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ORIGINAL PAPER

Causes and treatment outcomes of revision surgery after open reduction and internal fixation of tibial plateau fractures

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Abstract

Purpose Treatment of a tibial plateau fracture (TPF) remains controversial and is generally challenging. Many authors report good results after conventional open reduction and internal fixation in TPF, but complications still occur. This study analyzed causes and outcomes of revision surgery for TPF. The usefulness of a flow chart for revision surgery in TPF was also evaluated.

Methods We reviewed all patients who underwent more than two operations for a TPF between 2008 and 2015. Finally, 24 cases were selected and retrospectively investigated. The medial tibial plateau angle and proximal posterior tibial angle were radiologically evaluated. The American Knee Society Score (AKSS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), range of motion (ROM), and bone union time were investigated after surgery.

Results Revision surgery for infection was performed in eight cases, for nonunion in six cases, for posttraumatic arthritis (with total knee arthroplasty) in six cases, and for other reasons in four cases. The mean clinical AKSS at final follow-up was 87.3 ± 5.3 (range, 75–95), the functional AKSS was 81.9 ± 5.5 (range, 70–90), the WOMAC score was 9.9 ± 3.1 (range, 5–16), the flexion ROM was 119.8 ± 16.5° (range, 100–150°), and the extension ROM was 2.5 ± 3.3° (range, 0–10°).

Conclusions Although complications cannot be avoided in some cases, good clinical outcomes are possible when patients are divided according to the presence or absence of infection, with selection of appropriate revision surgery as shown in the flow chart. If an infection is present, treatment should be based on the presence or absence of bone union. If there is no infection, treatment should be based on the presence or absence of nonunion, post-traumatic arthritis, malunion, or immediate post-operative malreduction.

Keywords Tibial fracture · Postoperative complications · Reoperation · Flow chart

Introduction

Treatment of a tibial plateau fracture (TPF) remains controversial, and is generally challenging because patients can develop post-operative arthritis and functional disability of the knee joint [1–3]. Many authors report good results after conventional open reduction and internal fixation (OR-IF) in TPF, but complications still occur [4–7]. These complications include infection, posttraumatic arthritis, nonunion, malunion, and knee joint stiffness [6, 8–10].

The incidence of post-operative complications after treatment of TPF has not been firmly established [9, 11]. Yang et al. reported that 14% of 44 TPF (Schatzker type VI) cases involved deep infections [12]. Weiner et al. reported a 4% rate of nonunion requiring bone grafting in 50 severe fractures of the proximal tibia treated with internal fixation combined with external fixation and followed prospectively for two years [13]. In one study, posttraumatic arthritis after TPF was found in 44% of 131 cases at 7.6 years of follow-up [14]. Although many reports have described complications in TPF, few have focused solely on revision surgery. Furthermore, no studies have suggested appropriate treatment guidelines for revision surgery in a TPF.

This study analyzed causes and outcomes of revision surgery for TPF. The usefulness of a flow chart for decision-making of revision surgery in TPF was also evaluated.

