CLINICAL ARTICLE

Clinical Comparison of the "Windowing" Technique and the "Open Book" Technique in Schatzker Type II Tibial Plateau Fracture

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Objective: Surgical treatment for Schatzker type II tibial plateau fractures remains challenging and requires high-quality research. The aim of the study is to compare the "windowing" and "open book" techniques for the treatment of Schatzker type II tibial plateau fractures.

Methods: In this prospective study, all patients with Schatzker type II tibial plateau fractures between January 2014 and December 2017 were managed by open reduction and internal fixation using an anterolateral incision approach. "Windowing" group included 78 patients (53 men and 25 women), with an average age of 57.7 ± 13.5 years, who underwent the "windowing" technique, in which the procedure was performed through a small cortical window against the depressed zone of the lateral plateau. The "open book" group included 80 patients (56 men and 24 women), with an average age of 54.8 ± 12.4 years, who underwent the technique. The clinical outcomes included the Rasmussen classification of knee function and grading of post-traumatic arthritis. The radiographic outcome (x-ray and computed tomography [CT]) was the reduction quality of the lateral plateau based on the modified Rasmussen radiological assessment. The patient-reported outcome was visual analogue scale (VAS) scores.

Results: The mean follow-up time for the158 patients was 32 months (range, 24–42 months). The time elapsed from injury to surgery in "windowing" group and "open book" group were 3.7 ± 1.2 (range, 1–10 days) and 3.5 ± 1.4 days (range, 1–11 days), respectively, with no significant difference between the groups ($P > 0.05$). The operation times did not differ significantly between the "windowing" group (61.0 ± 8.3 min, range, 45–120 min) and the "open book" group (61.2 ± 10.4 min, range, 40–123 min) ($P > 0.05$). After surgery, CT revealed five (6.4%) and 15 (18.8%) cases of articular depression in the "windowing" and "open book" groups, respectively. Significant differences were observed in the articular depression of tibial plateau fractures between the groups ($P < 0.05$). However, condylar widening or valgus/varus did not differ significantly between the groups. Furthermore, no significant differences in knee function were observed during follow-up ($P > 0.05$). VAS scores were similar between the groups at 24 months after surgery ($P > 0.05$). There were significant differences in the number of severe post-traumatic arthritis (grades 2 and 3) cases between the groups ($P < 0.05$).

Conclusions: The "windowing" and "open book" techniques are both effective for the treatment of Schatzker type II tibial plateau fractures. However, the "windowing" technique provides better reduction quality, leading to a satisfactory prognosis.

Key words: Knee function; "Open book" technique; Schatzker classification; Tibial plateau fracture; "Windowing" technique

Introduction

Tibial plateau fracture is relatively common, accounting for approximately 1% of all fractures[1]. The main mechanism of tibial plateau fracture is a varus or valgus load with or without an axial load, leading to intra-articular injuries. Fractures require careful evaluation and preoperative

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planning to prevent the development of post-traumatic arthritis[2]. The treatment of tibial plateau fractures is challenging. Open reduction and internal fixation are the most effective and direct methods to reconstruct the tibial plateau. In these fractures, successful functional outcomes mainly depend on the restoration of the axial and rotational alignment of the limb, knee stability, and anatomical reduction of articular congruity.

The magnitude of the energy determines the degrees of fragmentation and displacement, which leads to diverse fracture types. The Schatzker classification is widely used to assess the morphology and severity of tibial plateau fracture[3]. The lateral tibial condyle is convex in shape and is thinner, weaker, and more proximal than the medial tibial condyle. Thus, lateral tibial plateau fractures are more prevalent than medial tibial plateau fractures. Schatzker type II (lateral tibial plateau split-depressed fracture) is more likely to result from low-energy injuries, especially in osteoporosis population.

Schatzker type II is the most common fracture type encountered clinically, accounting for 25%–33% of all fractures[4,5]. In terms of fracture patterns, only split fracture and articular depression are encountered, and both require sophisticated management. The importance of restoring articular congruency to prevent post-traumatic arthritis in these fractures has been well described in previous studies[6,7]. Both minimally invasive and conventional approaches are used to treat type II fractures[8–10]. Donald *et al.* described a minimally invasive technique using a modified 3-mL syringe and bone tamps for Schatzker type II or III tibial plateau fractures. However, this technique is more appropriate for specific fracture types and increases radiation exposure. Several studies have demonstrated the effectiveness of arthroscopic-assisted management of tibial plateau fractures, leading to satisfactory clinical and radiological outcomes[11–14]. However, increased popularity of arthroscopic instruments and advancement in the operative technique among orthopedic trauma surgeons are expected in the future. Generally, the anterolateral approach and lateral buttress plating for subchondral raft support are the classical methods and are widely recommended[1]. Concerns that split-depressed fractures require proper alignment and a smooth articular surface have led to the development of surgical sequences for fractures of split and depression. In clinical practice, surgeons expose the articular surface using the "open book" technique, in which the articular depression is first corrected and the split fracture is addressed subsequently. Cheryl *et al.* described the technique in pure depression fractures of the posterolateral tibial plateau[15]. Osteotomy of the lateral condyle between Gerdy's tubercle and the tibia tuberosity was performed, leaving an intact posterior hinge. The technique allowed adequate visualization and fracture reduction. In Schatzker type II tibial plateau fracture, osteotomy can be omitted for existing split fracture. "Open book" technique may be applicable in this fracture type. In contrast, in the "windowing" technique, surgeons reduce the split fragment first and use a Kirschner wire for temporary fixation, converting a Schatzker type II fracture to a Schatzker type III fracture. Articular depression is then reduced through a small cortical window against the depressed zone of the lateral plateau. Several studies[16–18] have described the technique and verified the surgical outcome in Schatzker type III fractures. However, the "windowing" technique in Schatzker type II fractures has not been reported. Furthermore, to the best of our knowledge, no study has compared the clinical prognoses between the "windowing" and "open book" techniques for type II tibial plateau fractures.

