to VI fractures; (3) Meeting the indications for internal fixation surgery; (4) Having intact cognitive and language communication functions and confirming acceptance of surgical treatment. Exclusion criteria: (1) Open tibial plateau fractures or fractures caused by pathological factors; (2) Preoperative imaging findings indicating fractures in other areas around the knee joint or severe meniscal injury; (3) Having a history of previous knee surgery or degenerative knee disease; (4) Having motor dysfunction in the affected lower limb; (5) Having a history of stroke or mental disorders; (6) Confirming intolerance to surgery or having surgical contraindications.

2.2. Methods

(1) Preparation of precisely pre-bent plates for three-dimensional reconstruction of the proximal tibia *in vitro*: Prior to surgery, based on CT scan images of the affected knee joint, a 1:1 three-dimensional solid model of the fracture was prepared after three-dimensional image reconstruction using image processing software (MIMICS17.0). The attending physician performed simulated fracture reduction based on the model, selected the appropriate type and number of internal fixation plates as needed, pre-bent the plates according to surgical requirements, and recorded the steps of the simulated surgical procedure in detail to refine surgical preparation.

(2) Surgical procedure: After anesthesia induction, a lateral (or medial) arthrotomy incision (transverse) along the joint line was made. Through this incision, tissues were dissected to expose the joint capsule, which was then incised transversely beneath the meniscus. The meniscus was sutured and suspended above the incision. Two Kirschner wires were inserted into the distal femur and the area distal to the tibial fracture, respectively, and connected to a fluoroscopically visible retractor for distraction. According to the preoperative plan, a separate 1.5 cm skin incision was made approximately 5 cm distal to the tibial plateau. A window was created in the tibia, and through the use of a percutaneous reduction device, the collapsed plateau fracture was precisely reduced. Multiple fine Kirschner wires were temporarily inserted through the subchondral bone on the lateral aspect of the plateau for fixation. After confirming accurate reduction of the plateau through anteroposterior and lateral fluoroscopy, a pre-bent plate was inserted through the incision for internal fixation.

Postoperatively, all patients received standardized analgesia, anti-infection treatment, and functional rehabilitation therapy, with continuous follow-up for 6 months.

2.3. Observation indicators

(1) Surgical treatment indicators: Based on surgical records, the mean surgical duration and intraoperative blood loss were calculated. Based on postoperative follow-up information, the mean time to fracture healing was calculated.

(2) Treatment outcomes: At the 6th month postoperatively, the reduction effect of tibial plateau fractures was evaluated. Based on CT images of the affected knee joint obtained on the follow-up day, the Rasmussen imaging score was used to assess joint surface collapse, knee varus/valgus deformity, and condylar width changes, with a total score ranging from 0 to 18. Based on the assessment results, the reduction effect was classified as excellent (18 points), good (12–17 points), fair (6–11 points), or poor (≤ 5 points) [4].

(3) Incidence of complications: The overall incidence of surgery-related complications within six months postoperatively was recorded, including five categories: incision infection, delayed fracture healing, joint stiffness, traumatic arthritis, and internal fixation failure.

(4) Range of motion (ROM) of the knee joint: The maximum extension and flexion ROM of the patients' knee joints were evaluated before surgery and during follow-up visits at the third and sixth months postoperatively, and the mean values for each group were calculated.

(5) Knee joint function scores: The Hospital for Special Surgery (HSS) score and the International Knee Documentation Committee (IKDC) score were employed to assess the patients' knee joint function before surgery and during follow-up visits at the third and sixth months postoperatively. Both the HSS and IKDC scores range from 0 to 100, with higher scores indicating better knee joint function [5,6].

2.4. Statistical methods

Statistical analysis was performed using SPSS 23.0 software. Categorical data were expressed as *n* (%), and the composition ratio data were analyzed using the chi-square test. Continuous data conforming to a normal distribution were presented as mean ± standard deviation (SD), and paired *t*-tests were used for within-group comparisons. A *P*-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Analysis of surgical treatment indicators, therapeutic effects, and complication incidence rates

The average surgical duration for patients was 65.32 ± 15.07 minutes, with a mean intraoperative blood loss of 53.52 ± 6.71 ml. The average time for fracture healing after surgery was 14.65 ± 2.21 weeks.

The Rasmussen imaging score assessment results at 6 months postoperatively indicated that among the patients, 11 cases had excellent reduction of tibial plateau fractures, 14 cases had good reduction, 3 cases had fair reduction, and 0 cases had poor reduction, with an overall excellent and good rate of 89.29%.

