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Original Article

Reasons for failure of surgical treatment in 25 tibial plateau fractures

Po-Hua Huang, Chun-Ying Cheng, Yeung-Jen Chen, Alvin Chao-Yu Chen, Kuo-Yao Hsu, Yi-Sheng Chan*, Wen-Jer Chen

Department of Orthopedic Surgery, Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Taoyuan, Taiwan, ROC

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ABSTRACT

Background: The management of tibial plateau fracture is challenging. Restoration of articular congruity and early range of motion should be the primary goal. Proper and adequate preoperative planning is essential for a good outcome.
Purpose: The study was a retrospective analysis of failed surgical treatment of tibial plateau fractures.
Methods: Twenty-five patients with tibial plateau fractures were referred to our hospital after having undergone surgery elsewhere. Because of functional disability, the patients received revision surgery with concomitant treatment of associated soft tissue injuries. The average age at operation was 43.5 years (range, 27–71 years). The average interval between the first treatment and the secondary operation was 10.4 months (range, 6–24 months). From the radiographs and operative findings, we analyzed the factors that cause failure of the index surgical treatments for tibial plateau fractures.
Results: Schatzker classification identified five type II, one type III, four type IV, seven type V, and eight type VI fractures. Among these 25 cases, nonunion was found in seven (28%) patients and malunion in 18 patients (72%). The causes of failed surgeries included inadequate fixation (76%), malreduction (84%), and bone defect (100%). In addition, there were associated soft tissue injuries in nine patients (36%).
Conclusions: The main elements of the surgical management of tibial plateau fractures are anatomical reduction, firm fixation, and bone grafting. Inadequate fixation, malreduction, and bone defects can lead to the failure of surgical treatment. The key to successful surgical treatment is a well-designed surgical scheme tailored on the specific fracture type and soft tissue condition; this can prevent serious complications and resultant malpractice suits.

1. Introduction

Tibial plateau fracture is a complex intra-articular injury in which a variety of fracture patterns may be seen, together with associated soft tissue injuries. Management of tibial plateau fractures is challenging, and clinicians must first decide between nonoperative and surgical treatment. Fractures that are stable and minimally displaced (<3 mm of articular incongruity), or those occurring in patients who are nonambulatory, have advanced osteoporosis, or who are not medically fit may be amenable to management by cast immobilization or bracing.[1] Honkonen[2] recommended surgical correction under the following conditions: step-off exceeding 3 mm in the articular surface; condylar widening of up to 5 mm; or a lateral tilt exceeding 5°. Bernfeld et al[3] also reported that indications for operative fixation included a medial tibial plateau fracture at full extension with varus instability exceeding 10°, or a lateral plateau fracture with valgus instability exceeding 10°. Other indications for surgery include open fracture, compartment syndrome, and vascular injury.[4] Several operative methods are in use, including conventional open reduction and internal fixation (ORIF), hybrid external fixation,[5] fluoroscopically-assisted reduction and internal fixation,[6] and arthroscopically-assisted reduction and internal fixation (ARIF).[3,7–9]

The primary goal of surgical treatment is restoration of articular congruity and early range of motion. However, a second challenge is to avoid the serious complications associated with operative treatment, such as knee stiffness, ankylosis, deep infection, post-traumatic arthritis, malunion, and nonunion.[10] In the present study we retrospectively analyzed the causes of failed surgical treatment for tibial plateau fracture, in order to identify important lessons to be learnt and thus help clinicians to prevent serious complications when handling a complex fracture of this nature.

* Corresponding author. Department of Orthopedic Surgery, Division of Sports Medicine, Chang Gung Memorial Hospital, Chang Gung University College of Medicine, 5 Fu-Hsing Street, Kweishan, Taoyuan, Taiwan. Tel.: +886 3 3281200x2420; fax: +886 3 3278113.
E-mail address: chan512@adm.cgmh.org.tw (Y.-S. Chan).

