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Double Plating for the Treatment of Comminuted Distal Femur Fractures with Medial Instability

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Abstract

Background: Treatment of comminuted Distal Femur Fracture (DFF) is challenging owing to metaphyseal instability caused by high-energy trauma. When comminution involves the medial column of the distal femur, the single lateral plate is unable to provide enough fixation, leading to implantation failure and knee varus. The objective of this study was to investigate the clinical efficacy of double plating for the treatment of DFFs with medial comminution.

Methods: Sixty-five DFFs were enrolled in this retrospective study. Based on medial stability of distal femur, participates were divided into three groups. MI-DP group: medial-instable DFFs treated with double plating; MI-SP group: medial-instable DFFs treated with single plate; MS-SP group: medial-stable DFFs treated with single plate. Fracture healing, surgical duration, blood loss during surgery, Range of Motion (ROM) and Keen Society Score (KSS) were compared between groups.

Results: Except for one delayed union and one nonunion in the MI-SP group, all fractures healed within 6 months. Moreover, fracture healing time of MI-SP group was significantly longer than that of MI-DP group and MS-SP group ($P<0.05$). For all three groups, there was no neurovascular injury happened during operation. Compared with single plate implantation, implantation of double plating did not increase surgical duration or blood loss. There was no significant difference between ROM of each two groups. Nevertheless, mean KSS of MI-SP group was significantly lower than MI-DP group and MS-SP group ($P<0.05$).

Conclusion: Compared to traditionally laterally single plate, double plating provided stronger fixation which could accelerate fracture healing, prevent hardware failure, and improve knee function for patients with medial-instable DFFs.

Level of Evidence: Level IV, Therapeutic Study

Introduction

Distal Femur Fractures (DFFs) are uncommon and account for approximately 0.4% of adult fractures [1]. However, this number has increased over the past three decades [2]. Management of these injuries (especially comminuted ones) is challenging because they are often caused by high-energy accidents or osteoporosis, resulting in comminution, bone defect, and instability [3]. Since 1970s, surgical management is performed in the most distal femur fractures due to the better clinical outcomes followed [4,5]. A variety of strategies have been used in the treatment of distal femur fractures, such as external fixation, intramedullary nailing, plates, and arthroplasty [5]. External fixation is a major method to handle with open fracture, and often serves as a temporary treatment before secondary internal fixation surgery. Another popular option is the intramedullary nail, which provides axial stability and biological osteosynthesis [5,6]. However, its natural micromotion could impede the healing of comminuted fractures. Moreover, nailing surgery is difficult considering that the instable distal fragments provide a poor grip for distal locking screws. Arthroplasty is usually performed on patients with severe arthritis [7]. At present, a laterally locking plate is the most prevalent and effective method for the treatment of DFFs [3]. It provides rigid fixation while protecting soft tissues when minimally invasive approaches are used.

Nevertheless, the clinical outcomes of patients who treated with single lateral plate is disappointed because of relatively high complication rate. Varus deformity is a common complication, its incidence could be as high as 30.7% for patients treated with single lateral plate [8-11]. This may be attributed to reduction difficulty and reduction loss caused by medial instability. Another frequent complication is implant failure. A recent report identified 11 (12.4%) implant failures in 89 patients who were treated with single locking plates. Notably, all the 11 patients had medial comminution without medial plating support [12]. For comminuted DFFs, once comminution involves the medial column of the distal femur, the single lateral plate loses stability in the medial column, which may lead to knee vaurs and fixation failure. To increase fixation rigidity, double plating strategy was introduced by several studies [13-15]. But few of them has compared the double plating versus single lateral plate. Moreover, medial stability of distal femur has been neglected by researchers. Thus, we conducted this retrospective study which aimed to investigate the clinical efficacy of double plating for the treatment of comminuted DFFs involving the medial column, and to emphasize the importance of medial column stability.

Methods

Study Design and Setting

This was a retrospective study which enrolled 65 patients with DFFs from December 2010 to January 2015. These patients were surgically treated with either double plating or single lateral locking plate in our department. Data were extracted from inpatient records and outpatient records.

