

Three-column Subdivision for Isolated Posterolateral Tibial Plateau Fractures and Perspective Surgical Approaches

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Abstract

Background

Management of the tibial plateau fracture involving posterolateral compartment is technically challenging. This study aimed to introduce a computed tomography-based classification of the posterolateral compartment of tibial plateaus based on the fibula and to propose the individualized surgical approaches for each zone; and 2) to determine the surgical approach based on the classification, would achieve a safe and effective reduction and can improve postoperative clinical outcomes.

Methods

Eighteen cases of tibia plateau fracture involved the isolated posterolateral compartment in a single institution were retrospectively analyzed. The posterolateral compartment of tibial plateau was segmented into three zones based on the fibular position and individualized surgical approach was proposed for each zone. In anterior Zone I, surgical treatment was performed using an extended anterolateral approach and patient was placed in the supine position; In middle Zone II, using the transfibular approach in the supine position; In posterior Zone III, using the posteromedial approach in prone. Articular reduction (intra-articular step off in CT images) and mechanical medial proximal tibial angle (mMPTA) in simple radiographs taken in the immediate postoperative period and clinical outcomes of the Lysholm knee scoring scale and range of motion were evaluated at postoperative 1-year follow-up,

Results

In all cases, anatomical articular reduction (intra-articular step off < 2 mm) was achieved, maintained for the follow-up period. The average mMPTA was increased from 87.6° before surgery to 88.2° in immediate postoperative period ($p = 0.060$), and maintained for the follow-up period (mean 89.9° at one-year follow-up). At the 1-year follow-up, the knee range of motion averaged 140 degrees and the Lysholm knee function scored 95.0 points.

Conclusion

An individualized surgical approach and fixation according to three-zone subdivision for isolated posterolateral tibial plateau fractures provided an effective and safe method to treat posterolateral tibial plateau fractures.

Level of evidence: Therapeutic study, IV

Background

Tibial plateau fracture involve the articular surface, should be anatomically reduced to minimize complications such as arthritis and angular deformation. Isolated posterolateral tibial plateau fractures account for about 7–10% of all tibial plateau fractures. Several approaches and reduction techniques

have been introduced to prevent the neurovascular injury in close proximity to the posterior nerve and vessels during surgical treatment and to overcome the technical difficulty of the access and reduction to fracture site by proximal fibula [1].

However, respective approaches for posterolateral tibial plateau fracture surgery have their pros and cons. The anterior and anterolateral approach has the advantage of easy access to the joint, while the displaced articular surface can be fixed with no possibility of direct fracture manipulation. In that sense, the anterolateral approach combined with the fibular osteotomy is advantageous to identify a large area of the articular surface including the posterolateral area with direct vision. However, there would be a risk of nonunion of the osteotomed fibula or the peroneal nerve injury. The posterior or posterolateral approach has the technical advantage to enable to position the posterior buttress plate and to reduce the posteriorly incarcerated and depressed bony fragments with direct vision to the posterior articular surface. However, the posterolateral approach itself may injure the posterolateral ligament complex of the knee and can result in knee instability and has a possibility of iatrogenic injury to the popliteal artery and nerve [2].

Therefore, preoperative planning based on individual fracture patterns and configurations is important to achieve the accurate reduction and to minimize postoperative complications. Several authors have segmented the tibial plateau and proposed respective surgical approaches and fixation methods accordingly. Luo et al. proposed “Three-column concept” for the analysis of the fracture pattern of tibial plateau. They suggested individual surgical approach for each compartment, the posteromedial approach for medial and posterior compartment fractures, the anterolateral approach for lateral compartment fracture [3].

However, the previous “Three-column concept” did not resolve which surgical approach and reduction technique would be appropriate for the tibial plateau fracture involving posterolateral compartment. The structures at the posterolateral corner region such as proximal fibula and lateral collateral ligament obscure to visualize the posterolateral articular surfaces and to allow access to the space. Therefore, Hoekstra et al. proposed a revised three-part classification that additionally classified the posterolateral corner region based on the fibula region [4]. Cho et al. introduced a modified posterolateral approach that allows access to the space around the lateral collateral ligament which between the lateral collateral ligament and the lateral plateau margin, exposing the lateral and posterolateral articular surfaces, and reducing them [5].

In this study, the posterolateral compartment of tibial plateau was divided into three zones based on the fibular head position and individualized surgical approaches were proposed for each zone. It was hypothesized that the individual understanding of fracture pattern and configuration at the posterolateral tibial plateau fractures, would be useful to determine the preoperative planning as surgical approach, and our strategy would provide clinical applicability to achieve a safe and effective reduction and to improve postoperative clinical outcomes.

Materials And Methods

Patient population

A retrospective analysis was performed on 42 cases of tibia plateau fracture involved the posterolateral compartment in a single institution for a total of 7 years from 2011 to 2017. All patients with tibia plateau fractures were studied by CT scans and classified by AO/OA classification and three column classification by Luo et al. [3]. Out of this 42 cases, isolated posterolateral tibial plateau fractures account for 18 cases, about 8.3% (18/215 cases) of all tibial plateau fractures. All 18 patients were operated and followed for more than one year (Fig. 1.). This study was approved by the institutional ethics committee at our hospital and got the IRB approval.

