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Comparison of radiological and functional results in osteoporotic distal femur fractures operated with single plating, lateral incision, and double plating, anterior paramedial incision

A retrospective study

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Abstract

Treatment of osteoporotic distal femur fractures is often complicated by a high rate of nonunion and varus collapse. For such fractures, lateral plating with lateral incision and double plating with anterior paramedial incision have shown promising results in the recent literature. The hypothesis of this study was that bilateral plating of comminuted distal femur fractures in osteoporotic patients would result in higher union rates and lower revision rates compared to an isolated lateral locking plate. The study included 56 patients (23 males, 33 females) with supracondylar femur fracture. According to the OA/OTA classification, 9 were type A3, 8 were A2, 13 were C1, 16 were C2, and 10 were C3. The mean follow-up period was 12 months, with 29 patients treated using lateral mini-incision, lateral locking plate, and 27 patients treated with anterior paramedial incision, dual plating. The clinical and radiological results were evaluated. The mean duration of radiological union in the studied population was 15 ± 2.1 months (range, 11–21 months) in the single plate group (Group A), and 13.5 ± 2.6 months (range, 9–19 months) in the double plate group (Group B). Mean ROM was 112.3° and flexion contracture 4° in Group A, and ROM 108.3° and flexion contracture 6.7° in Group B. (P = .15). The average Western Ontario and McMaster Universities Arthritis Index (WOMAC) score was 85.6 points in Group A and 83.5 points in Group B (P = .2278). The postoperative anteversion measurement in the operated extremity ranged from −15 to 19 in Group A, and from 5 to 18 in Group B. When the anteversion degrees were compared between the injured and uninjured extremities in the postoperative period, a significant difference was observed within Group A (P = .0018), but no significant difference was observed in Group B (P = .2492). Dual plate fixation using the anterior paramedial approach is an effective operative method for osteoporotic distal femur fractures. This has many advantages such as precise exposure, easy manipulation, anatomic reduction, and stable fixation. However, for surgical indications and medial bone defects > 1 cm, grafting should be performed.

Abbreviations: aLDFA = anatomic lateral distal femoral angle, aPDFA = anatomic posterior distal femoral angle, MIPPO = minimal invasive percutaneous plate osteosynthesis, ORIF = open reduction and internal fixation, WOMAC = Western Ontario and McMaster Universities Arthritis Index.

Keywords: distal femur, dual locking plate, fractures, osteoporotic

1. Introduction

Distal femur fractures are a common orthopedic problem that constitutes 3% to 6% of all femur fractures and 0.4% of all fractures.[1,2] These fractures can result from direct axial loads or, less frequently, twisting or rotational forces applied to the lower extremities.[3,4] In the elderly, distal femur fractures often occur in the distal part of the femur, are often comminuted, and are the result of low-energy trauma.[4] Clinically, fractures within 9 cm of the distal femoral joint surface are defined as distal femur fractures.[5] The metaphyseal bone of the distal femur is located between the diaphyseal cortical bone and the arthritic knee joint in the geriatric population. The stress concentration at this weak point of the femur leads to low-energy osteoporotic fractures.

Neuromuscular coordination and proprioception problems make the elderly more prone to osteoporotic distal femur

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

This article does not contain any studies with human participants or animals performed by any of the authors.

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fractures and treatment failure. Patients may have difficulty maintaining walking balance and mobilizing them after surgery can also be a challenge.[6] In cases of widespread metaphyseal fragmentation, there is a functional loss of medial cortical support in osteopenic distal femur fractures. In these cases, the chances of medial callus formation are reduced. The addition of a medial plate helps provide additional stability and reduces the likelihood of implant failure.[1,7]

Initial studies using lateral locking plates reported promising results with failure rates ranging from 0% to 14%, but mostly <6%.[8] However, recent years have seen a change in the results, with failure rates reaching up to 17% to 21%, decreasing callus formation, up to 32% healing problems, and other complications.[9–11] Factors recently reported to be associated with higher failure rates include obesity, diabetes, open fractures, age, fracture comminution, alcoholism, smoking after surgery, and technical factors such as plate length and screw density, cortical inadequate reduction.