Participants

Inclusion criteria were as follows: 1) patients were diagnosed as distal femur fractures; 2) patients with age over 18 years old; 3) fractures were fixed by either double plating or single lateral locking plate; 4) patients who were able to walk without assistance before injury. Exclusion criteria were as follows: 1) pathologic fractures; 2) periprosthetic fractures; 3) fractures associated with neurovascular injuries; 4) follow-up time less than 6 months. Diagnosis were made by history inquiry, physical examination, and imaging test. Patients were divided into three group based on medial stability of distal femur and treatment methods. A medial-stable DFF were defined as: after reduction, medial cortex of distal femur was complete and continuous. Contrarily, a discontinuous and incomplete medial cortex was defined as medial-instable DFF (Figure 1). Thus, medial-instable DFFs treated with double plating were enrolled in MI-DP group; medial-instable DFFs treated with single plate were enrolled in MI-SP group; medial-stable DFFs treated with single plate were enrolled in MS-SP group (Figure 1).

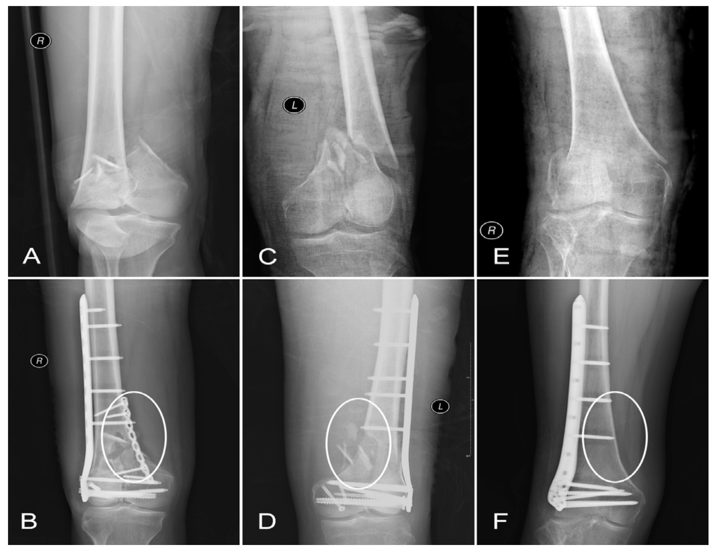

Figure 1: Typical X-ray of three groups. A, B: MI-DP group: medial-instable Distal Femur Fracture (DFF) was treated with double plating, the oval showed that medial comminution was fixed by a medial plate. C, D: MI-SP group: medial-instable DFF was treated with single lateral locking plate, the oval showed that medial cortex was comminuted, discontinuous and unsupported. E, F: MS-SP group: medial-instable DFF was treated with single lateral locking plate, the oval showed that medial cortex was continuous and stable.

Basic information was tabulated (Tables 1,2).

Group	Number	Sex (male/female)	Age (years old)	Multi-injuries	Open fracture	Follow up (month)
MI-DP	20	11-Sep	60.4±19.7	8	3	21.7±5.6
MI-SP	24	13-Nov	60.6±18.7	6	2	21.8±9.5
MS-SP	21	14-Jul	52.0±21.7	6	1	22.8±7.3
Total	65	27/38	57.8±19.7	20	6	22.1±7.7

Table 1: Basic information of three groups. MI-DP: medial-instable distal femoral fractures (DFFs) treated with double plating; MI-SP: medial-instable DFFs treated with single lateral locking plate; MS-SP: medial-stable DFFs treated with single lateral locking plate.

	Statistic value (F/χ^2)	P value
Sex	χ^2=3.058	0.217
Age	F=1.353	0.266
multi-injuries	χ^2=1.223	0.543
Open fracture	χ^2=1.318	0.517
Follow up	F=0.117	0.89

Table 2: Statistical analysis of basic information between groups. There was no significant difference between basic characteristics of three groups.

Details were tabulated in Supplementary Material (S Tables 1-3).

No.	Sex (M/F)	Age	Fracture Type	Injury Mechanism	Multi-injuries (Yes/No)	Open fracture (Yes/No)
1	M	78	A3	mild	N	N
2	M	22	C3	traffic	Y	N
3	F	74	C2	traffic	N	N
4	F	85	A2	fall	N	N
5	M	33	C2	traffic	N	N
6	M	66	A3	traffic	N	Y, IIIb
7	F	59	C3	traffic	Y	Y, II
8	F	77	A3	fall	N	N
9	F	67	C2	fall	Y	N
10	M	59	C2	traffic	Y	N
11	F	78	C3	fall	N	N
12	M	53	C3	traffic	Y	Y, II
13	F	67	C3	fall	N	N
14	M	66	C2	traffic	Y	N
15	F	64	C2	fall	N	N
16	F	74	C3	traffic	N	N
17	M	18	A3	traffic	N	N
18	F	58	C2	traffic	Y	N
19	F	59	C2	traffic	N	N
20	M	51	C2	traffic	Y	N

S. Table 1: Baseline information of each patient in MI-DP group. Fracture type was classified based on the AO/Orthopedic Trauma Association (OTA) classification system (AO/OTA). Open fracture was classified based on Gustillo and Anderson grade. MI-DP: medial-instable distal femoral fractures (DFFs) treated with double plating.