Therefore, this prospective study investigated the efficacy and feasibility of the "windowing" and "open book" techniques for Schatzker type II tibial plateau fractures using clinical findings to provide guidance regarding the following three points in clinical practice: (i) reduction quality of the lateral plateau of the two surgical techniques; (ii) advantages and disadvantages of the two techniques; and (iii) intermediate prognosis of the fracture after the use of the two techniques.

Patients and Methods

Inclusion and Exclusion Criteria

In this prospective study, we enrolled 211 patients with closed lateral tibial plateau fractures (AO-OTA 41B3.1; Schatzker type II) requiring surgery with the "windowing" technique or the "open book" technique by an orthopedic trauma surgeon from January 2014 to December 2017. Among them, eight cases of tibial plateau fractures presenting old fractures, previous surgery for tibial plateau fractures and existence of tibial shaft fracture that may affect surgical protocol were excluded. Furthermore, 45 cases of tibial plateau fractures, who were lost to follow-up within 24 months, were also excluded.

Patient information

This study was approved by the medical ethics committee of Ningbo No. 6 Hospital (L2021095), and all patients provided informed consent before participating in this study. Before surgery, each patient underwent routine examinations using standard radiography and computed tomography (CT) with reconstruction. Fracture lines and zones of depression are superimposed to create a visual map of fracture morphology before surgery (Fig. 1). In total, 158 patients (96 men and 62 women) completed the study and were included in the final outcome analysis. Patients were prospectively randomized into groups by a computer, and the allocation details were enclosed in sequentially numbered opaque envelopes. The envelopes were opened inside the operating theater by a nurse who was blinded to the allocation. Odd numbers were assigned to the "windowing" group, and even numbers were assigned to the "open book" group. All surgeries were performed by one attending trauma surgeon and two trauma fellows as surgical assistants, all of whom had significant experience in traumatic surgeries at a single institution. The "windowing" group included 78 patients who underwent the "windowing" technique, in which surgical procedures were performed through a small entry portal against the depressed

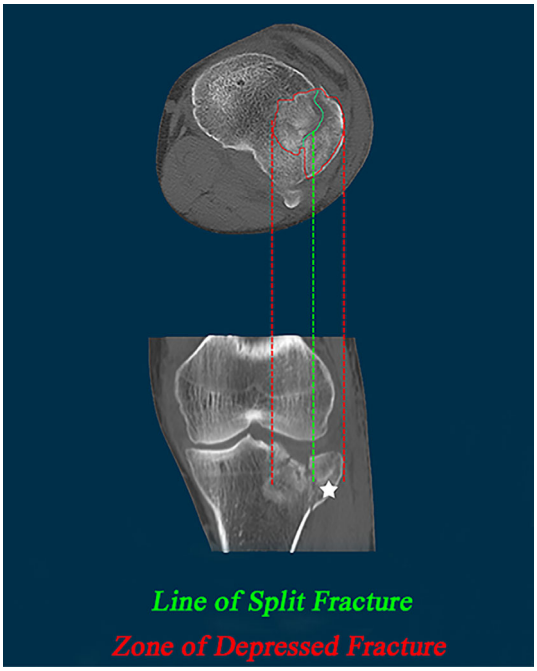

Fig. 1 Characteristics of split-depressed tibial plateau fractures on computed tomography (CT). The upper and lower parts show the transverse and coronal sections of the tibial plateau fracture, respectively. The fracture zone is shown in red, and the line of depression is shown in green (asterisk: zone of articular depression involved in the split fragment)

zone of the lateral plateau after achieving split fragment reduction and temporary fixation. The "open book" group included 80 patients who underwent surgery using the "open book" technique. The sample size met the requirements indicated by power analysis. Surgical implants were provided by a single-device manufacturer (Wego Group Co., Ltd., Shandong, China). Postoperative assessments were performed by two surgical fellows. Patient demographics and injuries are provided in detail and compared in Table 1.