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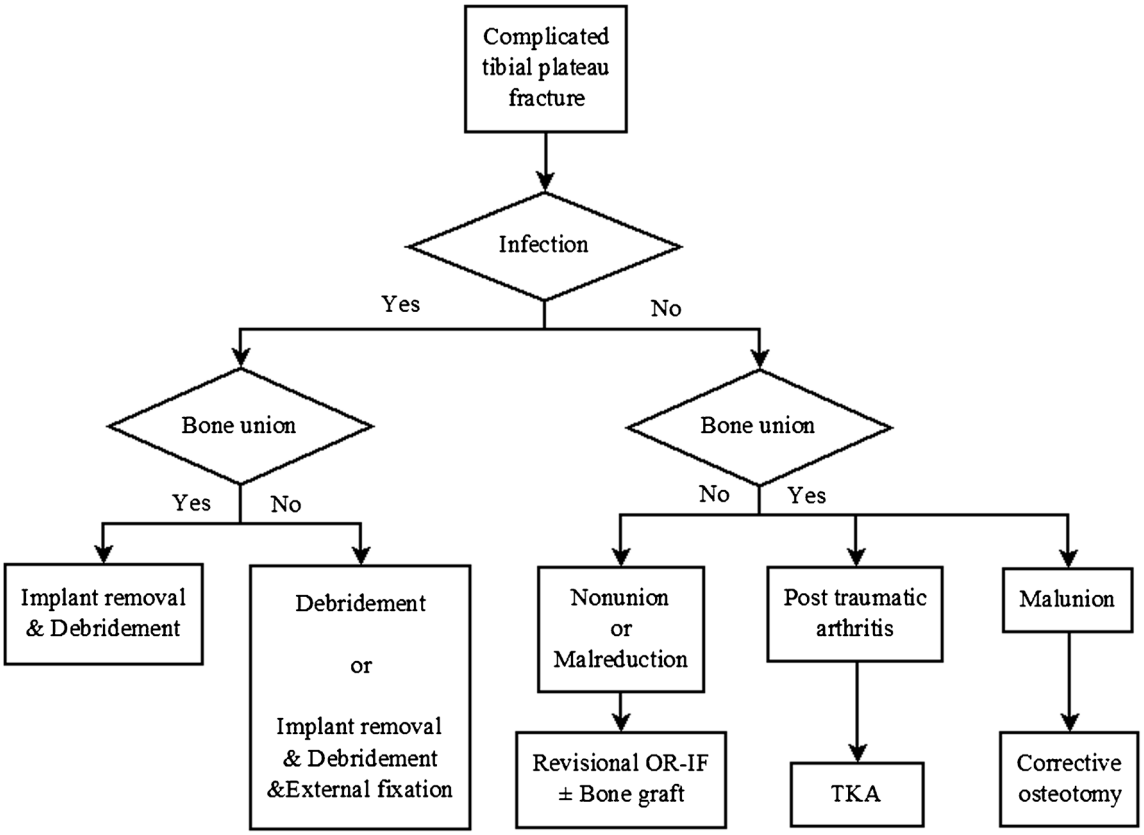

Fig. 1 Flow chart shows decision-making for complicated tibial plateau fractures

Materials and methods

Patient selection

This study was approved by our hospital institutional review board. We reviewed all patients who underwent more than two operations for a TPF between January 2008 and January 2015. Of 174 cases, those with simple implant removal ($n = 125$) or follow-up less than two years ($n = 23$) were excluded. Patients older than 60 years with post-traumatic arthritis were also excluded ($n = 2$). Finally, 24 cases were selected and retrospectively investigated. Mean follow-up was 3.7 years (range, 2.2–10.9 years). Revision surgery for infection was performed in eight cases, for nonunion in six cases, for post-traumatic arthritis (with total knee arthroplasty [TKA]) in six cases, and for other reasons in four cases.

Surgical procedure and post-operative care

The decision-making was selected using a flow chart (Fig. 1). Patients were positioned supine on a radiolucent operating table before receiving general or spinal anesthesia. A skin incision was made over pre-existing surgical scars except in TKA and arthroscopic procedures.

In cases of infection, copious irrigation was followed by soft tissue debridement using a rongeur and curette. If bone union was sufficient, implant removal was performed. However, if bone union was not apparent, only debridement or implant removal with external fixation was performed. In cases of joint infection after implant removal, arthroscopic debridement was performed. Drainage was maintained until discharge had nearly resolved. Antibiotics specific for cultured organisms were given intravenously for three to six weeks.

In cases of aseptic nonunion, autogenous iliac bone grafting was performed with revision of osteosynthesis. In cases of malreduction, immediate revision OR-IF was performed. In cases of malunion, corrective osteotomy was performed after thorough pre-operative evaluation.

If required for posttraumatic arthritis, a routine TKA was performed, using a median skin incision and medial parapatellar approach. The articular capsule was exposed and soft tissue excision included medial soft tissue release. Meniscus and anterior cruciate ligament excision was followed by osteotomy of the proximal tibia and distal femur. No patellar resurfacing was performed in any cases, but the patellar margin was cauterized.