Within 6 months postoperatively, the overall incidence of surgical complications was 14.29%, including 2 cases of incision infection, 1 case of delayed fracture healing, and 1 case of joint stiffness. All these conditions improved or resolved after symptomatic clinical intervention, and no cases of traumatic arthritis or internal fixation failure were observed.

3.2. Comparison of knee joint mobility before and after surgery

The range of knee extension and flexion increased postoperatively compared to preoperative levels, and the knee joint mobility at 3 and 6 months postoperatively was higher than that before surgery, with statistically significant differences ($P < 0.05$). See **Table 1**.

Table 1. Comparison of knee joint mobility before and after surgery (mean ± SD)

Time point/n	Extension ROM (°)	Flexion ROM (°)
Preoperative/28	-17.58 ± 2.16	35.15 ± 5.21
3 months postoperative/28	-11.21 ± 1.45*	94.56 ± 7.39*
3 months postoperative/28	-2.18 ± 0.47*#	126.58 ± 14.32*#
F	27.056	25.677
P	< 0.001	< 0.001

Note: *$P < 0.05$ indicates a statistically significant difference compared to preoperative values; #$P < 0.05$ indicates a statistically significant difference compared to values at 3 months postoperatively.

3.3. Comparison of HSS and IKDC scores before and after surgery

After surgery, the patients' knee extension and flexion range of motion showed a significant increase compared to pre-surgery levels. Moreover, the HSS and IKDC scores at 3 and 6 months post-surgery were higher than those before surgery, with statistically significant differences ($P < 0.05$). See **Table 2**.

Table 2. Comparison of HSS and IKDC scores before and after surgery (mean ± SD)

Time point/28	HSS score	IKDC score
Preoperative/28	51.74 ± 7.36	53.08 ± 6.85
3 months postoperative/28	68.93 ± 5.68*	71.04 ± 5.54*
6 months postoperative/28	85.14 ± 4.37*#	87.25 ± 4.12*#
F	14.134	15.277
P	< 0.001	< 0.001

Note: *$P < 0.05$ indicates a statistically significant difference compared to pre-surgery levels; #$P < 0.05$ indicates a statistically significant difference compared to the scores at 3 months post-surgery.

4. Discussion

Surgical treatment, as the preferred treatment option for patients with complex tibial plateau fractures, can repair knee joint collapse and maintain the morphology and functional health of the knee joint's bone tissue after surgical reduction and internal fixation, yielding definite therapeutic effects. However, an analysis of the efficacy of previous traditional internal fixation surgeries revealed that the traditional anterolateral surgical approach (combined with medial or posterior incisions when necessary) involves relatively extensive soft tissue dissection. It requires the use of retractors to maintain the incision field and operative range, which can increase the risk of related surgical complications and affect the quality of intraoperative fluoroscopic image acquisition. Additionally, the lack of adaptability in adjusting the shape of the steel plate during surgery can impact the actual internal fixation effect and postoperative rehabilitation, as well as prolong the time required for pre-bending and shaping the steel plate during surgery. Therefore, adjustments and improvements are needed based on the current advancements in surgical techniques to optimize the actual surgical outcomes for patients with complex tibial plateau fractures [7].

As an auxiliary technology widely applied in the treatment of complex fractures in recent years, three-dimensional (3D) reconstruction technology can provide a basis for surgical plan evaluation and simulation operations after collecting CT scan images of the patient's preoperative fracture site, followed by 3D image reconstruction and model printing. This technology optimizes the individual adaptability of surgical treatment operations for patients and has demonstrated definite clinical application effects [8]. Using fracture models, steel plates are precisely shaped *in vitro* to achieve an exact fit between the plates and the bones. After intraoperative fracture reduction, the steel plate is inserted through a soft tissue tunnel created via an incision along the joint line, simplifying the surgical procedure and significantly reducing the operation time. The radiolucent retractor, a surgical instrument made of carbon fiber material, offers advantages such as being lightweight, having high load-bearing capacity, and being radiolucent. It actively enhances the clarity of intraoperative fluoroscopic images and avoids the impact of artifacts on the operation. Therefore, the aforementioned techniques have definite application advantages in the treatment of complex tibial plateau fractures.

