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Schatzker IV tibial plateau fractures: are they always unicondylar?

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Abstract

Objective: The objectives of this study were to describe the incidence and morphology of medial tibial plateau fractures that extend into the lateral articular surface and to describe trends in their management.

Design: Retrospective.

Setting: Level I Urban Trauma Center.

Patients: Seventy consecutive patients sustaining OTA/AO 41 B1 and B3 fractures.

Intervention: Open reduction internal fixation of medial tibial plateau fractures.

Main Outcome Measurements: Incidence of medial tibial plateau fractures that extend into the lateral articular surface. Secondary outcomes include localization of lateral articular surface depression, neurovascular injury, and trends in surgical management.

Results: Seventy patients were included with 9 fractures (12.9%) isolated to the medial condyle (MC) and 61 fractures (87.1%) extending to the lateral condyle (LC). Compartment syndrome was present in 2 patients (2.9%), peroneal nerve palsy in 2 (2.9%), and arterial injury in 1 (1.4%). Initial external fixation was used more frequently in the LC group compared with the MC group ($P = 0.028$). Of the 61 fractures in the LC group, 49 (80.3%) included lateral articular surface depression which localized to the posteromedial quadrant of the lateral articular surface in 36 of 49 fractures (73.5%). Lateral articular surface depression depth ≥10.6 mm was associated with the use of dual incisions ($P < 0.001$).

Conclusions: Schatzker IV fractures frequently extend to the lateral condyle and often present with depression of the posteromedial lateral articular surface. Fractures with lateral articular surface depression depth ≥10.6 mm were more likely to undergo fixation with dual incisions.

Level of Evidence: Therapeutic level IV.

Key Words: medial tibial plateau, fracture, Schatzker

1. Introduction

Tibial plateau fractures are complex intra-articular injuries with variable etiology and morphology. Schatzker and OTA/AO classification systems are the common language for describing tibial plateau fractures.[1,2] Schatzker IV tibial plateau fractures depict a heterogeneous group of fractures of the medial tibial plateau with or without extension to the lateral articular surface, often associated with a fracture-dislocation mechanism. The OTA/AO classification system provides a more finite description of the medial tibial plateau fracture with extension to the lateral articular surface as classified by a 41B3.3(f) fracture.[2] These injuries portend worst outcomes and include high rates of neurovascular compromise, compartment syndrome, and soft tissue injury including ligamentous and meniscal pathology.[3–7] Schatzker IV fractures are commonly discussed to include either an isolated medial split-wedge fragment or comminution of the medial tibial condyle,[1] yet evidence from Wahlquist et al[6] and similar studies[8–11] show that extension of the primary fracture line to the lateral condyle is exceedingly common.

Management of Schatzker IV injury is dictated by the extent of soft tissue compromise and the fracture orientation, often including staged fixation with initial external fixation before definitive fixation.[12] As with any tibial plateau fracture, anatomic articular reduction, restoration of mechanical alignment, and stable fixation allowing for early range of motion are paramount to fracture management. Articular reduction is preferentially

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performed under direct visualization with instrumentation through the fracture line or a cortical window.[13] An especially challenging presentation is a Schatzker IV fracture with concomitant lateral articular surface depression, whereas an increased distance between the medial fracture line and the lateral joint depression makes for difficult reduction and visualization of the lateral articular surface.[4,8–11] Options available to augment access to the lateral articular surface include dual incisions with lateral metaphyseal cortical osteotomy, submeniscal arthrotomy, and arthroscopy to assess articular reduction.[13–19]

There is a paucity of literature to date describing the incidence, morphology, and management of medial tibial plateau fractures with lateral condyle extension and lateral articular surface depression. The primary aim of this study was to identify the incidence of medial tibial plateau fractures that extend into the lateral condyle. Secondary aims included identifying the incidence and morphology of lateral articular surface depression, identifying the incidence of compartment syndrome and neurovascular injury, and identifying fracture characteristics associated with the use of dual incision. We hypothesized that medial tibial plateau fractures are rarely isolated to the medial condyle. Furthermore, we hypothesized these injuries commonly present with lateral articular surface depression, infrequently present with compartment syndrome and neurovascular injury, and show use of dual incisions in cases of increasing severity of lateral articular surface depression.

