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Triple-incision treatment of the posterior condylar triad in the lateral prone position

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Abstract

Background Posterior tibial plateau bicondylar fracture combined with anterior cruciate ligament injury, also known as the "Posterior Condylar Triad", is a regular combination injury. The traditional surgical strategy involves first fixing the posterior condyle in the prone position and then treating the anterior cruciate ligament avulsion injury after the patient turns over. This surgical strategy is cumbersome, requires multiple surgical preparations, prolongs the surgical time, and increases the patient's risk. Our centre proposed one lateral prone position with three incisions to treat the "Posterior Condylar Triad".

Methods This was a retrospective analysis of the clinical data of 11 "Posterior Condylar Triad" patients who underwent surgical treatment at our centre from February 2017 to August 2020. Using a unified surgical strategy, the patient rotates the limb in a lateral prone position. The posterior condyle fracture of the tibial plateau is treated through a posterior medial incision and posterior lateral Frosch approach. Finally, anterior cruciate ligament avulsion fracture is treated through a small incision on the medial side of the patella. All patients were encouraged to perform functional exercises of the knee joint early after surgery. The postoperative complications (deep vein thrombosis, poor wound healing, deep infection, internal fixation failure and fracture reduction loss) and knee joint function (knee joint range of motion, Lysholm score and SF36 scale) of the patients were recorded 1 year after surgery.

Results All patients' fractures healed smoothly, with an average fracture healing time of 17.0 weeks, ranging from 12 to 22 weeks. There were 2 patients with deep vein thrombosis (DVT) after the operation. One patient experienced wound fat liquefaction, and no patients reported serious complications, such as loss of fracture reduction, failure of internal fixation, or deep infection. One year after surgery, the average range of motion (ROM) of the affected limb's knee joint was 3.6–120.5°, the average Lysholm score was 86.7, ranging from 61 to 100, and the average SF36 score was 76.96, with a range of 52.45–94.75.

Conclusion The "Posterior Condylar Triad" is a serious injury, and our proposed surgical strategy can simplify the surgical process, avoid large-scale changes in patient position during surgery, shorten surgical time, and reduce the risk of surgical anaesthesia, enabling patients to achieve good clinical prognosis.

Keywords Tibial plateau fracture, Bicondylar fracture, Posterior condylar triad, Dual incision

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Introduction

Tibial plateau fracture is a common injury, and the Schatzker and AO-OTA classifications are the most used classification systems [1, 2]. However, the above two classification systems cannot describe fractures in the posterior part of the tibial plateau. This may be due to the lack of CT technology in the past, which resulted in a poor description of posterior condylar fractures. Chen et al. [3] divided posterior tibial plateau fractures into (I) split fractures of the posteromedial condyle, (II) split fractures of the posterolateral condyle, (III) collapse fractures of the posterolateral condyle, (IV) split and collapse fractures of the posterolateral condyle, and (V) split fractures of the posteromedial condyle and collapse fractures of the posterolateral condyle. In a study by Hua et al. [4] on the morphology and injury mechanism of tibial plateau fractures, tibial plateau posteromedial split combined with posterolateral compression is usually combined with avulsion fractures with intercondylar eminence. This type of injury was named "Posterior Condylar Triad" and emphasised the importance of intercondylar fractures for the recovery of knee joint function. The injury mechanism may be that during knee flexion, the anterior cruciate ligament is tightened, and external forces cause the femoral condyle to collide with the posterior condyle of the tibial plateau, resulting in damage to the three important structures of the posterior medial, posterior lateral plateau, and anterior cruciate ligament avulsion fractures. Some studies have shown a strong correlation between anterior cruciate ligament (ACL) and posterior tibial plateau fractures [4–6], so "Posterior Condylar Triad" injury should be clearly diagnosed before surgery, and in cases of unstable knee joints, ACL injury should be surgically fixed.

