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Treatment of a collapse fracture of the anterolateral tibial plateau with a lateral locking plate and the Jail screw technique

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Abstract

Background To explore the advantages of a lateral tibial locking plate combined with Jail screw fixation in the treatment of anterolateral tibial plateau collapse fracture (ATPCF).

Methods A retrospective analysis was conducted on patients with ATPCFs admitted to our hospital from February 2019 to February 2023. Twenty-six patients were successfully included, including 15 males and 11 females, with an average age of 58.6 ± 7.8 years (range 45–68 years). All fractures were Schatzker type II fractures. After fracture reduction and fixation, a lateral locking titanium plate was placed through the anterolateral approach of the tibial plateau, and two screws of appropriate length were placed in the sagittal direction according to the Jail screw technique. Postoperative evaluation indices included surgery time, fracture healing time, the degree of tibial plateau collapse shown by computed tomography (CT) images at 3 days and 1 year after surgery, and the patient's knee range of motion at 1 year after surgery. The effects of fracture reduction and fixation before surgery, 3 days after surgery and 1 year after surgery were evaluated by the Rasmussen radiological score. The Hospital for Special Surgery (HSS) knee score was used to evaluate the knee joint function of patients at 1 year after surgery.

Results The average operation time was 64 ± 6.8 min (range 56–82 min). The fractures healed clinically at 13.8 ± 2.8 weeks (range 12–18 weeks) postoperation. After 15 ± 3.1 months (range 12–19 months) of average follow-up, all the patients were pain-free with a full range of motion and stable knees. At the 1-year postoperative assessment, the CT images showed no secondary collapse of the articular surface, the average knee range of motion was 136.3 ± 2.5° (range, -5° to 135°), the average Rasmussen radiological score was 16.2 ± 0.8 points, and the average HSS knee score was 93.6 ± 3.2 points.

Conclusions The fixation of a anterolateral tibial plateau collapse fracture(ATPCF) using a lateral locking plate and the Jail screw technique has achieved good knee joint function, providing a new option for the treatment of ATPCFs. The clinical efficacy is satisfactory in the short term, avoiding secondary articular surface collapse.

Keywords Proximal tibial fracture, Jail screw, Locking plate, Platform collapse, Fracture reduction and fixation

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Introduction

Tibial plateau fractures account for 1% of total body fractures and 5–8% of lower limb fractures [1]. There are several fracture classifications of tibial plateau fractures, of which the Schatzker classification system is the most widely used. The system can be divided into three subgroups: type I to III fractures are caused mostly by low- and medium-energy injuries and involve the lateral tibial plateau; type IV fractures involve the medial tibial plateau; and type V to VI fractures involve the medial and lateral tibial plateaus due to high-energy injuries.