2. Materials and Methods

After Institutional Review Board (IRB) approval was obtained at the Saint Louis University School of Medicine (protocol number: 32440, principal investigator: Thomas Revak), a retrospective chart review was completed. Informed consent of the study's subjects was not required by the IRB given the de-identified, retrospective nature of the study. All patients undergoing operative intervention for tibial plateau fractures at a single American College of Surgeons Level 1 trauma center were identified. Patients were identified between January 2016 and March 2022 using current procedural terminology codes 27535 and 27536 for open reduction internal fixation of unicondylar and bicondylar tibial plateau fractures, respectively. Patients meeting inclusion criteria were those older than 18 years who underwent open reduction internal fixation of OTA/AO 41 B1 and B3 fractures involving the medial tibial plateau. Fractures meeting inclusion criteria were defined as having a primary medial metaphyseal fracture line without fracture lines extending into the lateral metaphyseal flare, which indicated a bicondylar tibial plateau fracture. To meet inclusion criteria, patients required computer tomography imaging before definitive fixation and appropriate operative documentation. Exclusion criteria included pathologic fractures, fractures secondary to ballistic injury, and patients older than 90 years per institutional policy. All fractures were treated by trauma fellowship-trained orthopaedic surgeons.

For patients meeting inclusion criteria, demographic data were recorded for age, sex, and body mass index (BMI). The mechanism of injury was recorded and categorized according to high-energy versus low-energy etiologies. High-energy mechanisms included motor vehicle/motorcycle collisions, pedestrian struck incidents, falls from a height, and crush injuries. Low-energy mechanism included falls from standing and twisting injuries. Additional data included fracture laterality and classification of open fractures according to the Gustilo–Anderson classification.[20,21] The presence of vascular injuries, nerve palsy, compartment syndrome, and soft tissue injury was documented. The use of staged fixation with initial external fixator application before definitive fixation was recorded.

Computer tomography (CT) imaging was reviewed independently by the study authors. Measurements were averaged and classifications determined based on a consensus of the 3 authors. In cases of discrepancy, the classification made by the board-certified fellowship-trained orthopaedic surgeon was used. CT imaging was used to classify the location of the articular fracture line as either isolated to the medial condyle (MC) or extending to the lateral condyle (LC), which was defined as a fracture line extending lateral to the lateral tibial spine, synonymous with Wahlquist group C fractures (Fig. 1).[6] If the fracture extended to the lateral condyle, the presence and location of lateral articular surface depression was recorded. When lateral articular surface depression was present, coronal and sagittal slices of the computer tomography images were used to measure the depth of the articular depression with Synapse picture archiving and communication system (Fujifilm Healthcare, Lexington, MA). Measurements were taken from the most inferior depressed articular fragment and the uninjured lateral articular surface. Axial slices of the CT imaging scan at the level of the lateral articular surface were used to determine the primary and secondary quadrants of lateral articular surface depression, defined by dividing the lateral articular surface into 4 quadrants of equal area and identifying the quadrant with the greatest area of depression (Fig. 2). The 4 quadrants were denoted as follows: posteromedial (PM), anteromedial (AM), posterolateral (PL), and anterolateral (AL). The area of depression was measured as a percentage of the total area of the lateral articular surface using the polygonal region of interest function in the Synapse picture archiving and communication system. The primary quadrant of lateral articular surface depression was the single quadrant with the greatest surface area of depression. In cases with articular depression extending into multiple quadrants, the secondary quadrant of depression was defined as the quadrant with the second greatest surface area of articular depression. The presence of an arcuate sign (avulsion of the proximal fibula) and a Segond fracture (avulsion of the lateral tibial plateau) was recorded using preoperative CT imaging.

