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Analysis of Surgical Techniques and Therapeutic Effects for Hyperextension Tibial Plateau Fractures

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Abstract: *Objective:* To explore the surgical techniques and clinical efficacy of plate fixation for hyperextension tibial plateau fractures. *Methods:* A retrospective analysis was conducted on 20 patients with hyperextension tibial plateau fractures who underwent surgery in our hospital from January 2018 to October 2022. The operation time, hospital stay, preoperative and postoperative posterior tibial slope angles, knee function score (HSS), and postoperative complications were recorded. *Results:* All patients were effectively followed up for at least 6 months, with an average follow-up of 14.6 months. The average operation time was 153 minutes, and the average hospital stay was 18.7 days. The average preoperative posterior tibial slope angle improved from -3.7° to 7.3° postoperatively ($P < 0.05$), with a statistically significant difference. At the last follow-up, the HSS score was 81.2. One case of incision infection was reported, with no other serious complications. *Conclusion:* Hyperextension tibial plateau fractures present a significant clinical challenge. Strong fixation with a plate, restoration of the posterior tibial slope angle, and maintenance of knee joint stability provide an effective treatment approach for hyperextension tibial plateau fractures.

Keywords: Hyperextension tibial plateau fractures; Surgical efficacy analysis; Plate fixation

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1. Introduction

Tibial plateau fractures pose a significant challenge in clinical treatment, and hyperextension tibial plateau fractures represent a unique subtype. The primary injury mechanism involves an external force applied to the anterior tibial plateau while the knee is in an extended position, with the foot serving as the fulcrum. This results in a distinct fracture pattern characterized by anterior compression and posterior opening, often accompanied by severe soft tissue injuries and complications, making it a current research focus [1]. Without timely intervention, fracture healing may be compromised, leading to difficulties in restoring knee joint function. This study retrospectively analyzed 20 cases of hyperextension tibial plateau fractures treated with plate fixation, all of which achieved favorable outcomes. The findings are reported below.

2. Materials and methods

2.1. Baseline data

This study retrospectively analyzed 20 patients with hyperextension tibial plateau fractures who underwent surgical treatment in our department from January 2018 to October 2022. There were 10 males and 10 females, aged between 29 and 64 years old, with an average age of 53.3 years old. Injury mechanisms included 12 car accidents, five falls from heights, and three heavy object injuries. Among them, five cases were complicated with fibular head fractures, one case with femoral condyle fracture, one case with popliteal artery injury, four cases with ligament and posterolateral complex injuries around the knee joint, and two cases with patellar fractures. There were 10 cases involving bilateral platform fractures, eight cases of lateral platform fractures, and two cases of medial platform fractures.

Inclusion criteria: Patients diagnosed with hyperextension tibial plateau fractures based on medical history and imaging examination. Exclusion criteria: (1) Conventional flexion-type tibial plateau fractures; (2) Old tibial plateau fractures; (3) Incomplete clinical data or loss to follow-up.

2.2. Surgical method

The position of the fracture was carefully analyzed based on preoperative radiographs, CT, and MRI. The procedure was performed under general anesthesia with a tourniquet. For fractures involving only the medial condyle, a direct medial incision was used, and after protecting the pes anserinus tendons, reduction was performed, followed by fixation with a plate or a plate-assisted screw. For isolated lateral tibial plateau fractures, an anterolateral proximal tibial incision was made, and the knee was flexed. The lateral joint capsule was incised, a meniscal retractor was inserted, and the lateral meniscus was suspended. Under direct visualization, the fracture fragments were exposed, and the posterior tilt of the articular surface was reduced first using a pry or push technique to correct anterior tilt. The depressed articular surface fracture was then reduced, and an allogeneic bone graft was implanted. Temporary fixation was achieved with Kirschner wires, and a rafting plate was placed laterally for fixation.

For fractures involving both condyles, a dual-incision approach was used. The lateral incision was routinely made through an anterolateral proximal tibial approach, while the medial incision was chosen based on the location of the medial tibial plateau fracture—either a posteromedial or slightly medial approach. The distance between the two incisions was maintained at a minimum of 7 cm. Under direct visualization through the dual incisions, mutual assistance was provided during the reduction process. The simpler fracture side was reduced first to restore the lower limb alignment, correct the anterior tilt of the tibial plateau, and elevate the collapsed articular surface. After bone grafting, Kirschner wires were used to maintain reduction, and both medial and lateral rafting plates were applied for fixation. Intraoperative fluoroscopy was performed to assess the alignment of the proximal tibia, the restoration of the plateau line, and the correction of joint surface collapse. A lateral fluoroscopic view was used to evaluate the restoration of the tibial posterior slope. Additionally, the surgeon conducted lateral stress and hyperextension tests on the knee joint to determine postoperative stability.

2.3. Postoperative treatment

Postoperatively, the patient was elevated, and ice therapy was applied for swelling reduction and pain relief. Dressing changes were reinforced. If no ligament repair around the knee joint was required, the patient was encouraged to begin knee flexion exercises within one week. If ligament repair had been performed, the functional exercise period was extended to three weeks. The patient was encouraged to walk with crutches. Radiographic follow-up was conducted at three months postoperatively, and if fracture healing was confirmed, the patient was encouraged to begin weight-bearing walking.

2.4. Evaluation indicators

The operative time and follow-up data were recorded. Standard radiographs were used to assess the restoration of the tibial posterior slope. The knee function was evaluated based on the Hospital for Special Surgery (HSS) score, with assessments conducted at three months and at the final follow-up.