Evaluation methods

The medial tibial plateau angle (MTPA) and proximal posterior tibial angle (PPTA) were radiologically evaluated. The

Table 1 Patient demographics of the infected group

Case	Sex	Age (years)	Vector	Schatzker type	AO	BMI	Associated injury	G-A classification	Compartmentsyndrome	Days from injury to internal fixation
1	M	36	F/D	5	C2	44.1	–	–	–	7
2	M	55	F/D	2	B3	27.7	Ipsilateral ACL and MCL rupture	–	–	4
3	M	73	Motorcycle TA	6	C3	23.6	Ipsilateral patella open and calcaneus fracture	IIIA	–	0
4	F	74	F/D	5	C1	16.0	Ipsilateral lateral malleolar fracture	–	–	15
5	M	71	Pedestrian TA	5	C2	25.0	–	–	–	14
6	F	23	In car TA	2	B3	21.8	Ipsilateral femur shaft fx	–	–	9
7	M	50	Pedestrian TA	6	C3	24.8	Ipsilateral foot lisfranc injury	–	–	4
8	M	67	F/D	6	C3	24.6	–	IIIA	–	14

Case	Union time (months)	Implant removal	No. of debridement	Skin coverage	Culture	Intravenous antibiotics duration (days)	Comments
1	4	After bone union	2	–	*Klebsiella pneumoniae*	37 → D/C → 13	Infection occurs 40 days after first D/C.
2	7	After bone union	2	–	No growth	10 → D/C → 15	First OR-IF at outside institution. 1 month later, ACL reconstruction. 3 months later, infection occurred and transferred to our hospital.
3	6	After bone union	18	Skin graft	MRSA	212	Initially severe open fracture.
4	3	Immediately after bone union	2	Anterolateral thigh free flap	MRSA	182	Initially, OR-IF was performed at outside institution.
5	4	After bone union	2	Skin graft	*Klebsiella oxytoca*	122 → D/C → 94	After discharge, implant was exposed.
6	4	After bone union	1	–	*Acinetobacter baumannii*	20 → D/C → 14	Superficial infection occurs 3 months after D/C.
7	5	After bone union	1	–	No growth	14 → D/C → 30	Septic knee occurs 1 year after D/C. Arthroscopic debridement was performed.
8	7	Before bone union	5	–	*Pseudomonas aeruginosa*	119	First OR-IF at outside institution. After 2 months, OM occurred and transferred to our hospital. Implant removal and Ex-fix applied. Anti-bead was inserted.

AO the AO Foundation and Orthopaedic Trauma Association classification, *BMI* body mass index, *G-A* Gustilo and Anderson classification of open fracture, *F/D* fall down, *ACL* anterior cruciate ligament, *MCL* medial collateral ligament, *TA* traffic accident, *MRSA* methicillin-resistant *Staphylococcus aureus*, *D/C* discharge, *OR-IF* open reduction and internal fixation, *OM* osteomyelitis

