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Flexion-valgus unicondylar tibial plateau depression fracture pattern: Classification and treatment

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ABSTRACT

Purpose: The authors have identified a subset of unicondylar tibial plateau depression fracture patterns caused by a flexion-valgus force. The purpose of this study was to describe this fracture pattern and suggest a modified lateral approach that may allow for improved reduction and stabilization.
Methods: The preoperative radiographs and CT scans of 102 patients who sustained unicondylar tibial plateau fractures (OTA 41B) were reviewed. Twenty-six fracture patients had posterolateral (PL) tibial plateau depression fractures. By medical record review and telephone follow-up, the injury mechanism of the 22 unicondylar tibial plateau fractures was confirmed as a flexion-valgus force. The radiographic features of those cases were analyzed and measured. To address this specific fracture pattern, a modified approach combined with a novel intra-articular osteotomy was applied.
Results: According to the morphological characteristics, this tibial plateau fracture pattern could be divided into two subtypes: type A was a confined, basin-like articular surface depression fracture located in the PL quadrant, and type B was a cancellous fracture involving the PL tibial plateau resulting in a decrease in the posterior slope. One radiographic hallmark of this fracture pattern is an anatomically or a mechanically intact posterior column wall. The novel approach was applied to both types. The postoperative radiographic measurements revealed excellent reduction quality. On axial scans, the distance between the most posterior rafting screw and the tangent line of the tibial plateau rim was 3.0 ± 2.07 mm (from -1.9 to 4.3), and the angulation between them was $8.9 \pm 3.02^{\circ}$ (from -7.3 to 15.6). These results indicated excellent PL quadrant coverage from the rafting screws.
Conclusion: Flexion-valgus force-induced unicondylar tibial plateau depression fracture is a unique injury pattern. We suggest a novel surgical approach to address this injury's key features, which may facilitate exposure and enhance fixation strength.

Introduction

Fractures of the posterolateral tibial plateau (PTP) are persistently challenging for orthopedic surgeons. Surgical access is technically demanding due to their deep location. A previous study reported that fractures of this region constitute only 7% of all tibial plateau fractures [1]. Anwar suggested 3 different forms of PL injury but did not analyze and summarize their features [2]. Split fracture (Schatzker type I) and split-depressed fracture (Schatzker type II) of the PTP in bicondylar tibial plateau fracture have been studied radiographically [3], biomechanically [4] and clinically [5]. However, the pure depression fracture (PDF) involving the PTP in unicondylar tibial plateau fracture has not been fully investigated.

Recent studies suggested that the incidence of this distinct fracture is increasing [6,7]. We believe this increase merits particular attention from treating surgeons. The first reason is that no classification system has comprehensively described the nature of the PDF involving the PTP. The Schatzker classification scheme is based on plain radiography and does not encompass the PL quadrant of the tibial plateau [8]. The AO/OTA classification system classifies depression fracture of the tibial plateau into 41-B-2.1 to 2.4 according to its site. This classification system emphasizes the important function of the PTP as bearing load when the knee flexes beyond 90° [9]. However, the pathoanatomical characteristics of the pure depression affecting this region have not been comprehensively investigated. According to the three-column theory, the tibial plateau articular surface

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depression fracture without cortical disruption is defined as a zero-column fracture by Luo [6]; however, the cause of injury and treatment strategy have not been fully assessed.

Furthermore, thorough acknowledgment of the fracture pattern is an essential prerequisite to a favorable treatment result. For example, the morphology and extent of the articular surface damage determines the surgical strategy, reduction techniques and prognosis. The status of the adjacent bone structures, such as breaching of the column cortex, will influence the surgical approach selection. We believe detailed analysis and judicious classification will improve our understanding of this special fracture pattern.

Finally, numerous approaches have been developed for split-depression fracture of the PTP. Exposure, manipulation and reduction of the depressed articular fragment are performed routinely through the cortex fracture line. However, this maneuver is not suitable for PDF because the column cortex of the lateral plateau is anatomically or mechanically intact. Window osteotomy through the metaphyseal cortex to elevate the depressed articular fragment is a classic reduction technique [10]. However, this posterior-based approach requires extensive soft tissue dissection, compromises the mechanical property of the PL column and is not suitable for an articular depression progressing to the AL quadrant. Furthermore, the indirect reduction maneuver and insufficient exposure may not guarantee a satisfactory reduction.

To investigate the injury mechanism, pathoanatomy and treatment strategy for PDF of the PTP, a retrospective analysis of tibial plateau fractures was conducted at a level 1 trauma center. By exploring the injury mechanism and radiographic features, two distinct patterns of PDF affecting the PTP were identified. Based on an understanding of the pathoanatomy, a novel modified lateral approach combined with an intra-articular osteotomy was applied.