Operative documentation and intraoperative fluoroscopic imaging were reviewed to determine whether the lateral articular surface depression was addressed and to record the use of additional incisions, number of plates used for fracture stabilization, and use of bone graft or bone graft substitute to maintain joint elevation (Fig. 3). For patients who underwent an additional lateral incision and lateral arthrotomy, the presence of a lateral meniscus tear and lateral meniscus repair was recorded.

Demographic, injury, and management characteristics were compared between the MC and LC groups. The depth, area, and reduction of the primary quadrants of lateral articular surface depression were compared. The characteristics of reduced and not reduced lateral articular surface depressions were further compared. Fractures with lateral articular surface depression that underwent dual incisions to achieve lateral articular surface reduction were compared with those that were able to be reduced through the medial fracture line.

Continuous variables were reported as a mean with a SD. Categorical variables were reported as a count with a frequency. Statistical comparisons of continuous variables were performed with Mann–Whitney U tests, independent samples *t*-tests, and Kruskal–Wallis tests, as indicated. Categorical variables were

Figure 1. Coronal computed tomography slices of medial tibial plateau fractures. A, Fracture lines medial to the lateral tibial spine. B, Fracture line extending into the lateral condyle. C, Medial tibial plateau fracture with lateral articular surface depression.

compared using Fisher exact tests and Fisher–Freeman–Halton exact tests, as indicated. Receiver operating characteristic (ROC) curves and Youden J point method, maximizing sensitivity and specificity, were used to identify thresholds of continuous variables associated with a binary outcome.[22–24] An area under the ROC curve (AUC) of ≥0.70 was deemed to have clinically significant diagnostic utility in predicting its associated binary outcome.[25] A P-value of <0.05 was deemed significant.

3. Results

Initial review identified 664 patients who underwent operative fixation of tibial plateau fractures between January 2016 and March 2022. Of those, 586 were identified as lateral or bicondylar tibial plateau fractures which were excluded leaving 78 fractures identified as medial tibial plateau fractures. An additional 7 patients were excluded for ballistic injuries, and 1 patient was excluded for lack of preoperative imaging which left 70 patients who met inclusion criteria.

Nine fractures (12.9%) were identified as isolated medial (MC) condyle fractures and 61 (87.1%) were medial tibial plateau fractures with extension to the lateral condyle (LC) (Table 1). The MC and LC groups were similar in age, sex, BMI, and laterality ($P \geq 0.127$). No difference in the frequency of high-energy mechanisms was observed between the MC and LC groups (77.8% vs. 68.9%, $P = 0.714$). Three open fractures were identified which were Gustilo–Anderson Type II injuries. Common peroneal nerve palsy was diagnosed in 2 fractures (2.9%), arterial injury requiring repair in 1 fracture (1.4%), and compartment syndrome in 2 fractures (2.9%). All instances of

