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Case Series

Stable internal fixation with dual plate technique for osteoporotic distal femur fractures

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ABSTRACT

Background: Osteoporotic distal femur fractures are difficult in terms of fracture treatment and recovery. We hypothesized that the minimally invasive plate osteosynthesis (MIPO) with dual plate technique increased fixation stability and encouraged early mobilization and return to pre-fracture activity.
Material and methods: Between 2016 and 2019, 22 patients were treated with the dual plate technique for osteoporotic distal femur fractures. To evaluate the clinical outcome, the modified Western Ontario and McMaster Universities (WOMAC) score, Tegner activity score, knee range of motion (ROM), time to pain free full weight bearing from operation and patient satisfaction score were used. To evaluate the radiological outcome, the time to radiological union and varus or valgus angulation were measured.
Results: The mean modified WOMAC score was 37.0 ± 6.5 (range, 26–42). There was no significant difference between preoperative and postoperative Tegner activity score ($p = 0.436$). Among 22 patients, 16 patients (72.7%) achieved preoperative activity level. The mean knee ROM was 106.1° ± 16.8° (range, 80–135). The time to pain free weight bearing was 7.4 ± 1.5 (range, 5–10) weeks. In patient satisfaction, 20 patients (90.9%) were very satisfied or somewhat satisfied. Bone union was achieved in all patients at 16.4 ± 4.3 (range, 13–22) weeks. The final follow-up valgus angle was 3.6° ± 4.0° (range, −2.5° - 10.9).
Conclusion: MIPO with the dual plate technique can provide rigid fixation for osteoporotic distal femur fractures. This stable and rigid fixation may allow early mobilization and return to pre-fracture activity.

1. Introduction

Osteoporotic fractures have been becoming more common and a challenging clinical entity as the population of old age increases [1]. Surgical treatment with inadequate fixation or prolonged immobilization may result in loss of fixation, mal- or non-union, joint stiffness, and other medical life-threatening complications, such as thromboembolism or pulmonary complications [2]. Despite bone fragility in osteoporotic fractures, not only rigid fixation but also early rehabilitation is critical for an early return to preoperative ambulatory function and level of daily activity.

Distal femur fractures account for 4–6% of fragility fractures of the femur [3]. Approximately half of these fractures occur in patients over 70 years of age [4]. Distal femur fractures in elderly population frequently present with comminution and its distal location and are more prone to fixation failure due to the poor bone quality associated with osteopenia or osteoporosis [5]. Moreover, the distal femur is the most common site for periprosthetic fracture after total knee arthroplasty (TKA) [6]. Even though periprosthetic fractures in distal femur after TKA are becoming more common with the increasing number of TKA performed annually, these fractures are difficult and challenging in operative planning and postoperative recovery in function [7]. Poor bone stock, preexisting implants and bone cement may impede fracture reduction and fixation [8]. In addition, the majority of patients are elderly and often have osteoporosis [9].

Fractures in osteoporosis require firm and stable fixation due to relatively higher possibilities of implant loosening or cut-outs caused by thin cortex and hollow bony trabeculae. A number of novel surgical

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techniques, such as minimally invasive plate osteosynthesis (MIPO) and locking compression plates (LCP), are introduced in order to preserve periosteal circulation at the fracture site and to prevent fixation failure associated with screw loosening, respectively [10]. Currently, the application of the dual (medial & lateral) plate augments fixation stability, increases graft impaction, and encourages early rehabilitation without a loss of reduction in the distal femur fracture [11].

Therefore, we hypothesized that MIPO with the dual plate technique for osteoporotic distal femur fracture increased plate fixation stability, encouraged early mobilization and return to pre-fracture activity. We analyzed the clinical and radiologic outcomes of MIPO with the dual plate technique for osteoporotic distal femur fractures.

2. Methods

2.1. Patients

This retrospective case series study was approved by the appropriate Institutional Review Board (Ethics Committee) under protocol number (2020-12-014). All methods were performed in accordance with the relevant guidelines and regulations (Declaration of Helsinki). The requirement for informed consent was waived by the Institutional Review Board because of the retrospective nature of the study. This study is fully complaint with the PROCESS 2020 [12]. This research is registered at Research Registry under unique identifying number: researchregistry 7514.

