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A combined prone and supine approaches for complex three column tibial plateau fracture with posterolateral articular injury

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ABSTRACT

Introduction: Updated three column fixation of tibial plateau fractures (TPFs) arouse the importance of posterior column articular reduction. Complex TPFs with posterolateral (PL) articular injury is difficult to manage. We presented a strategy of combined positions and approaches to treat these injuries. Surgical technique was described and outcome of these were reported.

Materials and Methods: From 2014 Jan to 2016 Dec, there were 132 patients of TPFs treated in our institute. Preoperative evaluation included plain films and 2D/3D CT scan to evaluate the involvement of articular surface and associated columns. Inclusion criteria were three column TPFs with PL corner injury. We put patients in prone position first with reverse L incision to manage PL articular impaction and posteromedial (PM) fractures. Then we repositioned the patients in supine to treat anterolateral fixation. Postoperative radiographic analysis, physical examination findings, and patient reported outcome scores from the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire were recorded.

Results: Patient demographic information was retrospectively reviewed with a mean follow-up time of 34.4 months (range 24–48 months). The average time to union was 5.2 months (range 4-8months). 13/16 (81%) of patients had satisfactory articular reduction by plain films (less than 2 mm articular step off). All patients demonstrated healed without secondary displacement or infection. All patients demonstrated satisfactory coronal (medial proximal tibia angle 84.68 degrees) and sagittal alignment (posterior proximal tibia angle 84.75 degrees). Condylar width averaged 3.93 mm. 3/16 (19%) of cases required posterolateral columnar plating in addition to posteromedial columnar plating. The knee range of motion averaged 115 degrees (ranged from 0 degrees of extension to140 degrees flexion). The average KOOS score was 83/100 (range 76–90). 3 patients in the series developed a surgical site superficial infection and resolved after debridement and oral antibiotics use. No patient eventually received total knee arthroplasty at the last follow up.

Conclusions: Our strategy provides an effective method to treat three column tibial plateau fractures with PL articular injury.

Introduction

Three column classification of tibial plateau fractures has been published for years. It arouses the importance of posterior column which should be managed properly [1]. Historically, surgical tactics for tibial plateau fractures have emphasized anterior surgical approaches and techniques because supine patient positioning is most commonly performed to avoid potentially vulnerable posterior neurovascular structures. Lin et al [2] described prone position to treat posterior column tibial plateau fracture yielding good outcome. Luo et al [3] reported undated three column concept for managing tibial plateau fracture which give first priority of reduction of key articular injury. In three column TPFs with posterolateral corner injury, supine positioning has inherent disadvantages about visualization of the posterior apical spike. It is difficult with no possibility of direct fracture manipulation. Row et al proposed [4] a staged method to treat high energy multicolumnar tibial plateau fractures. Meulenkamp et al [5] used cross-sectional imaging to examine the rate of articular malreduction. They found the rate was as high as 32.3%. An important finding was malreduction mostly located in the posterior quadrants of the lateral plateau. We faced malreduction of posteolateral articular impaction injury that resulted in very poor outcome. A case of inadequate