No.	Sex (M/F)	Age	Fracture Type	Injury Mechanism	Multi-injuries (Yes/No)	Open fracture (Yes/No)
1	F	49	A3	traffic	N	N
2	M	19	C3	traffic	N	N
3	F	67	A2	fall	N	N
4	F	75	A3	fall	N	N

5	F	66	A3	traffic	Y	N
6	M	57	C3	traffic	Y	N
7	F	85	A2	mild	N	N
8	M	38	C3	traffic	Y	Y, II
9	M	67	C3	traffic	Y	N
10	M	42	C3	traffic	Y	N
11	M	25	A3	traffic	N	N
12	F	82	C2	fall	N	N
13	F	59	A2	traffic	N	N
14	F	56	A3	traffic	N	Y, II
15	M	54	A3	traffic	N	N
16	M	57	C3	traffic	N	N
17	M	93	A3	fall	N	N
18	F	78	A2	fall	N	N
19	F	81	C3	traffic	N	N
20	F	80	C3	fall	N	N
21	F	72	C2	fall	N	N
22	M	45	C3	traffic	Y	N
23	M	55	A3	traffic	N	N
24	F	53	C2	traffic	N	N

S. Table 2: Baseline information of each patient in MI-SP group. Fracture type was classified based on the AO/Orthopedic Trauma Association (OTA) classification system (AO/OTA). Open fracture was classified based on Gustillo and Anderson grade. MI-SP: medial-instable distal femoral fractures (DFFs) treated with single lateral locking plate.

No.	Sex (M/F)	Age	Fracture Type	Injury Mechanism	Multi-injuries (Yes/No)	Open fracture (Yes/No)
1	F	25	A2	traffic	Y	N
2	F	63	C2	traffic	N	N
3	F	24	C2	traffic	N	N
4	M	56	C2	fall	N	N
5	F	44	C2	traffic	N	N
6	F	43	A3	traffic	N	N
7	M	48	A2	traffic	N	Y, IIIa
8	F	54	C2	fall	N	N
9	F	77	A2	fall	N	N
10	F	55	A2	traffic	N	N
11	F	78	A3	fall	N	N
12	M	19	C2	traffic	Y	N
13	M	75	C2	traffic	N	N
14	F	81	A2	fall	N	N

15	F	18	A2	traffic	Y	N
16	F	74	A2	fall	N	N
17	F	90	A2	fall	N	N
18	M	44	C3	traffic	Y	N
19	M	27	C2	traffic	N	N
20	F	52	A2	fall	Y	N
21	M	45	C1	traffic	Y	N

S. Table 3: Baseline information of each patient in MS-SP group. Fracture type was classified based on the AO/Orthopedic Trauma Association (OTA) classification system (AO/OTA). Open fracture was classified based on Gustillo and Anderson grade. MS-SP: medial-stable Distal Femoral Fractures (DFFs) treated with single lateral locking plate.

Surgical Techniques

For single plate fixation, surgical procedure was as follows. Under general or epidural anesthesia, patients were placed in the supine position on a fluoroscopic table. Folded towels were placed beneath the knee to create slight knee flexion, which ease the traction of the gastrocnemius muscle to the condyles. The distal-femur lateral approach was performed for type A DFFs, and the lateral parapatellar approach was chosen for type C fractures to create good exposure of the articular surface. For type A2 DFFs, reduction was performed under direct visualization. Regarding types A3, C2, and C3 DFFs, we preferred to use the following sequence: 1) articular fragments, if necessary, were anatomically restored via the lateral parapatellar approach and were temporarily fixed by two to four Kirschner wires (2.5 mm); 2) insertion of the lateral locking plate with the Minimally Invasive Plate Osteosynthesis (MIPO) technique and placement of two Kirschner wires (3.0 mm) at terminal holes of the plate to regain femur length were performed; 3) correction of the sagittal angulation deformity was performed under direct visualization or fluoroscopy; 4) assessment of coronal alignment by fluoroscopy was performed, in cases of valgus or varus using a Kirschner wire (3 mm) that was passed through the condyles to pry the distal fracture part and correct the valgus or varus; 5) wires were removed and screws were placed on the lateral plate; 6) cortex screws were used to reduce and fix the main comminuted fragments; 7) based on the size of the bone defect, autologous iliac bone chips or bone substitutes were grafted.