Three-part classification of tibial plateau fracture involving isolated posterolateral compartment.

The posterolateral compartment of the tibial plateau was divided into three zones centered on the fibula. These three zone are separated by four connecting lines, namely OA, OC, OB, and OD. Point O is the center of the knee (midpoint of two tibial spines); Point A represents the lateralmost part of the tibia; Point B is the the anterior border of the fibula; Point C is the posterior border of the fibula; and Point D is the posterior sulcus of the tibial plateau. The accurate classification usually was done with the help of frontal view and three-dimensional reconstruction. Zone I was defined as the most anterior compartment surrounded with OA and OB; Zone II was defined as the compartment facing the fibula surrounded with OB and OC; Zone III was defined as the most posterior compartment surrounded with OC and OD (Fig. 2).

Individual surgical approach and operative techniques based on zone classification

All surgeries were performed by one experienced orthopedic surgeon and surgical approach was differently chosen according to where is the most displaced area in posterolateral compartment. When the configuration of fracture showed most displaced in Zone I (Fig. 2-b), treated using an extended anterolateral approach. The patient was placed in the supine position, the tourniquet was applied, the location of the fibula and the joint surface were checked, and an inverted L-shaped curved incision was made. Then, the iliotibial ligament was detached from the Gerdy's tubercle (Fig. 3-a) to expose the posterolateral part of the tibia (Fig. 3-b). The articular surface can be visualized with enough space for direct fracture manipulation (Fig. 3-c).

In Zone II (Fig. 2-c), treated using the trans-fibular approach with fibular head osteotomy [6]. The patient was placed on the supine position, the tourniquet was applied, and the thigh holder was used for flexion of the knee. The border between the thigh biceps tendon and fibular head was checked, and a longitudinal incision was made in front of the thigh biceps tendon. (Fig. 4-a). After confirming the femoral biceps tendon and the iliotibial ligament, the femoral fascia was dissected. After identification and protection the common peroneal nerve, the fibular head osteotomy was done (Fig. 4-b). The articular

surface was fixed with possibility of direct visualization (Fig. 4-c and d). The fibular head was re-fixed using the tension band wire after fixation.

In Zone III (Fig. 2-c), treated using the posteromedial approach [7]. The patient was placed on prone position and the tourniquet was applied. The knee was flexed about 20 degrees, and an inverted "L" shaped incision, starting from the parallel popliteal fold, was bent from the medial to the distal. Blunt dissection performed to expose the medial head of the gastrocnemius muscle, which was retracted with important neurovascular structures. After exposing the fractured site by blunt dissection between the soleus and the retracted medial head of the gastrocnemius (Fig. 5-a), the displaced fragment was reduced and fixed using posterior buttress plate under the direct vision (Fig. 5-b and c).

Radiologic and clinical outcome evaluations

Postoperatively, anteroposterior X-rays of the knee were taken in the immediate postoperative period, 6 weeks, 12 weeks, and every 6 to 8 weeks until bony union occurred and then one year after the index operation. The radiographic evaluations entailed full-length, standing hip-to-ankle, knee AP, and lateral and patellar Merchant radiography. Before acquiring each radiograph, a radiology technician ensured that neutral alignment was achieved using the method described by Paley [8] to achieve a true AP image. This involved maintaining a forward knee position with the patella centered on the femoral condyles. To control the rotational position during the two radiographic examinations, an identical neutral foot rotation angle was obtained using a reference template on the platform incorporated for the plain radiographic system. In addition, during both radiographic examinations, the patients were requested to maintain knee extension to get an identical knee angle. The positions of the weight-bearing line (WBL), Mechanical femorotibial angle (MFTA), and mechanical medial proximal tibial angle (mMPTA) were measured on full-length, standing hip-to-ankle radiography in the postoperative 6-month and 1-year after surgery [9]. WBL was defined as the distance (%) of the total width of the tibia from the innermost point of the tibial plateau to the point where the mechanical axis passes. The MFTA was defined as the angle between the mechanical axes of the femur and the tibia, and the mMPTA as the medial angle between a line drawn parallel to the proximal tibial condyles and the mechanical axis of the tibia [10]. An independent investigator drew these angles on postoperative full length radiographs and compared the values between the sides.

Within a week after operation, CT scan images were acquired to evaluate whether the accurate restoration of depressed articular surface was achieved and the appropriate fixation was attained with no reduction loss in the immediate postoperative period and at postoperative one-year follow-up. Anatomical reduction of the articular surface was defined as intra-articular step off of less than 2 mm. Secondary loss of reduction was defined as an articular depression of 2 mm or more when compared with the first postoperative CT scan at postoperative one-year follow-up [3] (Fig. 6).

To confirm the functional outcomes after the surgery, the Lysholm knee scoring scale was evaluated from 3 months postoperatively, when the weight bearing and gait were allowed, followed by 6-month and 1-

year follow-up. The range of motion of the knee joint was also evaluated at the outpatient follow-up.

Statistical analysis

All data analysis was done using SPSS 20.0 (SPSS Inc., Chicago IL). Descriptive statistics were used to determine ranges, means, and standard deviations. Binary outcomes for the two groups were analyzed using Fisher's exact test and continuous outcomes were analyzed with the unpaired t-test. Pre and post-operative changes were evaluated by the paired T-test. Correlations were analyzed by using the Pearson correlation coefficient. $P < 0.05$ was considered statistically significant.