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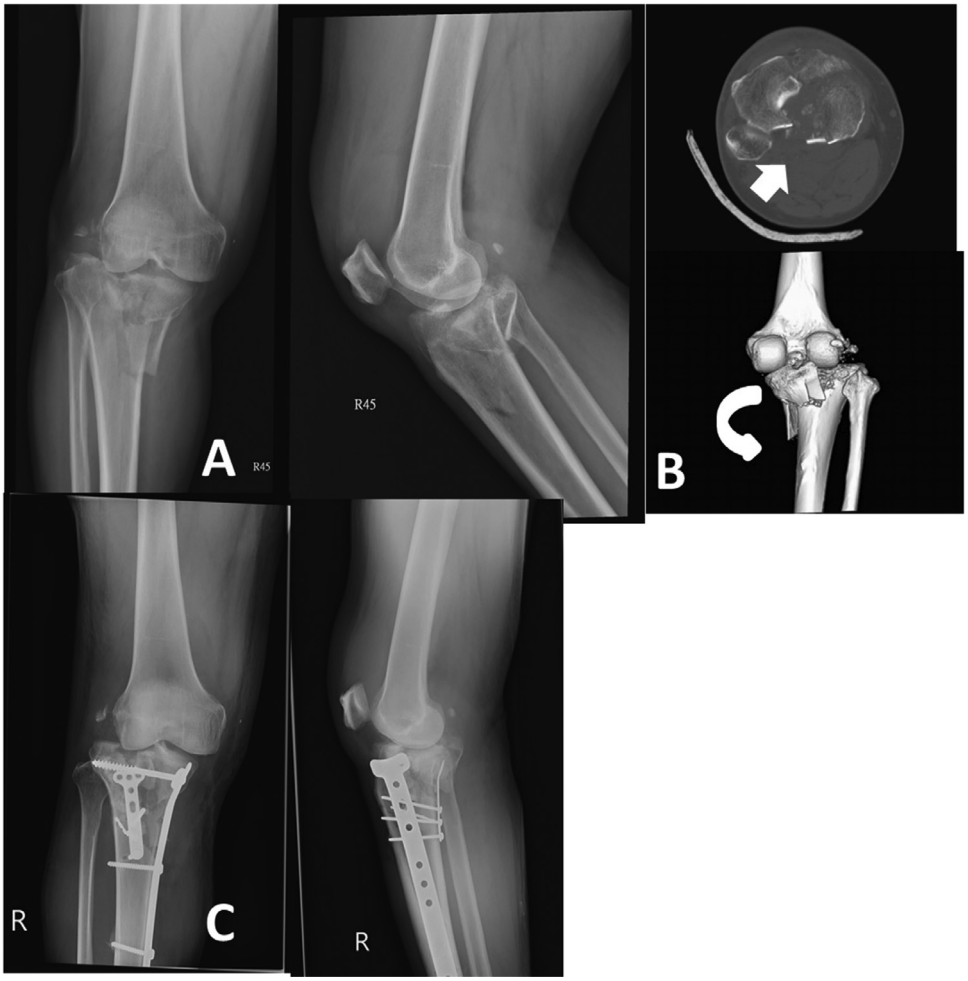

Fig. 1. A case of thee column tibial plateau fractures underwent malreduction and fixation.
1A. A 50-year-old male sustained a closed right tibial plateau fracture dislocation, AO/OTA 41.C3/Schatzker type IV injury in a motorcycle crash injury.
1B. Axial CT view showed important posterolateral articular impaction (white arrow). 3D CT showed fracture of medial coronal lesion on the right knee showing a large posteromedial fragment with significant varus inclination (curved arrow).
1C. Postoperative x ray showed malreduction of lateral articular surface resulted in persistent subluxation of knee joint. Patient suffered pain while ambulation. He could not live without walking aid after trauma.

reduction of PL corner impacted articular surface leading poor outcome was demonstrated in Fig. 1. Thus we started our new strategy to treat complex TPFs with PL corner injury by combined prone and supine approaches. We reported our experiences of using this strategy. Surgical technique and radiographic outcomes were described.

Materials and methods

Preoperative planning

All patients with TPFs were studied by CT scans and classified by AO/OA classification and three column classification [1]. Patients with three column TPFs with PL corner articular impaction injury were enrolled in our study. Typical case of 2D CT revealed PL corner articular impaction injury and 3D CT disclosed unstable PM fragment was found. From axial 2D CT scan, we planned to reduce PL corner impaction injury directly from posterior approach by prone position. From 3D CT scan, we planned to address retrocondylar access in the prone position showing comminuted or posteriorly directed apical inferior spike (PM fragment). One example of our study cases was demonstrated in Fig. 2 with 2D CT revealed PL corner articular impaction injury and 3D CT disclosed displaced rotated PM fragment.