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2. Materials and methods

Between June 1999 and December 2007, 25 patients were referred to our hospital following unsuccessful treatment for a closed tibial plateau fracture. All patients underwent initial operations in other hospitals that resulted in poor functional recovery with several complications. In the injured knees, the limited range of motion after index operation averaged 99.4° (range, 30–140°). Data were gathered retrospectively on these 25 patients (nine men, 16 women). The average age at the time of revision operation was 43.5 years (range, 27–71 years). The average interval between the index surgery and the revision operation was 10.4 months (range, 6–24 months). Tibial plateau fractures were categorized according to the Schatzker classification.[11] Table 1 lists the patient demographics. A total of 23 patients (92%) were injured in traffic accidents (motorcycle or car), and two patients (8%) were injured in a fall. Two patients had a history of wound infection that subsided after antibiotic treatment.

In each case, preoperative and postoperative articular depressions were measured from the anteroposterior and lateral radiographs, using the fibular head as a reference. The degree of articular depression was measured from the opposite remaining articular surface. A line was drawn at the level of the normal articular surface, across the depressed area. A measurement was made from this line to the point of maximum depression. This was as reproducible a measurement as that described by Kumar and Whittle;[12] as all of the radiographic projections were similar, the measurement could be compared. When both plateaus were involved, a line was drawn at the level of the femoral condyles and another line parallel to it was drawn through the base of the tibial spine. Lines were then drawn to the point of maximum depression of both plateaus. Computed tomography (CT) was the imaging standard for intra-articular fractures and was used in cases in which additional assessment of intra-articular injuries was needed, particularly in those patients where there was articular depression or comminution.

We assessed each index procedure radiologically and clinically, to determine why it had failed. Preoperative radiographs, using plain film, were taken to evaluate the incidences of nonunion, malunion, and malreduction. Nonunion was defined as no presence of bridging callus on anteroposterior and lateral radiographic views more than 6 months after index surgery. Malunion was defined as angular varus or valgus deformity $>5°$.[13] Malreduction was defined as articular step-off >3 mm or tibial condylar widening >5 mm.[2,14] A clinical assessment was conducted during the revision operation, for bone defect and soft tissue injury around the knee joint. The bone defects were preoperatively measured by three-dimensional CT. The same radiographs were evaluated by five observers (visiting orthopedic staff) in a blinded fashion to assess interobserver variance. These five observers also classified the fracture type and measured articular depressions in the 25 patients. Statistical analysis was used to determine the interobserver variance of the diagnosis for fracture type and articular depression. All interobserver variabilities for the diagnoses of fracture type and articular depression measurements were insignificant ($p > 0.05$).

The revision operation entailed removal of the previous fixation implants following the formal arthroscopically assisted surgery.[7–9] Corrective osteotomy, allografting combined with use of artificial bone substitute, scopic drilling or debridement, and soft tissue repair were performed according to the type of injury observed. All of the operations and evaluations were performed by the senior author (Y-S. C.).

3. Results

Schatzker classification identified the following fractures: five type II (split and depression), one type III (depression), four type IV (medial plateau), seven type V (bicondylar), and eight type VI (bicondylar with diaphyseal extension) (Table 1). Four of the five type II fractures were initially treated using the closed reduction and internal fixation (CRIF) method with multiple screws (three cases) or multiple K wires (one case), and one patient had received ORIF using a buttress plate. In all of these patients the result was malunion. Malunion was also the result in one type III fracture treated with ORIF and four type IV fractures, one treated with CRIF and three treated with ORIF. For three type V fractures treated with CRIF and four treated with ORIF, the result was nonunion (three patients) or malunion (four patients). Treatment of eight type VI fractures with ORIF had resulted in nonunion (four patients) or malunion (four patients). The nonunion and malunion rates of the 25 patients were 28% (7/25) and 72% (18/25), respectively.

4. Causes of failed surgeries

4.1. Inadequate fixation

Inadequate fixation was found in 19 (76%) of 25 patients (Fig. 1). The most common mistake, use of multiple pinning or screwing fixation by the CRIF method, was the cause of seven (37%) of these 19 complications; of the seven patients, four had a type II fracture, one a type IV; and two a type V (Table 2).

