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Staged Treatment of Bicondylar Tibial Plateau Fracture (Schatzker Type V or VI) Using Temporary External Fixator: Correlation between Clinical and Radiological Outcomes

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Purpose: This study is to investigate clinical and radiological results of staged treatment using a temporary external fixator in bicondylar tibial plateau fractures (TPFs) and to evaluate correlation between prognostic factors and postoperative clinical outcomes.
Materials and Methods: Twenty-four bicondylar TPF patients were selected. All patients were operated by a temporary external fixator first and then open reduction and internal fixation with dual plating. Clinical and radiological outcomes were evaluated.
Results: The mean American Knee Society score (AKSS) was 85.3. The mean Western Ontario and McMaster Universities Osteoarthritis index was 11.2. The mean range of motion (ROM) was 123.4°. The mean medial tibial plateau angle (mTPA) was 88.3°, and the mean proximal posterior tibial angle (PPTA) was 8.4°. Compared with the uninjured limb, the mean difference of mTPA was 1.5° and that of PPTA was 4.0°. The difference of PPTA and the AKSS demonstrated negative correlation (p=0.007). Patients with normal mTPA showed better ROM than those with abnormal mTPA (p=0.041).
Conclusions: Staged treatment using a temporary external fixator in bicondylar TPFs showed good clinical and radiological outcomes. Surgeons should evaluate the reduction status intraoperatively by fluoroscopy and also refer to the uninjured limb radiologically.

Keywords: **Tibia, Plateau, Bicondylar, Fracture, External fixator**

Introduction

Bicondylar tibial plateau fractures (TPFs) usually accompany severe comminuted fractures and soft tissue injuries because of high energy trauma. Based on the complexity of the fracture that involves both medial and lateral condyles, extensive dissection of soft tissue can aggravate soft tissue injury because soft tissue of proximal tibia is very thin[1-3]. As a result, complications, such as skin necrosis, superficial or deep infection, and non-union, can occur.

Treatment of bicondylar TPFs is still a controversial issue and is generally difficult because patients can suffer from postoperative arthritis and functional disability of the knee joint[4-7]. Many authors have reported that conventional open reduction and internal fixation (OR-IF) in bicondylar fractures can cause soft tissue injuries, leading to complications such as non-union, knee joint stiffness, and metal failure[8-10]. Several fixation methods can be employed to solve soft tissue problems including the use of a hybrid external fixator[11,12] and staged treatment using a temporary external fixator[13-15]. Some authors have reported favorable clinical outcomes with staged treatment using a temporary external fixator[9,16]. The benefits of temporary external fixation include immediate osseous stabilization, prevention of further articular damage, access to wounds, increased patient comfort, ease of subsequent reduction, and potential for decreased narcotic re-

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quirements[14].

In the present study, authors have investigated clinical and radiological results of staged treatment using a temporary external fixator in bicondylar TPFs and evaluated correlation between prognostic factors and postoperative clinical outcomes.

Materials and Methods

1. Patients

This study was approved by our hospital's Institutional Review Board. Of the 70 patients who underwent operation for TPFs in our hospital between January 2012 and January 2014, 33 patients who presented with a Schatzker type V or VI fracture were selected. Patients were excluded if they had injuries in both limbs or an injury to the spinal cord with motor weakness, underwent above-knee amputation or early ambulation with metal failure, or were lost to follow-up. Ultimately, 24 patients were selected and retrospectively investigated (Fig. 1). The mean follow-up was 24.2 months (range, 15 to 32 months). Clinical details of the patients are described in Table 1.

2. Surgical Technique and Rehabilitation

Patients were positioned supine on the radiolucent operating table before receiving general or spinal anesthesia. In cases where patients were diagnosed with compartment syndrome, the operator immediately made dual incisions (anterolateral and posteromedial incisions) on the calf followed by fasciotomy to all compartments. Compartment syndrome was diagnosed clinically by using 5P physical signs and symptoms (pain, pallor, pulselessness, paresthesia, and paralysis). In case of an open fracture, massive irrigation and wound debridement was done first and then a temporary external fixator was applied. However, in case of a closed fracture, an external fixator was applied immediately.