The primary fracture line of a posterior tibial plateau fracture is in the coronal plane, and the main affected area is the rear [7]. Therefore, it is difficult to visualise through the anteromedial or anterolateral approach [8, 9]. The reduction and fixation of fractures require reduction and direct vision. In the case of instability of the knee joint caused by "Posterior Condylar Triad" combined with ACL injury, an additional anteromedial incision is needed to fix the protruding fractures between the condyles, which may face the problems of re-disinfection and repeated laying of surgical sheets. In addition, excessive concentrations of surgical incisions may increase the risk of wound complications. Previous studies have focused mainly on the surgical treatment of posterior tibial plateau fractures [10], but few have focused on combined ACL injury. This series of studies introduce a surgical strategy for treating "Posterior Condylar Triad" injury, which can avoid changes in body position and multiple disinfection arrangements during surgery, simplifying the surgical procedures. A lateral prone position was adopted, and the affected limb was rotated to perform three-incision surgical procedures. First, the knee joint was flexed, and the affected limb was internally rotated to treat the medial plateau fracture through an internal incision. Then, the affected limb is externally rotated with the fibula facing upwards, and the Frosch [11] approach is used to treat the lateral plateau fracture. Finally, the hip joint was externally rotated and abducted, and a small incision was made on the medial side of the patella to treat the anterior cruciate ligament avulsion fracture. Our centre used this surgical strategy to treat 11 patients with "Posterior Condylar Triad". This study aimed to explore and illustrate the advantages of this surgical strategy. We assume that this surgical strategy can simplify the surgical process, shorten the surgical time, and facilitate better patient recovery.

Patients and methods

This was a retrospective analysis of the clinical data of 213 patients with tibial plateau fractures who underwent surgical treatment at our centre from February 2017 to August 2020. After admission, all patients underwent standard X-ray and computed tomography (CT) for radiological examination. Twenty-eight patients were diagnosed with "Posterior Condylar Triad", of whom 10 patients with severe fractures in other areas were excluded, 4 patients with a history of surgical trauma or limb dysfunction on the same side of the lower limb were excluded, 2 patients with open fractures were excluded, and 1 patient who refused to cooperate during follow-up was excluded. Finally, 11 patients were included in this study and received complete follow-up. The demographic and preoperative data of the patients are shown in Table 1. All patients underwent surgery performed by an experienced orthopaedic surgeon. The patient used an internal incision and the Frosch approach to expose the tibial plateau condyle in a lateral prone position, while the anterior inner incision was used to fix the ACL injury. This study was approved by the Ethics Committee of Xi'an Honghui Hospital, and all patients included in the study signed written informed consent forms.

Operative planning and surgical technique

After anaesthesia, the patient was put in a prone position, and a pneumatic tourniquet was used at the thigh root after disinfection. During surgery, the internal incision, the Frosch approach, and the anterior medial patellar incision are sequentially used to treat fractures of three important structures. During the operation, only the affected limb needs to be rotated to meet the needs of each incision exposure.

Posterior medial tibial plateau Surgery is performed through a posterior medial incision in the case of flexion

Table 1 Basic data of patients in the "Posterior Condylar Triad" group

Patient	Age(years)	Sex	Location of Injury	Mechanism of Injury	Time from injury to operation(days)
1	36	Male	Left	Traffic accident	6
2	53	Male	Left	Traffic accident	4
3	51	Female	Left	Traffic accident	5
4	39	Female	Right	Traffic accident	11
5	56	Male	Left	Sports injury	4
6	43	Female	Left	Traffic accident	4
7	28	Male	Right	Fall	8
8	47	Male	Right	Sports injury	12
9	52	Female	Left	Traffic accident	4
10	37	Male	Left	Sports injury	3
11	44	Male	Right	Traffic accident	6

of the knee joint and internal rotation of the affected limb (Fig. 1a). The soft tissue is cut layer by layer, the medial head of the gastrocnemius muscle is pulled outwards, and the fracture of the posteromedial tibial plateau can be observed after peeling exposure. The joint and the blood stasis around the fracture were carefully removed, and then the fracture was reset. The posteromedial fracture was fixed with the posteromedial anti-sliding plate of the tibial plateau (Fig. 1b-d). After the wound was repeatedly rinsed, it was stitched layer by layer.

Posterior lateral tibial plateau Based on the lateral prone position, the affected limb is rotated outwards to make the fibula face upwards, and then the Frosch [11] approach is used to fix the posterior lateral platform (Fig. 1e). The skin, subcutaneous tissue and fascia were cut layer by layer along the posterior edge of the iliotibial tract and pulled forwards to expose the first window (the lateral surgical window). The tendon of the biceps femoris muscle is then exposed backwards, the common peroneal nerve is explored, the common peroneal nerve is pulled forwards and protected, the lateral head of the gastrocnemius muscle is pulled backwards, the second window (posterolateral surgery window) is exposed, the popliteus muscle is opened, the articular capsule is opened, and the split and collapsed joint surfaces are observed. After the fracture and surrounding blood clots and clots around the joint are cleared, the fracture is reduced. A window was opened on the tibial bone surface below the tibialis anterior muscle in the first window, a bone graft was inserted to restore the height of the joint surface, and the bone in the bone canal was implanted. The reduction of the fracture can be observed in the second surgical win-