Schatzker type II (lateral plateau split-collapse) fractures are the most common, accounting for 25–33% of all tibial plateau fractures and 50–84% of lateral plateau fractures [2, 3]. The current treatment of fractures is encouraged for evaluation via CT scans, which can better define joint consistency and fracture displacement. The indications for operative management include intra-articular fractures with > 2mm joint depression or separation, metaphyseal components which are significantly displaced or angulated > 5°, open injuries, vascular injury, and associated ligamentous injuries requiring stabilisation[4]. These guidelines were based only on individual opinions and did not form a consensus. According to our clinical treatment experience, surgical treatment can be considered for an articular step greater than 3mm, plateau widening of more than 5 mm, or compression fracture of the lateral tibial plateau with valgus axis deviation > 5°. For Schatzker type II and III fractures, some orthopedic surgeons have proposed a modified percutaneous technique for lateral plateau depression fractures, they believe that the combination of subchondral screws with a bioabsorbable interference screw holds promise as a true percutaneous reduction and fixation technique for patients with reasonable bone quality [5]. Many biomechanical studies domestically and abroad have investigated different internal fixation methods for tibial plateau fractures. Internal fixation methods include lag screws, various types of plates (locking and nonlocking plates) and raft screw constructs [3]. Secondary articular surface collapse is an important factor affecting the postoperative clinical outcome. The gold standard for fixation is the use of subchondral raft screw constructs and buttress plates. Smaller-diameter (typically 3.5 mm) screws parallel to the subchondral bone can be used to achieve better stability [6, 7]. However, subsidence of the joint surface is still inevitable. In recent years, the rim plate fixation technique has also been a good treatment technique for tibial plateau fractures [8–10] and is mostly used to treat lateral tibial plateau fractures. However, there is no anatomic rim plate; usually, a 1/3 tubular plate or distal radius plate is shaped and used as a rim plate, which has the problems of plate nonapplication and prolonged operation time. Part of the rim plate is not used as the main plate and is often used for auxiliary support fixation of anterolateral or posterolateral platform fractures. Most of the screws used in rim plates have a diameter of 2.7 mm, and the fixed strength is weaker than that of 3.5 mm screws. The fixing method is relatively simple and often involves single-plane fixing. For Schatzker type II fractures, there is articular surface collapse and condylar widening of the tibial plateau, and the fixation strength of the rim plate alone is weak. Further biomechanical studies and clinical follow-up studies are needed to determine whether the full range of functional exercise and partial weight-bearing activities at the knee joint after surgery can be carried out in the early stage. Therefore, the rim plate is usually used in combination with another tibial underplatform locking plate. The Jail screw technique is a fixation method for the treatment of Schatzker type II fractures [5] that can satisfy the stereoscopic fixation requirements of anterolateral tibial plateau collapse fracture (ATPCF), increase the fixation strength to facilitate early postoperative rehabilitation and functional exercise, and simultaneously decrease the risk of trauma and operation time. Biomechanical studies have shown that it can achieve better initial stability than conventional lag screw fixation and that the increased axial load capacity of the articular surface can reduce postoperative subsidence of the articular surface [11]. Therefore, to achieve early rehabilitation exercise of the knee joint without significantly increasing the risk of trauma or operation time and simultaneously increase the fixation strength to avoid secondary articular surface collapse after fixation of the ATPCF, we conceived and designed fixation technology involving a lateral locking plate combined with Jail screws. This study provides a new surgical method for the treatment of ATPCFs.

Data and Methods

Inclusion and exclusion criteria

The inclusion criteria for patients were as follows: 1) fracture of the anterolateral tibial plateau confirmed by X-ray and CT examinations before the operation, and the collapse distance of the articular surface measured by CT examination was more than 3 mm; 2) Schatzker type II fracture treated with a lateral tibial locking plate combined with the Jail screw technique.

The exclusion criteria were as follows: 1) open fracture; 2) fracture involving the medial condyle and metaphysis; 3) severe osteoarthropathy combined with varus and valgus deformity of the knee; 4) vascular and nerve injury; 5) incomplete imaging data; and 6) less than 1-year follow-up.

General information

A total of 31 patients with Schatzker type II tibial plateau fractures were treated with a lateral locking plate combined with the Jail screw technique from February 2019 to February 2023; 2 patients did not visit our outpatient clinic for reexamination after surgery, and 3 patients were followed up for less than 1 year. A total of 26 patients were included.

Preoperative design

DICOM images were used to reconstruct the bilateral knee joint solid model through a preoperative CT scan of the patient's knee joint (Fig. 1a), and then the successfully modeled lateral plate-screw system was loaded on the software, which included two sets of screws and plates on the left and right sides (Fig. 1b). The combination operation was performed on the healthy side of the tibial plateau in advance, ensuring that the top raft screws of the plate were as close to the subchondral bone of the tibial plateau as possible (Fig. 1c). The lateral plate-screw system and Jail screw position data were collected by the built-in length measurement tool on the software before the operation to guide the placement of internal fixation in the affected limb during surgery (Fig. 1d).

Preoperative management

The injured limb was provisionally fixed with calcaneal pin traction or leg brace. Enoxaparin sodium was used to avoid venous thrombosis in the lower limb. The injury to surgery interval was 6.3 ± 2.4 days (range 3–12 days), and all patients underwent definitive surgical treatment only after the presence of wrinkle sign of the skin.

Surgical technique

Anesthesia and operative position

The patient underwent general anesthesia and was placed in a supine position with a knee pad height of approximately 30° knee flexion on the affected side. Bleeding was controlled with a lower limb tourniquet.