This study indicated that among the 28 patients, the overall excellent and good rate of tibial plateau fracture reduction at 6 months postoperatively was 89.29%, and the overall incidence of surgical complications within 6 months postoperatively was 14.29%, with no cases of severe complications observed. Compared to preoperative values, the range of motion of the knee joint and the HSS and IKDC scores of the knee joint at 3 and 6 months postoperatively were significantly increased, with statistically significant differences ($P < 0.05$). The analysis suggests that the combined application of precisely pre-bent steel plates through three-dimensional reconstruction *in vitro* and radiolucent retractors can, after improving preoperative preparations for patients, provide a convenient foundation for effective treatment through individually designed surgical plans and plate shaping. During actual surgical procedures, the use of radiolucent retractors can effectively avoid radiographic artifacts, offering clear images for evaluating fracture reduction and fixation outcomes, thereby reducing the number of intraoperative fluoroscopic examinations. This, in turn, actively optimizes surgical efficiency for patients, minimizes the exposure time of surgical incisions, and, through refined internal fixation techniques, comprehensively reduces the risk of surgical complications, providing a positive basis for patients' postoperative recovery [9,10].

5. Conclusion

In summary, the application of 3D reconstruction for precise *in vitro* pre-bending of steel plates and radiolucent retractors in the internal fixation surgery of Schatzker type III to VI tibial plateau fractures via an arthrotomy

approach can actively enhance surgical efficiency and the effectiveness of internal fixation. Furthermore, it aids in optimizing postoperative fracture reduction and the rehabilitation of knee joint function in patients.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Ren W, Ji L, Zhang N, et al., 2025, Observation on the Efficacy of Internal Fixation with Steel Plate and Screws through a Single Conventional Anterolateral Approach for Lateral Tibial Plateau Fractures Involving the Posterior Column. Chinese Journal of Bone and Joint Injury, 40(2): 194–196.

[2] Wang G, Gao H, Bai X, et al., 2022, Observation on the Efficacy of Internal Fixation with a Single Locking Plate for Lateral Tibial Plateau Fractures Combined with Ipsilateral Tibial Shaft Fractures. Chinese Journal of Bone and Joint Injury, 37(12): 1311–1313.

[3] Hong G, Lv T, Zhang Y, et al., 2025, Efficacy of Internal Fixation with Dual Approaches and Dual Plates under Variable Positions for "Schatzker Type IV over the Midline" Tibial Plateau Fractures. Chinese Journal of Trauma, 41(6): 580–586.

[4] Zhang D, Li J, 2025, Research on the Application Value of 3D Printing Technology in Emergency Lateral Approach Surgery for Traumatic Tibial Plateau Fractures. China Medical Engineering, 33(10): 43–47.

[5] Zeng Z, Xu S, Zhang W, 2022, Open Reduction and Internal Fixation with Locking Plates through an Approach above the Fibular Head Combined with a Posteromedial Approach for Schatzker type IV Tibial Plateau Fractures Complicated by Knee Dislocation. Journal of Traditional Chinese Orthopedics and Traumatology, 34(11): 74–77.

[6] Hong G, Lv T, Zhang Y, et al., 2025, Efficacy of Double-approach and Dual-platform Internal Fixation for the Treatment of "Schatzker Type IV Crossing the Midline" Tibial Plateau Fractures under Variable Positions. Chinese Journal of Traumatology, (6): 580–586.

[7] Du F, Wang L, Jiang Y, 2025, Short-term Efficacy and Safety of Modified Anterolateral Combined with Medial Approach versus Traditional Anterolateral Combined with Posteromedial Approach for the Surgical Treatment of Schatzker Type V and VI tibial Plateau Fractures. Henan Journal of Surgery, 31(3): 131–133.

[8] Qiu X, Cai H, Zheng L, et al., 2025, Short-term and Long-term Value of Combined Anterior and Posterior Approach Reduction and Internal Fixation for the Treatment of Wahlquist Type C Medial Tibial Plateau Fractures. Medicine Theory and Practice, 38(15): 2587–2590.

[9] Wen W, 2025, Observation on the Effect of CT Three-dimensional Reconstruction Technology-guided Percutaneous Minimally Invasive Plate Internal Fixation for the Treatment of Tibial Plateau Fractures. China Medicine and Pharmacy, 15(16): 117–120, 126.

[10] Wang B, Chen C, 2023, Efficacy Analysis of CT Three-dimensional Reconstruction Technology-guided Percutaneous Minimally Invasive Plate Internal Fixation for the Treatment of Tibial Plateau Fractures. Journal of Primary Medicine, 27(31): 56–58.