Distal femur fractures can result in relatively high mortality and comorbidity compared to proximal femur fractures.[11,12] Limiting weight-bearing postoperatively can prolong healing, increase complication risks, and adversely affect patients' quality of life.[13] Double plating, such as more rigid fixation, provides better stability for a sufficient period of time to allow bone healing in distal femur fractures with wide metaphyseal fragmentation, osteoporotic fractures, and high-energy or open fractures.[14] Double plating reduces the lever arm effect on the femoral axis, resulting in decreased load on the fracture site.[15]

The medial parapatellar approach provides appropriate visualization in double plate fixation and provides controlled access to the distal femur while minimizing medial side stripping. The anterior approach allows reduction and application of the medial plate, preventing medial dissection. Both the front and side plates can be placed 90° orthogonal to each other to provide rigid stability.[7]

The aim of this study was to compare the clinical and radiological results of internal fixation using a single plate with lateral incision for multi-fragmented distal femur fractures in patients with osteoporosis, and double plate fixation performed with an anterior paramedian incision. The femoral anteversion angles and the results of knee function scores when rigid stability was achieved were also evaluated.

2. Material and methods

A retrospective study was conducted on geriatric osteoporotic patients who underwent osteosynthesis using a single plate or double plates for distal femur fracture diagnosis between January 2014 and April 2021, and who were followed up for at least 24 months. Our study has been approved by the Local Ethics Committee of Hitit University with decision number 2021-59. Patients over 60 years of age with osteoporotic distal closed femur fractures who had not undergone any bone surgery on the same side or opposite lower extremity before were retrospectively analyzed based on periodic examination and clinical findings. Patients who had suffered multiple trauma, open fractures, pathological fractures, preoperative neuromuscular disorders, or orthopedic trauma association 33-A1, 33-B1, 33-B2, and 33-B3 type fractures were excluded from the study. The osteoporosis criteria were based on the patients' medical records. The fracture pattern and detection of union were defined by simple radiographic imaging and three-dimensional computed tomography with 1.25 mm sections.

A total of 56 patients met our inclusion criteria. All patients had sustained low-energy injuries secondary to falls, and there were no additional injuries in the patients. According to the orthopedic trauma association classification, there were 9 type A3, 8 were A2, 13 were C1, 16 were C2, and 10 were C3. All patients were operated on within the first 5 days, depending on their morbidity, comorbidities, and referral time. A long leg plaster cast was applied for fixation until the operation. According to our hospital protocol, all patients were given thromboembolic deterrent stockings on the unaffected lower extremity.

Enoxaparin was given for pharmacological thromboprophylaxis at a dose of 40 mg/day for 50–90 kg and 60 mg/day for 91 to 130 kg, and was applied until the patient was fully mobilized for at least 14 days. One gram of tranexamic acid was given 2 hours before the surgery, and 3 doses of 500 mg were continued at 8-hour intervals. Cefazolin was applied at a maximum of 24 hours with 1 gram for patients under 80 kg, 2 grams for patients over 80 kg, and 3 grams for patients over 130 kg, repeated every 6 to 8 hours before skin incision.

All procedures were performed under combined spinal and epidural anesthesia without the use of a tourniquet. Surgically, a small incision was made initially on the distal lateral thigh, and a locked anatomical plate was placed submuscularly. In complex cases, the incision was extended into the joint to facilitate joint reduction. The distal femur fragments were reduced with clamps and K-wires according to the fracture configuration. Satisfactory length and rotation were achieved with manual traction, and the plate was fixed to the femur with distal and proximal screws. This was followed by position control using a C-arm fluoroscope and screw fixation control at the distal and proximal ends (Fig. 1).