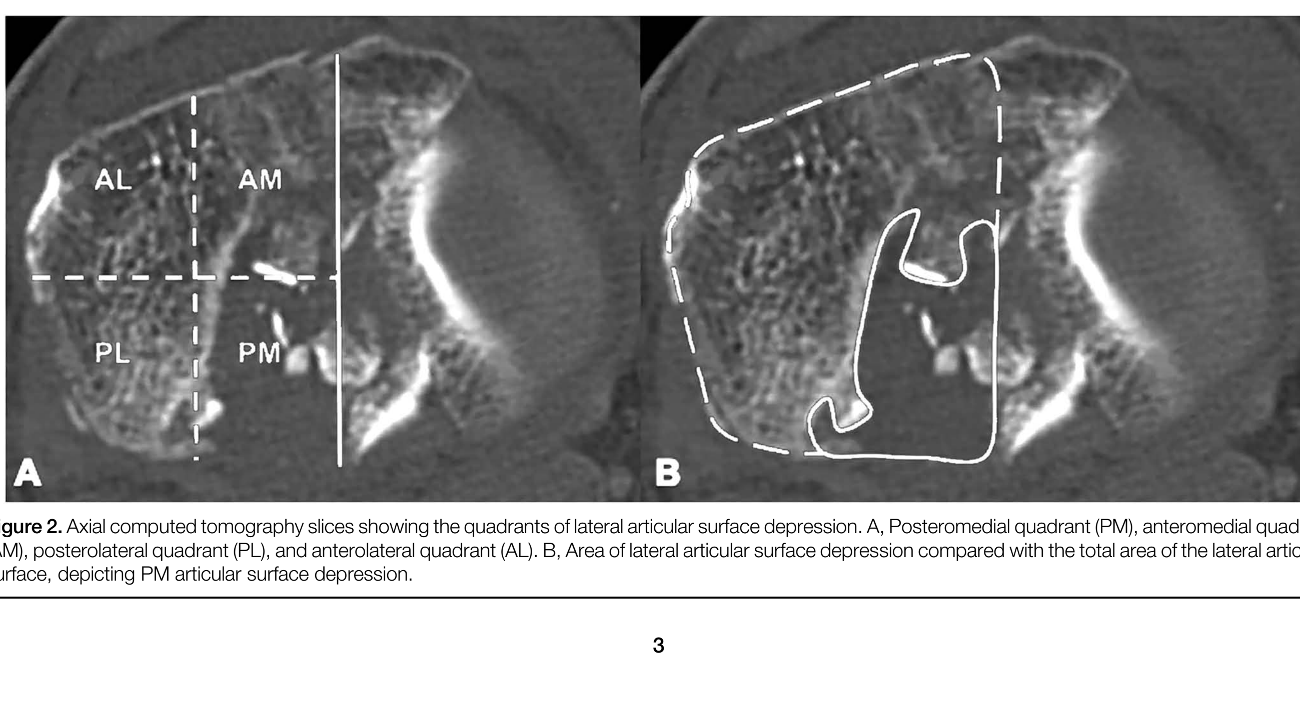

Figure 2. Axial computed tomography slices showing the quadrants of lateral articular surface depression. A, Posteromedial quadrant (PM), anteromedial quadrant (AM), posterolateral quadrant (PL), and anterolateral quadrant (AL). B, Area of lateral articular surface depression compared with the total area of the lateral articular surface, depicting PM articular surface depression.