Surgical Techniques

"Windowing" Technique

Anesthesia and Position. After subarachnoid block anesthesia, patients were placed in the supine position with a cushion beneath the ipsilateral hip to prevent external rotation of the operative limb. The operative limb was inflated and appropriately straightened. The maximum tourniquet duration of was 90 min, and the tourniquet was released before final closure.

Approach and Exposure. A slightly curvilinear anterolateral incision was made 3–5 cm above the joint line proximally and extending distally below the inferior margin of the fracture site, slightly anterior to the lateral femoral epicondyle and Gerdy's tubercle. Then, a fascial incision was made in line with the skin incision to undermine a full-thickness flap to the tibia. Intra-articular exposure was achieved by incising the coronary or inframeniscotibial ligament and dragging the meniscus superiorly with tagging sutures. After achieving an excellent surgical view, the meniscal injuries were examined and repaired.

Reduction and Fixation. The split fragment was reduced to the tibial plateau and temporarily fixed with multiple small Kirschner wires, ensuring that the wires would not interfere with the subsequent elevation of the depressed articulation. A cortical window was then created 5 cm below the lateral articular surface. With the help of intra-articular exposure, a periosteal elevator was inserted through the cortical window well beneath the depressed articular fragments. Through slow and meticulous elevation, the articular fragments were temporarily reduced and fixed with Kirschner wires. Bone grafts (calcium phosphate; Ruibang Group Co., Ltd., Shanghai, China) were used for large bone defects, which made maintaining the reduction of the fracture fragments difficult. Finally, a buttress plate with subchondral raft screws was applied to the anterolateral proximal tibia (Fig. 2A,C).

"Open Book" Technique

The surgical preparation and approach for tibial plateau fractures were similar to those for the "windowing" technique. The lateral fragment was used to gain access to the central tibial condyle. This lateral fragment often hinges open like a book, exposing the depressed articular surface and the cancellous bone of the central depression. Meniscal injuries were also observed. Subsequently, depression fragments were reduced under direct vision. The cavity in the metaphysis was then filled with bone substitutes (calcium phosphate; Ruibang Group Co., Ltd., Shanghai, China). After reduction, the lateral fragment was closed and fixed using a buttress plate (Figs 2B,D). Meniscal tears were also repaired.

Clinical Assessments

Data on operative and clinical parameters were collected, including those on the time elapsed from injury to surgery, operative time, and duration of postoperative hospital stay. Prognosis was assessed using the Rasmussen anatomical scoring criteria with x-rays and CT, visual analogue scale (VAS) score, clinical function score (Rasmussen classification), and arthritic changes (Resnick–Niwoyam criteria). Post operative assessments were performed by two surgical fellows. When there were disagreements in the assessment, the attending surgeon conducted the final scoring.

Rasmussen Anatomical Scoring Criteria

The Rasmussen anatomical scoring criteria were used to assess the quality of tibial condyle fracture reduction. At the postoperative follow-up, all patients were assessed using

TABLE 1 Patient demographics[a]

Demographics	"Windowing" group ($n = 78$)	"Open book" group ($n = 80$)	t value/χ^2 value	P value
Age, Mean (SD)	57.7 ± 13.5	54.8 ± 12.4	1.407	0.161
Male, *n* (%)	53 (67.95)	56 (70)	0.078	0.78
BMI, mean (SD)	23.11 ± 2.75	23.54 ± 2.92	0.952	0.343
Right side, *n* (%)	41 (52.56%)	43 (53.75%)	0.022	0.881
Smoker, *n* (%)	20 (25.64%)	19 (23.75%)	0.076	0.783
Hypertension, *n* (%)	14 (17.95%)	16 (20%)	0.108	0.742
Diabetes mellitus, *n* (%)	10 (12.82%)	10 (12.50%)	0.004	0.952
Fracture etiology, *n* (%)				
Vehicle accident	38 (48.7%)	32 (40%)	3.086	0.379
Fall	27 (34.6%)	32 (40%)		
Sprain	9 (11.5%)	7 (8.8%)		
Other	4 (5.1%)	9 (11.2%)		

[a] Patients were assigned to the "windowing" or "open book" technique groups and the groups were compared.; Abbreviation: BMI, body mass index.