For double plating fixation, a medial mini-invasive incision was made based on the position of the medial plate and the reduction requirements. According to the difficulty of the reduction, the insertion order of the plates could be changed. In most cases (16 cases), satisfactory reduction was achieved via a lateral or parapatellar incision; next, using the MIPO technique, a medial plate was inserted as a medial column support. However, in four patients, fracture reduction was unattainable via lateral approach. A reduction plate was inserted firstly to facilitate fracture reduction from medial side.

Aftercare

Postoperatively, the wound dressing was changed every 2 to 3 days. Cefotiam (2 g/day) was injected via intravenous drip. Nadroparine (5000U/q12h) was prescribed to prevent venous thrombosis in patients older than 65 years old. Immediate passive motion was started postoperatively under an analgesic; patients were encouraged to perform non-weight-bearing active motion and toe-touch weight bearing as the pain disappeared. Partial weight bearing was recommended after apparent callus formation was found on the radiograph.

Outcome Measures

Patients were discharged from the hospital when the wounds were well controlled. Follow-up visits were required at 2, 6, and 12 weeks and at 6, 9, 12, and 24 months at outpatient clinic in which physical examination and radiographic test were performed. Surgical duration and blood loss during surgery were analyzed to assess surgical difficulty. Fracture healing criteria included no tenderness or percussion pain, no abnormal activity, and continuous callus across fracture line on X-ray. Delayed union was defined as a fracture took more than 6 months to heal; and nonunion was defined as a fracture did not heal in 9 months or longer postoperatively. The same attending doctor conducted the physical examination, and another two independent orthopedic surgeons evaluated the radiographs. The period between surgery and fracture healing was defined as healing time. Range of motion (ROM) is the sum of extension degree and flexion degree. Flexion degree was the obtuse angle between thigh and calve when knee extremely flexed; extension degree was the acute angle between thigh and calve when knee extremely extended. Keen Society Score (KSS) was applied to evaluate knee function.

Statistical Analysis

For measurement data (surgical duration, blood loss, healing time, ROM, and KSS), student t test was used to compare difference between each two groups. For categorical data, chi-square test was used. When P value was less than 0.05, the difference would be considered statistically significant. Data were presented as the mean ± standard deviation. And data were analyzed with SPSS 13.0 software (Statistical Package for the Social Sciences, Chicago, IL, USA).

Results

Fracture Union

Fracture union was considered as the primary factor to assess the clinical outcome. Except for one delayed union and one nonunion in the MI-SP group, all fractures healed within 6 months (Figure 2).

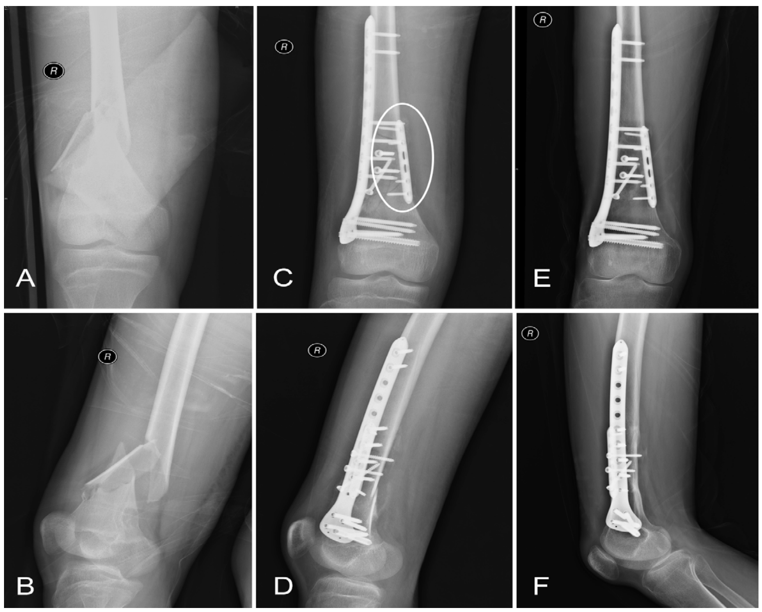

Figure 2: A medial-instable distal femur fracture treated with double plating. Male, 18 years old, right distal femur comminuted fracture in fall injury. A, B: Radiographs after trauma, type A3 AO/OTA classification. C, D: Immediate images after surgery showed that anatomical reduction was achieved and maintained by double plating, the oval showed that medial comminution was stabilized by a small medial plate. E, F: Twelve weeks postoperatively, the fracture healed uneventfully.