Results

All 18 patients were available at the one-year follow-up (mean, 19.8 months). Of the 18 patients, 12 were male and 6 were female. The mean age was 52.1 years old. The details of patients' demographic data were presented in Table 1.

Table 1

Classification of patient demographic data and type of fracture, injury mechanism, trauma to surgery and follow up period.

Classification							
Case No.	Sex	Age (Years)	AO/OTA	Schatzker	Injury mechanism	Trauma to surgery (days)	f/u period (months)
1	F	49	41-B	□	T*	18	12.7
2	M	70	41-B3	□	T	10	27.2
3	M	55	41-B	□	F*(1.5 m)	9	13.0
4	M	41	41-B3	□	F(7 m)	9	26.4
5	M	73	41-B3	□	T	9	40.7
6	M	57	41-B3	□	T	9	24.2
7	M	50	41-B3	□	S	8	18.4
8	F	52	41-B3	□	F*(1.5 m)	7	12.2
9	M	19	41-B	□	S	6	13.2
10	F	56	41-B	□	T	6	12.2
11	M	39	41-B	□	T	6	14.4
12	F	62	41-B2	□	T	5	16.2
13	M	45	41-B3	□	T	4	13.9
14	M	33	41-B	□	S	3	21.0
15	F	57	41-B	□	T	3	36.9
16	M	51	41-B	□	S	2	27.5
17	M	59	41-B2	□	T	2	13.4
18	F	69	41-B	□	T	2	16.5
<i>F: fall down, T: Traffic accident</i>							

Most of the surgeries were performed using individualized approach according to zone classification, except for one case with a window through fracture site (Table 2). Nine (50%) of the 18 patients had fractures confined to zone I fractures. The reduction and fixation were performed using an extended anterolateral approach. Three patients (17%) had fractures confined to the zone II fracture and were reduced and fixed using the trans-fibular approach with fibular head osteotomy. Two cases (11%) were found to have fractures extending from the zone II to the zone I, and one case was using the trans-fibular

approach and the extended anterolateral approach. One case was using an extended anterolateral approach and window through fracture site. One case (6%) was confined to the third zone fracture and the reduction and fixation were performed using the posteromedial approach. One case (6%) was found to have fractures extending from the zone III to the zone I and zone II. Reduction and fixation were performed using the posteromedial approach and the extended anterolateral approach (Table 3).

Table 2
Surgery using individualized surgical approach according to fracture zone

Zone	N (%)	Surgical approach
I	9 (50%)	ExAL (9)
II	3 (17%)	TF (3)
→ I	2 (11%)	TF + ExAL (1), AL + Window (1)
→ I or III	2 (11%)	TF + ExAL (1), TF + ExAL + PM (1)
III	1 (6%)	PM (1)
→ I or II	1 (6%)	PM + TF + ExAL (1)
<i>ExAL: Extended anterolateral approach, TF: Transfibular approach, PM: Posteromedial approach</i>		

Table 3

Three-part classification of posterolateral plateau fractures and perspective surgical approach, and radiologic and clinical results at postoperative one-year follow-up.

Case No.	Zone Classification	Surgical approach	Radiologic findings (At postop. 1-yr f/u)				Functional findings (At postop. 1-yr f/u)	
			mMPTA (°)	MFTA (°)	PS (°)	WBL (%)	Lysholm scores	ROM
1	Zone I	ExAL	89.6	5.3	12.9	44.2	100	0-145
2	Zone I	ExAL	87.4	7.0	4.1	42.9	90	0-140
3	Zone I	ExAL	87.6	7.2	7.5	58.2	94	0-140
4	Zone I	ExAL	88.2	6.6	7.2	-	100	0-135
5	Zone II	TF	89.6	4.7	5.7	42.6	95	0-140
6	Zone II \diamond I	TF + ExAL	86.4	8.4	14.0	58.2	95	0-140
7	Zone III \diamond I, II	PM + ExAL	91.1	9.0	11.7	34.8	92	0-140
8	Zone I	ExAL	87.5	15.4	4.5	35.8	100	0-140
9	Zone I	ExAL	86.3	9.0	11.7	52.5	97	0-140
10	Zone I	ExAL	87.8	4.2	7.8	43.6	93	0-150
11	Zone II \diamond I, III	TF + ExAL + PM	87.9	6.7	9.1	44.5	92	0-135
12	Zone II	TF	86.8	3.8	7.2	33.1	93	0-140
13	Zone I	ExAL	90.4	10.8	5.7	47.9	93	0-140

ExAL: extended anterolateral approach, TF: transfibular approach, PM: posteromedial approach, ROM: range of motion, MFTA: Mechanical femorotibial angle, mMPTA: mechanical medial proximal tibial angle, PS: posterior tibial slope angle, WBL: the positions of the weight-bearing line