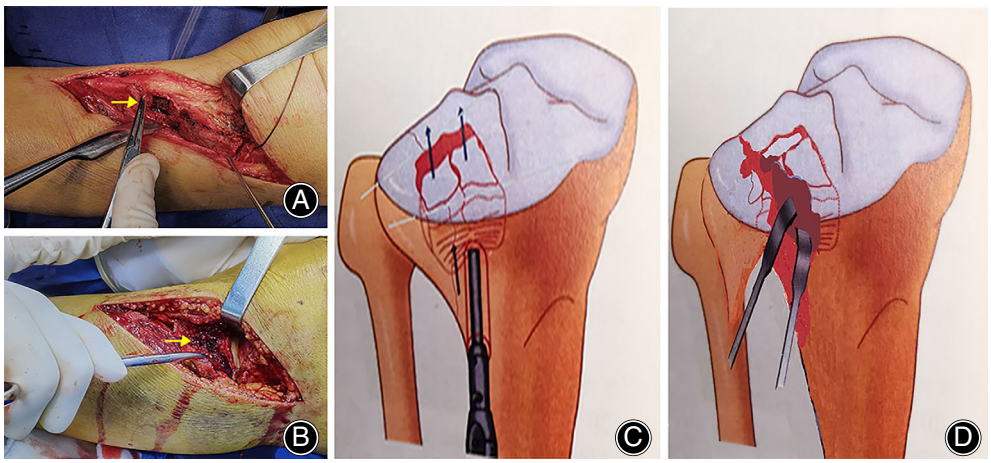

Fig. 2 Images and illustrative diagrams of the operative procedures for split-depressed fractures of the lateral tibial plateau. (A) A cortical window 5 below the area of depression ("windowing" technique; arrow: bone cortex of the window). (B) Lateral fragment hinges open like a book, exposing the depressed articular surface and cancellous bone of the central depression ("open book" technique; arrow: lateral fragment). (C) Illustrative diagrams of the "windowing" technique for type II Schatzker type II fractures. (D) Illustrative diagrams of the "open book" technique for type II Schatzker type II fractures

radiography and CT within 24 h. The images were evaluated by two surgical fellows, who assessed the degree of articular depression (good: <5 mm; poor: ≥5 mm), condylar widening (good: <5 mm; poor: ≥5 mm), and valgus or varus (good: <10°; poor: ≥10°).[19]

Knee Pain Evaluation

The degree of knee pain was evaluated in all patients using the visual analogue scale. The VAS score was evaluated at 3, 12, and 24 months after surgery. The scoring criteria were as follows: 0, no pain; 1–3, mild pain, tolerable, and not affecting sleep; 4–6, moderate pain, mildly affecting sleep, and tolerable; and 7–10, severe pain, unbearable pain, and pain resulting in an inability to sleep or wake up from sleep.

Rasmussen Classification of Knee Function

The postoperative clinical evaluation was performed using the Rasmussen classification, which assesses pain, walking capacity, and clinical findings (extension of the knee joint, range of motion, and knee joint stability)[20], at 3, 12, and 24 months after surgery. The total possible score for the Rasmussen classification of knee function initial plateau fractures was 30. A score of ≥20 was considered satisfactory (20–26: good; ≥27: excellent), while a score of <20 was considered unsatisfactory (10–19 points: fair; ≤9: poor).

Resnick–Niwoyam Criteria for Arthritic Changes

Arthritic changes were classified according to the Resnick–Niwoyam criteria[21] as follows: grade 0, no arthritic changes;

grade 1, minimal narrowing of the joint space, mild sclerosis, and no appreciable arthritic changes; grade 2, moderate narrowing of the joint space, osteophyte formation, no bony collapse, moderate subchondral sclerosis, intra-articular osseous bodies, and moderate bony aberrations; and grade 3, marked joint space narrowing to obliterated joint space, bony collapse, severe subchondral sclerosis, intra-articular osseous bodies, and marked deformity or angularity severe bony aberration. The criteria were evaluated in all patients at the last follow-up, at least 24 months after surgery.

Statistics

The sample size calculation was based on the postoperative radiological evaluation of the two surgical techniques in our preliminary experiment. Previous data from our hospital showed joint depression or condylar widening rates of 14% and 34% for the "windowing" and "open book" techniques, respectively. Based on a two-sided test, $\alpha = 0.05$, and $\beta = 0.2$, we used the following formula: $n = 2 \times \overline{R}_{12} \times \left(1 - \overline{R}_{12}\right) \times \left(\left(Z_\alpha + Z_\beta\right)^2 / \left(R_1 - R_2\right)^2\right)$. Thus, a minimum of 72 patients was deemed sufficient for each group in this study. The final outcome analysis included 158 patients with Schatzker type II tibial plateau fractures (78 patients in the "windowing" group and 80 patients in the "open book" group).

Descriptive statistics were recorded and collated, and the mean and standard deviation for patient demographics