There were consecutive 42 patients who underwent surgical treatment for distal fractures between January 2016 and January 2019 in single center. We included the following patients: (1) who had undergone MIPO with the dual plate technique for distal femur fracture; (2) whose T-score of bone mineral density was below −2.5 (osteoporosis) in one of the locations of the femur or in the spine; (3) who were followed for more than a year; and (4) whose clinical and radiographic data were completely available. Nine patients were excluded because the T-score was above −2.5. Four patients treated with retrograde nailing and seven patients treated with lateral LCP were excluded. A total 22 patients were included in this study (Fig. 1). There were three male patient and 19 female patients. The mean age was 73.5 ± 8.4 years (range, 53–89). Nine fractures were AO classification type 33-A3, and 13 fractures were Su type 2 periprosthetic distal femur fractures after TKA. The mean body mass index (BMI) and BMD (T-score) were evaluated. The cause of injury and follow-up period were recorded.

2.2. Surgical technique

The patient was placed in a supine position on the radiolucent operating table. In all cases, an indirect fracture reduction technique was used. If satisfactory reduction was achieved on both the anteroposterior and lateral fluoroscopic views, minimally invasive plate osteosynthesis was performed. Small (4–5 cm) proximal and distal incisions were made over the lateral aspect of the femur. The lateral cortex of the femur was exposed. Then, the lateral LCP was advanced submuscularly and extraperiosteally. The lateral LCP was fixed with locking or cortical screws. Then, a medial skin incision was made over the medial aspect of the distal femur with deep dissection down through the vastus medialis muscle in line with its fibers. The medial cortex of the distal femur was exposed. However, the fracture site was not exposed or visualized. The medial LCP was positioned on the medial aspect of the distal femur and was fixed with locking or cortical screws. The stability of the fracture site was augmented with a medial LCP (Figs. 2 and 3).

Patients were initiated on range of motion (ROM) exercises of the knee joint starting on postoperative 2nd day. The knee joint ROM was gradually increased depending on patient's tolerance on pain. Full weight-bearing were encouraged on postoperative 2nd day. Advancement to full weight-bearing was permitted depending on patient's tolerance to the pain.

2.3. Clinical assessment

To evaluate the clinical outcome, the modified Western Ontario and McMaster Universities (WOMAC) score, Tegner activity score, knee ROM, time to pain free full weight beari0ng from operation and patient satisfaction score were used. This modified WOMAC score (Jeju Lower Extremity Trauma Scale: JLETS) is used for the functional outcome of the knee joint and consists of three criteria grouped into three categories: pain (10 points), activity score (30 points), ROM (10 points) and tenderness at the fracture site (5 points) (Table 1) [13]. Tegner activity score is used for grading the activity level based on work and sports activities on a scale of 0–10. Zero represents disability because of knee problem and 10 represents competitive sports activity. Knee ROM was measured using a standard goniometer. Patient satisfaction was evaluated, and the result was very satisfied (5), somewhat satisfied (4), neither satisfied nor dissatisfied (3), somewhat dissatisfied (2) and very dissatisfied (1) with a score of 1–5. The modified WOMAC score, knee ROM, time to pain free full weight bearing from operation and patient satisfaction score were evaluated at final follow up period.

2.4. Radiologic assessment

The radiographic outcome was measured with plain radiographs. The time to radiological union, varus-valgus angulation and leg length discrepancy (LLD) were measured. Radiological bone union was defined