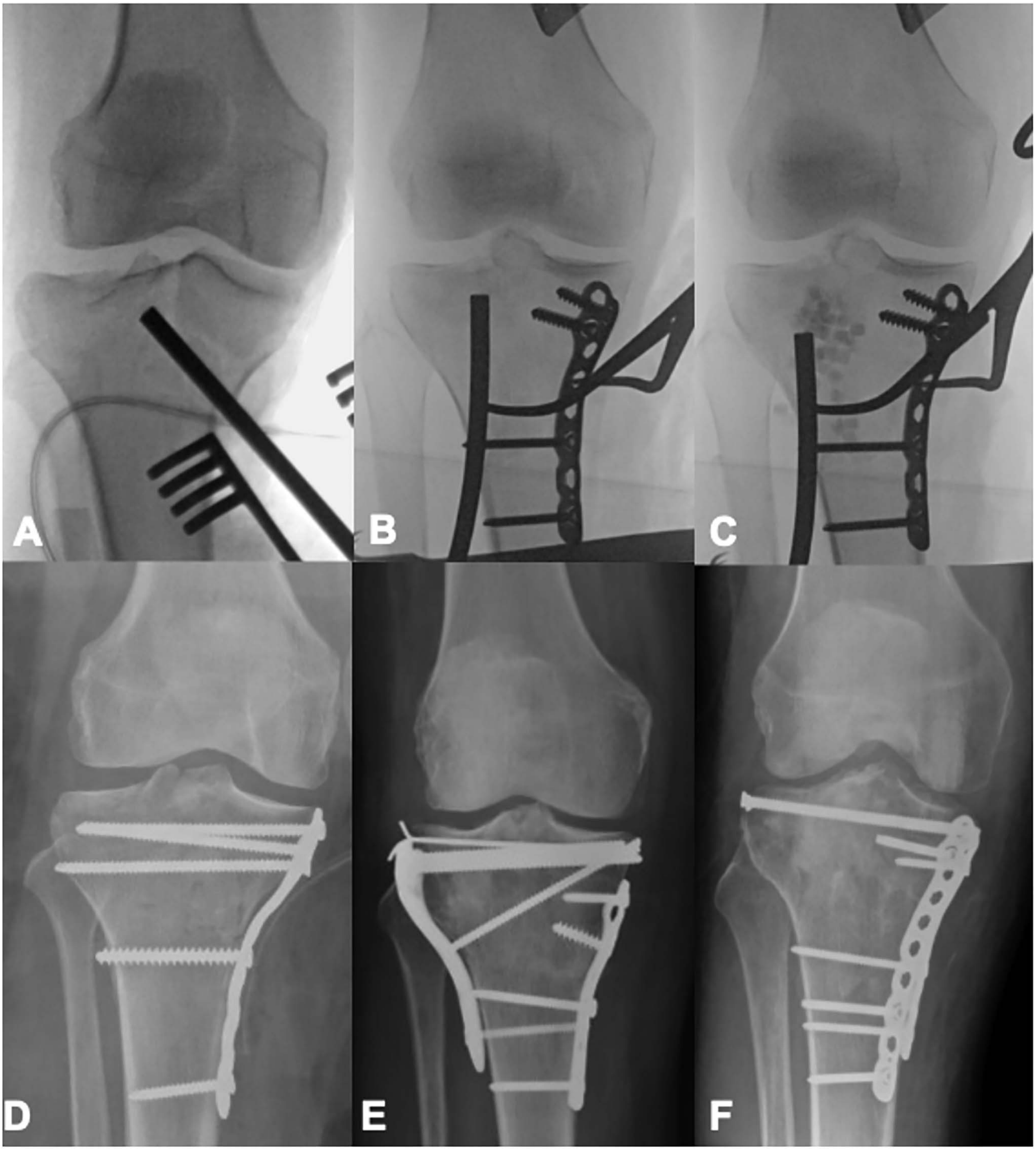

Figure 3. Anteroposterior radiographs showing the management of medial tibial plateau fractures with and without lateral articular surface depression. A, Intraoperative fluoroscopic image of a bone tamp through the medial fracture line. B, Bone tamp through a lateral cortical window. C, Bone void filler in the metaphyseal defect. D–F, Varying fixation strategies.

neurovascular injury and compartment syndrome occurred in the LC group. Staged fixation with an initial external fixator was used more frequently in the LC group (63.9% vs. 22.2%, $P = 0.028$).

Of the 61 fractures in the LC group, 49 (80.3%) were found to have lateral articular surface depression. The primary quadrant of lateral articular surface depression was found to be the PM quadrant in 36 cases (73.5%), followed by the AM quadrant in 10 cases (20.4%), and the PL quadrant in 3 cases (6.1%) (Table 2). Thirty-seven of 49 fractures (75.5%) had lateral articular surface depression in multiple quadrants. PM fractures showed the greatest average depth of lateral articular surface depression at 13.2 mm ($P = 0.009$). The surface area of lateral articular depression was similar between locations and averaged 28.8% of the total area of the lateral articular surface.