Demonstrated a representative medial-instable DFF treated by double plating. Fracture healing rate and mean healing time was tabulated (Table 3) and (S. Tables 4-6).

Group	Surgical time (minute)	Blood loss (ml)	Healing rate	Healing time (week)	ROM (degree)	KSS
MI-DP	108.5±32.3	187.5±84.5	20/20 (100%)	15.1±2.3*	118.5±26.1	88.7±9.4*
MI-SP	99.0±20.5	154.2±57.9	22/24 (91.7%)	21.0±13.9*#	125.4±11.8	82.9±7.5*#
MS-SP	94.3±17.6	147.4±45.0	21/21 (100%)	14.9±2.2#	125.8±15.0	89.1±7.3#
Total	100.4±24.3	162.2±65.2	63/65 (96.9%)	17.2±9.0	123.1±18.2	86.7±8.5

Table 3: Clinical outcomes of three groups. * signified significant difference between MI-DP group and MI-SP group; # signified significant difference between MI-SP group and MS-SP group. **Abbreviation:** MI-DP: Medial-Instable DFFs treated with Double Plating; MI-SP: Medial-Instable DFFs treated with Single Plate; MS-SP: Medial-Stable DFFs treated with Single Plating. ROM: Range of Motion; KSS: Knee Society Score.

No.	Follow up(month)	Surgical Time(min)	Blood loss (ml)	Graft (Yes/No)	Healing Time (week)	ROM (flexion/ extension)	KSS	complications
1	18	100	230	N	14	105°/5°	83	none
2	30	90	150	N	14	130°/0°	99	none
3	20	120	300	Y, TCP* granules	25	120°/0°	76	none
4	16	90	180	N	18	100°/5°	85	none
5	24	110	250	Y, TCP* block	14	135°/10°	100	none
6	24	80	150	N	14	90°/5°	83	none
7	36	100	180	Y, iliac bone	12	135°/10°	100	none
8	24	90	150	N	15	120°/0°	91	none
9	24	90	200	N	16	135°/0°	84	none
10	24	120	300	N	12	135°/10°	96	none
11	12	90	50	N	16	115°/5°	83	none
12	26	200	400	N	20	30°/0°	61	Deep infection, stiffness
13	24	100	230	N	18	120°/5°	94	none
14	21	180	250	Y, TCP* block	14	110°/5°	91	none
15	24	100	100	N	16	135°/5°	96	none
16	20	100	120	N	16	90°/5°	82	none
17	18	90	110	N	12	120°/10°	95	none
18	19	150	180	Y, TCP* granules	18	110°/0°	90	none
19	15	90	100	N	15	135°/5°	95	none
20	15	80	120	Y, iliac bone	12	110°/5°	89	none
average	21.7±5.6	108.5±32.3	187.5±84.5	6	15.1±2.3	118.5±26.1	88.7±9.4	1

S. Table 4: Clinical outcomes of each patient in MI-DP group (medial-instable distal femur fractures treated with double plating). *TCP: Beta-tricalcium phosphate. ROM: Range of motion; KSS: Keen society score.

No.	Follow up(month)	Surgical Time(min)	Blood loss (ml)	Graft (Yes/No)	Healing Time (week)	ROM (flexion/ extension)	KSS	complications
1	15	90	150	N	18	125°/5°	85	none
2	28	110	200	N	16	125°/0°	77	Valgus
3	24	70	100	N	15	130°/0°	81	none
4	17	120	130	N	20	130°/5°	93	none
5	21	90	50	Y, iliac bone	14	125°/10°	87	none
6	40	100	170	N	46	120°/5°	69	Delayed union
7	23	100	140	N	24	105°/10°	83	none

8	22	170	300	N	16	130°/5°	91	none
9	22	100	170	N	15	115°/0°	79	none
10	16	90	140	N	18	135°/5°	98	none
11	14	70	100	N	16	110°/0°	80	none
12	20	90	150	Y, TCP* block	20	130°/5°	84	none
13	20	80	150	N	16	130°/0°	86	none
14	10	80	90	N	15	130°/5°	91	none
15	31	120	200	Y, iliac bone	20	115°/5°	77	none
16	12	100	130	N	16	125°/5°	82	none
17	14	85	300	N	22	110°/0°	72	none
18	11	95	120	Y, TCP* block	16	120°/10°	83	none
19	27	100	150	N	18	110°/5°	78	none
20	29	90	130	N	15	130°/10°	80	none
21	15	90	100	N	18	120°/5°	90	none
22	48	110	200	N	18	90°/5°	74	none
23	12	110	150	N	14	130°/10°	95	none
24	33	115	180	N	79	105°/5°	74	nonunion
average	21.8±9.5	99.0±20.5	154.2±57.9	4	21.0±13.9	125.4±11.8	82.9±7.5	3

S. Table 5: Clinical outcomes of each patient in MI-SP group (medial-instable distal femur fractures treated with single lateral locking plate). *TCP: Beta- tricalcium phosphate. ROM: Range of motion; KSS: Keen society score.