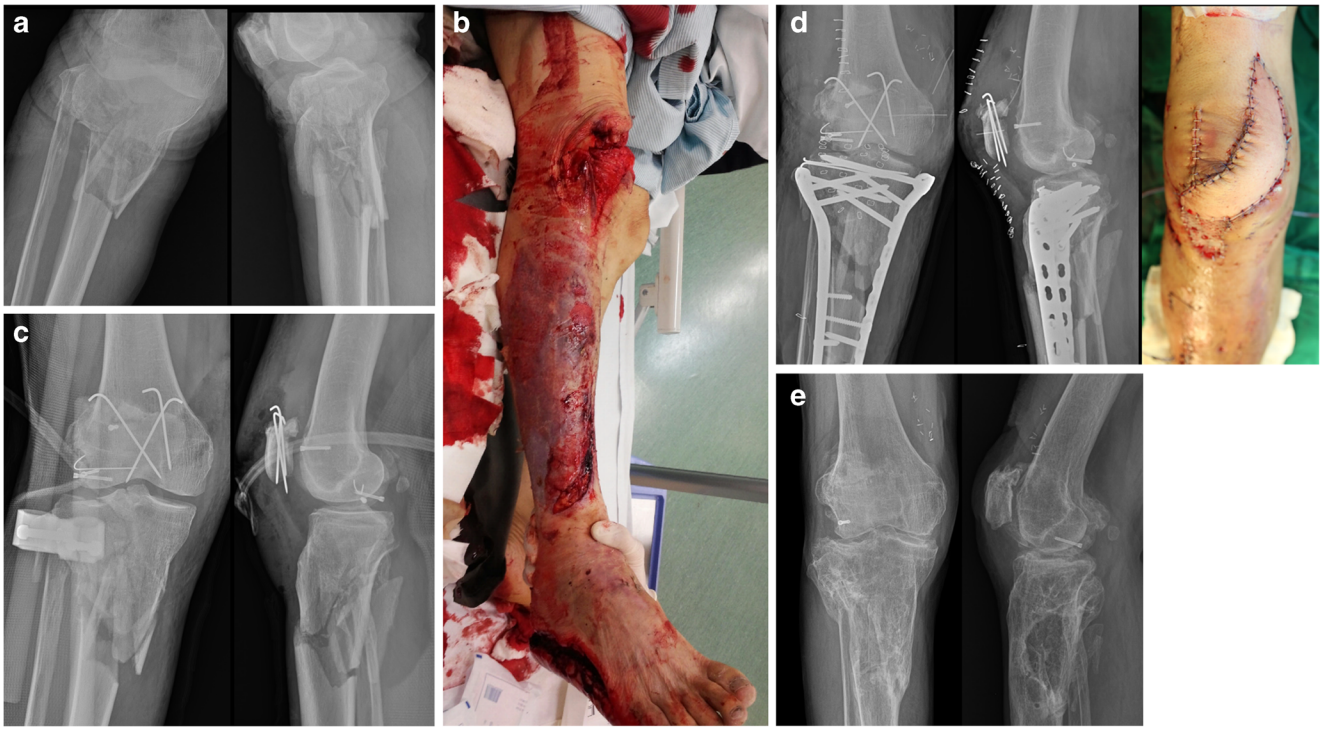

Fig. 2 Case number 3 is shown in Table 1. **a** A 73-year-old male was injured in a motorcycle accident and had a tibial plateau fracture (Schatzker type VI) as well as an ipsilateral open patellar fracture. **b** The initial photo shows degloving injury around the knee joint. **c** A temporary external fixator and temporary Kirschner wires were immediately placed after injury. **d** Three weeks after the first operation, dual plating using medial and lateral approaches was applied. Simultaneously, an anterolateral thigh perforator fasciocutaneous free flap was performed. **e** Simple radiographs 4 years after initial injury

American Knee Society Score (AKSS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), range of motion (ROM), and bone union time were investigated after surgery. Bone union was defined as formation of callus on the fracture site as clinically evident from anterior-posterior and lateral radiographs and when patients no longer felt pain at the fracture site on weight-bearing.

Results

Of eight patients with infection after initial OR-IF (Table 1, Fig. 2), five (62.5%) had a severe associated injury on the ipsilateral side; however, only two (25%) patients had open wounds. No patients had a compartment syndrome. The average duration from injury to OR-IF was 8.4 days and the average time to bone union was 5.0 months. Other than in one patient (12.5%), implants were removed after bone union. In one case, an external fixator was applied with wide debridement. An average of 4.1 debridements was performed, and additional skin coverage procedures were required in three patients (37.5%). Methicillin-resistant *Staphylococcus aureus* was cultured in two patients (25%); these required a longer period of intravenous antibiotic treatment.