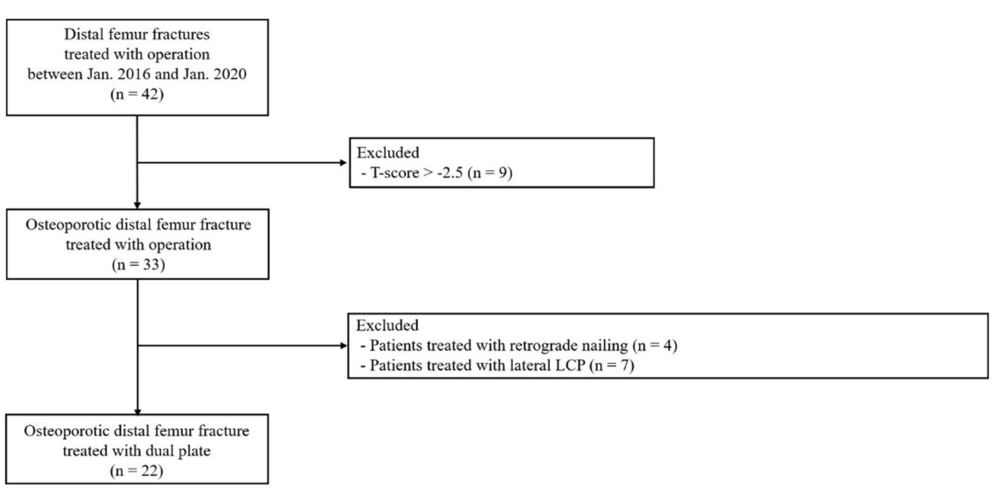

Fig. 1. Flowchart of patient inclusion. LCP, locking compression plates.

Fig. 2. Case 1: A 77-year-old male with AO classification type 33-A3 distal femur fracture (BMD: 2.8). (a) Preoperative plain radiographs. (b) Postoperative plain radiographs.

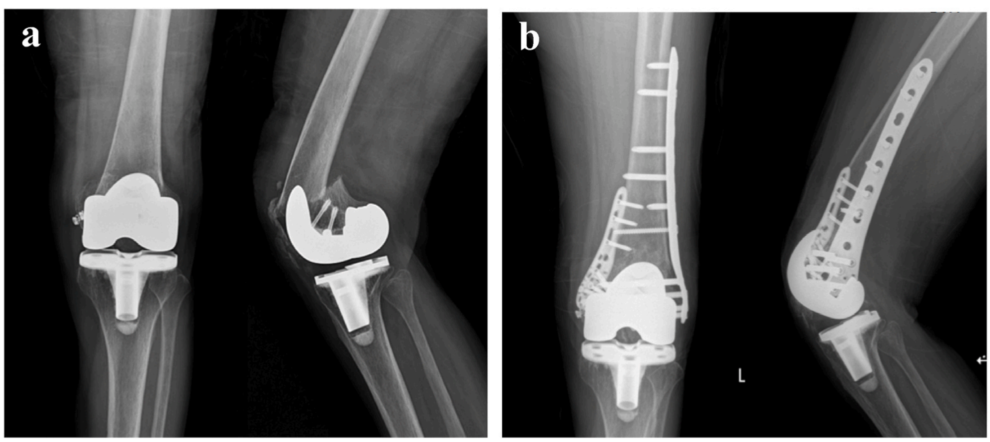

Fig. 3. Case 2: A 74-year-old female with Su type 2 periprosthetic fracture after TKA (BMD: 2.6). (a) Preoperative plain radiographs. (b) Postoperative plain radiographs.

when the bridging callus crossed the fracture site on both anteroposterior and lateral plain radiographs. Nonunion was defined as a lack of fracture healing within six months. The varus-valgus angle was determined as the angle between the femoral shaft axis and the horizontal line connecting the medial and lateral condyles on the AP radiograph.

2.5. Statistics

Continuous variables are presented as the mean ± standard deviation, and continuous variables are expressed as the frequency. To determine significant differences in Tegener activity score between preoperative and postoperative periods, a two-sided *t*-test was performed. A P value ≤ 0.05 was considered statistically significant. Data were analyzed using SPSS 19.1 software (SPSS Inc., Chicago, IL, USA).

3. Results

Mean T score was −3.1 ± 0.8 (range, −2.5 to −5.3). Among 22 patients, only four patients were taking osteoporosis medication (bisphosphonate). After operation, all patients took anabolic agent such as parathyroid hormone. Mean BMI was 23.2 ± 3.6 (range, 23–29). Fifteen fractures were caused by minor trauma (slip down), and seven fractures were associated with major trauma (traffic accident). The mean follow-up period was 31.8 ± 15.5 (range, 12–58) months (Table 2).