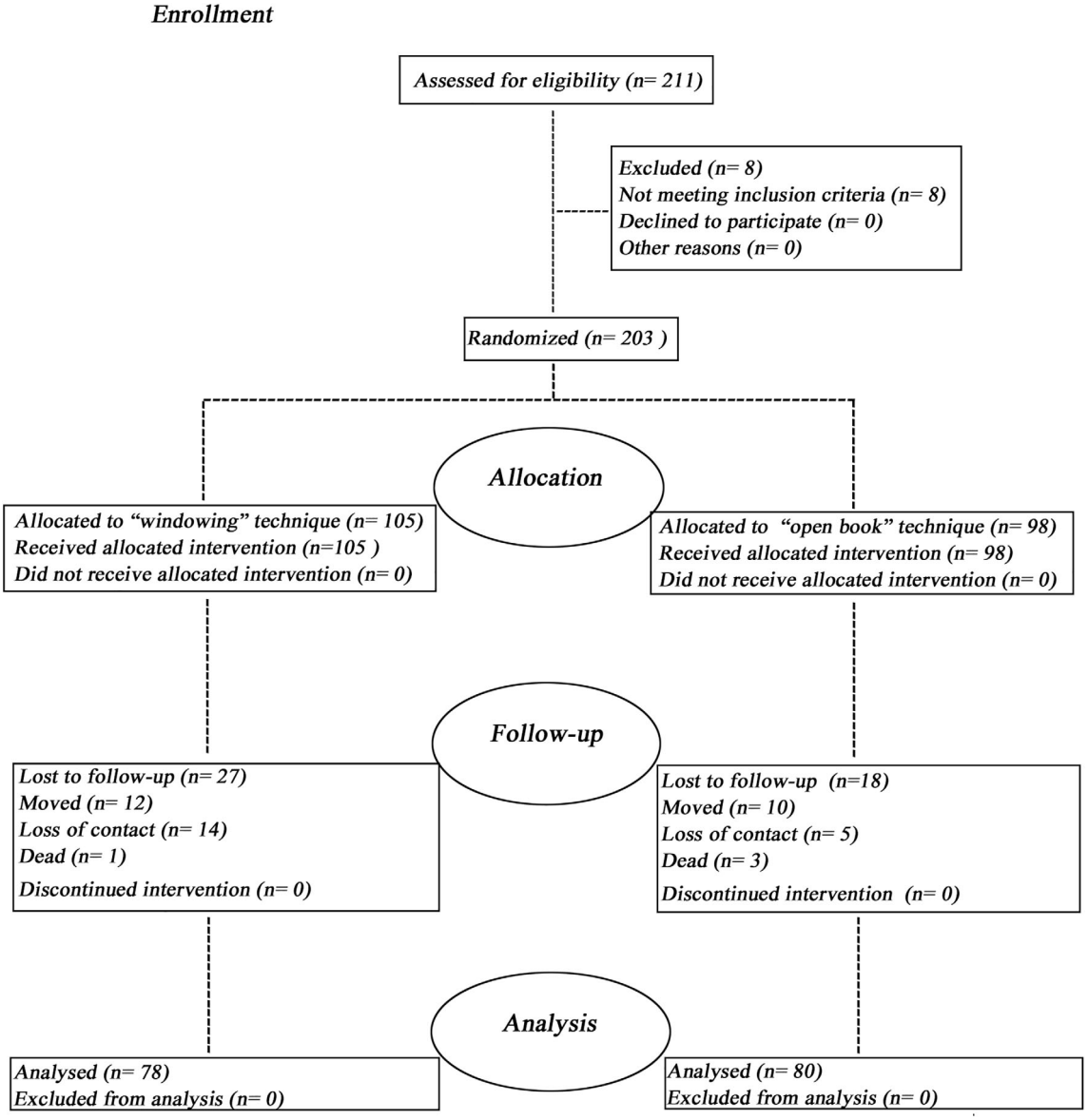

Fig. 3 Flowchart demonstrating patient selection and analysis

and intraoperative outcomes were calculated from the original dataset. Unpaired *t*-tests were used to compare patient demographics and intraoperative outcomes between the two groups, while chi-square tests were used to measure the associations between the categorical data of the two groups. Differences were considered statistically significant at $P < 0.05$. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA).

Results

Follow-up

A total of 203 patients who underwent surgery using one of the two techniques in our institution were enrolled. Finally, 158 patients who were followed up for at least 24 months (median, 32 months; range, 24–42 months) were included in the final outcome analysis. A flowchart of the inclusion process is shown in Fig. 3. All patients were assessed using x-ray and CT within 24 h and x-ray postoperatively at each clinic visit. The VAS score was ascertained from the patients' statements 24 months after surgery, and knee function (Rasmussen classification) was measured at 3, 12, and 24 months. Furthermore, the Resnick–Niwoyam criteria for arthritic changes were evaluated according to the radiological results at 24 months.

General Results

Preoperative demographic characteristics did not differ significantly between the groups ($P > 0.05$; Table 1). The period between injury to surgery was 3.7 ± 1.2 days (range, 1–10 days) and 3.5 ± 1.4 days (range, 1–11 days) in the "windowing" and "open book" groups, respectively, with no significant difference between the groups ($P > 0.05$). During surgery, 55 patients (34.8%, 24 patients in the "windowing" group and 31 patients in the "open book" group, $P > 0.05$) had detectable meniscal tears. Tear types were categorized according to the O'Conner classification (Table 2). One case of anterior cruciate ligament tear was detected in each group ($P > 0.05$). The operation times also did not differ significantly between the "windowing" (61.0 ± 8.3 min, range, 45–120 min) and "open book" groups (61.2 ± 10.4 min, range, 40–123 min) ($P > 0.05$).

Radiographic Evaluation

All patients were assessed using X-ray and CT within 24 h. Articular depression, condylar widening, and valgus/varus of the tibial plateau fractures were evaluated. There were five (6.4%) and 15 (18.8%) cases of articular depression in the "windowing" and "open book" groups, respectively. Significant differences were observed in the articular depression of tibial plateau fractures between the groups. However, condylar widening or valgus/varus did not differ significantly between the groups (Fig. 4).