Six patients required additional surgery due to nonunion (Table 2, Fig. 3). Four patients (66.7%) in this group had high-energy trauma; however, only one patient (16.7%) had both an open wound and compartment syndrome. Three of these six patients (50%) had severe associated ipsilateral injuries. All patients in this group received autogenous iliac bone grafts. The average MTPA and PPTA were 86.9 and 84.0° respectively. Two (33.3%) patients had an abnormal MTPA and three (50%) had an abnormal PPTA [15, 16].

Six patients required arthroplasty due to posttraumatic arthritis (Table 3, Fig. 4). The average age at injury was 44.0 years and five patients (83.3%) had high-energy trauma. No patients had pre-operative osteoarthritis, open wounds, or a compartment syndrome. The average duration from injury to arthroplasty was 1.7 years. All but one patient (16.7%) showed joint line incongruity in post-operative radiographs. The average MTPA and PPTA were 86.9 and 84.0°, respectively. Four (66.7%) patients had an abnormal MTPA and three (50%) had an abnormal PPTA [15, 16]. One patient (16.7%) with an infection five years after initial TKA was treated with wide debridement and polyethylene exchange.

One patient each had revision OR-IF for malreduction and metal breakage, respectively (Table 4). Two patients had corrective osteotomy for malunion.

Table 2 Patient demographics of the nonunion group

Case	Sex	Age (years)	Vector	Schatzker type	AO	BMI	Preop OA	Associated injury
9	M	55	In car TA	1	A3	23.3	–	Contralateral tibia shaft and lateral malleolar fracture
10	M	69	In car TA	2	B1	26.4	OA	–
11	M	46	Crushing injury	6	C2	22.8	–	Ipsilateral femur neck and shaft open fracture
12	M	51	Pedestrian TA	6	B3	23.9	–	Ipsilateral femur neck and shaft fx/ipsilateral distal tibiofibular fracture
13	M	48	Pedestrian TA	6	C2	24.1	–	L2 bursting fracture
14	M	45	Pedestrian TA	6	C3	24.2	–	Ipsilateral femur shaft and distal femur fracture

Case	MTPA	PPTA	Interval to revision (months)	Bone graft	Union time after revision (months)
9	90.3	91.8	8	Autogenous bone graft	4
10	78.1	77.5	23	Autogenous bone graft	6
11	89.3	89.2	12	Autogenous bone graft	5
12	87.8	81.1	9	Autogenous bone graft	4
13	86.5	76.5	9	Autogenous bone graft	5
14	89.1	87.9	7	Autogenous bone graft	5

AO the AO Foundation and Orthopaedic Trauma Association classification, *BMI* body mass index, *Preop* preoperative, *OA* osteoarthritis, *G-A* Gustilo and Anderson classification of open fracture, *B/G* bone graft, *MTPA* medial tibial plateau angle (at initial internal fixation), *PPTA* proximal posterior tibial angle (at initial internal fixation), *TA* traffic accident

Fig. 3 Case number 13 is shown in Table 2. **a** A 48-year-old male was injured in a pedestrian traffic accident and had a tibial plateau fracture (Schatzker type VI). **b** Postoperative radiographs. **c** Nine months after initial open reduction and internal fixation, nonunion persisted. Revision surgery was performed immediately. **d** Simple radiographs 9 months after revision surgery showed bone union

Table 3 Patient demographics of arthroplasty

Case	Sex	Age (years)	Vector	Schatzker type	AO	BMI	Preop OA	Associated injury	G-A classification	Compartment syndrome	Union time (months)	Time to TKA (years)	Joint line congruence	MTPA	PPTA	Comments
15	F	29	F/D	5	C3	20.1	–	Ipsilateral femur neck fracture, bilateral calcaneus fracture	–	–	4	1.4	Incongruent	88.9	87	Infection occurs 5 years after initial TKA. Wide debridement and polyethylene changed was performed.
16	M	53	F/D	6	C3	26.2	–	–	–	–	6	3.0	Incongruent	78.6	81.5	–
17	M	41	F/D	5	C3	29.1	–	Ipsilateral LCL rupture, meniscus injury	–	–	6	2.1	Incongruent	86.6	85.5	Initial OR-IF at outside institution. Malreduction occurred and transferred to our hospital at 3 weeks later. Immediate revisional OR-IF was performed.
18	M	51	F/D	6	C3	22.8	–	Contralateral calcaneus fracture, L3 bursting fracture	–	–	8	0.8	Incongruent	91.2	84.7	–
19	M	47	F/D	4	C1	22.0	–	–	–	–	6	1.0	Incongruent	80.5	85.7	–
20	M	43	In car TA	2	C1	28.3	–	–	–	–	6	2.0	Congruent	74.1	78.4	–