Description of surgical technique

Soft tissue evaluation was completed first. Application of external fixator will be done once soft tissue was not tolerable to definite fixation especially those with compartment syndrome. When soft tissue was recovered, definitive fixation will be arranged. The patient is first placed prone on a well-padded radiolucent table, and the injured leg is slightly elevated, with flexion of the knee joint. The knee flexion relaxes the gastrocnemius, minimizing the risk of intraoperative nerve injury. A reverse L-shape medial incision (Lobenhoffer incision) was used. The superficial fascia was incised in the same direction, followed by dissection of the soft-tissue flap. The popliteal neurovascular bundle was retracted and protected. The origin of the medial gastrocnemius was detached if needed, leaving a stump for repair at the end of the procedure. The soleus was then gently elevated from its medial tibial origin, and the popliteus was mobilized from its medial origin on the retrocondylar surface medially. This allowed complete access to the retrocondylar fragment medially and mobilization of any lateral condylar components compromising reduction. By this approach,

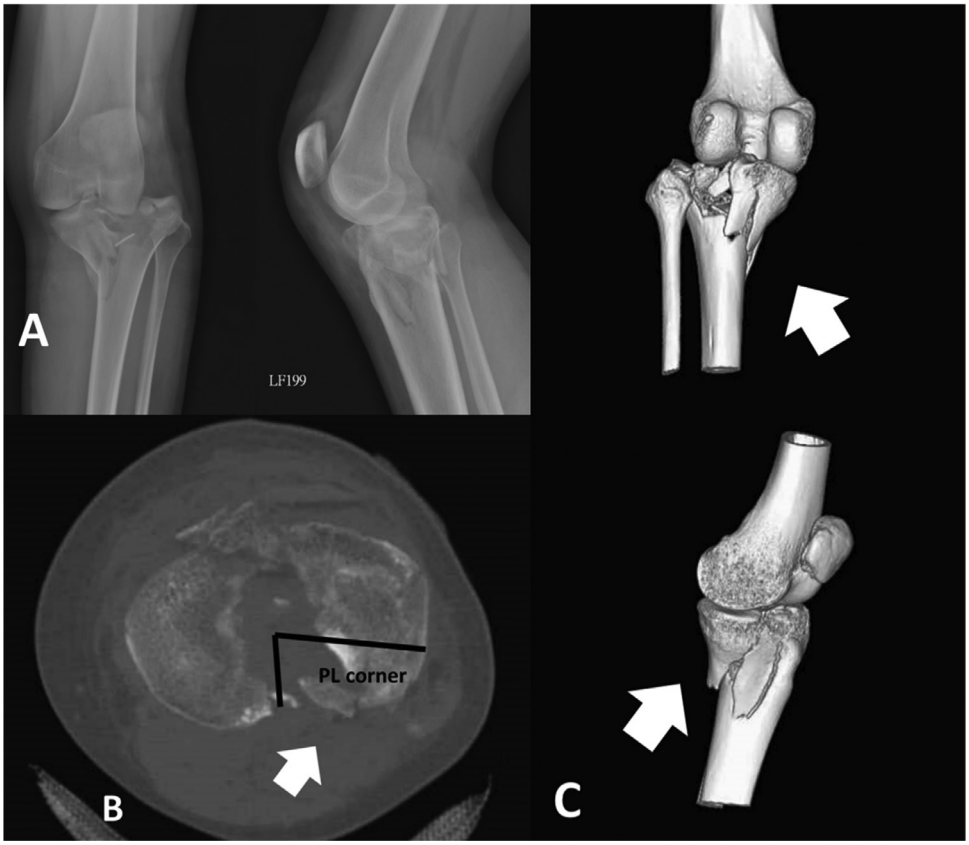

Fig. 2. Typical case in our study was shown.
2A. A 40-year-old female sustained a closed left tibial plateau fracture dislocation, AO/OTA 41.C3/Schatzker type IV injury in a motorcycle crash injury.
2B. According to three column classification, axial CT view showed main articular impaction was located in posterolateral corner (white arrow).
2C. Above. 3D CT from posterior view showed posterolateral corner involvement and a large posteromedial fragment with significant varus inclination (white arrow). By using posterior approach, this area can be reduced directly. Below. 3D CT from medial view showed PM fragment and posterior buttress plating will be planned.