Table 1
Data of the 25 patients referred for revision of tibial plateau fracture surgery: Schatzker classification of fracture types and results of index surgery.

	Type II	Type III	Type IV	Type V	Type VI	Patients, *n* (%)
Patients, *n* (%)	5 (20)	1 (4)	4 (16)	7 (28)	8 (32)	
Average age (y)	36.8 ± 16.4	48	50.8 ± 18	49 ± 12.3	38.6 ± 16.4	
Sex (male/female)	2/3	0/1	1/3	3/4	3/5	
Side (R/L)	4/1	1/0	1/3	2/5	3/5	
Index surgery						
CRIF	4	0	1	3	0	8 (32)
ORIF	1	1	3	4	8	17 (68)
Surgical results						
Nonunion	0	0	0	3	4	7 (28)
Malunion	5	1	4	4	4	18 (72)
Causes of failed surgery						
Inadequate fixation	4	0	2	6	7	19 (76)
Malreduction	4	1	3	6	7	21 (84)
Bone defect	5	1	4	7	8	25 (100)

CRIF = closed reduction and internal fixation; ORIF = open reduction and internal fixation.

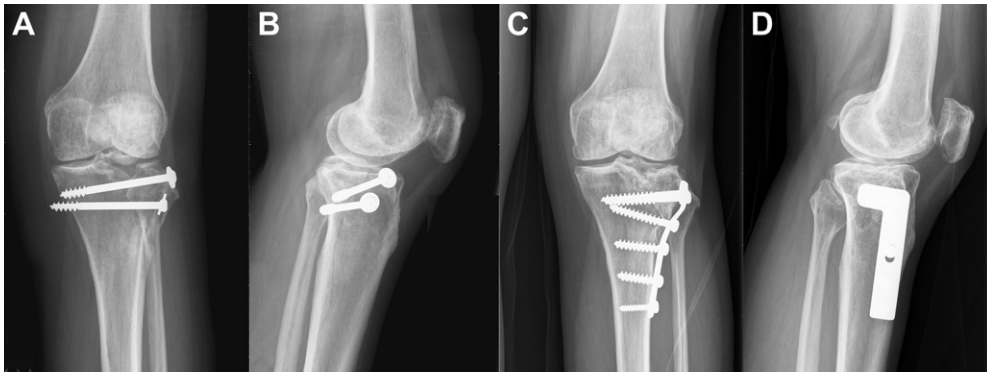

Fig. 1. A 43-year-old female motorcycle accident victim with Schatzker type II tibial plateau fracture. (A) and (B) are plain radiographs (anteroposterior and lateral views) showing inadequate fixation with two screws and washers; malreduction, with a missed diagnosis of posterolateral fragment; and huge bone defects without bone grafting. (C) and (D) show a solid union 1 year after revision surgery using rigid buttress plate fixation with anatomical reduction and allografting.

4.2. Malreduction

Twenty-one (84%) of the index surgeries resulted in malreduction. The average articular surface depression in each fracture type was 9–17 mm. The malreductions were closely related to inadequate fixation during index surgery (Fig. 2).

4.3. Bone defects

According to the referral charts or the patients' histories, all 25 tibial plateau fractures had been managed without bone grafting during the index surgeries. During the revision surgeries, all patients (100%) had large bone defects, ranging from 69 to 190 cm^3. Moreover, all the 25 patients had severe disuse osteoporosis around the fracture site after the index surgery. These huge bone defects were solidly filled by means of with allografts and artificial bone substitutes during the revision surgeries (Fig. 3).

Intraoperatively, we found that nine patients (36%) had associated soft tissue injuries. The most common soft tissue injury was meniscal tearing, which was noted in eight (32%) of 25 patients, and always occurred on the same side as the fracture. Type V and type VI fractures were accompanied by multiple soft tissue injuries, including those of the cruciate and collateral ligaments (Table 3).