AO the AO Foundation and Orthopaedic Trauma Association classification, *BMI* body mass index, *Preop* preoperative, *OA* osteoarthritis, *G-A* Gustilo and Anderson classification of open fracture, *TKA* total knee arthroplasty, *MTPA* medial tibial plateau angle (at initial internal fixation), *PPTA* proximal posterior tibial angle (at initial internal fixation), *F/D* fall down, *TA* traffic accident, *LCL* lateral collateral ligament, *OR-IF* open reduction and internal fixation

Fig. 4 Case number 17 is shown in Table 3. **a** A 41-year-old male was injured in a fall from a height and had a tibial plateau fracture (Schatzker type V), as well as ipsilateral lateral collateral ligament rupture and meniscal injury. **b** Initial open reduction and internal fixation was performed at an outside institution. However, malreduction occurred. **c** Three weeks after the initial operation, he was transferred to our hospital and dual plating using medial and lateral approaches was immediately performed. **d**, **e** Simple radiographs before and 2 years after arthroplasty

The mean clinical AKSS at final follow-up was 87.3 ± 5.3 (range, 75–95), the functional AKSS was 81.9 ± 5.5 (range, 70–90), the WOMAC score was 9.9 ± 3.1 (range, 5–16), the flexion ROM was 119.8 ± 16.5° (range, 100–150°), and the extension ROM was 2.5 ± 3.3° (range, 0–10°) (Table 5).

Discussion

This study was conducted to determine appropriate treatment for a TPF when revision surgery is needed. If unavoidable complications necessitate revision surgery, good clinical outcomes can be achieved when the patients are divided into groups according to the presence of infection with selection of appropriate revision surgery as shown in the flow chart.

Studies in TPF patients have reported different incidence rates of infection after OR-IF [12]. In comminuted or bicondylar fractures, infection rates have been as high as 23% [17] to 28% [6]. Studies of infection rates for all types of TPF patients show a lower prevalence, from 5.7% [10] to 15.7% [18]. In this study, the incidence of infection was about 4%, similar to that of one study [10]. This is presumed to be due to inclusion of less severe TPF cases. In fact, 75% of infected patients in this study had bicondylar fractures. The severity of the fracture seems to be closely related to infection. However, all patients were

Table 4 Patient demographics of other patients

Case	Sex	Age (years)	Vector	Schatzker type	AO	BMI	Preop OA
21	F	58	Bicycle TA	5	C3	26.4	OA
22	M	70	Pedestrian TA	5	C3	17.4	OA
23	F	37	F/D	2	B3	30.2	–
24	M	41	In car TA	2	B3	30.7	–

Case	Associated injury	Union time (months)	MTPA	PPTA	Comments
21	–	4 (after revision)	83.6	82	Revisional OR-IF at 5 days later due to malreduction
22	–	4 (after revision)	87.1	86.9	Metal breakage occurs 3 months after first OR-IF
23	–	6	88.6	75.7	Initial OR-IF at outside institution. Malunion occurs and transferred to our hospital
24	Ipsilateral patella fracture	4	82.3	85.5	Revisional OR-IF due to malunion

AO the AO Foundation and Orthopaedic Trauma Association classification, *BMI* body mass index, *Preop* preoperative, *OA* osteoarthritis, *G-A* Gustilo and Anderson classification of open fracture, *MTPA* medial tibial plateau angle (at initial internal fixation), *PPTA* proximal posterior tibial angle (at initial internal fixation), *TA* traffic accident, *F/D* fall down, *OR-IF* open reduction and internal fixation

treated according to the flow chart and showed good clinical outcomes. Treatment should be determined based on bone union.