PL depressed cartilage was identified and directly addressed. Disimpaction method for articular reduction was completed by using instruments. An image intensifier was used to assist reduction. Filling of the subchondral defect with an allogenous bone graft for large articular defect was then performed. It is our rationale that prone position can approach posterolateral region articular injuries more efficiently and precisely. If additional posterior lateral visualization was required, prone position can help to assess PL corner more well. After we achieved this goal, posterior spike of PM fragment was easily reduced and fixed consequently with buttress

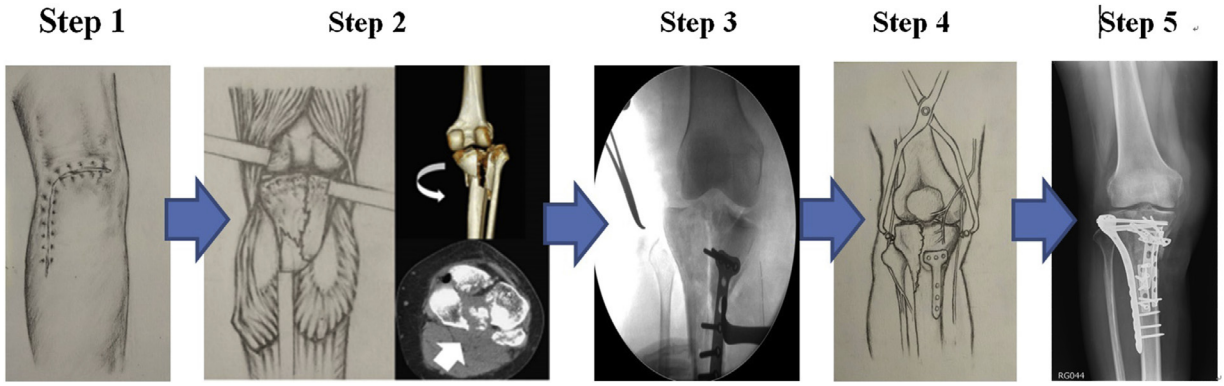

Fig. 3. Strategy of treating TPFs with PL corner injury in this study was demonstrated.
Step 1. Prone position with reverse L incision (Lobenhoffer approach) was used.
Step 2. Deep dissection to expose impaction of posterolatral articular fracture (white arrow) and posteromedial spike (curved arrow) was key point. You can reduce posterior plateau fracture directly and efficiently.
Step 3. PL corner disimpaction was done and was filled with allogenous bone graft. Buttress plating over posteromedial fragment underneath the spike was then done and was very critical.
Step 4. Then reposition the patient in supine with anterolateral approach. Lateral condylar fracture was reduced and fixed. Reduction clamp was used to restore condylar width. Buttress plating of AL condition was thereby completed.
Step 5 Post op x rays showed excellent reduction and fixation of this fracture.