Surgical approach

Using the anterolateral approach of the knee joint, a longitudinal curved incision was made between the lateral epicondyle of the femur and Gerdy's tubercle. The skin and subcutaneous tissue were dissected layer by layer, and the iliotibial tract was dissected. The anterior tibial muscle was bluntly separated with a periosteal stripper and retracted laterally to expose the proximal tibia, and the joint capsule was cut horizontally to expose the anterolateral meniscus. The anterolateral meniscus was suspended with sutures, and the anterolateral articular surface of the knee joint was fully exposed.

Reduction and fixation with locking plates and Jail screws

During surgery, the collapse of the anterolateral tibial plateau was examined. An osteotome was inserted approximately 1.5 cm below the tibial plateau collapse site to slowly lift the collapsed platform and the cancellous bone beneath it upward. Under direct visualization, the cartilage on the collapsed joint surface was reduced

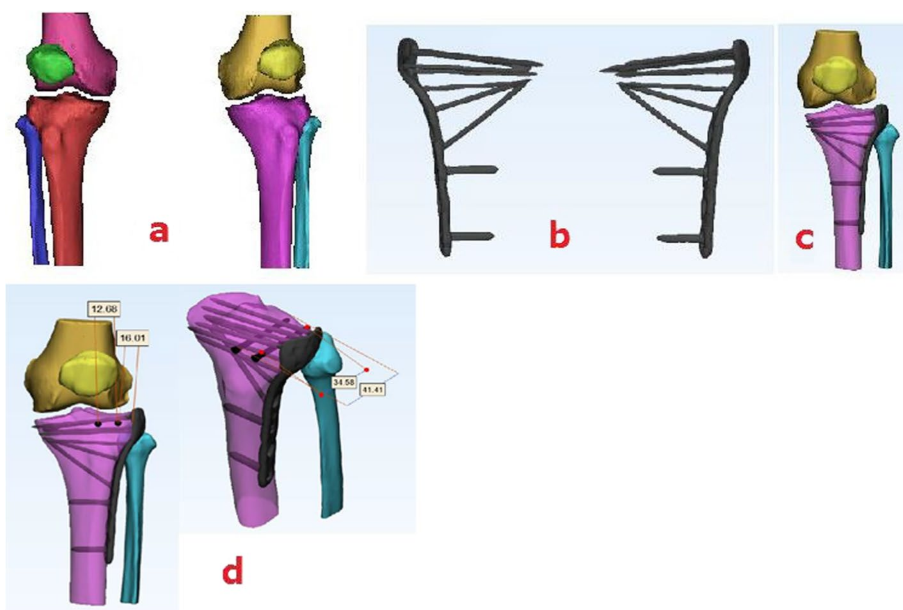

Fig. 1 3D reconstruction of bone tissue and surgical simulation via Mimics software (Materialise, Belgium). **a**: Solid models of the bilateral knee joint (left: affected side; right: healthy side). **b**: Bilateral tibial plateau plate-screw system. **c**: Simulated placement of the plate-screw system on the healthy side. **d**: The placement and length of the Jail screws were measured on the software of the healthy side (the lateral Jail screw is approximately 15 mm from the plate and 35 mm in length; the medial Jail screw is approximately 10 mm inward from the lateral Jail screw, and the length is approximately 40 mm) to guide the precise placement of the Jail screws on the affected side during the operation

and tightly connected to the lower surface of the lateral meniscus. Point-type reduction forceps were used to clamp and fix the ATPCF in the coronal position, correcting the widening of the tibial plateau articular surface. The ATPCF was completely reduced under direct vision and C-arm fluoroscopy, and when there was no broadening of the plateau or valgus deformity of the knee joint, the reduction was considered effective. Multiple Kirschner wires with a diameter of 1–1.5 mm were temporarily used to fix the fracture, and allogeneic bone was implanted at the defect of the metaphysis. The preoperative design of the simulated surgical data for the healthy knee joint, including the lateral plate-screw system and Jail screw position data, was used to guide the placement of internal fixation after reduction of the ATPCF in the affected knee. A proximal lateral locking plate was placed at a predetermined position on the anterolateral side of the proximal tibia. The placement of the raft screws under the platform was carried out first, paying attention to the existence of the posterior tibial slope angle (PTSA) to prevent the screws from accidentally entering the joint cavity. At the same time, the temporarily fixed Kirschner wires were gradually removed to avoid collision between the drill bit and Kirschner wires causing Kirschner wire breakage, and the position of the raft screws was as close to the subchondral bone of the platform as possible. After the lateral plate-screw system placement was complete, the Jail screws were placed. The position data of the Jail screws obtained from preoperative simulation surgery and intraoperative C-arm X-ray fluoroscopy were used to determine the direction and length of the Jail screw placement under the tibial plateau articular surface. Kirschner wires (3.0 mm) were used to drill the Jail screw channel in the predetermined sagittal direction between the first and second rows of raft screws. X-ray fluoroscopy showed that the Kirschner wires were placed in a satisfactory position and passed through the collapsed fracture site of the ATPCF, which had already been reduced. After the Kirchner wires were removed, two locking screws with a suitable length and diameter of 3.5 mm were inserted into the screw channel. X-ray fluoroscopy revealed that the ATPCF was reduced and fixed adequately. The operation diagram of the Jail screw placement is shown in Fig. 2.