Pins of temporary external fixators were carefully applied considering the position of medial and lateral plating. Subsequently, on a daily basis, authors carefully observed soft tissue of patients and planned appropriate time for final internal fixation with dual plating. In secondary plate fixation, under supine position, separate skin incisions which were anterolateral and posteromedial for dual plating (tubular plate or proximal medial plate [Synthes, Oberdorf, Switzerland], proximal lateral locking plate [Zimmer, Warsaw, IN, USA]) were done and the distance between skin incisions was kept to be more than 8 cm (Fig. 2).

Basically, antibiotics were used for approximately 5 to 7 days after the second operation. However, antibiotics were used longer if the patient had other complications due to systemic trauma or open fractures upon confirming the wound status.

We did not apply any splint or cast immobilization to prevent iatrogenic paralysis. The stitches were removed about 2 weeks after surgery. Range of motion (ROM) exercises using a continuous passive motion machine were started about 1 week after surgery and were increased gradually thereafter. Weight bearing was attempted at 6 to 8 weeks after surgery, and the degree of bony union was periodically evaluated.

3. Evaluation Methods

Authors evaluated the clinical and radiological outcomes as well as complications. Clinically, the American Knee Society score (AKSS), the Western Ontario and McMaster Universities Osteoarthritis index (WOMAC), the ROM, and bone union time

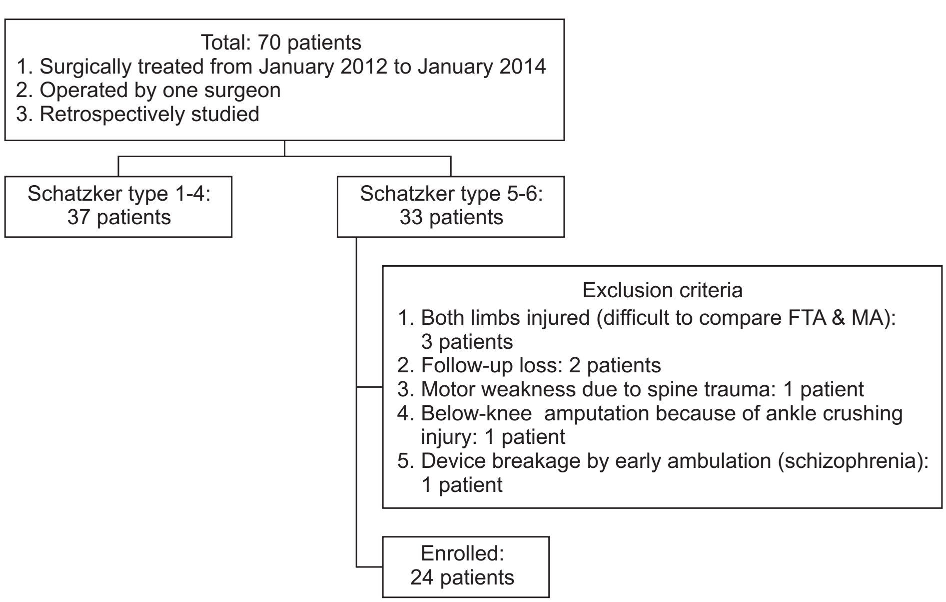

Fig. 1. Patient enrollment flow chart. FTA: femoral tibial angle, MA: mechanical axis.