The mean operating time was 114.9 ± 10.5 min (range, 93–147). The final follow-up mean modified WOMAC score (JLETS) was 37.0 ± 6.5 (range, 26–42). Preoperative Tegner activity score was 2.9 ± 0.9 (range, 1–4) and postoperative Tegner activity score was 2.6 ± 0.8 (range, 1–4). There was no significant difference between preoperative and postoperative Tegner activity ($p = 0.436$). Among 22 patients, 16 patients (72.7%) achieved preoperative activity level. The final follow-up mean knee ROM was 106.1° ± 16.8° (range, 80–135), and the final follow-up mean flexion contracture was 5.8° ± 5.4° (range, 0–15). The time to pain free weight bearing was 7.4 ± 1.5 (range, 5–10) weeks. In patient satisfaction, seven patients were very satisfied, 13 patients were somewhat satisfied and two patients were neither satisfied nor dissatisfied.

Bone union was achieved in all patients at 16.4 ± 4.3 (range, 13–22) weeks. The final follow-up valgus angle was 3.6° ± 4.0° (range, −2.5° - 10.9). There was no nonunion or LLD. For complications, there was no secondary surgery or revision arthroplasty (Table 3).

4. Discussion

The incidence of distal femur fractures was reported 4–8.7/100,000 in the general population. A rapid increase in the incidence of distal femur fractures was observed frequently in females over the age of 60 [3, 14]. The 6-month mortality rate was reported to be 16%, rising to 30% at 1 year in geriatric population [4]. The primary goal of treatment for

Table 1
Modified Western Ontario and McMaster Universities (WOMAC) score.

Subject	Range	Points
I. PAIN: VAS SCORE (10 points)	0–1	10
	2–3	8
	4–5	6
	6–7	4
	8–9	2
	10	0
II. Activity Score (30 points)	1.Standing	0 1 2 3
***Scale of difficulty:**	2. Walking	0 1 2 3
3 = None	3. Ascending stairs	0 1 2 3
2 = Mild		
1 = Moderate	4. Descending stairs	0 1 2 3
0 = Extremely		
	5. Running	0 1 2 3
	6. Sitting	0 1 2 3
	7. Rising from sitting	0 1 2 3
	8. Rising from bed	0 1 2 3
	9. Bending to floor	0 1 2 3
	10. Heavy deomestic duties	0 1 2 3
III. ROM – flexion contracture affected joint: hip/knee/ankle (10 points)	<5°	10
	5°–9°	8
	10°–14°	6
	15°–19°	4
	20°–24°	2
	≥ 25°	0
IV. Tenderness at fractured site (5 points)	No	5
	Yes	0
TOTAL Points	()/55	
*Additional questions		
IV. Full Weight Bearing period (weeks)	()Weeks	

VAS: visual analog scale, ROM: range of motion.

Table 2
Demographics.

Parameter	Value
Number of patients	22
Mean age (years)	73.5 ± 8.4 years (range, 53–89)
Gender (male/female)	3/19
BMI (kg/m2)	23.2 ± 3.6 (range, 23–29)
BMD (T-score)	−3.1 ± 0.8 (range, −2.5 to −5.3)
Mean follow-up periods (months)	31.8 ± 15.5 (range, 12–58)

BMI: body mass index, BMD: bone mineral density.

Table 3
Clinical and radiologic results.

Parameter	Value
Operating time (min)	114.9 ± 10.5 (range, 93–147)
Modified WOMAC score (JLETS)	37.0 ± 6.5 (range, 26–42)
Preoperative Tegner activity score	2.9 ± 0.9 (range, 1–4)
Postoperative Tegner activity score	2.6 ± 0.8 (range, 1–4)
Knee joint ROM (°)	106.1° ± 16.8° (range, 80–135)
Knee joint flexion contracture (°)	5.8° ± 5.4° (range, 0–15)
Time to pain free weight bearing (weeks)	7.4 ± 1.5 (range, 5–10)
Patient satisfaction (score)	Number of patients
Very satisfied (5)	7
Somewhat satisfied (4)	13
Neither satisfied nor dissatisfied (3)	2
Somewhat dissatisfied (2)	0
Very dissatisfied (1)	0
Time to bone union (weeks)	16.4 ± 4.3 (range, 13–22)
Final follow-up varus-valgus angle (°)	3.6° ± 4.0° (range, −2.5° - 10.9)
Complications	None

WOMAC: Western Ontario and McMaster Universities, ROM: range of motion, JLETS: Jeju Lower Extremity Trauma Scale.

distal femur fractures is to return to the preinjury activity level as early as possible. Rigid, reliable and stable fixation is the most important in achieving this goal [9,15].