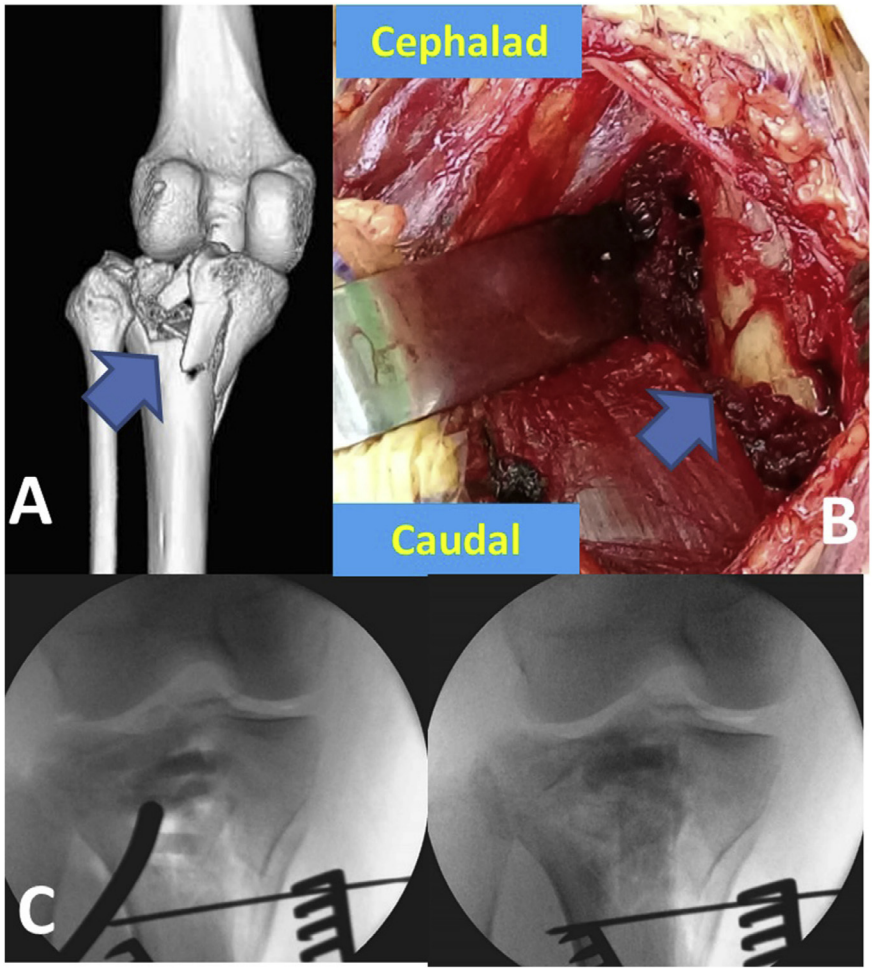

Fig. 4. A case of articular reduction was directed achieved by our method.

plating. Usually, we used a 3.5-mm small fragment plate system (Synthes, Paoli, PA, USA) to fix the PM fragment. If the PL fragment needed to be buttressed sometimes, the plate will be placed more laterally or using more transverse hole plate. Intraoperative fluoroscopic imaging was used in order to ensure proper reduction of the fracture and the accurate location of the implants. Patient repositioned supine with established posterior fixation. Then from anterolateral approach, placement of the precontoured plate for anterior fixation was completed. Strategy of our study was shown in Fig. 3. And exposure of PL plateau and filling with bone graft after articular reduction was also shown in Fig. 4.

Patients collections

From 2014 Jan to 2016 Dec, there were 132 patients with TPFs were evaluated. Inclusion criteria were complex TPFs (three columns involvement) with PL corner impaction injury. 18 patients met our criteria but 2 patients were excluded due to loss of follow up. There were total 16 patients in our study. All patients received surgery using our strategy.

Post-operative care

All patients were immobilized in a knee brace with full extension for 2 weeks, then a gradual range of motion (ROM) of 0–90 degrees was achieved in the next 4 weeks. Full ROM could be achieved after 3 months. Toe-touching or partial weight-bearing (about 5–10 pounds) was allowed during the first 6 weeks postoperatively. Subsequently, full weight bearing was allowed and the patient was referred for physiotherapy. Following discharge from hospital, the patients were seen for clinical and radiological assessment at 6 weeks, 3, 6, 12, and 24 months.

Results

There were 16 patients (16 knees) operated by this technique in a level I trauma center. Demographic information was retrospectively reviewed and listed in Table 1. Mean follow-up time was 34.4 months (range 24–48 months). The average time to bone union was 5.2 months (range 4–8months). The average time of surgery with combined approaches was estimated to be 3.8 h. 13 patients (81%) had satisfactory articular reduction (less than 2 mm articular step off). All patients demonstrated healed without secondary displacement or deep infection. Three patients in the series developed a surgical site superficial infection and resolved

Table 1
Patient Demongraphic Data.

Sex	5 males, 11 females
Age, mean (range)	53 (38-70)
Fracture classication (AO/OTA)	2C1, 7C2, 7C3
Duration of follow up, mean, months (range)	34 (24-48)
Staged operation by external fixator first	4 patients

after formal irrigation and debridement. Two patients received IV antibiotics, the other one received only oral antibiotics. All incisions eventually healed without further return to the operating room.