Materials and methods

We obtained institutional review board approval for this study. Between January 2014 and October 2017, 119 patients with 120 tibial plateau fractures underwent surgery at our hospital, and their preoperative and posteroperative CT scans were studied by two researchers (Z.Y and S.L.J.). The inclusion criteria were PDF of the PL quadrant of the tibial plateau with a mechanically intact cortex (undisrupted PL cortex of the proximal tibia or undisplaced and simple fracture line) and an injury mechanism verified by medical record review or telephone follow-up. The exclusion criteria were patients with lower limb compartment syndrome, previous knee fracture, knee deformity, severe multiple trauma (Injury Severity Scale, ISS >16) [11], and depression fracture with recognizable cortical split. After identification, the enrolled cases were classified according to their fracture pattern by the same researchers. In case of disagreement between the two, consensus was obtained after discussion.

Surgical technique

A novel lateral surgical approach was applied. The patient was placed in the lateral decubitus position with the injured limb elevated. After sterilization and draping, a tourniquet was inflated. A 12-cm-long curved skin incision was made one finger width anterior to the fibular head. The incision coursed along the anterior edge of the biceps femoris and ended 4 cm distal to Gerdy's tubercle (Fig. 1a).

Full-thickness subcutaneous tissue flaps were raised, then the interval between the biceps femoris and the iliotibial band (ITB) was developed (Fig. 1b) and incised. Sharp dissection and anterior retraction of the ITB will sufficiently expose the fibular collateral ligament (FCL) (Fig. 1c). With the knee flexed 60°, the space between the FCL and the lateral knee capsule was created by scalpel (Fig. 1d). Then, a Blount knee retractor was placed between the lateral tibial rim and the FCL to protect the popliteal tendon which was not visible and did not require exposure. Through this sequence, most of the lateral coronary ligament was exposed (Fig. 1d) and its tibial footprint was incised.

The entire lateral tibial plateau was exposed by proximally retracting lateral meniscus (Fig. 1e). The anterior compartment muscles were subperiosteally elevated from the lateral surface of the proximal tibia (Fig. 1f). To facilitate exposure and direct manipulation of the fragment, an intra-articular osteotomy was performed using an oscillating saw at the AL tibial plateau between the fibular head and Gerdy's tubercle. According to the pathoanatomic features of the depression fracture, the osteotomy fashioned was a wedge osteotomy providing sufficient surgical access to the PTP or a fleck osteotomy exposing the cancellous compression expanding to the AL metaphysis of the proximal tibia (Fig. 1g). Following evacuation of the hematoma in the cavity, the depressed articular fragment was elevated using an osteotome. After the bone allograft was impacted under the elevated articular fragment, the osteotomized bone block was repositioned. A 3.5-mm precontoured angular locking plate (Synthes Inc., Oberderf, Switzerland) was placed above the fibular head as posteriorly as possible, and all the rafting screws were inserted (Fig. 1h). The incised lateral coronary ligament and the anteriorly mobilized ITB were sutured back before skin incision closure.

Measurements

On coronal scan of the postoperative CT, the minimal distance from the most posterior screw to the tibial rim was measured by the gauge tool of the picture archiving and communication system (PACS). The angle between the tangent line of the posterior rim and the most posterior raft screw was also measured (Fig. 2a and b). When the projection of the posterior raft screw crossed with the tangent line, this angle was defined as negative.

Results

Twenty-two PDFs located within the PTP were identified. By medical record review and telephone follow-up (8 and 14 respectively), the injury mechanisms of 16 cases were determined as collisions while riding electric bicycles and falls from a height in 6 cases. The patients consisted of 17 males and 5 females, with a mean age of 47.6 years.

All the patients recalled the injured knees as flexed at the moment of the accident, and the force was applied to the lateral side of the knee directly or to the medial side of the ipsilateral foot. By analyzing the preoperative CT scans, the cohort was divided into two types. Type A was characterized by a basin-like depression of the articular surface confined to the PTP. Type B was a tongue-like fracture characterized by a cancellous bone depression of the entire lateral plateau but with significant displacement of the PTP. This fracture pattern resulted in a significant increase in the lateral tibial plateau slope (Fig. 3 and Table 1).

All operations were performed by the same physician (S.L.J.) when the soft tissue conditions permitted. No operative complications were observed. All the incisions healed uneventfully. The reduction quality of all cases was rated excellent with the residual displacement less than 2 mm on the posteroperative CT scan (Fig. 4). The mean distance from the tibial plateau rim to the most posterior screw was 3.0 ± 2.07 mm (from -1.9 to 4.3). The mean angle between the plateau rim to the most posterior screw was $8.9 \pm 3.02°$ (from -7.3 to 15.6).