TABLE 2 Intraoperative data and postoperative follow-up[a]

Indexes	"Windowing" group	"Open book" group	*t* value/χ^2 value	*P* value
Mean operating time (min), Mean (SD)	61.0 (8.3)	61.2 (10.4)	0.133	0.894
Period from injury to surgery (days), Mean (SD)	3.7 (1.2)	3.5 (1.4)	0.963	0.337
Cruciate ligament tear, *n*	1	1	0	1.0
Meniscal tear, *n*	24	31	1.108	0.292
Pattern of meniscal tear, *n*				
Longitudinal	8	11	0.638	0.888
Horizontal	6	9		
Oblique	5	7		
Radial	5	4		
Radiological evaluation (Rasmussen classification), *n*				
Joint depression	5	15	5.439	0.02*
Condylar widening	6	10	1.003	0.917
Valgus/varus	0	0	/	/
Clinical function score (Rasmussen classification), mean (SD)				
3 months	22.41 (3.32)	21.50 (2.51)	1.94	0.053
12 months	25.68 (1.44)	25.55 (1.89)	0.487	0.628
24 months	27.00 (1.84)	27.08 (2.25)	0.245	0.808
Grade of posttraumatic arthritis (Resnick–Niwoyam criteria), *n*				
Grade 0	28	17	3.884	0.049*
Grade 1	32	33		
Grade 2	14	23		
Grade 3	4	7		
Visual analog scale, mean (SD)	0.75 (0.69)	0.78 (0.70)	0.271	0.787

[a] Mean operating time, period from injury to surgery, soft tissue injury, radiological evaluation, visual analog scale, knee function, and grade of post-traumatic arthritis were recorded and compared.; * $p < 0.05$, statistical significance between "windowing" group and "open book" group.

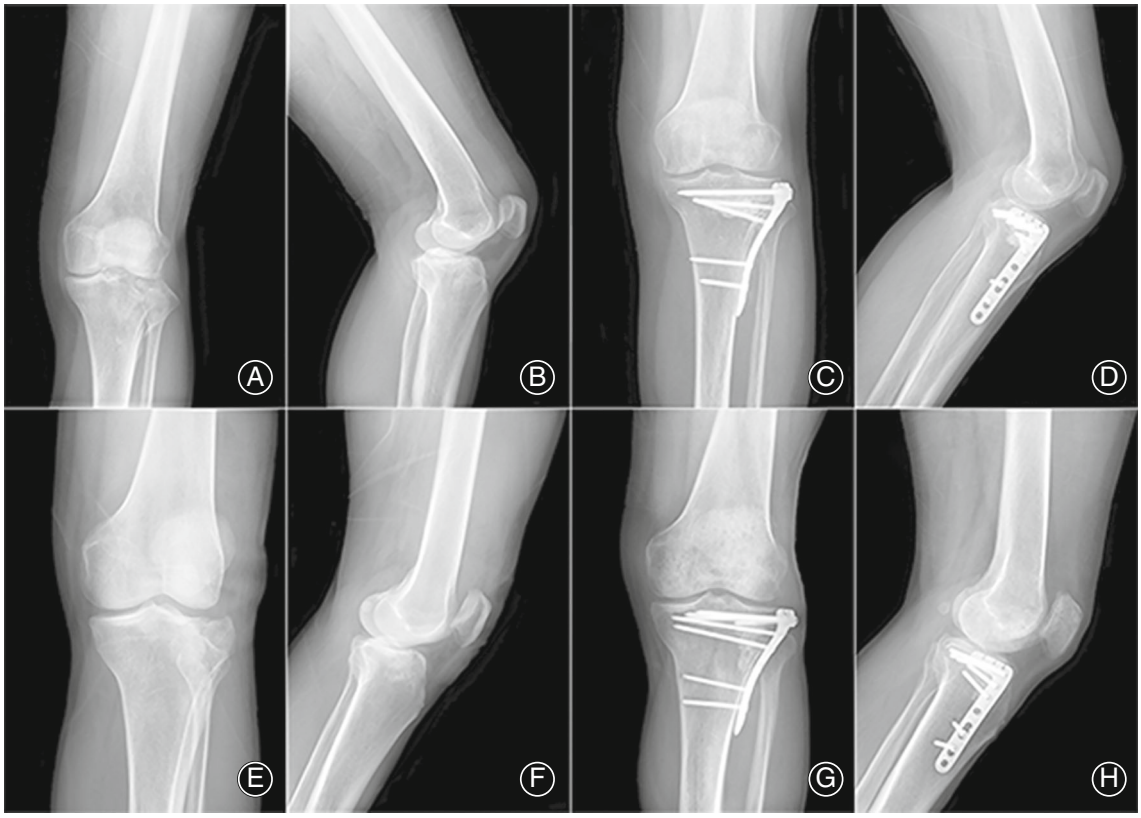

Fig. 4 Two cases of Schatzker type II tibial plateau fracture. (A–D) Case 1 (male, 56 y/o, vehicle accident) underwent surgery involving the "windowing" technique. (E–H) Case 2 (female, 42 y/o, vehicle accident) underwent surgery involving the "open book" technique. (A) and (E) Preoperative anteroposterior (AP) radiograph. (B) and (F) Preoperative lateral radiograph. (C) and (G) Postoperative AP radiograph at 24 months. (D) and (H) Postoperative lateral radiograph at 24 months

Functional Evaluation

No significant differences were observed in knee function (Rasmussen classification) during each follow-up visit ($P > 0.05$). VAS scores were similar between the groups at 24 months after surgery ($P > 0.05$).