For Group B patients who underwent double plate application, the patient was placed in a supine position with the affected knee supported from below, bringing it to 90° flexion. A longitudinal straight midline incision was used. Additionally, a longitudinal incision was made on the knee joint capsule and the quadriceps tendon on the patellar side, and the distal cut of the joint capsule was extended towards the anterior tibial surface to dislocate the patella laterally. During this process, the cut in the quadriceps tendon was extended proximally to adequately expose it for reduction according to the size of the fracture, facilitating the easy placement of medial and lateral metal plates. The extensor retinaculum was preserved in front of the patella. The reduction of the fracture was planned preoperatively based on 3D reconstructed computed tomography scans and fixation was applied using C-arm fluoroscopy during the surgery. Once anatomical reduction was achieved, a temporary lateral metal plate (locking compression plate) was initially placed using K-wires or reduction forceps, and then the medial distal plate was fixed to the medial side with screws. To ensure proper screw direction, the plate was held in 20° of internal rotation in the coronal plane. The lateral metal plates were fixed with 4 or more screws distally and 3 or more screws proximally, depending on the fracture line. In the presence of small osteochondral fragments in the joint, appropriate size surgical sutures or absorbable pins were used for fixation. For bone defects larger than 1 cm, bone grafting was performed using allogenic bone grafts. Finally, the quadriceps flap was closed with absorbable sutures side by side. The skin was closed with suture wires, and aspiration drainage was used for 24 hours. All patients received wound infiltration analgesia perioperatively according to local protocols (Fig. 2).

Postoperatively, continuous passive knee motion was applied with constant passive knee movement starting from 30 degrees on the first day, increasing according to the patient's tolerance until flexion >90 degrees was achieved during the postoperative period. Patients were also mobilized with thromboembolic stockings and hinged knee braces until the day of discharge. Starting from the first postoperative day, all patients undergoing physiotherapy were allowed full weight-bearing as tolerated. Regular radiological follow-up was performed at 2-week intervals for the first 6 weeks to assess if there was any loss of reduction with early weight-bearing. Afterward, monthly X-rays were taken until 6 months, and then every 3 months until union occurred. In cases of delayed union, computed tomography scans were performed. The minimum follow-up period was 12 months,