No.	Follow up(month)	Surgical Time(min)	Blood loss (ml)	Graft (Yes/No)	Healing Time (week)	ROM (flexion/ extension)	KSS	complications
1	13	90	120	N	16	135°/5°	99	none
2	28	110	180	Y, iliac bone	14	125°/0°	97	none
3	14	100	150	N	12	130°/5°	92	none
4	18	90	170	N	14	110°/5°	76	none
5	20	75	200	N	20	130°/10°	95	none
6	28	120	100	N	12	120°/5°	83	none
7	33	90	130	Y, iliac bone	14	135°/5°	94	none
8	18	85	140	N	15	110°/0°	86	none
9	22	80	150	N	14	130°/5°	86	none
10	24	110	150	N	18	100°/0°	80	Valgus
11	36	90	175	N	15	120°/5°	83	none
12	16	80	80	N	16	100°/0°	97	none
13	22	110	180	N	14	125°/10°	78	none

14	22	130	80	Y, TCP* block	18	130°/5°	94	none
15	20	120	200	Y, iliac bone	12	130°/5°	90	none
16	18	80	250	N	18	130°/0°	91	none
17	24	70	140	N	12	95°/5°	78	none
18	14	90	70	N	14	130°/10°	96	none
19	29	70	110	N	14	110°/0°	92	none
20	19	80	140	N	15	135°/5°	98	none
21	40	110	180	N	16	100°/5°	86	none
average	22.8±7.3	94.3±17.6	147.4±45.0	4	14.9±2.2	125.8±15.0	89.1±7.3	1

S. Table 6: Clinical outcomes of each patient in MS-SP group (medial-stable distal femur fractures treated with single lateral locking plate). *TCP: Beta- Tricalcium Phosphate. ROM: Range of Motion; KSS: Keen Society Score.

There was no statistical difference between healing rates of each two groups. However, healing time of MI-SP group was significantly longer than that of MI-DP group (t=-2.080, P=0.048). Also, healing time of MI-SP group was significantly longer than that of MS-SP group (t=2.133, P=0.043). But there was no statistical difference between MI-DP group and MS-SP (t=-0.238, P=0.813).

The delayed union was caused by insufficient stability. The secondary procedure was performed at 8 months post-operation. In brief, fibrous tissue in the fracture ends was debrided, beta-tricalcium phosphate enriched with autologous Bone Mesenchymal Stem Cell (BMSCs) was grafted, and a small medial plate was inserted to enhance stability without removing lateral fixation [16]. After 14 weeks, delayed union healed uneventfully (Figure 3).