TABLE 1

Demographics, Injury Data, and Management

	Isolated Medial Condyle Fracture (MC) n = 9	Fracture Extension to Lateral Condyle (LC) n = 61	P
Age (y ±SD)	36.5 ± 16.4	44.8 ± 14.8	0.127
Sex (% Male)	5 males (56%)	33 males (54%)	1.000
BMI (kg/m^2 ± SD)	25.6 ± 4.6	28.5 ± 6.1	0.194
High-energy mechanism	7 (77.8%)	42 (68.9%)	0.714
Laterality (% Right)	4 right (44%)	32 right (52%)	0.731
Gustilo–Anderson	0	3 (all type II)	1.000
Vascular injury	0	1	1.000
Nerve injury	0	2	1.000
Arcuate sign	1 (11.1%)	11 (18.0%)	1.000
Segond fracture	1 (11.1%)	10 (16.4%)	1.000
Compartment syndrome	0	2	1.000
Initial external fixation	2 (22.2%)	39 (63.9%)	**0.028**

Bold text indicates statistical significance at predetermined *P*-value of <0.05.
BMI, body mass index; SD, standard deviation.

Lateral articular surface depression was reduced in 31 fractures (63.3%) (Table 3). Reduction was performed most commonly in fractures with increased depth of lateral joint depression ($P < 0.001$), fractures involving larger surface areas ($P < 0.001$), and fractures with a primary quadrant of articular depression in either the PM or AM quadrant ($P < 0.001$). Compared with cases where reduction of the lateral articular surface depression was not performed, reduction more commonly involved dual incisions (45.2% vs. 0%, $P = 0.001$), fixation with 2 or more plates (64.5% vs. 27.8%, $P = 0.019$), and use of bone void filler (54.8% vs. 5.6%, $P = 0.001$). Of the 31 patients who underwent reduction of the lateral articular surface depression, 3 distinct operative trends were observed. First, lateral articular surface reduction and fixation was achieved solely through the single medial incision with lateral reduction through the primary fracture line in 17 cases (54.8%). Second, lateral articular surface reduction and fixation was achieved through addition of a lateral incision, creation of a lateral cortical window, and placement of lateral hardware in 11 cases (35.5%). Third, lateral articular surface reduction was achieved through the medial fracture line with addition of a lateral incision for lateral hardware placement in 3 cases (9.7%). In cases of staged repairs where an initial external fixator was placed, the external fixator was used to achieve joint distraction. When the external fixator was in place, it was prepped in the second stage of fixation.

Lateral articular surface depression depth ≥10.6 mm was found to be significantly associated with the use of dual incisions to achieve lateral articular surface reduction (AUC: 0.76). A clinically significant threshold was unable to be determined for the area of the lateral articular surface depression that underwent a lateral incision to achieve reduction (AUC: 0.63). The primary quadrant of lateral articular surface depression was not found to be significantly associated with the use of a lateral incision ($P = 0.550$). Of the 14 total cases with dual incisions, 10 underwent a lateral arthrotomy. Arthrotomy revealed a lateral meniscus tear in 5 of 10 cases. The presence of a lateral meniscus tear was not significantly associated with the depth, area, or quadrant of lateral articular surface depression ($P \geq 0.511$). All meniscus tears underwent repair.

4. Discussion

The Schatzker classification system persists as the common language for tibial plateau fractures and has retained popularity for its simplicity of use in describing 6 types of tibial plateau fracture patterns, yet it is limited in describing the complex three-dimensional morphology of tibial plateau fractures.[1] The OTA/AO classification system offers more descript differentiation between isolated unicondylar tibial plateau fractures, fractures involving the tibial spines, and fractures with articular surface depression opposite the fractured condyle.[2] This study expands on the current literature through additional evaluation of medial tibial plateau fractures that present with lateral articular surface depression.

The aims of this study were to determine how often Schatzker IV tibial plateau fractures are isolated to the medial condyle and to delineate the incidence, morphology, and management of medial tibial plateau fractures that extend to the lateral condyle and present with lateral articular surface depression. The findings of this study are four-fold. First, extension of medial tibial plateau fracture to the lateral condyle with and without lateral articular surface depression is exceedingly common. Second, lateral articular surface depression most often involves the posteromedial quadrant. Third, we found the incidence of neurovascular injury and compartment syndrome to be lower than previously described.[6,26,27] Fourth, a lateral articular surface depression depth ≥10.6 mm was found to be associated with the use of dual incisions to achieve lateral articular surface reduction.