Table 1. Clinical Details of the Patients

Case	Sex	Age (yr)	Vector	AO	Type	Preop OA	Associated injury	Days from injury to internal fixation	Antibiotics duration	G-A classification	Compartment syndrome	Complication
1	F	70	Pedestrian TA	C1	V	OA	Ipsilateral tibia shaft fracture	13	25			
2	F	74	Motorcycle TA	C1	VI	OA	Ipsilateral distal tibia open fracture	7	24	IIIA		
3	F	65	Pedestrian TA	C1	V		Ipsilateral fibular head fracture	9	14			
4	F	64	Motorcycle TA	C1	VI			7	14		Compartment	
5	M	48	Pedestrian TA	C2	V		Ipsilateral fibular avulsion fracture & LCL rupture	5	11			
6	F	49	Motorcycle TA	C2	V			14	18		Compartment	
7	M	37	F/D	C2	V			14	36		Compartment	
8	F	48	In car TA	C2	VI	OA		8	13	II		
9	F	54	Motorcycle TA	C2	V			9	15			
10	M	71	Bicycle TA	C2	V	OA		21	42	IIIB	Compartment	Revision due to metal failure
11	F	76	F/D	C2	VI			14	19		Compartment	
12	M	57	Motorcycle TA	C3	VI		Ipsilateral popliteal artery intima injury	30	44		Compartment	TKA due to postoperative OA
13	F	60	In car TA	C3	VI	OA		6	31			
14	M	57	In car TA	C3	VI	OA	Ipsilateral femur shaft fracture	14	25	IIIB		
15	M	79	Motorcycle TA	C3	VI	OA		18	23	II	Compartment	
16	M	36	F/D	C3	V			7	36			
17	M	61	In car TA	C3	VI			13	34	IIIA		
18	M	60	Pedestrian TA	C3	V			6	28	IIIA		
19	M	61	F/D	C3	VI	OA	Contralateral calcaneus fracture	14	19		Compartment	
20	F	59	Bicycle TA	C3	VI			9	15			
21	F	65	Pedestrian TA	C3	VI	OA	Ipsilateral pelvic ring fracture, lateral malleolar fracture	14	31		Compartment	
22	M	57	In car TA	C3	VI	OA	Ipsilateral MCL & LCL rupture, fibular shaft fracture	10	65			
23	M	58	F/D	C3	VI			13	27		Compartment	
24	M	51	F/D	C3	VI			22	43	IIIA		

AO: the AO Foundation and Orthopaedic Trauma Association classification, Preop: preoperative, OA: osteoarthritis, G-A: Gustilo and Anderson classification of open fracture, TA: traffic accident, LCL: lateral collateral ligament, F/D: fall down, TKA: total knee arthroplasty, MCL: medial collateral ligament.

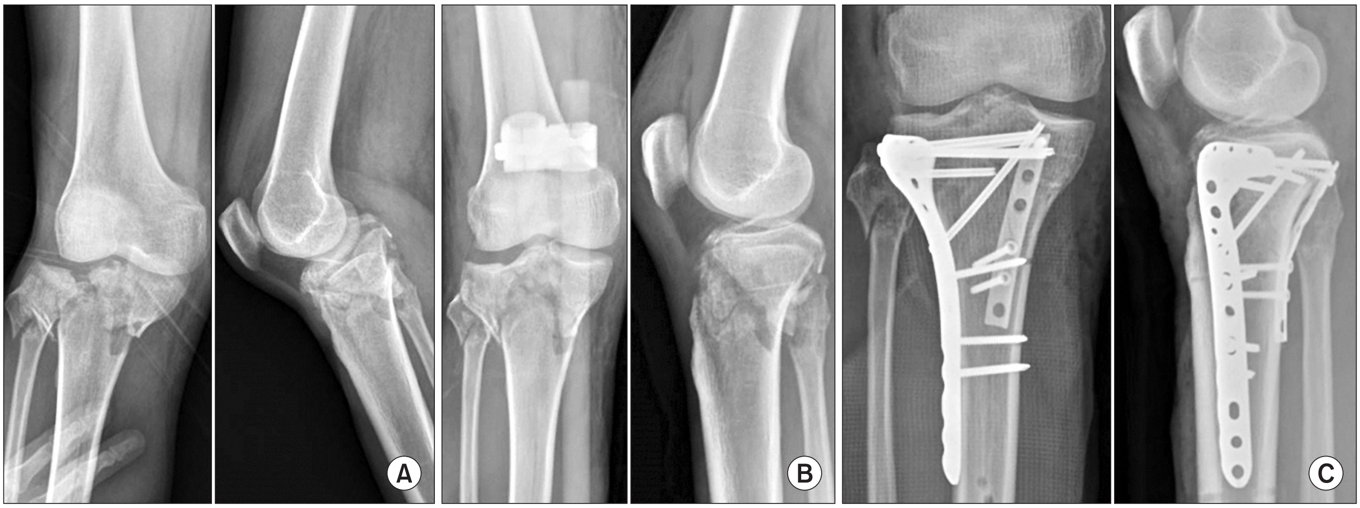

Fig. 2. Radiographs of case no. 19 presented in Table 1. (A) A 60-year-old male patient was injured in a pedestrian traffic accident and suffered a tibial plateau fracture (Schatzker type VI) as well as a fracture of the fibula. (B) A temporary external fixator was immediately applied after injury. (C) Six days after the first operation, dual plating using medial and lateral approaches was applied.