Incision closure

During the operation, the joint capsule was repaired, the bleeding was completely stopped after loosening the tourniquet, and there was no active bleeding. A drainage tube was placed inside the incision, the iliotibial tract was sutured discontinuously, and the subcutaneous and skin tissues were sutured layer by layer.

Postoperative treatment

After the operation, the affected limb was elevated. Usually, 2–3 days after surgery, when the daily continuous drainage volume was less than 50 ml, the drainage tube should be removed. Knee joint flexion and extension exercises were performed in bed, enoxaparin sodium anticoagulation treatment was administered for 12–14 days, partial weight bearing was carried out using crutches after 2 weeks, and full weight bearing was carried out after 3 months according to the follow-up images.

Curative effect evaluation

The operation time of the patients were measured. X-ray and CT examinations of the knee joint were performed 3 days after surgery. X-ray imaging at 1 month, 3 months and 6 months after surgery was used to evaluate fracture healing. X-ray and CT examinations at 12 months after surgery were used to determine whether there was a secondary

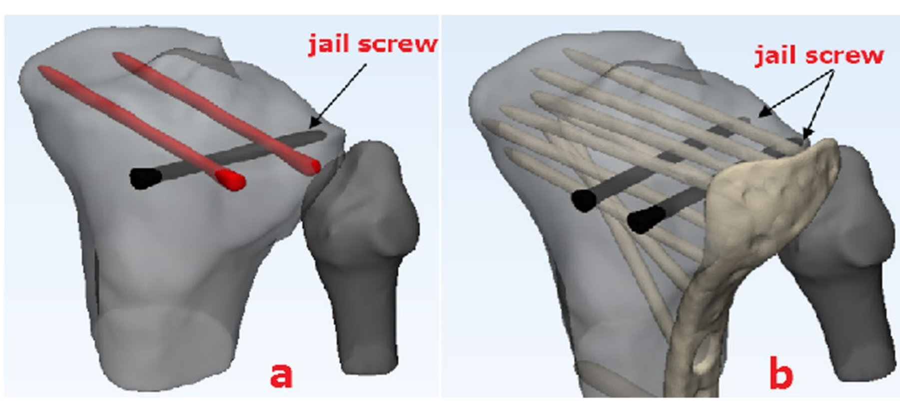

Fig. 2 Schematic diagram of the Jail screw placement. **a**: Jail screw concept map. **b**: Lateral tibial locking plate combined with the Jail screw technique

collapse of the articular surface. The Rasmussen radiological score was used to evaluate the curative effect on the knee joint before surgery, 3 days after surgery, and 1 year after surgery. The Rasmussen radiological score examined whether the condyle was widened, whether the articular surface collapsed, and whether there was an angulation deformity. The maximum total score was 18 points; 18 points indicate excellent results, 12–17 points indicate good, 6–11 points fair, and < 6 points poor. Knee joint function was evaluated according to the Hospital for Special Surgery (HSS) knee score at 1 year after surgery. Out of 100 points, ≥85 points indicate excellent results, 70–84 points indicate good results, 60–69 points fair, and ≤59 points poor.