Case No.	Zone Classification	Surgical approach	Radiologic findings (At postop. 1-yr f/u)				Functional findings (At postop. 1-yr f/u)	
14	Zone III	PM	84.2	6.1	18.0	44.4	94	0-130
15	Zone II	TF	87.0	0.7	11.5	41.4	95	0-145
16	Zone II \diamond I	AL + Window	87.4	2.6	9.9	55.2	97	0-140
17	Zone II \diamond I,III	TF + ExAL	86.9	3.0	8.6	16.6	97	0-130
18	Zone I	ExAL	89.6	9.1	6.0	58.4	93	0-150
ExAL: extended anterolateral approach, TF: transfibular approach, PM: posteromedial approach, ROM: range of motion, MFTA: Mechanical femorotibial angle, mMPTA: mechanical medial proximal tibial angle, PS: posterior tibial slope angle, WBL: the positions of the weight-bearing line								

Simple radiographs and CT images taken immediately after surgery and at follow-up confirmed the acquisition of anatomical reduction of the articular surface of all patients. Loss of reduction was not found on radiographs taken during the follow-up period. The average mMPTA on simple radiographs was increased from 87.6° before surgery to 88.2° in immediate postoperative period ($p = 0.060$), and it was maintained for the follow-up period (mean 89.9° at one-year follow-up). The average MFTA of 6.84° at postoperative 3-month follow-up was not significantly changed at postoperative 1-year follow-up (mean 6.64°, $p = 0.688$). There was no significant difference in posterior tibial slope angle on the lateral knee radiographs between immediately postoperative period and at one-year follow-up ($p = 0.840$) (Table 3).

The knee range of motion averaged 140 degrees (ranged from 0 degrees of extension to 150 degrees flexion) at the 1-year follow-up and the average Lysholm knee function score was 95.0 points at the one-year follow-up.

Discussion

With the strategy of individualized surgical approach and manipulation of displaced fracture, based on the division into three zones based on the fibular head position, the accurate restoration of depressed articular surface could be achieved and the appropriate fixation could be attained with no reduction loss. The isolated posterolateral tibia plateau fractures show a rare incidence among the proximal tibia fractures, and can be easily overlooked. However, the accurate reduction of articular surfaced and the restoration of lower extremity alignment are important to avoid the progression of traumatic arthritis, thereby can require more complex treatment. Inadequate reduction of articular surface and tibial alignment result in functional deterioration and persisted pain at involved limb.

To date, there have been several studies that segmented the tibial plateau fractures and proposed perspective surgical approach and fixation techniques accordingly. Krause M et al. proposed the ten-compartment classification system, divided the entire tibial plateau into anterior and posterior compartments at first, then divided each anterior or posterior compartment into 5 sections [11]. However, their segmentation was just to describe the fracture configuration, not to provide clinical assistance for operation. Luo et al. proposed a three-column classification that classifies the tibial plateau into medial, lateral, and posterior as the center point between the two tibial spines, and explained that surgical planning can be made according to the classification [3]. However, they did not give more detailed explanations at posterolateral compartment.

Management of the tibial plateau fracture involving posterolateral compartment is technically challenging. There have been a few previous studies, suggested various surgical approaches and reduction techniques. Chih-Hsin et al. recommended the reduction and fixation using the anterior approach for posterolateral tibial plateau fracture because the posterior approach and fixation is risky to damage to the sural nerve, saphenous nerve, and popliteal arterial structures [12]. And they reported that satisfactory articular reduction and postoperative functional results can be achieved without postoperative complications even with reduction and fixation using the anterior approach. On the other hand, Solomon et al. conducted a comparative study over the two-year follow-up period for the patients using the anterolateral approach and the patients using the trans-fibular posterolateral approach. The results showed that the patients who underwent surgery by visually identifying the fracture site using the trans-fibular posterolateral approach showed excellent postoperative results without formation of the articular step off in all patients compared to the patient group using the anterolateral approach with an average of 5.5 mm of large articular layer formation [13].

In this article, we proposed the sub-divided classification of the previous “three-column concept” [3] for the posterolateral tibial plateau fractures, and reported the clinical efficacy and safety of individualized approach and fixation according the classification. The posterolateral area of the tibial plateau is restricted by the fibula. Therefore, when surgeons make an attempt to access into most posterior area from anterior, they can encounter the difficulty to identify with direct vision and get to have troublesome to achieve the accurate articular reduction. Also, when surgeons consider the posterolateral portion of the plateau as a column, they can experience problems at the exposure of fracture site and fracture manipulation by fibular head and neurovascular structures around posterolateral knee.

We divided the posterolateral column to three zones based on fibular head position, and suggested different surgical approaches, patients’ position and fixation methods accordingly. Our strategy was effective in establishing the precise planning of the surgical approach and fixation methods. To apply the individualized approach, the entire tibial plateau should be identified in the axial or three-dimensionally reconstructed images of the preoperative CT scan. In the selected image, the anterior and posterior boundary of the fibula, tibial spine, and the posterior sulcus of tibia can be indicated. The initial impacted area and extended fracture line can be identified and it can be classified according to the three-zone

classification. Surgeon can make a surgical planning using one or more individualized approaches according to the corresponding zone, not to be afraid of using additional approaches.

