CLINICAL ARTICLE

Modified Anatomic Locking Plate for the Treatment of Posteromedial Tibial Plateau Fractures

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Objective: To evaluate the safety and clinical efficacy of a modified anatomic locking plate for the treatment of posteromedial tibial plateau fractures.

Methods: A retrospective study was performed in our department. Between January 2014 and February 2017, 11 patients with posteromedial tibial plateau fractures underwent surgery with the new anatomic locking plate for the posteromedial tibial plateau via the posteromedial approach. The study included 7 male and 4 female patients, with a mean age at the time of the operation of 39 years. During surgery, operation time and blood loss were recorded. Clinical evaluation was performed using the Tegner–Lysholm functional score, the Rasmussen functional score, and the Rasmussen anatomical score.

Results: The mean follow-up time of the study was 35 months. The mean interval between the time of injury and the surgery was 7.4 days. Radiological fracture union was evident in all patients at 14 weeks. During surgery, the blood loss ranged from 50 to 150 mL, and the duration ranged from 55 to 90 min. The Tegner–Lysholm functional score ranged from 80 to 96 at the final follow up. Moreover, the final Rasmussen functional score ranged from 25 to 28, and the Rasmussen anatomical score ranged from 15 to 18. The mean knee arc of motion was 137° (range, 122°–153°). Symptoms of knee instability or severe pain were not found in any cases. No flexion contractures or extensor lag was seen. No infection, deep vein thrombosis, or graft site morbidity was seen at the follow up. No case of reduction loss or internal fixation failure was reported during the follow-up.

Conclusion: With the clinical data of the small-sample-size population (11 patients) during a 19 to 60-month follow-up, the modified anatomic locking plate for the posteromedial tibial plateau proved to be safe and effective and is an adequate fixation method for the treatment of posteromedial tibial plateau fractures.

Key words: Anatomic locking plate; Posteromedial approach; Posteromedial tibial plateau fractures

Introduction

The increase in frequency of high-energy trauma and fragility fractures has led to more complex tibial plateau fracture patterns. They often present as a diagnostic and interventional challenge that requires early and efficient intervention to minimize long-term complications of joint dysfunction and early osteoarthritis. Early anatomical reduction and stable internal fixation, followed by early mobilization is the principle for management of tibial plateau fractures1,2.

Fractures that involve the posteromedial tibial plateau are often encountered after high-energy injuries and require special attention when developing a preoperative plan3,4. Schatzker5 believed fractures that occurred in the medial plateau carried the worst prognosis, likely due to the high variability and combination of bony and soft tissue injuries. Thus, recent attention on the occurrence of posteromedial fracture fragments in complex tibial plateau fractures underscores the growing appreciation for the difficulty in treating these fracture patterns5,6. In a cadaveric model of a posteromedial tibial plateau fracture7, fracture fragments studied displaced with knee flexion, even at low flexion angles. Although such fragments may initially seem nondisplaced...

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after injury, posteromedial fragments similar to these tested are likely to displace during knee range of motion exercises in non-weight-bearing conditions. As a result, this fragment should be considered inherently unstable.

Some authors recommend a separate fixation for this fragment to maintain reduction, although lateral approaches for stabilizing medial tibial plateau fractures have had excellent early clinical outcomes. They suggest that these medial-sided fractures often require a separate medial approach and plating strategy because an isolated lateral plate will not rigidly fix an unstable medial plateau. On average, the fragment is described to encompass approximately 25% of the joint surface, with a sagittal angle around 73°–80° and around 45 mm in height. The vertical fracture pattern suggests shear forces and instability that are not necessarily addressed by the current laterally based approaches to fixation. One study by Higgins et al. argues that dual-plate fixation results in improved stability compared with lateral locked plating alone in bicondylar tibial plateau fractures. In a biomechanical study in composite tibiae, Yoo et al. compared load to failure in locked and non-locked single and dual plating systems. The dual plating construct tolerated higher loads, with the authors hypothesizing that the lateral locking screws insufficiently reduce the posteromedial fragment.

However, the commonly used posteromedial plate is either non-locked, and lacks angular stability, or has a proximal part that is not wide enough to wrap the entire posteromedial fragment, with contouring being difficult during surgery. Therefore, we modified a specialized anatomic locking plate for posteromedial tibial plateau fractures. The purpose of the study was: (i) to describe the details of an innovative anatomic locking plate for the posteromedial tibial plateau; (ii) to introduce the surgical method for treating posteromedial tibial plateau fractures with this modified plate; and (iii) to evaluate the safety and clinical efficacy of the innovative plate. To simplify the research, we retrospectively studied 11 patients with posteromedial tibial plateau fractures in our trauma center (lateral fixation was not needed).