Complications

Arthritic changes were classified according to the Resnick–Niwoyam criteria at the last follow-up. The number of severe post-traumatic arthritis (grades 2 and 3) cases differed significantly between the groups ($P < 0.05$; Table 2).

Discussion

The study assessed two surgical techniques for the treatment of Schatzker type II fractures. According to results, the perioperative data, such as mean operating time, was similar between two groups. And the clinical outcomes, evaluated by VAS and clinical function score (Rasmussen classification), showed good clinical effects in both groups. However, patients who underwent the "windowing" technique had better radiological outcomes and lower rates of severe post-traumatic arthritis (Resnick–Niwoyam criteria) than those who underwent the "open book" technique. The "windowing" technique may have advantages in reduction over the "open book" technique in most cases of Schatzker type II tibial plateau fractures, leading to less severe post-traumatic arthritis in intermediate prognosis.

Reduction Quality of the Two Techniques

The "windowing" and "open book" techniques are the two main surgical methods applied in open reduction and internal fixation of Schatzker type II fractures. The main distinction between these two methods is the surgical sequence used for split fractures and articular depression. Briefly, in the "open book" technique, articular depression is treated first, followed by split fracture management. In contrast, these steps are performed in the reverse order in the "windowing" technique. The other surgical procedures did not differ significantly between the two methods. Postoperative CT showed a better reduction with the use of the "windowing" technique than with the use of the "open book" technique. There were fewer cases of articular depression and condylar widening of the lateral tibial plateau in the "windowing" group than in the "open book" group, and there was a significant difference in articular depression between the groups.

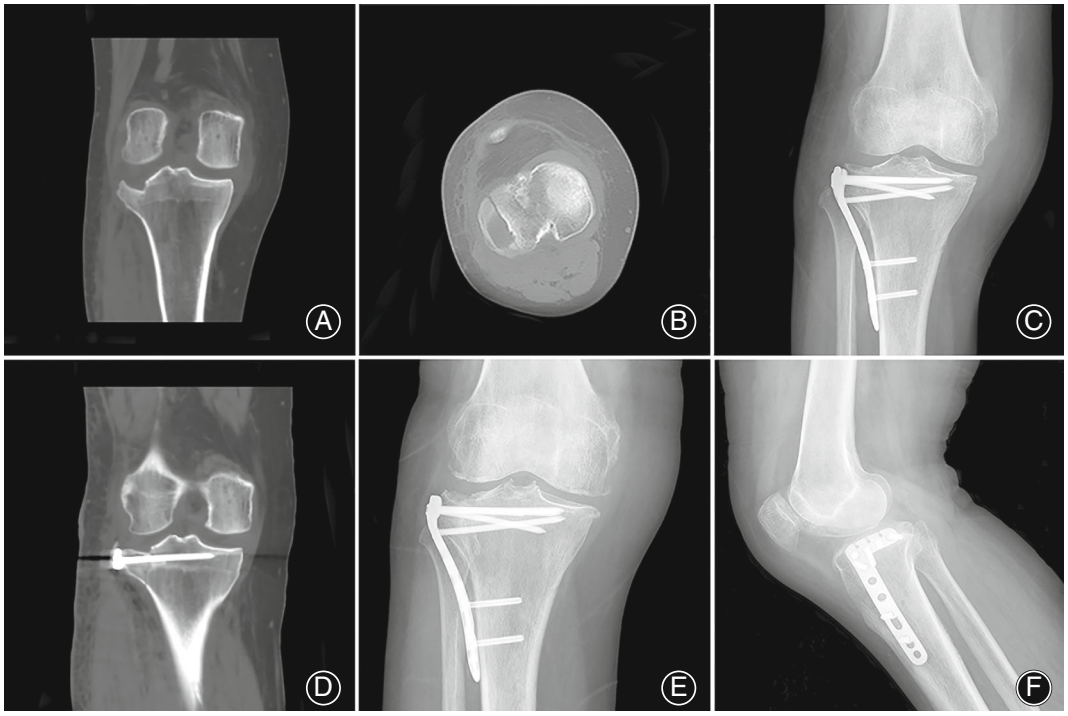

Fig. 5 Images of split-depressed lateral tibial plateau fractures before and after surgery. (A) and (B) Preoperative computed tomography showing a split-depressed lateral tibial plateau fracture. (C) and (D) Postoperative computed tomography showing fracture fixation using an anatomical locking plate. Mal reduction (articular depression) is visible on the articular surface of the split fragment. (E) and (F) Postoperative images at 24 months after surgery showing blurred fracture lines and post-traumatic arthritis (grade 2)