In this study, all posterolateral tibial plateau fractures were treated based on the three-zone classification, and different approaches were not applied for each zone. Merely, in the third zone, the most posterior part, the posteromedial approach was used [14–16]. The posterolateral approach presents the possibility of iatrogenic neurovascular damage such as the anterior tibialis artery [17], and venous bleeding during soft tissue exfoliation for fixation of distal screws often causes problems with hematoma and wound recovery [18]. Also, later, it is difficult to remove the plate due to the formation of scar tissue and adhesion on the plate when the plate needs to be removed later. Meanwhile, the posteromedial approach can secure a sufficient surgical field and supply efficient buttressing force from the posterior fixation of the metal plate and screw. We kept to stand on that extended posteromedial approach would be more safe, easier and lesser burdensome than posterolateral approach to surgeon.

The postoperative results of the individualized approach to the posterolateral tibial plateau were excellent. In all patients, anatomical articular reduction was achieved and maintained without the reduction loss until the final follow-up. Postoperative imaging showed a good alignment within the normal range. In all patients, satisfactory clinical outcomes and no complication was observed during the follow-up period.

The findings of the present study are limited by its retrospective design with a limited number of samples. It was because that this study is designed only on the relatively rare isolated posterolateral tibial plateau fractures, which account for about 8% of patients with tibial plateau fractures. The surgical results can be influenced by operator experience and would be have an inter-operator technique variation. The current study also lacks a control group and further studies on posterolateral plateau fractures of the tibia may be required to elicit clinical results for a larger patient group.

Conclusion

An individualized surgical approach and fixation according to three-zone subdivision for isolated posterolateral tibial plateau fractures provided an effective and safe method to treat posterolateral tibial plateau fractures. Our strategy can be useful for reviewing the fracture pattern and configuration and establishing the preoperative planning of surgical procedures.

Abbreviations

CT; computed tomography

MFTA; mechanical femorotibial angle

mMPTA; mechanical medial proximal tibial angle

Declarations

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CRediT authorship contribution statement

JA Sim: Conceptualization, Investigation, Methodology, Formal analysis, Data curation, Validation, Writing – original draft, review and editing. **JA Sim:** Conceptualization, Investigation, Methodology, Formal analysis, Data curation, Validation, Writing – original draft, review and editing. **BH Lee:** Investigation, Formal analysis, Writing- original draft. **JH Park:** Methodology, Validation, Writing – review and editing. **YG Na:** Conceptualization, Methodology, Validation, Supervision, Writing – original draft, review and editing.

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Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Figures