The majority of patients with distal femur fractures is in the elderly age group and is also characterized by female sex, underlying medical comorbidities, and osteoporosis [15]. A low BMD is considered a major determinant in operative planning and the timing of rehabilitation in the distal femur fractures because osteoporosis can make fracture fixation more difficult and delays rehabilitation [15,16]. Moreover, additional local osteoporosis or osteolysis can be advanced around the implant for several years after a TAK [17,18]. Rigid, reliable and stable fixation is very important for osteoporotic distal femur fractures [9].

In recent decades, treatment methods for distal femur fractures have advanced from nonoperative to operative treatment. Non-operative treatment may cause high rates of nonunion, malunion, pain and stiffness. Therefore, the conservative treatment should be reserved for stable fractures in the low activity demand and low comorbid individuals [19]. Common operative treatment includes internal fixation using condylar buttress plates, blade plates, dynamic condylar screws, LCPs and retrograde intramedullary nailing. These surgical methods have advantages and disadvantages.

Retrograde intramedullary nails are a good treatment option for distal femur fractures because intramedullary nailing minimizes soft tissue dissection and secondary damage to the blood circulation at the fracture site [20,21]. However, in osteoporotic bone, poor bone quality often results in failure of implant anchorage in the distal part [22]. The intra-articular entry portal could cause stiffness of the knee joint, patellofemoral pain and infection [23]. Moreover, unlike cruciate retaining prostheses, the posterior stabilized knee design is not applicable to retrograde nailing in a periprosthetic distal femur fracture after TKA [24]. Condylar buttress plates, blade plates and dynamic condylar screws do not provide stable fixation for comminuted fractures with poor bone stock. These metal plates cause large surgical exposure, extensive soft tissue damage and blood loss. These disadvantages increased the risk of nonunion [24,25]. LCP provides more rigid fixation than conventional metal plates and is related to early bone union and low rates of infection [26]. Moreover, LCP ensures better fixation and a low fixation failure rate in osteoporotic distal femur fractures [27]. Recently, MIPO with LCP technique have been introduced. This technique minimizes soft tissue injury with a minimal incision and preserves the periosteum and blood supply. It promotes early bone union with a low risk of complications [28,29]. MIPO with the LCP technique has been increasingly used for distal femur fractures and periprosthetic distal femur fractures after TKA in low BMD patients. Previous studies on MIPO with the LCP techniques have reported good clinical and radiologic outcomes in both native and periprosthetic distal femur fractures after TKA even in osteoporotic population [30,31].

However, recent studies reported a high rate of delayed union, nonunion or implant failure in distal femur fractures treated using MIPO with LCP [11,32]. In periprosthetic distal femur fracture after TKA treated using MIPO with LCP, Ricci et al. reported that the nonunion rate was 13% [33]. Streubel et al. reported that delayed union was 6% and nonunion was 15% [34]. Moreover, these complications were associated with a low return rate of the prefracture activity level in distal femur fractures [6]. This may be due to mechanical problems of monolateral LCPs, particularly in the absence of medial fracture compression in medial comminution distal femur fractures [35,36]. Jazrawi et al. reported that dual LCP in distal femur fractures provided significantly greater fixation than monolateral LCP plates. The application of medial LCP in MIPO with the dual LCP technique provides a more rigid fixation [31]. We also thought that the application of medial LCP in MIPO with the dual LCP technique provides a more rigid fixation than monolateral LCP plates in A3-type distal femur fracture and Su type 2 periprosthetic distal femur fractures of this study.