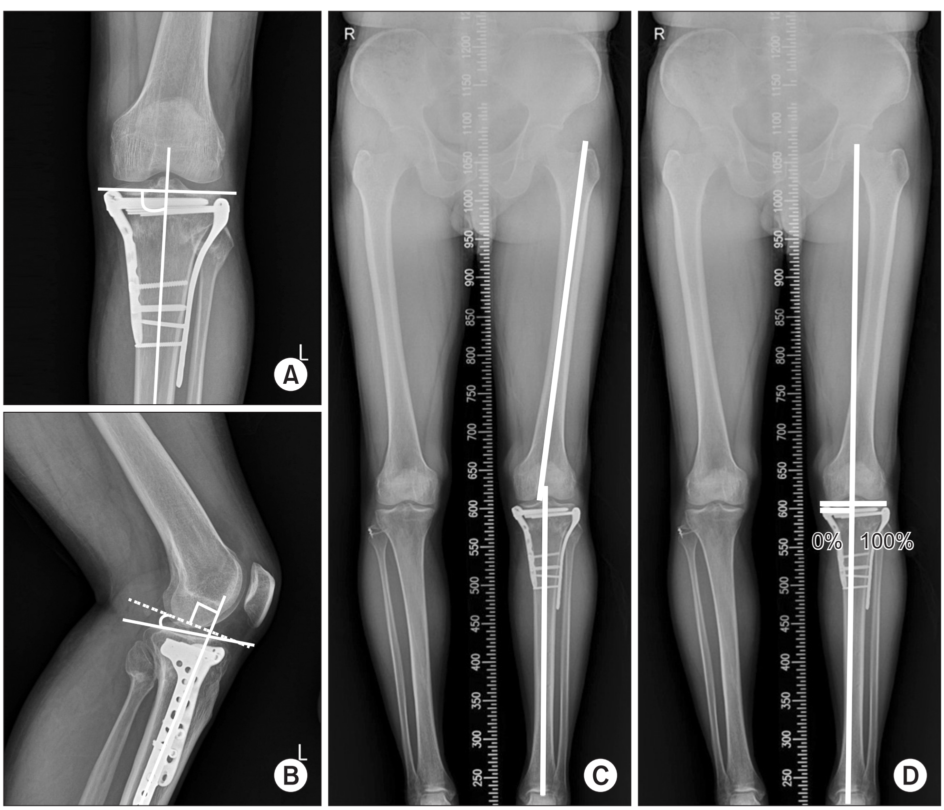

Fig. 3. Radiological evaluation. (A) The medial tibial plateau angle was measured between the axis of the articular surface of the tibial plateau and the anatomical axis of the proximal tibia on the anteroposterior view of the knee. (B) The proximal posterior tibial angle was measured between the articular surface of the medial tibial plateau and the perpendicular line to the anterior cortical margin of the proximal tibia on the lateral view of the knee. (C) The femoral tibial angle was measured between the anatomical axes of the femur and tibia. Genu valgum was given a positive angle. (D) Mechanical axis and deviation of the mechanical axis. The mechanical axis was defined as a line connecting the center of the hip and the center of the ankle. Mechanical axis deviation was measured by assessing the location of the mechanical axis crossing through the articular surface of the tibial plateau.

were investigated after surgery. Bone union was considered obtained when formation of callus on the fracture site was clinically evident on the anteroposterior and lateral radiographs and when patients do not feel pain on the fracture site on weight bearing.

The medial tibial plateau angle (mTPA), the proximal posterior tibial angle (PPTA), the femoral tibial angle (FTA), and the mechanical axis deviation (MAD) were also evaluated (Fig. 3). The MAD was measured by assessing the location of the mechanical axis crossing through the articular surface of the tibial plateau[17]. Authors also measured the mTPA and the PPTA of the uninjured limb preoperatively and calculated differences in the mTPA and the PPTA between the postoperative radiograph and the preoperative radiograph of the uninjured limb. Clinical results and radiological results were evaluated with regard to the correlation between the results. Furthermore, correlation between preoperative prognostic factors and clinical outcomes were evaluated.

The means and ranges for all continuous variables were obtained with IBM SPSS ver. 23.0 (IBM Co., Armonk, NY, USA). Mann-Whitney *U*-test, Spearman correlation analysis, Kruskal-Wallis test, and Fisher exact test were used. A p-value <0.05 was considered to be statistically significant.