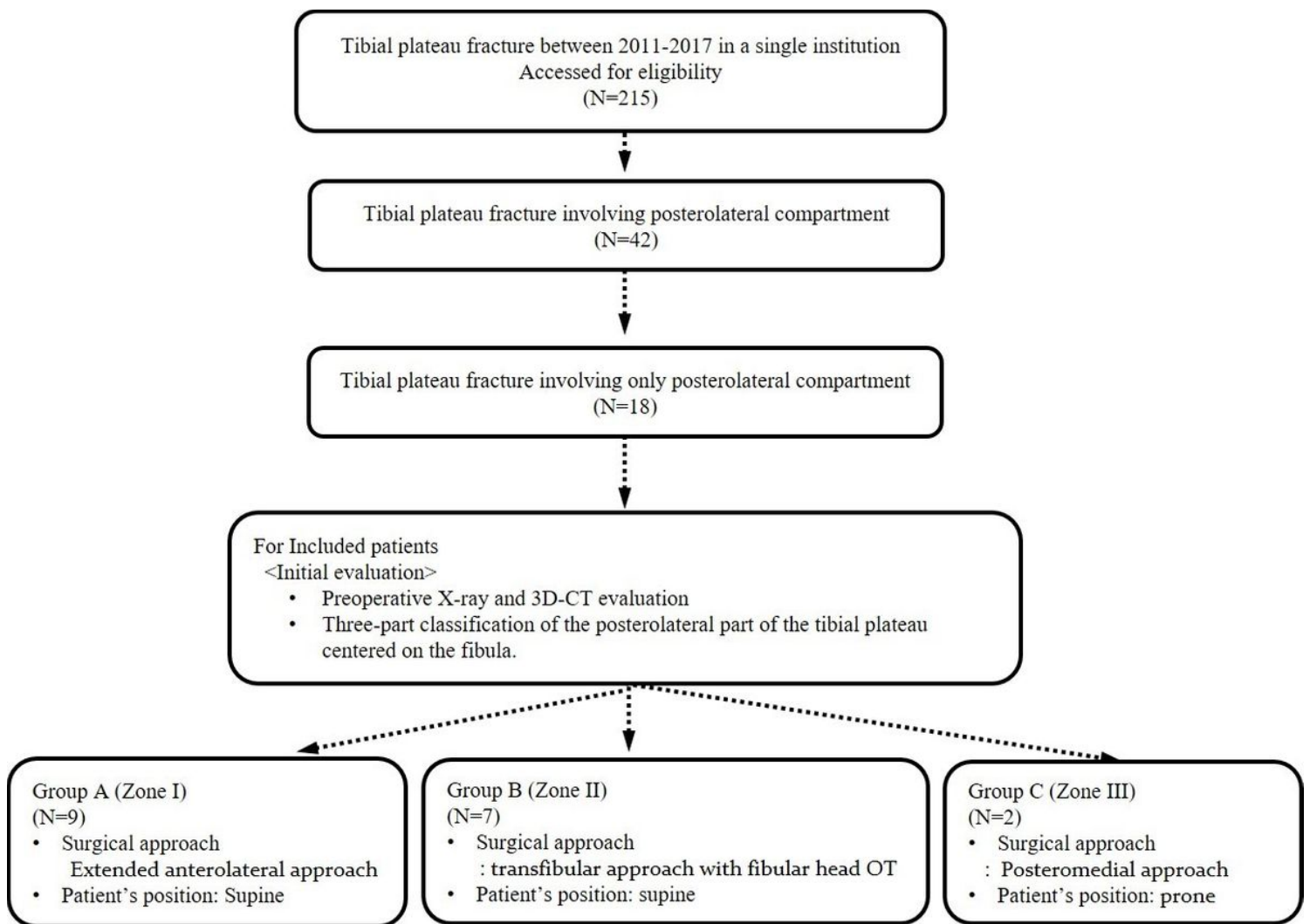


Figure 1

Patients' Flowchart

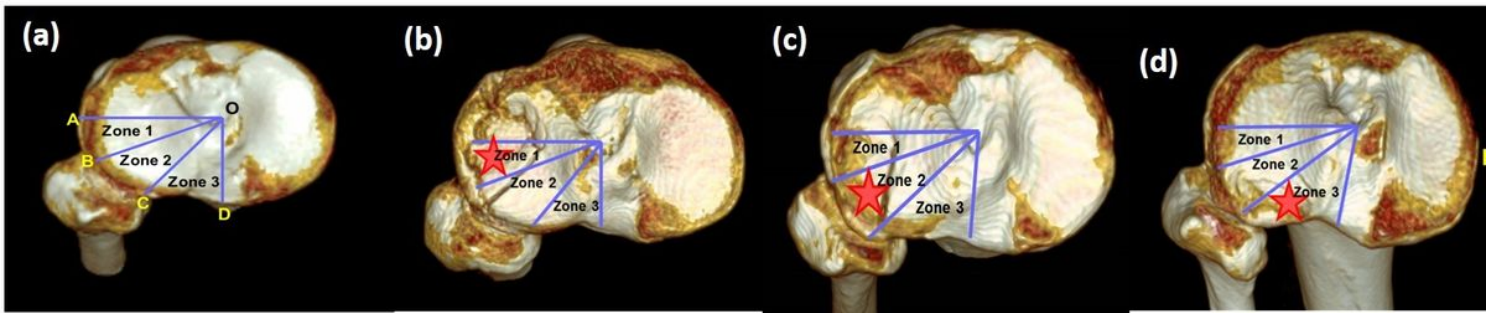


Figure 2

(a) Three-part sub-classifications of the posterolateral compartment in tibial plateau fracture (Point O: the center of the knee (midpoint of two tibial spines), Point A: the lateralmost part of the tibia, Point B: the anterior border of the fibula, Point C: the posterior border of the fibula, Point D: the posterior sulcus of the tibial plateau). (b) The definition of the fracture configuration. Zone I fracture was defined when the most displaced area positioned at zone I. (c) Zone II fracture was defined when the most displaced area positioned at zone II. (d) Zone III fracture was defined when the most displaced area positioned at zone III..

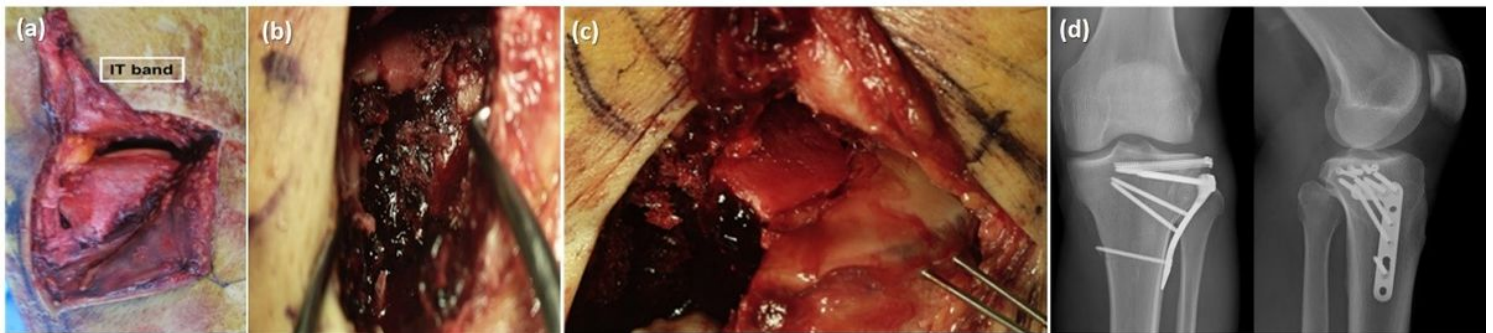


Figure 3

Surgical approach and operative techniques in zone I. (a) Detach iliotibial ligament from insertion site and exposure articular surface (b) Exposure and Visual Confirmation of the articular fractures in the Zone I (c) Reduction of articular surface