No patient eventually received total knee arthroplasty at the last follow up. No patient complained of knee instability. No patient developed osteomyelitis, wound necrosis, or loosening/failure of the implants. The most common complication was as expected radiographic evidence of posttraumatic arthrosis, which was seen in 5 knees (18%). There were no cases experiencing nonunion or delayed union.

Patients' radiographic and functional outcome were demonstrated in Table 2. All patients demonstrated satisfactory coronal (medial proximal tibia angle 84.68 degrees) and sagittal alignment (posterior proximal tibia angle 84.75 degrees). Condylar width averaged 3.93 mm. Three cases demonstrated unsatisfactory condylar width of 6 mm, respectively. 3 patients (19%) of cases required posterolateral columnar plating in addition to posteromedial columnar plating. When measuring the percentage from lateral tibial spine to lateral plateau rim anterior to fibular head, they are 50%, 55%, and 58% respectively for these 3 cases [15]. One of these 3 cases was demonstrated in Fig. 5. And radiographic result of a case was demonstrated in Fig. 6.

8 cases (50%) experienced staged operation with spanning external fixation first. The knee range of motion averaged 115 degrees (ranged from 0 degrees of extension to140 degrees flexion). The average Knee Injury and Osteoarthritis Outcome Score (KOOS score) was 83/100 (range 76–90). Physical examination did not reveal anterior or posterior and varus or valgus instability of any affected knee. The average time to radiographic union was 3.6 months (range 3–9 months, SD 8.5). 3 patients in the series developed a surgical site superficial infection and resolved after debridement and oral antibiotics use.

Discussion

Luo et al. [3] recently reviewed 287 cases using updated three column concepts (uTCC). The "uTCC" allows surgeons to apply a systematic approach to pre-operative planning. It allows one to determine the position, and number of the plate(s) to be utilized in the fixation construct as well as the appropriate plate size. This can achieve a more biomechanically and cost-effective plating construct. They emphasized factors which contribute to the successful treatment for TPF included the updated philosophy taking injury mechanism, articular surface involvement and soft tissue injury into consideration allowed for individualized fixation strategies to be well planned for each case. Recently, Meulenkamp et al [5]. demonstrated that articular malreductions are common after tibial plateau fracture fixation, reaching more than 30%. They also defined malreduction location, with a large predisposition for the posterior aspect of the lateral tibial plateau. Although the importance of obtaining an anatomic articular reduction as it relates to clinical outcomes remains controversial. Loss of reduction of PL corner can lead to poor outcome [6]. From a radiological outcome perspective, they advocate using adjuncts to assist in visualizing and reducing fractures of the lateral plateau. Under the suggestion of their concept, combined prone and supine positions and approaches can be the solution to achieve good reduction and fixation of TPFs.

We observed an increasing number of papers discussing how to management complex tibial plateau fractures in the past 10 years. In the literature, several descriptions of double and single approaches to the proximal tibia are published in supine position [7–11]. We found these papers had great disadvantages to treat complex TPFs with PL corner injury. So we proposed a strategy for fixing three tibial plateau fractures with a significant coronal posteromedial fragment and depressed PL corner injury. We hypothesized that this strategy could improve the ability to achieve a good reduction and potentially improve functional outcomes for these injuries. Row et al [4] proposed a staged protocol for fixing bicondylar tibial plateau fractures with a significant coronal posterior medial fragment. They reported cases of posterior fracture pattern where most articular involvement is located posteriorly with a coronal plane orientation, and the apex of the metaphyseal fragment is oriented directly posterior. The morphologic features of this fragment may have clinical implications when using currently available laterally applied fixed-angle screw/plate implants and supine positioning. Because of a high level of shear instability, they recommended that this pattern requires the posterior apex be directly buttressed to avoid loss of reduction with subsequent posteromedial collapse. There are several features of using our combined prone and supine approaches which were summarized in Table 3. We emphasize three points of views that favored combined approaches with prone posterior approach first. First, what is important is when the key articular impact injury is mainly located at the posterolateral tibia plateau. It is challenging to use supine position and anterior approach. Second, a reduction problem is created by the typical posteromedial

Table 2
Radiographic and funcional outcome in this study.