Results

Demographic characteristics of 24 patients are presented in Table 2. At the final follow-up, the mean AKSS was 85.3±6.2 (range, 68 to 93), the WOMAC was 11.2±6.2 (range, 1.0 to 21.3), and the ROM was 123.4°±10.0° (range, 101° to 142°). The bone union time at the final follow-up was 16.5±4.6 weeks (range, 10.9 to 26.1 weeks). In case of metal failure (case no. 10), bone union time was measured from revision surgery (Table 2).

The mean mTPA at the final follow-up was 88.3°±1.9° (range, 83.3° to 91.3°) and the PPTA was 8.4°±5.9° (range, 0.8° to 22.1°). The mean FTA at the final follow-up was 4.53°±1.9° (range, −3.3° to 10.6°) and the MAD was 44.9%±17.5% (range, 9.6% to 70.6%). Compared with the uninjured limb, the mean difference of mTPA (D-mTPA) was 1.5°±1.1° (range, 0° to 4.6°) and that of PPTA (D-PPTA) was 4.0°±2.8° (range, 0.1° to 10.7°). The mean difference of FTA (D-FTA) was 3.3°±2.0° (range, 0.5° to 8.0°), and that of MAD (D-MAD) was 12.3%±10.4% (range, 0.1% to

Table 2. Clinical and Radiological Results of the Patients

Case	AKSS	WOMAC	ROM (°)	Bone union time (wk)	mTPA (°)	PPTA (°)	D-mTPA (°)	D-PPTA (°)	FTA (°)	MAD (%)	D-FTA (°)	D-MAD (%)
1	88	5.2	123	8.4	87.7	3.3	1.6	7.9	6.3	50.0	2.5	16.6
2	78	13.5	120	11.4	88.0	13.7	1.7	4.0	3.5	36.5	0.5	1.4
3	81	21.3	142	14.4	89.7	4.2	3.2	4.2	5.9	50.9	4.8	25.0
4	93	17.7	130	18.9	89.5	22.1	0.1	2.7	−3.3	10.1	2.9	4.9
5	78	17.7	130	20.2	87.7	15.4	0.3	4.3	5.6	58.0	1.8	16.1
6	83	6.2	135	18.6	91.3	4.9	1.8	9.5	2.6	37.1	2.9	18.7
7	90	12.5	114	11.4	86.8	5.1	1.4	1.3	3.9	19.8	2.9	3.7
8	91	9.3	125	23.3	89.6	5.5	1.4	2.0	3.5	56.2	1.1	4.1
9	81	8.3	130	13.6	88.2	5.8	0.7	9.7	6.0	41.2	1.4	0.1
10	93	5.2	115	22.9	84.2	1.2	4.6	0.1	3.1	19.8	8.0	15.9
11	93	3.1	115	15.3	89.9	6.8	1.4	2.2	1.8	60.3	4.7	4.0
12	68	21.3	133	14.4	91.0	19.8	1.3	5.0	6.0	69.5	0.7	15.0
13	83	9.3	115	15.6	88.2	7.8	0.0	4.9	9.9	60.9	7.8	39.5
14	81	9.3	122	26.1	90.5	10.2	1.8	0.8	10.6	70.6	6.0	27.3
15	91	7.2	125	16.3	88.6	3.5	0.1	0.7	5.4	45.5	1.6	5.0
16	83	17.7	110	19.3	88.2	6.4	1.3	1.4	1.0	23.5	3.0	3.6
17	80	21.3	114	11.7	88.7	0.8	1.2	10.7	−3.1	9.6	2.5	18.8
18	88	7.2	120	24.7	88.8	4.7	1.1	1.9	10.3	61.0	3.0	2.5
19	88	10.4	130	13.9	86.4	7.9	0.8	3.3	5.0	46.2	1.8	0.4
20	88	5.2	130	13.1	83.3	6.0	2.1	2.5	1.7	47.5	3.1	7.8
21	78	21.3	110	19.3	86.6	17.4	2.9	4.0	4.3	46.4	2.9	17.0
22	91	1	135	10.9	90.0	17.9	3.1	4.5	9.9	59.7	5.6	25.0
23	90	10.4	137.2	15.1	89.1	5.3	1.7	3.9	8.4	62.2	3.1	22.2
24	89	7.2	101	17.3	86.3	5.8	0.9	3.9	−1.4	36.0	5.2	0.3

AKSS: American Knee Society score, WOMAC: Western Ontario and McMaster Universities Osteoarthritis index, ROM: range of motion (flexion/extension arc), mTPA: medial tibial plateau angle, PPTA: proximal posterior tibial angle, D-mTPA: mean difference of mTPA, D-PPTA: mean difference of PPTA, FTA: femoral tibial angle, MAD: deviation of the mechanical axis, D-FTA: mean difference of FTA, D-MAD: mean difference of MAD.