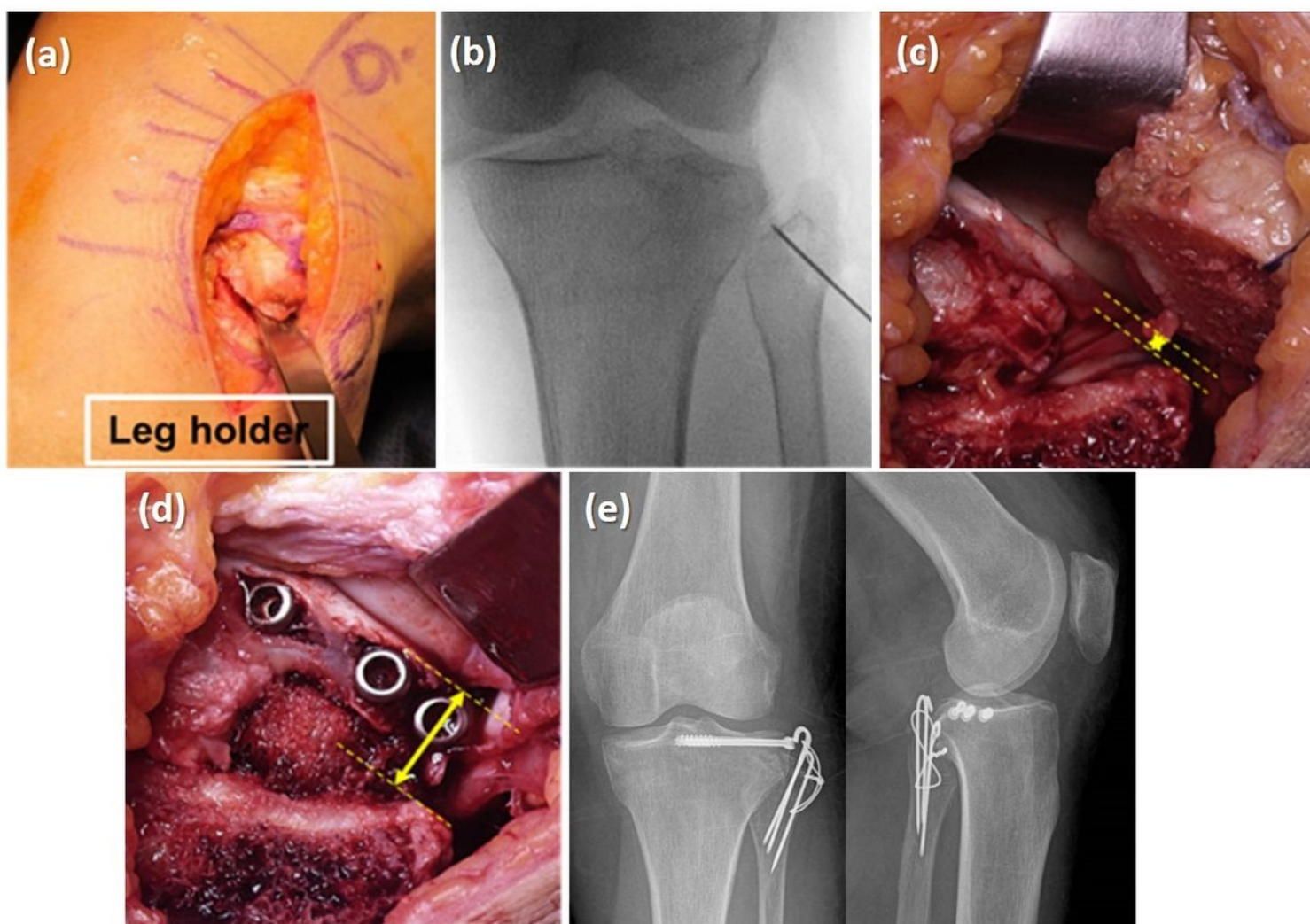


Figure 4

Surgical approach and operative techniques in zone II. (a) Incision with flexion of the knee using the thigh holder (b) Insertion of the guide pin for the location of the fibular head osteotomy (c) Exposure of depressed posterolateral articular surfaces after osteotomy (d) Restoration of articular surface; Elevated articular surface is supported through bone graft and insertion of rafting screw (e) The fibular head is refixed using the tension band wire after fixation.