2.5. Statistical analysis

Data were processed using SPSS21.0 statistical software and analyzed using an independent samples *t*-test. A *P*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Postoperative outcomes

All cases were followed up for at least 6–23 months, with an average of 14.6 months. The operation time ranged from 95 to 460 minutes, with the longest duration being 460 minutes. Due to injury to the popliteal artery, after fracture fixation during surgery, the patient was repositioned in the prone position to repair the damaged popliteal artery. Concurrent repair of peri-knee ligament injuries was performed in four cases. Additionally, fixation of patellar fractures was conducted in two cases, femoral condylar fracture in one case, and fibular head fracture in one case. The average operation time was 153 minutes. The hospital stay ranged from 8 to 32 days, with an average of 18.7 days. No early postoperative complications, such as incision infection, skin necrosis, or nerve injury, were observed. During follow-up, no late complications, such as internal fixation failure, were reported.

3.2. Radiology assessment

The primary evaluation focused on the restoration of the tibial posterior tilt angle. The preoperative angle of -3.7° was corrected to 7.3° postoperatively ($P < 0.05$, statistically significant). At the final follow-up, the angle was measured at 6.8°.

3.3. Functional assessment

The HSS knee scoring system was used for functional evaluation. The average score was 75.6 at three months postoperatively and 81.2 at the final follow-up.

4. Discussion

4.1. Characteristics of hyperextension tibial plateau fractures

Due to its unique injury mechanism, hyperextension tibial plateau fractures have a relatively low clinical incidence. The definition of knee joint hyperextension injury was first proposed by Nagel *et al.* in 1977 [2]. This injury was referred to as a "dashboard injury" of the knee joint. Its characteristics include an anteriorly directed force leading to anterior fracture compression and posterior fracture opening. In severe cases, the proximal tibia, along with the femur, may shift forward as a whole, resulting in more severe soft tissue tension injuries to the posterior structures. For patients with hyperextension tibial plateau fractures, both soft tissues and neurovascular structures are affected. Therefore, during surgical treatment, special attention must be given to protecting vital structures such as nerves and blood vessels, significantly increasing the complexity of the surgical procedure [3]. In this case series, one instance of popliteal artery injury and various ligament injuries around the knee joint were observed, all of which were repaired during the initial surgery. Therefore, for the treatment of such patients, the focus should be placed not only on the assessment and management of the fracture but also on the repair of soft tissues to prevent severe postoperative complications.

4.2. Selection of surgical approach

The fundamental principle in selecting a surgical approach is to ensure adequate exposure of the tibial plateau fracture [4]. This allows for direct visualization during reduction, and in combination with the stability of fracture fragment fixation, knee joint reconstruction can be completed to ensure its overall stability [5]. However, it should be noted that during the reconstruction phase, the procedure must be performed with the assistance of screws and plates [6]. It has been observed that the rational selection of a surgical approach significantly affects the quality of tibial plateau fixation and the prognosis [7]. Currently, for complex bicondylar hyperextension tibial plateau fractures, some researchers [8] have adopted a single anterior approach with broad exposure of the anterior plateau, achieving favorable clinical outcomes. However, an additional incision is often required for supplementary fixation of the posteromedial aspect. In clinical practice, the dual-incision approach, exposing both the medial and lateral sides, is more commonly used. This technique is relatively straightforward, ensures sufficient width of the skin flap between the two incisions, and allows for proper reduction of both condyles, enhancing fixation effectiveness and reducing the risk of surgical complications [9]. In this case series, a dual-incision approach was used in 10 cases of complex bicondylar fractures, with no postoperative complications such as incision necrosis or infection.

4.3. Reduction techniques

Reduction is the most challenging aspect of hyperextension tibial plateau fractures and the key to surgical success. In the reduction of complex bicondylar hyperextension tibial plateau fractures, not only must lower limb alignment be corrected to address varus and valgus deformities, but the anterior tilt of the tibial plateau must also be adjusted to a posterior tilt to ensure sagittal plane stability. It was reported by Kang *et al.* [7] that hyperextension tibial plateau fractures were reduced under fluoroscopic guidance using limited open assistance and traction, with satisfactory postoperative outcomes. Wang and Zhang [10] reported that excellent results were achieved in 15 patients through reduction methods that utilized the patient's own leg gravity, arthroscopic assistance, or leverage techniques. In our technique, bilateral incisions were used for exposure, and the knee joint was flexed with padding placed underneath. When posterior displacement of the lateral tibial plateau was involved, bilateral incisions were extended to the posterior aspect. The method described by Chu *et al.* [11] was employed to expose the posterolateral structures, allowing for continuous exposure to the posterolateral region, where an acetabular retractor was inserted and maintained in place using leverage. Anteriorly, a row of Kirschner wires was inserted beneath the articular surface. With one assistant providing traction to maintain varus and valgus alignment, another assistant applied cranial traction to the Kirschner wires to maintain the posterior tilt of the plateau. Once successful reduction was achieved, temporary fixation was performed with

Kirschner wires, followed by bone grafting and final fixation with medial and lateral plates to complete the surgery.

5. Conclusion

Hyperextension tibial plateau fractures present significant clinical challenges. Precise preoperative incision design, protection and repair of soft tissues, proficient intraoperative reduction techniques, and strong plate fixation are essential to ensuring favorable postoperative outcomes.

Disclosure statement

The author declares no conflict of interest.

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