Materials and Methods

General Data

The presented retrospective study was performed with the approval of our institution’s human subjects review board. Patients with a posteromedial tibial plateau fracture that underwent surgery with the anatomic locking plate for the posteromedial tibial plateau between January 2014 and February 2017 were included in our study.

The exclusion criteria were: (i) severe open fractures; (ii) multiple traumas; (iii) osteofascial compartment syndrome; (iv) pathologic fractures; (v) autoimmune diseases; (vi) blood disorders; and (vii) less than 18 months of follow-up.

Therefore, clinical documents and radiograph images of 11 included patients with a posteromedial tibial plateau fracture were reviewed in detail. Preoperative and postoperative plain X-rays as well as preoperative CT scans were obtained for all patients. All injuries resulted from high-energy traumas, including battery bike-related accidents (8 patients), falls from an elevated height (2 patients), and sport-related injuries (1 patient). Injuries were classified into Schatzker type IV fractures and AO/OTA 41 type B fractures (partial articular). According to the CT scan and reconstruction images, the main fragments were located in the posterior half of the medial condyle and/or a fracture line impacted the posterior aspect of the medial plateau. According to the three-column classification, all cases were fractures of the posteromedial column.

Every surgery was performed after the soft tissues were stabilized. For patients who also had severe soft tissue injuries, such as tense swelling, distal bony traction and splints were applied. The mean interval between the time of injury and the surgery was 7.4 days (range, 2–12 days). The surgeries were performed by three experienced surgeons (led by Dr Yu) who specialized in knee surgery or trauma.

Surgical Technique and Rehabilitation

Step 1: All operations were performed using spinal anesthesia or general anesthesia. The patient was placed in prone position on a radiolucent table, and the lower limb tourniquet was inflated.

Step 2: To address the posteromedial tibial plateau fracture site, a gentle S-shaped curvilinear incision was placed on the posteromedial aspect of the knee. After sharp dissection of the subcutaneous tissue, the popliteal fascia was incised, preserving the small saphenous vein as well as the medial sural cutaneous nerve. The medial head of the gastrocnemius muscle was then mobilized and retracted laterally. The oblique tendinous expansion of the semimembranosus tendon was identified and retracted medially. The superior border of the popliteal muscle was identified and the muscle was dissected subperiostially to allow for posteromedial fracture site visualization. An arthrotomy was performed to assess the reduction of the articular surface at the level of the main fracture.

Step 3: After preliminary fixation of the fracture fragment using multiple K-wires, reduction was controlled by fluoroscopy in the frontal and lateral view. The defect was packed with artificial bone graft if needed. Step 4: At this point, the modified plate was placed to stabilize the fragment and compression was applied by placing compression screws in a posteromedial–anterolateral direction. Step 5: The quality of joint reduction, location of the plate, and length of the screws were confirmed under fluoroscopic guidance. Physical examination of the knee stability was routinely conducted to exclude ligament injury. Then, the subcutaneous tissue and skin were closed over suction drains.

Mobilization of the knee joint began immediately after surgery. In addition, a daily injection of 4100 IU low
molecular heparin was applied to prevent deep vein thrombosis. All patients achieved 90° in flexion prior to discharge, usually 5–10 days after surgery. The knee range of motion, as well as muscle strength was increased immediately after surgical wound healing. Patients were initially treated as non-weight-bearing for 12 weeks to avoid early loss of reduction. Depending on radiographic signs of healing, partial weight-bearing was allowed and rapidly advanced to full weight-bearing as tolerated by the patients.

Clinical evaluation was performed using the Tegner–Lysholm functional score, the Rasmussen functional score, and the Rasmussen anatomical score. Reduction loss is an important indicator for measuring the effectiveness of internal fixation. The definition of reduction loss after tibial plateau fracture surgery is still controversial. Therefore, we used a method applied by Kim et al.6 and Weaver et al.15 Reduction loss was defined as a depression of the articular surface that is greater than 3 mm compared to the immediate post-operative radiographs, a condylar widening that is greater than 5 mm, and an alignment change that is greater than 5° towards the varus or valgus. Furthermore, reduction losses that occurred through loosening or breakage of the plate were also included.