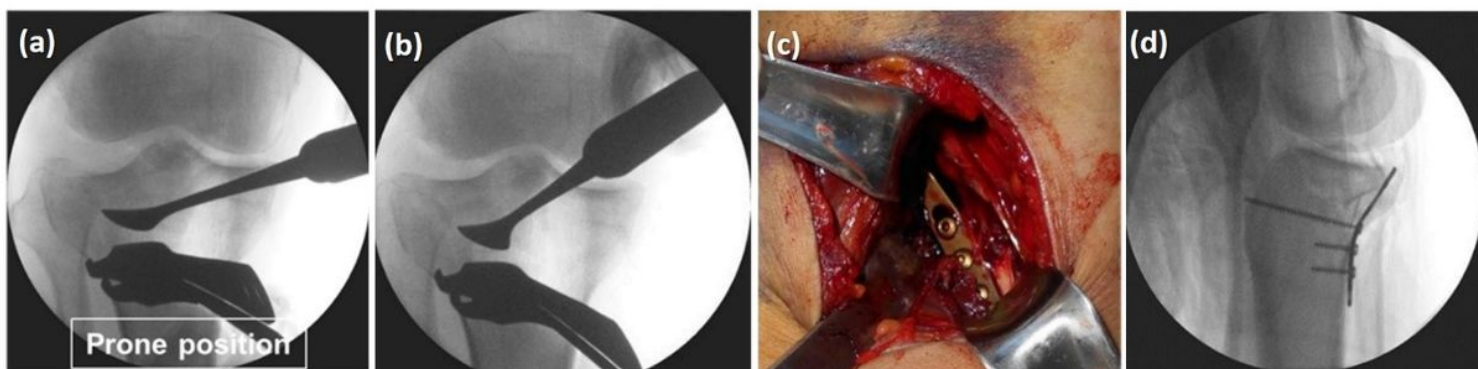


Figure 5

Surgical approach and operative techniques in zone III. (a) With access to fracture site using posteromedial approach, depressed articular fracture can be identified. (b) The depressed articular surface can be reduced using surgical instruments. (c) Reduced fragment was fixed using posterior buttress plate. (d) Intraoperative reduction and the appropriate positioning of plate can be monitored under the C-arm guidance.

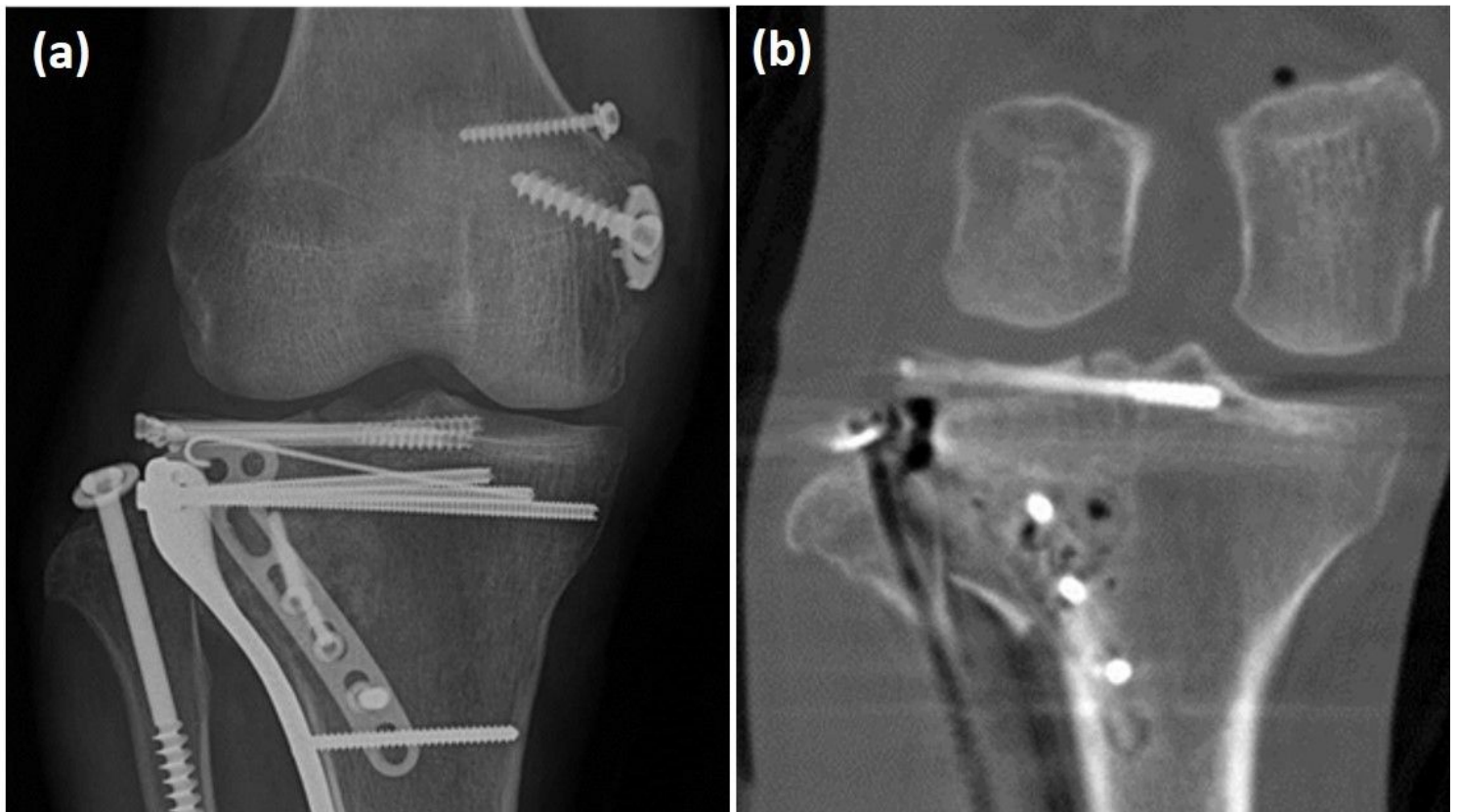


Figure 6

Radiologic evaluation to evaluate the anatomical reduction of the articular surface (a) Articular condition can be checked on simple radiograph taken after surgery. (b) The condition of articular reduction can be evaluated accurately on the coronal plane of CT scans