In this study, MIPO with the dual plate technique for distal femur fractures and periprosthetic distal femur fractures after TKA in low BMD patients increased plate fixation stability and encouraged early mobilization. All patients were allowed immediately full weight bearing after operation and able to early full weight bearing without pain. Early full weight bearing after operation improves the functional mobility and decreased both complications in distal femur fractures. However, the medial comminution and inadequate fixation were identified as risk factor of fixation failure or reoperation after early full weight bearing in distal femur fracture. Adequate fixation should be achieved to allow early full weight bearing. For this, we used the MIPO with the dual plate technique and were able to encourage patients to early full weight bearing after operation. The time to pain free weight bearing was 11.3 ± 3.4 weeks (range, 8–16) was earlier than 11 weeks of monolateral LCP plates and retrograde intramedullary nails. Moreover, most of patients were able to return of prefracture activity and satisfied with the results of operation. All patients achieved bone union and there was no delayed union, nonunion or implant failure. We believe that MIPO with the dual plate technique provides more rigid fixation and encourages early rehabilitation for patients. Cicek et al. also showed more rigid fixation obtained with dual LCP and advantages to postoperative rehabilitation in periprosthetic distal femur fractures after TKA in osteoporotic patients [9].

Osteoporosis is a systemic skeletal disease characterized by low bone mass and the deterioration of bone microarchitecture leading to bone fragility and a consequent increase in fracture risk. A decrease in cancellous and cortical BMD and an increase in cortical bone porosity can decrease the holding capacity of plates and screws [37,38]. While adequate internal fixation is necessary in osteoporotic fracture, MIPO with the LCP technique is a good treatment option for distal femur fracture in low BMD patients, compared to conventional nonlocked plates [24,39,40]. Because MIPO with the LCP technique depends on indirect bone healing with callus formation, improper fixation that is not stable and firm enough to maintain the fracture fragments together until the callus formation is likely to result in reduction loss and fixation failure [40]. Kim et al. reported that only lateral LCP is not enough to reliably fix osteoporotic distal femur fractures after TKA [40]. In a biomechanical study, Zhang et al. reported that dual plating proved stronger than single lateral plate plating in comminuted supracondylar femoral fractures [41]. Therefore, MIPO with the dual plate technique can provide enough fracture fixation for indirect bone heeling for distal femur fractures in low BMD patients.

Previous midline skin incisions and medial parapatella arthrotomy are the other concerns in periprosthetic fractures after TKA. The use of a previous skin incision for periprosthetic fracture may increase the risk for infection and skin necrosis [9]. Moreover, medial parapatellar incisions cause blood supply impairment to the patella, patella maltracking and anterior knee pain [42]. Rather than the previous skin incision, small lateral and medial incisions were made for the MIPO technique in periprosthetic distal femur fracture in order to maintain the periosteal blood supply to bone and to minimize soft-tissue dissection. These factors enhance fracture healing and are associated with early mobilization.

Because of the retrospective study design, the absence of a patient group treated with monolateral LCP for comparing the results of the dual LCP is a major limitation of this study. The follow-up period was not extensive enough to confirm posttraumatic arthritis after surgical treatment, and the small size was also a limitation of this study. Lastly, as this study was a single center study, future large, multi-centered and prospective study are needed.

5. Conclusion

MIPO with the dual plate technique can provide rigid fixation for osteoporotic distal femur fractures. This stable and rigid fixation may allow early mobilization and return to pre-fracture activity.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Ethical approval

This retrospective study was approved by the institutional review board of our hospital (IRB No. 2021–07–005). All methods were performed in accordance with the relevant guidelines and regulations (Declaration of Helsinki).

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Consent

The patient's informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Author contribution

Conceptualization, S.C. and H·K.; Data curation, T.H·C and S·K.; Writing – original draft preparation, C.L.; Writing – review and editing, C.L., T.H·C and S·K.; Supervision, S.C. and H·K.; Funding acquisition, H. K. All authors have read and agreed to the published version and the manuscript.

Registration of research studies

Name of the registry: Research Registry
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Hyperlink to your specific registration (must be publicly accessible and will be checked):https://www.researchregistry.com/register-now#home/registrationdetails/61d7083fd4e783001fa2fec5/

Informed consent statement

The patient's informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Guarantor

None.

Declaration of competing interest

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

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