Statistical analysis

Statistical analysis was performed via SPSS 18.0 statistical software (SPSS, USA). The height of the articular surface collapsed before surgery, and the vertical height from the highest point of the anterolateral articular surface of the tibia after reduction to the horizontal line of the articular surface 3 days and 1 year after surgery were calculated. The measurement data are presented as the means ± standard deviations. ANOVA was used for height comparisons across the three time points, and the q test was used for intergroup comparisons. Statistical significance was indicated by $p \leq 0.05$. A paired-samples t test was used to compare the Rasmussen radiological score before surgery, 3 days after surgery and 1 year after surgery, and $p \leq 0.05$ was statistically significant.

Results

Results

Twenty-six patients with ATPCFs received open reduction and internal fixation with our new technique. They were 15 men and 11 women, with an average age of 58.6±7.8 years (range 45–68 years), and 14 fractures were on the left side, and 11 were on the right. All patients underwent anteroposterior and lateral X-ray fluoroscopy, CT, and magnetic resonance imaging (MRI) examinations before surgery. Preoperative MRI showed coexisting conditions. Six patients had lateral meniscus injuries, 6 patients had lateral collateral ligament (LCL) injuries, and 3 patients had anterior cruciate ligament (ACL) injuries (See Table 1). Two cases of lateral meniscus peripheral tears and 1 case of partial tear of the LCL were found during the operation, all of which were repaired by suturing.

The average operation time was 64 ± 6.8 minutes (range 56–82 minutes). The fractures healed clinically at 13.8 ± 2.8 weeks (range 12–18 weeks) postoperation. After 15±3.1 months (range 12–19 months) of average follow-up, all the patients were pain-free with a full range of motion and stable knees. One year after surgery, CT images revealed a good reduction of the fracture and no collapse of the articular surface. One year after surgery, the range of motion of the knee was 136.3 ± 2.5° (range, −5° to 135°). A typical case is shown in Fig. 3.

Evaluation of the curative effect and statistical analysis

Patients with malreduction, loss of reduction or fixation breakage were not observed during the entire follow-up period. The height of the articular surface collapsed before surgery, and the vertical height from the highest point of the anterolateral articular surface of the tibia after reduction to the horizontal line of the articular surface 3 days and 1 year after surgery were calculated. There were significant differences among the three time points ($F = 6.365$, $p = 0.009$), between 3 days after surgery and before surgery (p=0.012), and between 1 year after surgery and before surgery ($p = 0.014$). However, there was no significant difference between 3 days after surgery and 1 year after surgery (p=0.386). These results indicate that the reduction in articular surface collapse after surgery was satisfactory and no secondary articular surface collapse occurred during the 1-year follow-up after surgery. The Rasmussen radiological score of the knee joint was compared before surgery, 3 days after surgery and 1 year after surgery. There was a significant difference between 3 days after surgery and before surgery ($p = 0.007$), and between 1 year after surgery and before surgery ($p = 0.009$). However, there was no significant difference between 3 days after surgery and 1 year after surgery ($p = 0.229$). These results indicate that during the short-term follow-up period of 1 year after surgery, there were no cases of malreduction, loss of reduction, or varus and valgus deformity of the knee joint. These patients showed good recovery of knee joint function at 1 year after surgery (the average HSS knee score was 93.6 ± 3.2 points) (See Table 2, Table 3, Table 4, and Table 5).

Table 1 Preoperative information of patients

Number of cases	Sex		Age (years)	Injury side		Coexisting injuries		
	Men	women		Left	Right	Lateral meniscus injury	LCL injury	ACL injury
26	15	11	58.6 ± 7.8	14	12	6	6	3