Patients No.	Articular Reduction (mm)	PPTA (degrees)	MPTA	Condylar Width (mm)	Final ROM	Time Radiographic Union (mo)	KOOS
1	Anatomic	85	84	6	15–135	4	84
2	Anatomic	86	87	5	5–130	5	86
3	Anatomic	88	88	4	0–140	6	80
4	Acceptable	84	86	6	5–125	6	90
5	Anatomic	84	87	2	15–135	4	78
6	Acceptable	82	80	5	5-110	3	80
7	Anatomic	84	83	4	10–130	7	76
8	Anatomic	85	86	4	15–120	7	80
9	Anatomic	85	88	2	5–135	4	88
10	Acceptable	84	84	5	10–135	5	80
11	Anatomic	88	83	6	15–120	4	90
12	Anatomic	85	86	3	5–140	8	88
13	Anatomic	87	85	2	10–130	5	90
14	Anatomic	80	81	3	15–140	6	76
15	Anatomic	86	85	3	10–130	3	80
16	Anatomic	83	82	3	10–120	6	84
Mean +/- S.D.		84.75 +/- 2.08	84.68 +/- 2.41	3.93 +/- 1.43		5.18 +−1.47	83.12 +/- 5.01

PPTA: posterior proximal tibia angle MPTA: medial proximal tibia angle, Anatomic reduction: 0 mm step off, Acceptable::0-2 mm step off, KOOS: knee injury and osteoarthritis outcome score.

Fig. 5. One case of three column tibial plateau fracture with PL corner injury treated by additional PL plating for posterior fixation was demonstrated. Percentage of PL was about 50% which should be approached extended reverse L incision in prone position.

displacement of the tibial fragment with knee flexion, which is necessary for visualization of the fragment. Finally, biomechanical principles require placement of a posterior antiglide buttress plate, which is difficult when the patient is supine. There are still some disadvantages in our strategy. First, it takes more time for preparation of position. Second, patients who had lung complications are not suitable for prone position. Third, sufficient muscle relaxation might be necessary to retract the gastrocnemius muscle which could result in a longer recovery after anesthesia. And neurovascular injury to the sural nerve and saphenous nerve is possible. Last, standard fluoroscopy might be difficult to handle.

Wang et al [12] described adopting a posterolateral/posteromedial approach primarily to fix the main fragment in posterior tibial plateau followed by an anterior approach if required to restore knee stability (based on intraoperative examination of the knee after posterior columnar fixation). He concluded high-energy fractures of posterior tibial plateau could be well treated based on posterior approaches combined with necessary anterior approach if required.

Berber [13] described a Lobenhoffer approach from the prone position to address posterior vertical shear fragmentation with intraoperative supine repositioning for lateral column reconstitution through an anterolateral approach. However, this strategy was implemented in only 5 patients in the series, whereas 11 patients underwent posteromedial fixation alone. We reported our strategy in complex TPFs with PL impaction. Kim et al [14] reported outcome of 138 knees and concluded that a tibial plateau fracture wih a coronal fracture is difficult to fix its fragments rigidly with medial or lateral plate fixation. They recommended to buttress plating or direct fixation of fragments through the posteromedial, posterolateral, or posterior approach should be considered.

T. Apivatthakakul et al [15] addressed a cadaver study and suggested TPFs with a fracture line located more than 43.72% lateral to the lateral tibial spine, the use of the posterolateral approach is recommended. This study emphasized PL buttress fixation. Our strategy focused on reduction of impaction of PL articular surface and buttress fixation. As we know, this is the first publication to treat these complex TPFs focusing on PL impaction with combined positions.