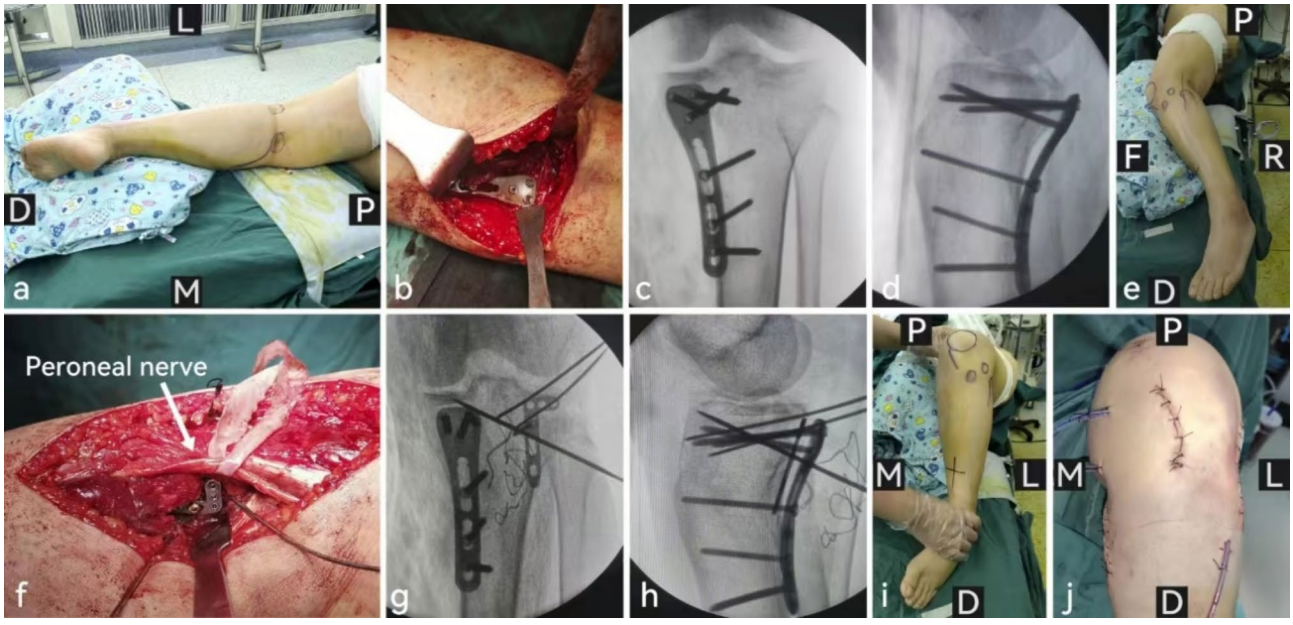

Fig. 1 **a**: During the surgical process, the medial plateau fracture was treated first, and the patient was placed in a lateral prone position; **b**: Treatment of posterior medial fractures through a posterior medial incision of the knee joint; **c-d**: Intraoperative fluoroscopy shows satisfactory reduction of the medial plateau fracture; **d**: Treatment of posterior lateral tibial plateau fractures via the Frosch approach on the posterior lateral side of the knee joint; **f**: "Two surgical windows" work together to fix the fracture; **g-h**: Intraoperative fluoroscopy shows satisfactory reduction and fixation of posterior lateral tibial plateau fractures; **i**: Treatment of anterior cruciate ligament avulsion fracture through the anterior medial incision; **j**:Final appearance photo of the surgical incision

dow. C-arm fluoroscopy revealed that fracture reduction was satisfactory, and the joint surface was flat. A miniature bone plate (Tianjin Zhengtian Company) was used to fix under the rear outer platform (Fig. 1f-h), the wound was repeatedly washed, and the plate was sutured layer by layer.

ACL injury Based on the patient's original position, the external rotation hip joint was abducted, and the knee joint was flexed. A surgical incision was made along the medial edge of the lower pole of the patella to the medial edge of the patellar tendon of the tibial tubercle (Fig. 1i-j). The soft tissue was cut layer by layer, the articular capsule was opened, the tibial articular surface was exposed, and the avulsion fracture of the anterior cruciate ligament insertion was observed. The bone canal on both sides of the avulsion fracture fragments was drilled, a wire rope was used to ride the surface of the avulsion fracture fragments, which was introduced into the bone canal, and finally, the wire rope was tightened to fix the fracture.