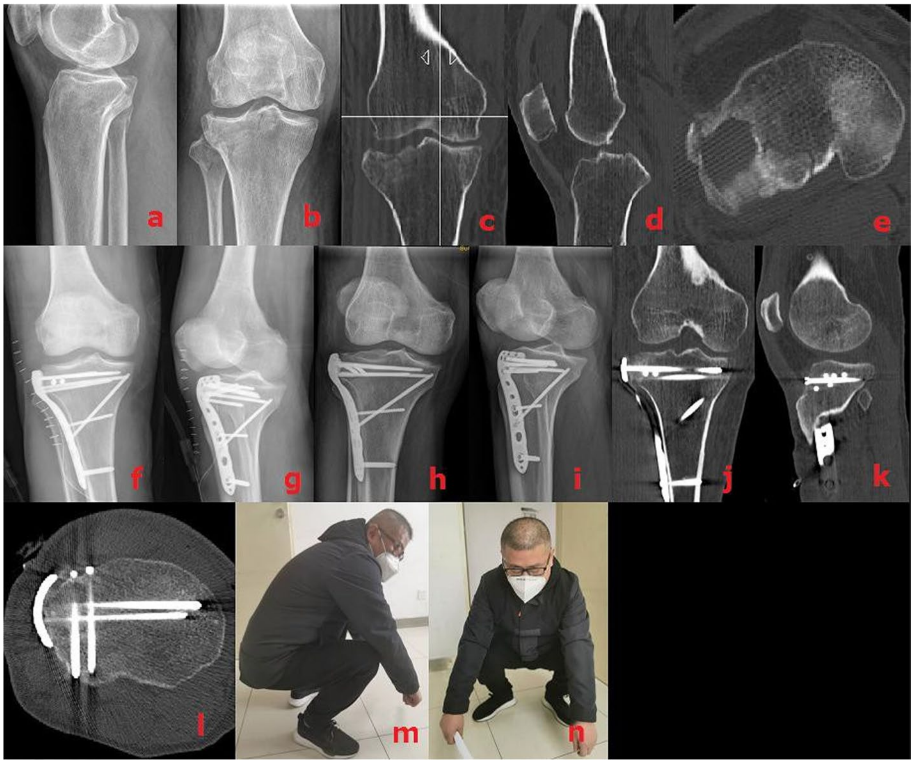

Fig. 3 Male, 56 years old, accidentally fell while riding an electric vehicle. **a**-**b**: Preoperative X-ray images revealed ATPCF on the right side. **c**-**e**: Preoperative CT images revealed a collapse of the anterolateral tibial plateau, Schatzker type II. **f**-**g**: 3 days after surgery, X-ray images of the right knee revealed good reduction and fixation of the fracture, and Jail screws were placed in a good position. **h**–**l**: One year after surgery, X-ray and CT images revealed that the fracture had healed well, no secondary collapse occurred on the articular surface, and the bony union was satisfactory at the bone graft site. **m**–**n**: One year after surgery, the patient's range of motion at the knee joint was normal, which was consistent with that of the healthy side

Table 2 Comparison of the vertical height of patients at different time points ($\bar{x} \pm s$)

Follow-up	Vertical height from the articular surface to the articular horizontal line (mm)
preoperation	9.2 ± 2.1
3 days after surgery	1.0 ± 0.4
1 year after surgery	0.9 ± 0.6
F value	6.365
P value	0.009

Discussion

The anterolateral approach is a classic surgical approach for the treatment of anterolateral tibial plateau fractures. The meniscus coronary ligament is cut horizontally, and the lateral meniscus is lifted slightly upward to obtain an adequate articular view of the tibia. After reduction, lag screws, anterolateral tibial proximal locking compression plates (LCPs), lateral tibial proximal minimally invasive stabilization systems (LISS plates), etc., can be used [12, 13]. In the surgical treatment of tibial plateau collapse fractures, especially in elderly patients with osteoporosis,

Table 3 Comparison of vertical height, Rasmussen radiological score at different time points ($\bar{x} \pm s$)

Follow-up time	Vertical height from the articular surface to the articular horizontal line (mm)	Rasmussen radiological score (points)
preoperation	9.2 ± 2.1	6.5 ± 1.2
3 days after surgery	1.0 ± 0.4	16.8 ± 1.4
t value	2.652	3.724
P value	0.012	0.007

Table 4 Comparison of vertical height, Rasmussen radiological score at different time points ($\bar{x} \pm s$)

Follow-up time	Vertical height from the articular surface to the articular horizontal line (mm)	Rasmussen radiological score (points)
preoperation	9.2 ± 2.1	6.5 ± 1.2
1 year after surgery	0.9 ± 0.6	16.2 ± 0.8
t value	3.106	2.528
P value	0.014	0.009

Table 5 Comparison of vertical height, Rasmussen radiological score at different time points ($\bar{x} \pm s$)

Follow-up time	Vertical height from the articular surface to the articular horizontal line (mm)	Rasmussen radiological score (points)
3 days after surgery	1.0 ± 0.4	16.8 ± 1.4
1 year after surgery	0.9 ± 0.6	16.2 ± 0.8
t value	3.274	4.106
P value	0.386	0.229

secondary articular reduction loss is often observed, and the long-term prognosis is poor [14].