The historic classification of Schatzker IV injury as commonly a medial plateau fracture under-appreciates the concomitant involvement of the lateral plateau. Studies have shown Schatzker IV fractures extend to the lateral condyle in 32%–84% of cases,[5,6,8,9,11] with our study supporting the upper end of these rates at 87%. We also found 49 of 70 medial tibial plateau fractures (70%) had lateral articular surface depression, further supporting our hypothesis. In contrast to previous studies[3,28] hypothesizing Schatzker IV injury resulting from axial loading on a varus knee, Zhang et al[4] revealed the role of the lateral femoral condyle in creating the lateral articular surface depression, demonstrating a pattern of lateral femoral condyle contusion on MRI after Schatzker IV fracture.

Our study found lateral articular surface depression localized to the posteromedial and anteromedial quadrants in a combined 93.9% of fractures, which also supports our hypothesis. These findings support a medial translation path of the lateral femoral condyle during a knee dislocation injury mechanism associated with medial tibial plateau fractures. The posteromedial localization of lateral articular surface depression is supported by Chang

TABLE 2

Primary Quadrants of Lateral Articular Surface Depression

	AM	PM	AL	PL	P
N (%)	10 (20.4%)	36 (73.5%)	0 (0%)	3 (6.1%)	
Depth of joint depression (mm ± SD)	7.8 ± 5.8	13.2 ± 9.5	—	2.5 ± 0.8	**0.009**
Percentage surface area of joint depression (% ± SD)	23.5 ± 15.8	30.9 ± 12.9	—	21.4 ± 14.9	0.190
Lateral joint depression reduced	7 (70%)	24 (67%)	—	0 (0%)	0.076

The primary quadrant of lateral articular surface depression was defined as the quadrant with the greatest surface area of articular surface depression.
Bold text indicates statistical significance at predetermined P-value of <0.05.
AM, anteromedial quadrant; PM, posteromedial quadrant; AL, anterolateral quadrant; PL, posterolateral quadrant; SD, standard deviation.

et al[8] who showed centeroposterior lateral articular surface depression in 64% of studied Schatzker IV cases and Yang et al[11] who showed similar posterior lateral articular surface depression in 84% of studied Schatzker IV cases.

Increased clinical instability after injury was demonstrated by our finding of increased use of initial external fixation in cases with lateral condyle extension compared with fractures isolated to the medial tibial condyle. Instability after lateral condyle fracture extension likely owes to the displacement of the tibial spines which contain anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) attachments as is supported by Yan et al[5] demonstrating ACL and PCL injury in 92.6% and 70.4% of Schatzker IV fractures, respectively. With compromise of the intrinsic knee ligaments, the medial collateral ligament (MCL) and lateral collateral ligament (LCL) are tasked with maintaining joint integrity, yet MCL and LCL injury are also shown to be prevalent at rates of 29.6% and 63.0% in Schatzker IV fractures, respectively.[5] Although our study is limited in its diagnosis of ligamentous injury given the paucity of magnetic resonance imaging obtained on our studied patients, we found an arcuate sign and a Segond fracture to be present in a combined 32.9% of cases, insinuating the high prevalence of lateral soft tissue injury associated with medial tibial plateau fractures.

Furthermore, our study revealed lateral meniscus injury in 5 of the 10 cases that underwent a lateral arthrotomy; although, we found no significant relationship between the fracture morphology and the presence of a meniscus tear, likely owing to the small number of cases that underwent arthrotomy for visualization of the meniscus in our study. This finding in part contrasts that of Salari et al[29] who revealed in a case series of 70 lateral tibial plateau fractures that increasing depth of lateral articular surface depression was significantly associated with the likelihood of lateral meniscus injury. In total, appreciating the lateral condyle extension of medial tibial plateau fracture lines may help anticipate clinical instability, soft tissue injury, and the need for staged fixation with initial external fixation.