Nonunion is a rare complication because of the predominance of cancellous bone and the rich blood supply of the proximal tibia [4]. Nonunion is usually the result of severe

Table 5 Clinical outcomes

Case	Follow-up period (years)	Clinical AKSS	Functional AKSS	WOMAC	ROM (°, flexion)	ROM (°, extension)
1	3.4	85	80	13	150	0
2	3.2	80	90	12	130	5
3	3.7	90	70	14	100	5
4	2.3	88	80	10	110	0
5	6.8	85	90	10	120	0
6	2.1	90	80	9	130	0
7	2.3	80	70	16	100	10
8	8.5	90	85	8	140	0
9	2.1	95	90	5	100	5
10	3.3	85	80	10	120	5
11	4.4	83	85	11	130	0
12	5.1	90	85	8	130	5
13	2.5	85	85	13	125	5
14	5.2	90	80	7	150	10
15	10.9	75	80	16	100	5
16	3.5	90	85	10	100	0
17	2.2	95	75	5	110	0
18	2.1	95	80	8	100	0
19	2.3	95	75	7	105	0
20	2.2	90	80	6	110	0
21	2.4	85	85	10	120	0
22	3.4	85	85	10	145	0
23	2.2	90	85	8	130	5
24	3.2	80	85	12	120	0

All variables were at last follow-up

AKSS American Knee Society score, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis index, *ROM* range of motion

comminution, unstable fixation, metal failure, infection, or a combination of these factors. Some authors reported a 4% nonunion rate requiring bone grafting of a proximal tibial fracture [13]. This study also showed a 4% incidence of nonunion. In this study, 75% of nonunion cases were severe bicondylar fractures. However, no cases had associated infection. All patients underwent revision OR-IF with autogenous iliac bone grafting, and the outcomes were acceptable.

Recently, Krettek et al. described in the German literature a classification of tibial plateau malunions based on location, geometry, severity, and progression [19]. Van Nielen et al. performed up to five osteotomies, including the fibula shaft, to correct tibial plateau malunion and reported good clinical outcomes [20]. In this study, there were two cases of malunion. We also performed several osteotomies and the outcomes were acceptable.

Articular incongruity and joint instability are reportedly the leading causes of post-traumatic arthritis [1, 21–23]. In this study, joint line incongruity was observed in all but one patient in the TKA group. One patient with a congruent joint line had a severe MTPA deformity and required arthroplasty.

This study had several limitations. First, the number of cases was insufficient for clinical evaluation. Moreover, some patients did not undergo initial OR-IF at our hospital, and the incidence may not be accurate. However, it is thought that complications after TPF surgery are rare; as this study was performed at a single centre, the validity increased.

We suggest that the decision-making for treatment of complicated TPF should be divided according to the presence or absence of infection, as shown in the flow chart. If an infection is present, treatment should be based on the presence or absence of bone union. If bone union is sufficient, implant removal is needed. However, if bone union is not apparent, only debridement or implant removal with external fixation should be performed. In cases of joint infection after implant removal, arthroscopic debridement is needed. If there is no infection, treatment should be based on the presence or absence of nonunion, post-traumatic arthritis, malunion, or immediate postoperative malreduction. In cases of aseptic nonunion, autogenous iliac bone grafting should be performed with revision of osteosynthesis. In the case of post-traumatic arthritis, a routine TKA is needed. In cases of malunion, corrective osteotomy should be performed after thorough pre-operative evaluation. In cases of malreduction, immediate revision OR-IF is needed.

Conclusion

Although complications cannot be avoided in some cases, good clinical outcomes are possible when patients are divided according to the presence or absence of infection, with selection of appropriate revision surgery as shown in the flow chart. If an infection is present, treatment should be based on the presence or absence of bone union. If there is no infection, treatment should be based on the presence or absence of nonunion, posttraumatic arthritis, malunion, or immediate postoperative malreduction.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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