The Jail screw technique was first proposed by Petersen W et al. [15, 16] and involves ensuring that the lower Jail screw is in direct contact with the upper lag screw. It was used to treat Schatzker type I and II fractures with small incisions or arthroscopy. The results revealed little damage to the lateral peripheral ligaments of the knee joint, less bleeding during surgery, and satisfactory clinical efficacy. Weimann A et al. [11] conducted a biomechanical study on the treatment of Schatzker type II fractures with the Jail screw technique and conventional lag screw technique, and the results demonstrated that the maximum axial load that the Jail screw technique could bear was significantly greater than that of lag screws, and that no intracancellous screw cutting occurred under the platform. Vauclair F et al. [5] applied the Jail screw technique to the percutaneous minimally invasive treatment of Schatzker type II and III tibial plateau fractures, and showed satisfactory clinical efficacy and no postoperative adverse events. The patients were allowed to perform knee flexion and extension exercises without weight bearing within 6 weeks. After 4 months of follow-up, the patients' range of motion at the knee joint was normal. X-ray review 1 year later revealed no fracture displacement or articular surface collapse in the operative area. Moran E et al. [17] simulated three different techniques for the treatment of Schatzker type I tibial plateau fractures in a tibial model. The findings indicated that the Jail screw technique is a good surgical method for the treatment of split fractures of the lateral tibial plateau; it increases the initial stability after fracture reduction and fixation and is conducive to early knee flexion and extension exercise in patients. In addition, the Jail screw technique has a unique advantage in the treatment of low-energy intra-articular collapse fractures (Schatzker type II, etc.) in elderly patients.

In this study, a lateral locking plate combined with the Jail screw technique was used to treat ATPCF. The Jail screw technique was used as the foundation to increase the axial bearing capacity and was combined with a lateral locking plate to treat ATPCFs caused by low-energy injuries. The frame support structure formed by the locking plate was conducive to the bony union, and the Jail screw technique reduced the shear force of the raft screws on the cancellous bone under the platform and increased the fixation strength of collapsed fractures to avoid the occurrence of internal fixation failure. This stereoscopic fixation mode was conducive to early knee flexion and extension exercise without weight bearing for osteoporosis patients, allowing patients to perform partial weight-bearing activities using crutches 2 weeks after surgery. All 26 patients followed up in this study began knee flexion and extension exercises after the drainage tube was removed after surgery, and some weight-bearing activities were also started earlier. CT images 3 days and 1 year after surgery revealed good fracture reduction and no secondary collapse of the articular surface. Doht S et al. [18] conducted a biomechanical study using cadaveric samples from elderly people. The average age of the donors was 85 years, and preoperative bone densitometry revealed tibial osteoporosis. The authors analyzed the stress of the lateral tibial plateau under partial loading via three different surgical procedures. The results showed that only the combination of a bone substitute and Jail screws prevented secondary loss of reduction and, at the same time, provided enough stability under axial loading. In this study, all 26 patients were treated with allogeneic bone grafting. Follow-up imaging data revealed good bone growth and satisfactory clinical efficacy.