TABLE 3

Lateral Articular Surface Depression Management

	Depression Reduced n = 31	Depression Not Reduced n = 18	P
Depth (mm ± SD)	15.1 ± 9.3	5.1 ± 3.7	**<0.001**
Percentage area (% ± SD)	34.1 ± 12.3	19.8 ± 11.6	**<0.001**
Primary quadrant			**<0.001**
PM	24	12	
AM	7	3	
PL	0	3	
Dual incision	14	0	**0.001**
Fixation with ≥2 plates	20	5	**0.019**
Bone void filler used	17	1	**0.001**

The primary quadrant of lateral articular surface depression was defined as the quadrant with the greatest surface area of articular surface depression.
Bold text indicates statistical significance at predetermined P-value of <0.05.
AM, anteromedial quadrant; PM, posteromedial quadrant; PL, posterolateral quadrant; SD, standard deviation.

Schatzker IV fracture is commonly associated with neurovascular injury and compartment syndrome.[3–7] Wahlquist et al[6] recorded compartment syndrome developing in 39% of 28 studied Schatzker IV fractures, with rates increasing to 67% in group C fractures, when the fracture line extends lateral to the tibial spines. Our study demonstrated a lower incidence of vascular injury, nerve injury, and compartment syndrome with rates of 1.4%, 2.9%, and 2.9%, respectively. Recent smaller studies of less than 30 patients support our finding of lower than previously recorded incidences for neurovascular injury and compartment syndrome through demonstration of no instances of neurovascular injury or compartment syndrome in their studied cases.[4,5] A high index of suspicion for neurovascular injury and compartment syndrome remains paramount for early identification and management.

Fixation of a traditionally described medial condyle injury with a sagittal fracture line often includes an isolated medial approach, yet Yang et al[11] showed that a traditional sagittal split-wedge fracture is only present in approximately half of Schatzker IV cases. The especially challenging presentation of a Schatzker IV fracture with lateral articular surface depression described in this article adds to the operative challenge of accessing the lateral articular surface. A mobile split-wedge fragment allows transosseous instrumentation to the lateral articular surface, but cases of increased distance from the medial cortex to the lateral articular surface depression makes access and direct visualization challenging, especially in the setting of staged fixation with potential for delay between temporary and definitive fixation. Our study revealed that a lateral articular surface depression depth ≥10.6 mm was associated with the use of dual incisions to obtain reduction. The importance of achieving adequate articular reduction is supported by a recent multicenter study by Assink et al[30] evaluating 477 tibial plateau fractures at 6.5-year average follow-up, showed that patients with residual articular incongruency 4.0–6.0 mm and ≥6.0 mm were 2.7x and 5.0x more likely, respectively, to undergo conversion to total knee arthroplasty. In planning articular reduction, surgeons may choose to use dual incisions in cases of increased depth of lateral articular surface depression. Within our study, of the 49 fractures with lateral articular surface depression, 18 (36.7%) did not undergo reduction of the lateral articular surface. Given that our study is retrospective in nature and was not randomized, this subset of patients reflects the decisions of the treating surgeons, likely related to the depth, area, and location of the lateral articular surface depression because patients who did not undergo reduction of the lateral articular surface depression were observed to have a significantly smaller depression depth and area as well as proportionally less cases of depression localized to the posteromedial quadrant of the lateral articular surface ($P < 0.001$).

Limitations of our study include its retrospective design and lack of prospective follow-up data. The incidence and morphology of the described fractures reflect those treated by trauma fellowship-trained orthopaedic surgeons at a level 1 trauma center, so the external validity of this case series may be limited. Fracture management was left to the discretion of the treating surgeon. Outcome data were not collected for this study but may be an area of future investigation.

5. Conclusion

Our study concludes that medial tibial plateau fractures frequently extend to the lateral condyle and often present with articular depression of the posteromedial quadrant of the lateral articular surface. A lateral articular surface depression depth ≥10.6 mm was found to be significantly associated with the use of an additional lateral incision to achieve lateral articular surface reduction. A low incidence of compartment syndrome and neurovascular injury was evidenced as well.

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