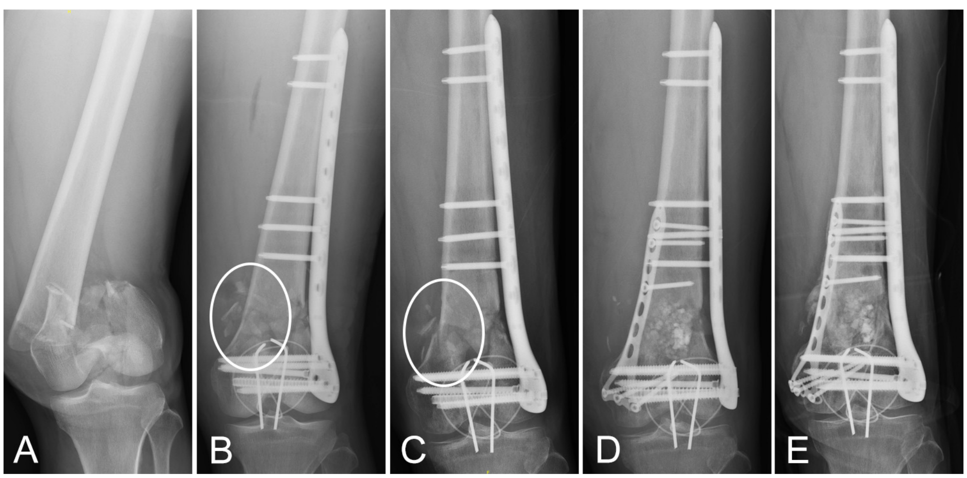

Figure 3: Sequential X-ray of the delayed union patient in MI-SP (medial-instable distal femur fracture treated with single lateral locking plate) group. Male, 57 years old, left distal femur comminuted fracture and patella fracture in traffic accident. A: The Distal Femur Fracture (DFF) was characterized by obvious displacement and metaphyseal comminution. B: The post-operative X-ray illustrated that the DFF was fixed by single lateral plate without medial support. C: Eight months post-operatively, the fracture stayed ununited due to insufficient stability. Obvious bone absorption could be seen in the oval. D: In secondary procedure, a medial plate was implanted to stabilize medial column, and biological bone substitute was grafted. E: Fourteen weeks after secondary procedure, the fracture united uneventfully.

The nonunion was caused by insufficient stability and implant failure. Sixteen months post-operatively, the secondary procedure was performed as above mentioned, and nonunion healed after 15 weeks [16].

Surgical Duration and Blood Loss

Surgical duration and blood loss during surgery were measured to assess the operation difficulty. Mean surgical duration and mean blood loss were tabulated (Table 3 and S. Table 4-6)). There was no significant difference between mean surgical duration of MI-DP group (108.5±32.3 minutes) and MI-SP group (99.0±20.5 minutes) (t=1.189, P=0.241). There was no significant difference between mean blood loss of MI-DP group (187.5±84.5 ml) and MI-SP group (154.2±57.9 ml) (t=1.546, P=0.130). Actually, there was no significant difference between each two groups. Moreover, no neurovascular injury happened in the surgery.

Knee Function

Knee function was assessed by ROM and KSS which were tabulated (Table3 and S Table 4-6). There was no significant difference between ROM of each two groups. Nevertheless, mean KSS of MI-SP group was significantly lower than MI-DP group (t=2.262, P=0.029) and MS-SP group (t=-2.817, P=0.007). While there was no statistical difference between MI-DP group and MS-SP (t=-0.170, P=0.866). Totally, five patients suffered from complications: one deep infection in the MI-DP group; one delayed union, one nonunion, and one knee varus in the MI-SP group; and another knee varus in the MS-SP group. The infected patient suffered a Gustillo and Anderson grade II open fracture. After debridement and wound healing, he underwent open reduction and fixed with double plating. Deep infection developed in 7th day postoperatively and lasted for three months. Then the patient underwent secondary operation including debridement, internal fixation removal, and external fixation. The infection was controlled after two-week Vacuum Sealing Drainage (VSD) and fracture united after two months. Unfortunately, several sequelae persisted, including chronic pain and stiffness of knee with a ROM of 30 degree. The knee varus in MI-SP group (14 degree) was caused by reduction loss. Another patient in MS-SP group has knee varus (13 degree) because of severe conmmunited DFF (C3) and the coronal difficult reduction. Both two patients refused further operation.

Discussion

Although there was a variety of methods for the treatment of DFF, few of them was proved to perfect [3,4,17]. And medial comminution, which was neglected by most surgeon, is one of most common reason for hardware failure and nonunion [12]. In this study, we compared double plating versus traditional lateral single locking plate for the treatment of medial-instable DFF. Consequently, patients treated with double plating has faster healing time, better knee function, and lower complication rate. MS-SP group served as another control group to illustrate that single plate was capable of treating medial-stable DFF. On the other hand, MI-DP group was comparable to MS-SP group, which indicated that comminuted medial column could be adequately stabilized by an auxiliary plate. The management of Distal Femur Fractures (DFF) usually follows three basic principles: anatomical reduction of articular surface, alignment restoration of lower extremity and adequately stable fixation [5,17]. For the treatment of comminuted DFFs, especially medial-instable DFFs, it is critical to sustain a strong fixation. With weight bearing, the lateral column of the femur bears tension and the medial column bears pressure.