Table 3. Correlation between Clinical and Radiological Results

	D-mTPA (°)[a]	D-PPTA (°)[a]	D-FTA (°)[a]	D-MAD (%)[a]	mTPA-group[b]	PPTA-group[b]
ROM	0.517	0.137	0.511	0.172	0.041	0.536
AKSS	0.977	0.007	0.086	0.471	0.431	0.637
WOMAC	0.420	0.376	0.066	0.779	0.225	0.252

D-mTPA: mean difference of medial tibial plateau angle, D-PPTA: mean difference of proximal posterior tibial angle, D-FTA: mean difference of femoral tibial angle, D-MAD: mean difference of deviation of the mechanical axis, mTPA-group: group difference between normal mTPA group and abnormal mTPA group, PPTA-group: group difference between normal PPTA group and abnormal PPTA group, ROM: range of motion (flexion/extension arc), AKSS: American knee society score, WOMAC: Western Ontario and McMaster Universities Osteoarthritis index.
[a]Spearman correlation analysis.
[b]Mann-Whitney *U*-test.

Table 4. Correlation between Clinical Results and Prognostic Factors

Variable	ROM	AKSS	WOMAC
Schatzker type[a]	0.881	0.631	0.810
AO classification[b]	0.596	0.592	0.367
Preoperative OA change[a]	0.536	0.637	0.289
Open[a]	0.060	0.644	0.601
Compartment syndrome[a]	0.637	0.118	0.601

ROM: range of motion (flexion/extension arc), AKSS: American Knee Society score, WOMAC: Western Ontario and McMaster Universities Osteoarthritis index, AO: the AO Foundation and Orthopaedic Trauma Association classification, OA: osteoarthritis.
[a]Mann-Whitney *U*-test.
[b]Kruskal-Wallis test.

39.5%) (Table 2).

The D-PPTA and the AKSS demonstrated negative correlation, which was statistically significant (p=0.007; Spearman correlation coefficient, −0.538). As in previous studies on comparison between the normal and abnormal groups[18,19], patients with normal mTPA showed better ROM than those with abnormal mTPA (p=0.041). However, other radiological outcomes were not in correlation with the clinical outcomes (Table 3).

Although it was not statistically significant, when the bicondylar fracture had open wounds, the ROM was worse (p=0.060). Other prognostic factors, for example, type of fracture, preoperative arthritic changes, compartment syndrome, and clinical outcomes showed no strong correlation (Table 4). Unlike in previous publications, the incidence of compartment syndrome in open fractures (25%) was relatively high; however, no statistically significant correlation was found between open fracture and compartment syndrome (p=0.388). By contrast, the incidence among closed fractures (50%) was typical (Fig. 4).

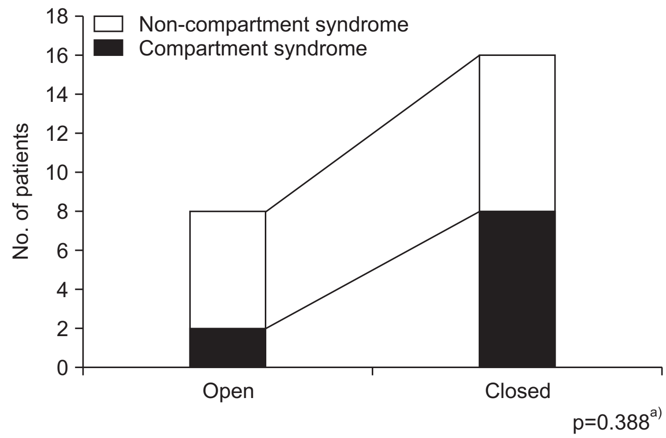

Fig. 4. Correlation between open fracture and compartment syndrome.
[a]Fisher exact test.