With the development of digital orthopedic technology in recent years [19–23], the preoperative simulation of surgical operations via software can shorten the operation time and improve the accuracy of intraoperative screw placement. Mimics software is a good interactive medical image control system for 3D solid modeling based on tomography images. CT or MR tomography images can be used to reconstruct bone tissue models. To reduce surgical complications and better restore knee joint function, the following precautions should be taken when combining the use of the Jail screw technique: 1) Preoperative planning should be performed, and the position data of the lateral plate-screw system and Jail screws are obtained by simulating the placement of the lateral locking plate and the Jail screw of the healthy tibial plateau to guide the placement of internal fixation devices after the reduction of the ATPCF in the affected knee and provide a good reference for intraoperative operations. 2) After the articular surface is reduced and bone grafting is performed under direct visualization during surgery, an anatomical locking plate is placed first in a suitable position on the lateral side. When implanting raft screws, the sleeve must be tightened, and the drill hole must be drilled once. A power screwdriver is used to slowly and uniformly drive in the screws, and a torque wrench is used to tighten the tail of the screws to avoid the phenomenon of "wrong locking" due to uneven force during manual screwing of raft screws (especially for patients with obvious osteoporosis). If there is a deviation in the up and down, front and back directions of the locking screw, it affects the fixation effect of the raft screws and the implantation of the Jail screws. 3) The implantation of Jail screws in the sagittal plane requires certain surgical techniques. Intraoperative anteroposterior and lateral X-ray fluoroscopy of the knee joint is used to clarify the direction and angle of screw implantation below the joint surface. Before the Jail screw is implanted, a 3.0 mm smooth Kirschner wire is used to drill the screw path along the predetermined sagittal direction to avoid screw damage and drill bit fracture. It is necessary to ensure that the screws are successfully implanted to avoid repeated adjustments that may damage the raft screws and decrease the biomechanical properties of the internal fixation device. 4) The Jail screws should be in contact with the raft screws as much as possible to support the raft screws and increase the stereoscopic fixation strength of the ATPCF. 5) The length of the Jail screws should be determined by intraoperative fluoroscopy and should not be too long or too short. Screws that are too short may reduce the fixation strength of the fracture, and screws that are too long may damage the posterolateral complex of the tibial plateau and important blood vessels and nerves in the popliteal fossa.

There are several limitations in this study. First, although the position and direction of the Jail screw placement were planned in detail through preoperative simulated surgery, owing to human errors such as the intraoperative perspective angle and surgical operation, the Jail screw may not be successfully placed in a satisfactory position at once, resulting in a decrease in the strength of fracture fixation. Second, the use of a lateral locking plate combined with the Jail screw technique for the treatment of 26 patients with ATPCF has shown significant short-term efficacy, but long-term follow-up is still lacking. Third, further studies including large clinical samples and controlled studies should be conducted. We will continue to follow up with the patients and evaluate outcomes such as the degree of subsidence of the articular surface and the incidence of osteoarthritis. Fourth, this study was a retrospective study with information bias. In the later stage, multicenter prospective studies should be carried out to increase the sample size to further demonstrate the clinical efficacy of the procedure.

To ensure the successful insertion of the Jail screw, we propose the following methods. First, the anterolateral tibial plateau collapse fracture should be anatomically reduced as much as possible. Only with anatomical reduction can the placement of the plate-screws system and the Jail screws be close to the preoperative modeling measurement. Second, our surgical team has designed a specialized guider for inserting Jail screws, which allows for precise placement of Jail screws. Third, by utilizing surgical robot technology, real-time monitoring and robotic arm guidance during surgery can effectively guide the precise placement of Jail screws. We will apply and summarize this in subsequent surgeries.

This study focused on the internal fixation treatment of ATPCFs, and the Jail screw has a unique role in fixing posterolateral tibial plateau fractures. Owing to the limited fixation direction of the raft screws of the lateral locking plate, the fixation effect of the posterior bone block on the lateral tibial plateau is not satisfactory, and some cannot be fixed [24]. If a plate is to be placed posterolateral to the tibial plateau, exposure is difficult, and an assisted posterior or posterolateral approach is usually required [25–27], increasing the complexity of the treatment process. In this study, the Jail screw can be directly fixed to the posterior bone block of the tibial plateau, which can effectively compensate for the deficiency of the lateral plate-screw system in fixing to the posterior lateral bone block of the tibial plateau while avoiding possible damage to the posterior ligament complex and important blood vessels and nerves caused by posterior or posterolateral approaches to the tibial plateau.

In summary, the short-term clinical efficacy of using a lateral locking plate and the Jail screw technique to treat ATPCF is satisfactory. It allows for early postoperative knee flexion and extension functional exercise, effectively avoiding secondary articular surface collapse.

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Authors' contributions
JW, LX and KXR did the study and drafted the manuscript. WB and SJN were involved in the design, main contribution in literature search. ZHB and CM were involved in the study design, and made further revision in this manuscript. All authors reviewed the manuscript.

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Data availability
Data is provided within the manuscript.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Nanjing Drum Tower Hospital Group Suqian Hospital, registration number 2023037. All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all individual participants included in the study.

Consent for publication
All participants gave their informed consent to use their data for publication.

Competing interests
The authors declare no competing interests.

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