For medial-stable DFFs, the medial cortex is complete and continuous, a lateral locking plate could sustain lateral tension and the continuous medial cortex could resist medial pressure. For medial-instable DFFs, however, its medial cortex is incomplete and discontinuous. When fixed with a single lateral plate, the unsupported medial pressure would transfer to the plate, increasing the susceptibility to implant failure and knee varus. Hence, patients in the MI-SP group developed one delayed union and one nonunion. They also spent more time to reach fracture union compared to patients in other two groups. In 2002, Ziran, et al. [15] designed a lateral peripatellar approach by which an anterior plate and a lateral plate were applied for comminuted DFFs. Through this approach two plates were implanted on the anterior side and lateral side of distal femur. This fixation pattern provided adequate stability for the unstable fracture. Locked double-plating construct was introduced in 2000, transverse cortical screws were used to lock two unlocked plates and its biomechanical test showed better in strength than unlocked double-plating construct [18]. The results in our study suggested that, medial stability was a critical factor for the treatment of comminuted DFF. Adding a small medial plate could significantly increase the medial stability and prevent implant failure.

When introducing a new treatment, clinical safety must be the first concern. The medial side of distal femur was historically considered dangerous because the neurovascular bundle passes through the area. However, there was no report of neurovascular injury in previous studies using medial plate in DFF [13,14,15]. Moreover, Jianmton and colleagues demonstrate that distal 3/5 part of femur is a safe zone to implant a medial plate via MIPO technique [19]. In the present study, short reconstruction plate or small locking plate was inserted in the distal half of femur. Thus, no neurovascular injury happened in the MI-DP group. Soft tissue and blood supply of fracture ends were well protected by MIPO technique, resulting in limited blood loss during surgery. Surgical duration is one of most meaningful factors to assess surgery complexity. The result showed double plating did not increased the surgical duration. For some cases MI-DP, fracture reduction from lateral approach could be difficult because of limited exposure and medial instability. In these cases, medial plate served as a reduction plate to ease the reduction difficulty and save the time. Therefore, double plating was believed to be a plausible method for the treatment of DFF.

Knee function is crucial for patients' social function and life quality. Besides fracture union, soft-tissue protection and rehabilitation exercise are required to obtain satisfactory knee function. In 1991, Sanders [14] and colleagues firstly reported double plating for comminuted DFFs in 9 patients. Although all fractures healed, no one had ROM beyond 120 degrees, and 8 patients complained about pain around knee joint. The poor function may be ascribed to severe trauma and excessive surgical injury. More recently, 12 patients with type C3 DFFs underwent double-plates fixation using a huge "V" shape patellar anterior approach [13]. This aggressive approach provides excellent visualization but fails to protect the surrounding soft tissues. In this study, both lateral and medial plates were inserted by MIPO technique. And under analgesic management, patients were encouraged to start rehabilitation exercise as soon as possible. Consequently, only one patient in MI-DP group developed knee stiffness due to long-term immobilization. Despite there was no significant difference between each two group, KSS of MI-SP group was lower than other two groups. This disadvantage may be related to delayed rehabilitation plan caused by slower fracture healing.

Complication rate of MI-SP group was as high as 12.5% (3/24). Knee varus is one of the most frequent complications of DFF [8]. As reported in literatures, its incidence ranges from 13.3% to 30.7% when treated with non-locking plates [8,9,10,11], and 3.6% to 10.3% in patients treated with locking plates [20,21]. Possible causes might be weak robustness of fixation, bone defect, and medial instability. Batista, et al.[4] reported that instant loss of reduction after surgery occurred in 27% patients fixed with lateral LISS (Less Invasive Stabilization System), they partly attributed the result to metaphyseal comminution, especially medial comminution. In our cases, one knee patient in MI-SP group was diagnosed as knee varus owing to reduction loss caused by medial instability. The medial cortex bears longitudinal pressure under loading, so medial column of distal femur seems much like a keystone to resist stress. By double plating fixation, medial pressure could be supported by medial plate, and stress conducted along the central longitudinal axis, which was accord with physiological stress distribution. Double plating offers an alternative therapy for the comminuted DFF, but it is not a standardized procedure for each DDF. Patients who suffer from an unstable comminuted DFF, especially with medial comminution, would be the perfect candidates. As for one deep infection in MI-DP group, contributing factors included open fracture, improper operation timing, excessive hardware implantation. Undeniably, double plating increased the infective risk in this case. Thus, surgeons should carefully assess infective risks before double plating implantation. This study had a number of limitations. First, this was a retrospective study in single center; second, sample size may be small in each group. Nevertheless, each group had at least 20 patients enrolled. Same surgeon team conducted all surgeries. And there was no distinctive difference between basic characteristics of three groups (Table 2).

Conclusions

Compared to traditionally lateral single plate, double plating provided stronger fixation which could accelerate fracture healing, prevent hardware failure, and improve knee function for patients with medial-instable DFFs. Still, large-sample randomized controlled clinical trials are needed.

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