5. Discussion

Tibial plateau fractures comprise approximately 1% of all fractures,[14] and a unified treatment method has yet to be established. Optimal management of this injury remains controversial and numerous authors have reported satisfactory results with both nonoperative and surgical treatment methods.[15] The best approach to a tibial plateau fracture depends on several factors, such as fracture configuration, concomitant soft tissue injury, patient age, patient activity level, and bone quality. Nonoperative management has historically been the preferred treatment for such fractures.[16] However, to avoid prolonged immobilization and unstable reduction, surgical treatment is now the preferred treatment for displaced fractures. Surgical treatment has gone through various phases, including the traditional ORIF method, hybrid external fixation,[5] locking fixation with less invasive stabilization system (LISS),[17] and ARIF.[7–9] These available operative methods do not always guarantee a favorable outcome, and unsatisfactory results most often occur in complex or bicondylar tibial plateau fractures.[18]

Papagelopoulos et al[10] reported on complications after tibial plateau fracture surgery. They divided the complications into early (i.e., loss of reduction, deep vein thrombosis, infection) or late (i.e., malunion and nonunion, implant breakage, post-traumatic

Table 2
Relationship between fracture type and causes of failed surgery in 25 patients.

	Type II (5 patients)	Type III (1 patient)	Type IV (4 patients)	Type V (7 patients)	Type VI (8 patients)
Causes of failed surgery					
Inadequate fixation (*n*)	4	0	2	6	7
	CRIF with multiple screws fixation (3)		Single screw fixation from lateral plateau (1)	CRIF with two cannulated screws (1)	ORIF with lateral buttress plate and medial screws fixation (6)
	CRIF with multiple K wire fixation (1)		CRIF with multiple screws fixation (1)	CRIF with multiple K wires (1)	ORIF with medial plate and lateral screws fixation (1)
				ORIF with lateral buttress plate and medial screws fixation (2)	
				ORIF with medial plate and lateral screw or staple fixation (2)	
Malreduction (*n*)	4	1	3	6	7
Average depression (mm)	Lateral depression: 9 (range, 5–15)	Lateral depression: 15	Medial depression: 16.3 (range, 10–20)	Lateral depression: 10 (range, 5–15) Medial depression: 17 (range, 5–40)	Lateral depression: 12.5 (range, 5–20) Medial depression: 15.8 (range, 10–25)
Average valgus/varus alignment (°)	Valgus 9.6 (range, 6–15)	Valgus 11	Varus 6.8 (range, 6–8)	Valgus 6/varus10.6 (range, 1–20)	Valgus 11.3 (range, 6– 18)/ varus10.2° (range, 3–15)
Bone defect (*n*)	5	1	4	7	8
Average volume (cm^3)	156 (range, 75–294)	80	69 (range, 18–120)	129 (range, 24–336)	190 (range, 24–343)

CRIF = closed reduction and internal fixation; ORIF = open reduction and internal fixation.