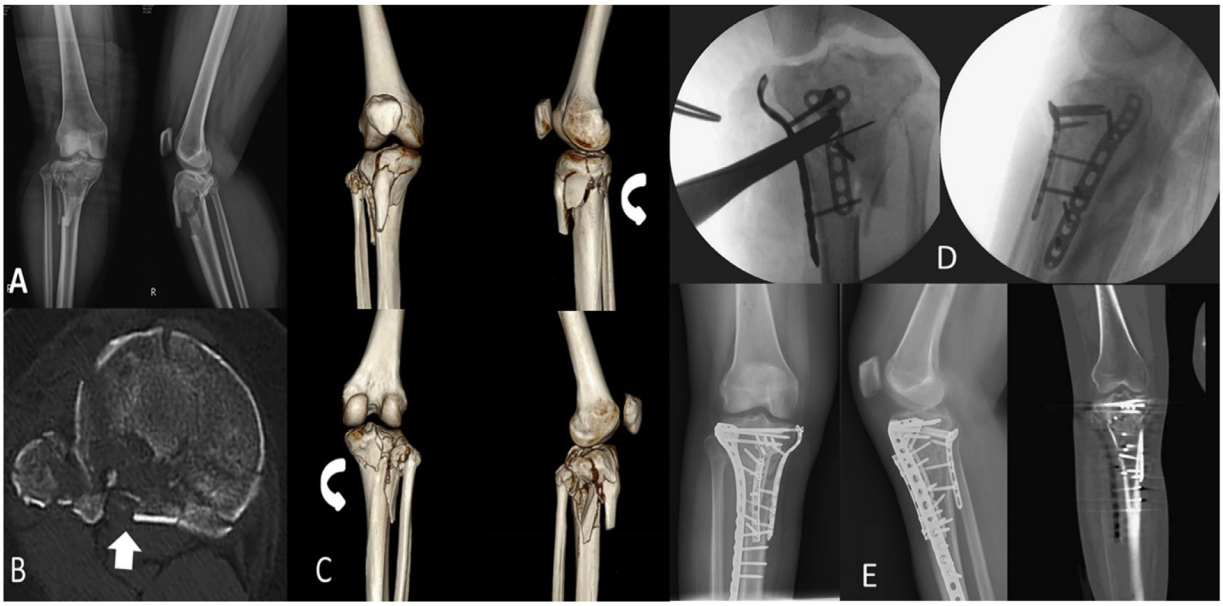

Fig. 6. One successful case of three column tibial plateau fracture with PL **corner** injury treated by our strategy.
6A. A 42-year-old female sustained a closed right tibial plateau fracture dislocation, AO/OTA 41.C3/ Schatzker VI injury in a motor vehicle accident.
6B. Axial CT view showed important PL corner articular impaction (white arrow).
6C. 3D CT image showed fracture of medial coronal lesion (a large posteromedial fragment) with significant varus inclination (curved arrow).
6D. Demonstration of intraoperative placement of the posterior antiglide plate to fix posterior column (focused on poseromedial fragment). It is very important to use posterior buttress plating after adequate subchondral allogenous bone grafting.
5E. Post operative radiograph was demonstrated including CT scan. Anatomic reduction with good alignment of lower limb was achieved by using this combined approaches.

Table 3
Features of combined prone and supine approaches for three column TPFs.

1	For posterior column with PL injuries, direct reduction of articular reduction of PL corner, direct fixation of PM fragment.
2	Buttress plating can easily put on PM fragment spike.
3	Screws can be inserted from posterior to anterior efficiently.
4	Restoration of posterior column first can be the base for anterior column reduction.
5	Supine position with anterolateral approach is necessary because meniscus rupture is common in complex TPFs.

This study has some limitations. First, it is a single center retrospective study. Second, due to complex injury pattern there is small number of our case series. Third, no comparison to a target population was designed, therefore no certainty as to the superiority of this technique compared to another. We hope to provide our experience for this complex injury.

In conclusion, combined prone and supine position to manage complex tibial plateau fractures with posterolateral impaction can have direct visualization and anatomic articular reduction with applicability with reasonable functional outcomes compared with previously described methods.

Disclaimers

We state that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.

Declaration of Competing Interest

No financial or material support has been received or will be received from any commercial party related directly or indirectly to this research. None of the authors have any potential conflicts of interest.

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