Advantages and Disadvantages of the Two Techniques

Most cases of malreduction (articular depression) were observed on the articular surface of the split fragment in the "open book" group. Surgeons may assume that the zone of articular depression is not involved in the split fragment (Fig. 5). In the "windowing" technique, the split fragment is reduced to the tibia and is temporarily fixed with a Kirschner wire, converting a Schatzker type II fracture to a Schatzker type III fracture. Articular depression can then be performed using a small cortical window against the depressed zone of the lateral plateau. However, five patients in the "windowing" group showed articular depression after surgery. In this study, the "windowing" technique resolved most Schatzker type II fractures, except in two situations. It was difficult for the surgeon to reduce the depressed zone of the articular margin through the cortical window, especially anteriorly. Furthermore, it is challenging for surgeons to obtain a good intra-articular view of the depressed zone involving the tibial intercondylar eminence and the posterior part of the lateral plateau[22] by retracting the meniscus superiorly. Inadequate vision or assessment of the fracture may lead to primary fixation failure, secondary articular depression, valgus deformity, and deterioration in the longterm.[23] In these situations, the injured limb is placed in internal rotation and adduction, with the knee bent to improve the view of the posterolateral corner. Furthermore, the "open book" technique may be an effective alternative for this type of fracture. Therefore, awareness of the possible fracture elements and variations in fragment morphology is important to help surgeons choose the optimal surgical technique.[9,24]

Complications

The number of severe post-traumatic arthritis (grades 2 and 3) cases were significantly different between the groups at the last follow-up. Without exception, these cases were accompanied by reduction inmal reduction of the lateral tibial plateau. However, the VAS and clinical function scores did not differ significantly between the groups. A longer follow-up is needed to confirm radiological findings and knee function.

Soft Tissue Injuries

Tibial plateau fractures are commonly associated with soft tissue injury and meniscal tears. In this study, meniscal injury necessitating surgery occurred in 34.8% knees with Schatzker type II tibial plateau fractures, consistent with previous descriptions of meniscal injuries in fracture[25–27]. During surgery, most tears occurred at the lateral margin and anterior horn of the meniscus. As preserving the meniscus is

believed to protect the articular cartilage and delay osteoarthritis[28], we repaired the meniscus with interrupted sutures when possible while performing internal fixation, finally fixing the meniscus to the plate. Furthermore, varus–valgus rotation and drawer tests were assessed intraoperatively for medial/lateral collateral ligament and anterior/posterior cruciate ligament injuries. Collateral ligament injuries require a cast for immobilization, whereas cruciate ligament tears require a second reconstruction. In this study, two cases had anterior cruciate ligament tears, for which delayed reconstructions were performed under arthroscopy until bone healing had occurred.

Strengths and Limitations

This is the first study comparing the clinical prognoses between the "windowing" and "open book" techniques for type II tibial plateau fractures. The prospective study including 158 cases of Schatzker type II tibial plateau fractures with reliable and complete data, met the requirements for final analysis and tried to minimize bias. As a result, the study concluded the advantages and disadvantages of the two techniques and showed intermediate prognosis of the fracture after the use of the two techniques, which may provide some guidance in clinical practice.

This study has several limitations. This study only compared open reduction and internal fixation using the "windowing" and "open book" techniques for split-depressed fractures of the lateral tibial plateau. Further research is needed to compare arthroscopy-assisted surgery with the conventional approaches. Furthermore, the period from surgery to the final follow-up was not similar in every case, which may have affected the radiological evaluation results. Further multicenter studies with more patients and long-term follow-up are needed to better compare the advantages and disadvantages of these surgical techniques.

Conclusion

This study assessed two conventional surgical techniques for the treatment of patients with split-depressed fractures of the lateral tibial plateau (Schatzker type II). Patients who underwent the "windowing" technique had better radiological outcomes and lower rates of severe post-traumatic arthritis than those who underwent the "open book" technique. However, the "open book" technique may be more applicable in cases with a depressed zone of the articular margin ortibial intercondylar eminence. Despite this, the "windowing" technique may have advantages in reduction over the "open book" technique in most cases and is a reliable method for achieving better outcomes for Schatzker type II tibial plateau fractures. Further multicenter, larger, randomized controlled trials are needed to confirm our results.

Author Contributions

Tianming Yu made the substantial contributions to the conception and design of the work; Jianlei Liu, Dichao Huang and Hailin Yan acquired and collected data for the work; Jichong Ying analyzed the data and drafted the work; Yunqiang Zhuang revised it critically for important intellectual content; Tianming Yu made the final approval of the version to be published; and all authors are in agreement with the manuscript and agree to be accountable for all aspects of the work.

Conflict of Interest

The authors declared no conflict of interest.

Ethical Statement

The study was approved by the medical ethics committee of Ningbo No. 6 Hospital (L2021095), and all patients provided informed consent before participating in this study.

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