Postoperative treatment

All patients adopted a standard management mode after surgery, with intravenous use of cefuroxime antibiotics within 24 h after surgery to prevent infection. The use of antibiotics is extended in cases of redness, swelling, or abnormal exudation of the wound. The prevention of postoperative DVT depends on 5000 IU low-molecular-weight heparin injection and physical therapy. We encourage patients to exercise their knee joint range of motion (ROM) early after surgery when the pain is tolerable. With the help of CPM machines, passive knee joint movement begins on the day of surgery. Knee joint flexion should be within the 45° range 1 week after surgery and increase to 90° in the 2nd week after surgery. Patients should be encouraged to achieve a complete range of motion within 4 weeks after surgery.

Table 2 Postoperative follow-up data and knee function of patients

Follow up (months)	Union (weeks)	Final ROM (flex/ext)	Complications	Lysholm score	SF36 (mean)
18	14	126/5°	No	95	92.35
20	18	121/1°	No	90	76.55
16	16	114/6°	DVT	85	76.88
18	16	112/1°	Wound fat liquefaction	61	52.45
14	12	124/5°	No	100	94.75
14	16	120/4°	No	88	64.37
16	18	126/6°	DVT	82	72.36
18	17	120/4°	No	90	82.41
19	22	130/5°	No	100	93.66
17	20	115/0°	No	68	58.47
15	18	118/3°	No	95	82.35

Outcome evaluation

On the second day after surgery, the drainage tube was removed, and an X-ray examination of the knee joint in the anterior and lateral positions of the affected limb was performed. All patients were followed up at least once a month for the first three months and once every three months. If there are special circumstances, follow-up can be conducted at any time. Postoperative complications, including DVT, poor wound healing, deep infection, failure of internal fixation and loss of fracture reduction, were recorded. Postoperative functional evaluation was conducted through outpatient and telephone follow-up. The standard for fracture healing is that an X-ray examination can detect continuous calluses passing through the fracture end, and the fracture line is blurred or even disappears. Patients can walk with full weight on their lower limbs without tools. Loss of fracture reduction refers to misalignment of the tibial plateau joint surface that collapsed by more than 2 mm or more than 5° at the last follow-up compared with the first postoperative X-ray examination. The knee joint function of the patient was evaluated one year after surgery via the ROM, the Lysholm rating score [12], and the SF36 general health survey [13].

Results

All 11 patients in the study completed at least 12 months of follow-up, with an average follow-up time of 16.8 months, ranging from 14 to 20 months. Two patients experienced DVT after the operation; 1 patient experienced wound fat liquefaction and received regular dressing changes and other treatments, resulting in smooth wound healing. No patients reported serious complications, such as loss of fracture reduction, failure of internal fixation, or deep infection. Ultimately, all patients' fractures healed, with an average fracture healing time of 17.0 weeks, ranging from 12 to 22 weeks (Table 2). One year after surgery, all patients achieved good ROM and knee joint function, with an average ROM of 3.6 to 120.5° for the affected limb's knee joint; the average Lysholm score was 86.7, ranging from 61 to 100, and the average SF36 score was 76.96, ranging from 52.45 to 94.75.

Typical case: A 43-year-old female patient experienced a traffic accident while riding a two-wheeled motor vehicle, resulting in left knee pain and limited mobility. After completing the X-ray and CT examinations, the patient was diagnosed with (1) bicondylar fracture of the left tibial plateau and (2) avulsion fracture of the left anterior cruciate ligament of the knee. After receiving surgical treatment at our centre, the patient's function recovered well. Below is a detailed report (Fig. 2).