**Tegner–Lysholm Functional Score**
The Tegner–Lysholm functional score is one of the most frequently used assessment tools for the functional outcomes of knee injury. Eight factors are rated to produce an overall score on a point scale of 0 to 100. The factors of limp, support, and locking are worth a potential 23 points, pain and instability 25 points each, swelling and stair climbing 10 points each, and squatting 5 points. Then an assignment is given as “excellent” for 95 to 100 points, “good” for 84 to 94 points, “fair” for 65 to 83 points, or “poor” for less than 65 points.

**Rasmussen Functional Score**
The Rasmussen functional score is used to evaluate knee function primarily, with special attention paid to the single plane stability and rotation stability. It consists of five categories, including pain (6 points), walking capacity (6 points), extension (6 points), total range of motion (6 points), and stability (6 points). The total score is the sum of these five items, and the higher scores indicate greater function. A score of 30 points is defined as normal, 27–30 as excellent, 20–26 as good, 10–19 as fair, and 6–10 as poor.

**Rasmussen Anatomical Score**
The Rasmussen anatomical score is a principal tool to evaluate reduction quality of tibial plateau fractures on radiological images after surgery. It consists of three categories, including depression (6 points), condylar widening (6 points), and angulation (6 points). A score of 18 points is defined as excellent, 12–17 as good, 6–11 as fair, and 0–5 as poor.

**Results**

**Patients**
All 11 patients underwent surgery with the anatomic locking plate for the posteromedial tibial plateau. Of the patients, 7 were male and 4 others were female. The mean age at the time of the operation was 39 years (range, 22–69 years). In addition, all patients were followed up by clinic review. The mean follow-up period was 35 months after the surgery (range, 19–60 months). The plate details were as follows.

**Plate Details**
According to the structure of the posteromedial tibial plateau in a Chinese population and anatomic locking plates for the posteromedial tibial plateau fracture accessible, we made modifications to obtain a new model (Fig. 1). It was oblique “T” shaped to fit the posteromedial structure of the tibial...
plateau, with a wide proximal end that achieved excellent wrapping of the posteromedial condyle. It had six 30° universal locking holes in two rows to ensure precise screw insertion in the head, which fixed the plate with the posteromedial side of the tibial plateau. Four proximal row screws paralleled with the plateau could buttress powerfully, having a "raft effect." Tiny holes in the top of the plate head were used in cases of temporary fixation or comminuted fragment fixation by K-wire insertion and capsule sutures. It was also designed with a low profile and beveled edges. After we obtained the plate patent, the plate was made by a qualified custom-made plate manufacturer (WASTON Medical Appliance, China). The whole structure was made of titanium. Finally, the plates obtained were completely consistent with our design in terms of their shape and distribution and the orientation of the screws. Our previous finite element study had identified the reliable stress distribution and stability.

**Operation Results**

During surgery, time and blood loss were recorded. The mean blood loss was 75 mL (range, 50–150 mL). The mean operation duration was 62 min (range, 50–90 min). Two patients' anterior cruciate avulsion fractures were fixed with either a cable or a screw during the operation (Fig. 2). Articular surface reduction was classified as anatomic in 9 patients and acceptable in 2 patients based on a combination of direct interoperative view and fluoroscopy.

**Clinical Improvements**

In all 11 patients, radiological fracture union was evident at 14 weeks (range, 11–18 weeks). The final follow-up report of knee function was performed by the Rasmussen anatomic score and Lysholm function score. The Rasmussen anatomic score was 16 (range, 15 to 18), with excellent reduction quality achieved in 1 case (9.1%) and good reduction quality achieved in all others (90.9%). Symptoms of knee instability or severe pain were not found in all cases. The mean knee arc of motion was 137° (range, 122°–153°).

**Complications**

No evidence of knee instability was observed. No flexion contractures or extensor lag was seen. No infection, deep vein thrombosis, or graft site morbidity was observed at the follow-up. Specifically, no case of reduction loss or internal fixation failure was reported.

**Discussion**

Medial tibial plateau fractures are caused by a high-energy mechanism of injury and account for approximately 10% of all tibial plateau fractures. In addition, there can be a transient knee dislocation that can cause tears of the cruciates and the MCL, resulting in both valgus and anteroposterior instability. It is generally understood that Schatzker type IV fractures are high energy injuries leading to excess axial load combined with varus stress on the knee.