There were two cases of complications. Case no. 10 (Table 1) required revision surgery due to metal failure 1 month after first fixation even though the patient did not start early weight bearing. Case no. 12 (Table 1) had total knee arthroplasty due to postoperative arthritis 2 years after first fixation. No other incidences of complications such as infection, knee joint stiffness, and malunion were seen.

Discussion

TPFs are generally caused by high energy trauma such as traffic accident or falling down. This intraarticular fracture is divided into many subtypes according to mechanisms of injury[20]. Reduction strategy and prognosis vary according to fracture types such as simple or complex. Nevertheless, the main goals of treatment of bicondylar TPFs are to recover the articular surface and alignment of the lower extremity and to maintain the length of legs[21,22].

There are several fixation methods of bicondylar TPFs such as conventional OR-IF, hybrid external fixation, and staged treatment using a temporary external fixator. Lee et al.[23] reported a series of 45 bicondylar TPFs in 45 patients using conventional dual plating. The mean WOMAC was 34.1±4.91 (range, 0 to worst 96), and one case of infection and two cases of non-union were noted. Chae et al.[24] also reported a series of 12 Schatzker type VI TPFs in 11 patients using conventional dual plating. The mean AKSS was 85.0±8.6, and there was one case of joint stiffness and one case of varus malalignment.

Stamer et al.[11] reported a series of 22 patients with Schatzker type IV TPFs treated with a hybrid ring external fixator using tensioned wires proximally and half-pins distally. The average AKSS was 84.7, and there was one case of pin tract infection, three cases of deep infection, and one case of malunion. Babis et al.[12] also described 33 cases of bicondylar TPFs, which were treated by minimal intervention and hybrid external fixation. According to AKSS criteria[25], the results were evaluated as excellent in 18 patients (55%), good in 10 patients (30%), fair in 4 patients (12%), and poor in 1 patient (3%).

Egol et al.[14] described staged management of high-energy proximal TPFs. The mean WOMAC was 95±55 (range, 0 to worst 240), the mean ROM was 106°±15°, and there were two cases of infection. Many other authors have also reported good clinical outcomes of dual plating using medial and lateral approaches after temporary external fixation[13-15]. Our study also demonstrated favorable clinical and radiological outcomes with staged treatment using a temporary external fixator. According to Chang et al.[26], compartment syndrome can occur in 30% of bicondylar TPFs. When compartment syndrome is suspected, emergent fasciotomy is essential and subsequent temporary fixation is recommended.

To our knowledge, there was no published report of comparison with uninjured limbs in TPFs. In our study, although not all radiological outcomes were statistically correlated to clinical outcomes, it was observed that patients with fewer differences with uninjured limbs on plain radiographs showed a tendency to have better clinical outcomes. In particular, the correlation was statistically significant for the PPTA. Some authors have reported that the reduction status on plain radiographs can affect clinical outcomes[27]. In our study, it was observed that when mTPA and PPTA were within normal range, the clinical outcomes were better, and especially, mTPA showed statistical significance. Authors propose that all patients should be evaluated not only for the injured limb but also for the uninjured limb to have better clinical outcome by referring to the angles intraoperatively. We did make an effort not only to recover mTPA and PPTA within normal limits using fluoroscopy intraoperatively but also to refer to the data of the uninjured limb in all patients.

According to Egol et al.[14], there was a significant association between the presence of external wounds and the need for a secondary surgery because of complications. In our study, although it was not statistically significant, clinical outcomes were not good in the presence of external wounds. Therefore, it is proposed that surgeons should warn the patients adequately about the possibility of worsening of clinical outcomes. Other prognostic factors such as the type of fracture, preoperative arthritic change, and compartment syndrome were not statistically correlated to the clinical outcomes. Although compartment syndrome occurs frequently in closed fractures, two patients (25%) of open fractures were accompanied by compartment syndrome in this study. Accordingly, primary physicians should do careful physical examination in cases of bicondylar TPFs.

Conclusions

Staged treatment using a temporary external fixator in bicondylar TPFs showed good clinical and radiological outcomes due to appropriate soft tissue management. Furthermore, excellent results could be obtained by radiological evaluation of not only the injured limb but also the uninjured limb. Moreover, it is important to warn bicondylar TPF patients with external wounds about the risk of worsening of clinical outcomes before surgery.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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