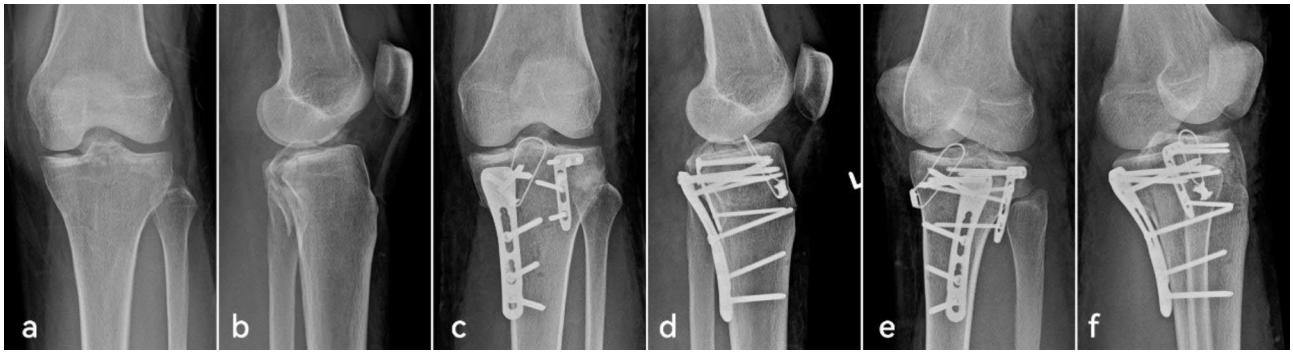

Fig. 2 **a-b**: Anterior and lateral X-ray images of the affected limb before surgery; **c-d**: Postoperative X-rays of the affected limb

Discussion

With the popularisation and continuous development of transportation, high-energy tibial plateau injuries are becoming increasingly common. The incidence of tibial plateau posterior condyle fractures is slightly lower than other types of tibial plateau fractures [4, 14]. However, as a special type of tibial plateau fracture, the "Posterior Condylar Triad" is not uncommon at our centre, which may be related to the widespread use of dual-wheeled electric vehicles in our region. The injury mechanism can be described as tibial plateau fractures caused by axial loading during knee joint flexion. When the degree of violence is greater, anterior dislocation of the tibia may lead to related cruciate ligament damage and even popliteal fossa vascular damage, which requires careful management [5].

The typical fracture morphology of "Posterior Condylar Triad" injury is posterior medial splitting combined with posterior lateral compression and ACL injury [4]. It is usually caused by high-energy injury and requires surgical open reduction and fixation under direct vision [15]. Unlike anterior and lateral fractures of the tibial plateau, which can be exposed and fixed through a standard anterolateral approach, posterior tibial plateau fractures are treated with a posterior surgical incision. After extensive exposure, the fracture is reduced and fixed under direct vision, avoiding the risk of damage to blood vessels and nerves [16]. Typically, we choose the Frosch approach and two posterior medial incisions to expose and fix posterior tibial plateau bicondylar fractures [11]. He et al. [10] proposed a posterior L-shaped single-incision approach to treat posterior tibial plateau bicondylar fractures, which achieved good clinical results. However, some studies suggest that a single incision can limit the exposure of a posterior condyle and that the need to open more flaps increases the risk of sural nerve injury [5]. This study used the posterior lateral Frosch approach and posterior medial incision of the knee joint to treat tibial plateau bicondylar fractures. In traditional surgery, regardless of the surgical approach used to expose the posterior part of the tibial plateau, most patients undergo surgery in a prone position [10, 17, 18], and the treatment of ACL injury requires an additional anteromedial incision, which means that patients need to change their position across a large range and multiple surgical procedures, which may increase the operation time (multiple applications of tourniquets) and increase the risk of anaesthesia. In response to this situation, our centre has proposed a surgical strategy for treating "Posterior Condylar Triad" injury, to simplify the surgical steps and avoid changing the patient's position on a large scale during surgery. A surgical preparation disinfection sheet can reduce and fix posterior tibial plateau bicondylars and prevent ACL injury.

Posterolateral tibial plateau fractures are difficult to expose, reduce, and fix through the anterolateral approach, which is quite challenging for orthopaedic physicians [5, 15]. The combination of the posterior lateral approach and the fibular head osteotomy is a traumatic surgery that carries risks [19]. Fortunately, in 2010, Frosch [11] proposed a surgical approach to treat posterior lateral tibial plateau fractures, which achieved good clinical efficacy by combining two surgical windows of a single skin incision to reduce and fix posterior lateral plateau fractures. The Frosch approach requires the patient to lie on their side and place a rolling pad below the knee joint to maintain a certain degree of inversion and increase the lateral space. During the operation of the lateral surgical window, the lateral position can be slightly raised, whereas during the operation of the posterior lateral surgical window, the lateral position can be slightly lowered. We performed triple-incision treatment for posterior condylar fractures in the lateral prone position and treated three injuries by rotating the affected limb, avoiding multiple disinfection procedures and simplifying the surgical process. For posterior lateral plateau fractures that are difficult to expose and handle, our method allows direct visualization of the collapsed posterior lateral plateau articular surface, monitoring the quality of reduction, and fixation with miniature steel plates beneath the fracture. Given the violent direction of the injury, this method of directly supporting and fixing the steel plate

on the back may be more compatible with biomechanical stability.