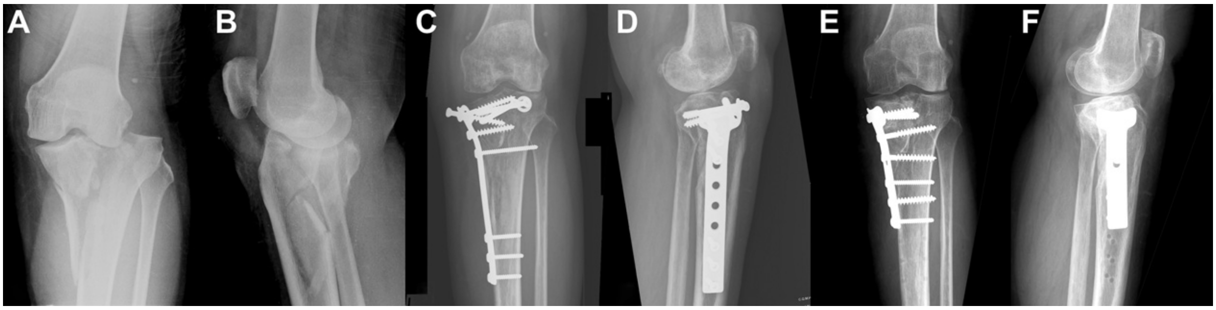

Fig. 2. This 52-year-old female sustained a severe injury to her left proximal tibia in a motorcycle accident. (A) and (B) are plain radiographs (anteroposterior and lateral views) showing a left medial plateau and inter-eminence comminuted fracture (Schatzker type IV). (C) and (D) show medial plateau depression 6 months after the index surgery as a result of malreduction and inadequate fixation without bone grafting. (E) and (F) show restoration of the medial plateau height, with union; revision surgery entailed corrective osteotomy using medial buttress plate fixation with solid bone grafting.

arthritis) categories. Among these complications, tibial plateau nonunion is uncommon because of the relatively large appositional cancellous bone as well as the cross-sectional area and abundant blood supply of the proximal tibia.[19] It is most commonly seen in Schatzker type VI injuries at the metaphyseal—diaphyseal junction.[10] Rademakers et al[20] analyzed 202 patients with tibial plateau fractures and followed them up for 1 year. Ten patients (5%) had a fracture healing complication (nonunion or malunion).

Data in our series revealed that seven patients (28%) with Schatzker type V and VI fractures had nonunions; the other 18 patients had malunions. Analysis of the causes of failure for these 25 patients revealed that 19 (76%) had inadequate fixation, 21 (84%) had malreduction, and 25 (100%) had bone defects. Severe comminution, unstable fixation, mechanical failure of the implant, malreduction, inadequate bone graft, or a combination of these factors results in nonunion or malunion. Careful preoperative planning and stable internal fixation will reduce the incidence of these complications.

The method of fixation is still the major controversial point in the treatment of tibial plateau fracture. On the basis of the Schatzker classification, fractures can be divided into low energy traumas (types I to III) and high energy traumas (types IV to VI). For the simple or unicondyle fracture (types I to IV), use of ORIF, transverse cannulated AO screws or a single buttress plate with a single incision is suitable, depending on patient age, bone quality, and comminution. Among our 16 patients in whom fixation failed, six patients had a simple or unicondylar tibial plateau fracture (four type II, two type IV). The index fixations used one or more cannulated screws or Kirchner wires. However, because of the presence of comminuted fractures with huge bony defects after reduction, malposition of the screws or wires fixation resulted in nonunion or malunion. Of the other 10 patients in whom fixation failed, three had a type V and seven a type VI tibial plateau fracture. Fixation with one buttress plate and one cannulated screw following inadequate incision and arthrotomy is the major cause of failure.

Biomechanical and clinical studies suggest that the best method of fixation for the complex or bicondylar fracture pattern (types V and VI) is dual buttress plate fixation.[21] Fernandez reported an anterior approach with an osteotomy of the tibial tubercle for bicondylar tibial fractures that avoided double incisions but required extensive dissection.[22] Chan et al[8,9] suggest that for type V and VI fracture patterns the use of arthroscopy-assisted surgery, to achieve dual buttress plate fixation through medial and lateral metaphyseal incisions with minimal periosteal stripping, can avoid complications such as wound infection, nonunion, malunion, or knee stiffness. Sufficient fixation with adequate reduction, in a clear surgical field, is essential to quickly restore the osseous nature of the plateau and provide sufficient biomechanical stability to allow immediate passive motion training.