Several retrospective studies identify the posteromedial fragment in 29%–74% of all bicondylar tibial plateau fractures, an incidence that until recently was largely underestimated if addressed at all. In morphology studies based on CT, the bone blocks of posteros-medial condylar splits were found to be larger while those of posterolateral condylar were smaller. Posterosmedial fractures are highly unstable injuries with a large posterosmedial condyle fragment prone to posterior shearing and the risk of popliteal vessel injury. Cuellar et al. report that although they may initially seem nondisplaced after injury, posterosmedial fragments are more likely to displace during knee range of motion exercises in non-weight-bearing conditions. Some authors recommend a separate fixation for this fragment to maintain knee stability.

Fractures of the anterior and lateral aspect of the tibial plateau and undisplaced posterior fragments can usually be stabilized through a standard anterolateral approach. However, reduction loss that received anterolateral and medial plate fixation in bicondylar tibial plateau fractures was reported to be as high as 48.5%. There was no plate located at the posterior aspect that could be regarded the possible cause of the high rate of reduction loss. The screw cannot rigidly fix the posterosmedial fracture fragments. When fixed with a lateral locking plate, the lateral screws are positioned in the coronal plane and are frequently parallel to the fracture line, which may fail to capture the posteromedial fragment. In a study of factors related to reduction loss in bicondylar tibial plateau fractures, Weaver et al. reported that posterosmedial coronal fractures were associated with a high rate of reduction loss. Operative treatment of this type of fracture requires direct exposure and posterior stabilization.

**Approaches for Posterosmedial Tibial Condyle**

Although many approaches have been reported to achieve appropriate exposure, there is no general consensus. As for split fractures of the posterosmedial condyle, traditionally, the anteromedial approach has been adopted to expose the medial posterior condyle. In this approach, the fracture site is shown from the lateral side; however, the medial collateral ligament (MCL) is easily injured during dissection. When dissecting over a large area, flap margin necrosis is likely to occur. Moreover, the limited exposure also adds to the difficulty of reduction and fixation. The Lobenhoffer approach allows for visualization of the posterosmedial tibia and, if needed, can be applied laterally to
allow access to the posterior and even posterolateral tibia. The neurovascular bundle is not exposed and, therefore, is protected within the posterior soft tissues. The visualization provided by the Lobenhoffer approach allows for accurate reduction of the extraarticular portion of the fracture followed by placement of a posterior antiglide plate.

Currently, a posteromedial approach is widely applied in the treatment of posterior medial condylar fractures. Satisfactory results have been achieved using this incision to expose the posterior medial condylar tibial plateau fracture.

The posteromedial key fragment may displace distally and medially, especially when the knee is flexed, so a
Modified Anatomic Locking Plate for Posteromedial Tibial Plateau

The modified locking plate for the posteromedial tibial plateau is also anatomically designed. It fits the posteromedial structure of the tibial plateau and reduces the need for plate contouring during surgery, potentially leading to shorter operative duration, lower blood loss, and decreased plate failure. Our early comparative finite element study showed that it had superior performance in postero-internal tibial plateau fracture fixation and could serve as a suitable clinical alternative fixation method. The new anatomic locking plate fits anatomically, requiring no additional manipulation. In addition, the proximal part of the plate is more scientific and reasonable. It has six 30° universal locking holes to ensure precise screw insertion in the head, which fixes the plate with the posteromedial side of the tibial plateau. The wide proximal part can achieve excellent wrapping of the posteromedial condyle. Four proximal row screws paralleled with the plate could buttress powerfully, having a “raft effect,” which provides firm strength holding the articular surface. Not only an effective buttress can be achieved, but also compression fixation of large fragments. According to the Rasmussen functional/anatomical score, all patients achieved “perfect or good” results. The plate was proven to be safe and effective in a small-sample-size population (11 patients) during a 19 to 60-month follow-up.

Limitations of the Study

There are some limitations in our study. The research is based on a retrospective clinical evaluation with a relatively small sample size. A large-sample study needs to be conducted to prove the efficacy of the fixation. In addition, further biomechanical studies are required to evaluate buttress performance, compression forces, and comparative features against traditional buttress line plates via the postero-medial approach. Finally, reduction loss was evaluated through simple radiographs in this study. CT is required to more accurately evaluate the existence of reduction loss, but in the present study it was impossible to perform follow-up CT for all patients.

Conclusion

In conclusion, the modified anatomic locking plate for the posteromedial tibial plateau was proven to be safe and effective in a small-sample-size population (11 patients) during a 19 to 60-month follow-up. The plate fit the irregular posteromedial tibial plateau well, without requiring additional contouring. Therefore, this new plate may be a favorable internal fixation choice for treatment of posteromedial plateau fractures.

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