Numerous studies have shown a correlation between tibial posterior plateau bicondylar fractures and intercondylar protrusion fractures [20, 21]. These ligament structures play important roles in maintaining the stability of the knee joint, and surgical repair is required for injuries that affect the stability of the knee joint. Treating simple anterior cruciate ligament or posterior cruciate ligament injuries can include exploration and repair under arthroscopy [22, 23]. For tibial posterior plateau bicondylar fractures, although the fracture can be observed under arthroscopy, for injuries with incomplete posterior cortical bone, satisfactory reduction may not be achieved. In addition, a multicentre clinical study has shown that open reduction and internal fixation have better clinical outcomes than arthroscopic fixation for acute tibial eminence fractures in adults [24]. In this study, we performed an additional incision on the anteromedial side of the knee joint to fix anterior cruciate ligament injury.

The literature reports that there is a certain risk of infection after surgery for tibial plateau fractures [25, 26]. The "Posterior Condylar Triad" injury is a more challenging type, with more severe injuries and more complex fractures. This means that the risk of infection after surgery for the "Posterior Condylar Triad" may be greater. A prolonged operation time, repeated application of a tourniquet and increased bleeding may increase the risk of infection. In our study, one patient experienced fat liquefaction and successfully healed after prolonged dressing changes, without complications such as wound or deep infections. On the one hand, our sample size is small, and large sample studies may yield different results. On the other hand, our surgical strategy can avoid changing the patient's position during the operation without the need for secondary sheet laying, which avoids the secondary use of tourniquets, shortens the operation time, and reduces the risk of infection after the operation. Three separate incisions were used to independently address the three "Posterior Condylar Triad" injuries, and the surgical strategy was clear. This also requires the operator's serious experience and 3D anatomical thinking.

There is a risk of loss of knee joint mobility after surgery for tibial plateau fractures [27, 28], and early exercise for joint mobility is necessary. Notably, some studies have reported that the risk of postoperative flexion contracture is greater in patients with tibial plateau fractures than in those with other knee joint injuries. Therefore, attention should be given to the recovery of postoperative knee joint flexion function and the exercise of postoperative knee joint extension function. In our study, all patients began passive knee joint movement with machine assistance on the day after surgery, informing each patient of the importance of postoperative rehabilitation exercise. At the 1-year follow-up, the average range of knee joint movement for 11 patients was 3.6 to 120.5°. The average Lysholm score was 86.7, ranging from 61 to 100. The average SF36 score was 76.96, with a range of 52.45 to 94.75. All patients achieved good knee joint function.

This study also has certain shortcomings. First, the number of cases was relatively small, and a control group was lacking. Studies with large samples and multiple centres may involve other situations. Second, this retrospective study inevitably leads to selection bias and interferes with the final research results. Finally, bilateral condyle fracture of the posterior lateral tibial plateau requires exposure through the Frosch approach, which requires the surgeon to fully understand the anatomical structure of the posterior lateral knee joint. Only experienced surgeons can perform this surgery due to a steep learning curve.

Conclusion

The "Posterior Condylar Triad" is a serious injury, and traditional surgical strategies require lying prone before lying supine. Our centre proposed a simple surgical strategy to avoid changing the body position across a large range during the operation, shorten the operation time, avoid multiple surgical sheets, and use tourniquets many times; moreover, three separate incisions can independently address the three injuries of the "Posterior Condylar Triad", and the surgical strategy is clear. This helps patients achieve better clinical outcomes.

Supplementary Information

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Supplementary Material 1

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Author contributions

Hongfei Qi and Ming Li were responsible for the study design, the definition of intellectual content, and the literature research. Chengcheng Zhang and Bo Wu analysed and interpreted the data. Hongfei Qi drafted the manuscript. Yao Lu and Yu Cui revised the manuscript. Zhong Li is responsible for coordinating, guiding, and correcting some of the difficulties in research process. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Human ethics and consent to participate
This study was performed in accordance with the principles of the Declaration of Helsinki. This study was approved by the ethics committee of Hong Hui Hospital, Xi'an Jiaotong University (Xi'an, Shaanxi, China; 20170127). All patients provided informed consent before participation in the study.

Consent for publication
The publication of any individual or any data of any person in this article was approved by the individual.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

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