All 25 patients (100%) had major bone defects. In 1990, Lachiewicz and Funcik analyzed the factors influencing the ORIF results of 43 tibial plateau fractures.[23] They found that eight patients (19%) who underwent no bone grafting had the worst results. Except for the simple type I split, or in young patients with good bone quality and minimal comminution, bone grafting should be applied to elevate the depressed fragment and to correct the varus or valgus deformity.[2,7–9] Furthermore, appropriate management of the soft tissue is an important factor in successful management of these fractures. Many studies have found that soft tissue injuries can occur in association with tibial plateau fractures.[7–9,24,25]

Nine patients in our series (36%) had associated soft tissue injuries, the most common injury being tearing of the lateral

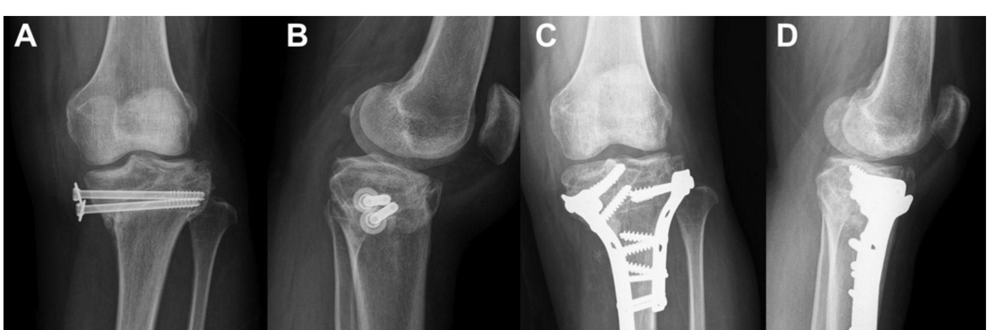

Fig. 3. A 36-year-old female motorcycle accident victim with a Schatzker type V tibial plateau fracture of the left knee. (A) and (B) show the causes of failure, including malreduction, improper fixation using only two medial cannulated screws with washers, and huge bone defects without bone grafting. (C) and (D) show restoration of bilateral plateau height, with union; revision surgery entailed corrective osteotomy, using bilateral buttress plate fixation with solid bone grafting.

Table 3
Data of the 25 patients: Schatzker classification of fracture types and associated soft tissue injuries.

	Type II	Type III	Type IV	Type V	Type VI
Patients	5	1	4	7	8
Patients with soft-tissue injuries, *n* (%)	1 (20)	0 (0)	1 (25)	5 (71)	2 (25)
Associated injuries	2	0	1	8	4
	LM tears (1); PCL partial tear (1)		LM tear (1)	LM tear (3); MM tear (1); ACL avulsion fracture (1); PCL partial tear (2); popliteal tendon avulsion fracture (1)	LM tear (1); PCL partial tear (2); MCL partial tear (1)

ACL = anterior cruciate ligament; LM = lateral meniscus; MCL = medial collateral ligament; MM = medial meniscus; PCL = posterior cruciate ligament.

meniscus (67%). Those who sustained a high energy and comminuted tibial plateau fracture (e.g., type V or type VI) had a high incidence of associated soft tissue injury. These patients need to achieve an early range of motion in order to prevent stiffness of the knee developing. The revision operations with the aid of arthroscopy allowed adequate management of the residual soft tissue injuries and intra-articular debris. As a result, smooth passive motion of knee during the rehabilitation allowed quicker recovery.

Because this was a retrospective study, and the patients received the index surgery in other hospitals, we lacked initial images of the injured knees and there was no unified postoperative rehabilitation program; these factors may cause bias in our study. The ultimate goals when treating a tibial plateau fracture are to re-establish joint stability, correct alignment, and restore articular congruity, while preserving the full range of motion. Each of the operative techniques requires considerable surgical skill and mature judgment. A surgeon must have a thorough understanding of the local anatomy, the biomechanics of the fracture fixation, and a vision of the fracture healing patterns after fixation. Preoperative planning for surgical repair is of the utmost importance. Operative treatment must be individualized with respect to each patient's age, level of activity, medical morbidity and expectations, extent of fracture comminution, joint impaction, and associated soft tissue injury.

6. Conclusion

The principal surgical procedures for the management for tibial plateau fracture are anatomical reduction, firm fixation, and bone grafting. Malreduction, improper fixation, and bone defects without grafting can lead to failure of surgical treatment. The key to successful surgical treatment is a well designed treatment scheme tailored to each patient's specific fracture type and soft tissue condition.

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