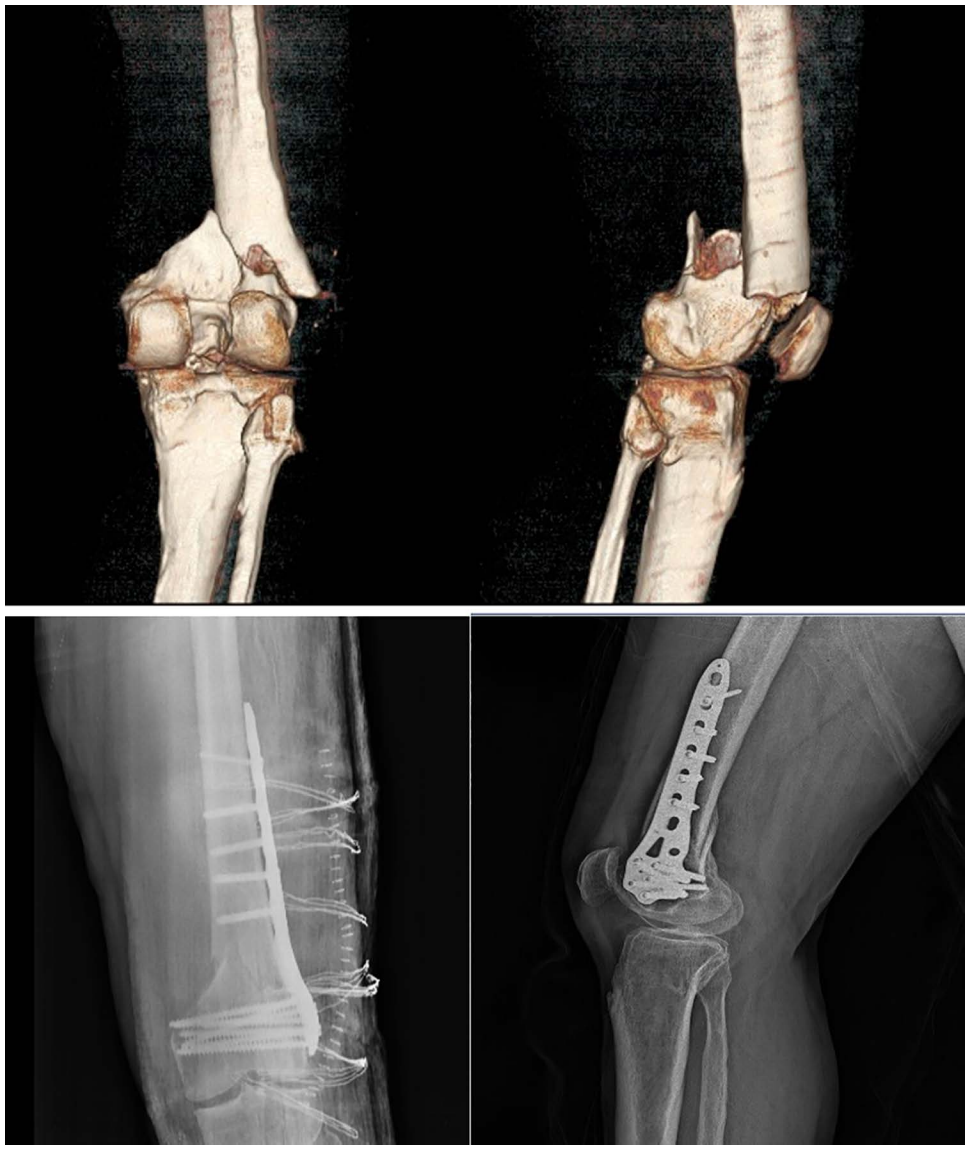

Figure 1. A supracondylar femur fracture operated with lateral incision and single lateral plate, preoperative and postoperative images.

the maximum was 38 months, and the average was 24 months. Full weight-bearing was postponed until radiological union was achieved, with at least 12 weeks postoperatively. Fracture union was determined by radiographic analysis of at least 3 healed cortices out of 4 cortices and/or the presence of callus formation; clinical healing was defined as the absence of pain with weight-bearing or stress application on the injured area during examination. Malrotation was assessed clinically by comparing the injured side with the normal side. Nonunion was determined by progressive radiographs without evidence of bone healing after a 6-month follow-up, confirmed by computed tomography scans and the need for future revision nonunion surgery. Delayed union was determined by surgical documentation in the medical records after a 6-month follow-up.

The analyzed parameters included demographics, fracture pattern type, radiographic fracture healing time, modified radiographic union scale for tibial fractures score, range of motion, flexion contracture, functional knee score at 6 months (Knee Society Score), and WOMAC score. Radiologically, the femoral anteversion angles of the anatomic lateral distal femoral angle (aLDFA), the anatomic posterior distal femoral angle (aPDFA), healthy and operated sides were measured. Normal values for these parameters were accepted as 81° (range 79°–83°) for The aLDFA and 83° (range 79°–87°) for the aPDFA. Scoring was done during outpatient follow-up. Any relevant clinical complications were recorded.

3. Statistical analysis

The data obtained in the study were analyzed statistically using SAS Enterprise Guide 7.11 HF3 software (SAS Institute, Inc, Cary, NC). Categorical variables were stated as number (n) and percentage (%), frequency (n, percent), and the chi-square or Fisher exact test were applied in comparisons. The normality of the numerical data was tested using the Kolmogorov–Smirnov and Shapiro–Wilk tests. The homogeneity of variances was tested using Levene test. Student *t* test was used to compare the numerical data between the 2 groups when the assumption of normal distribution was met, and Mann–Whitney U test was used when the assumption of normal distribution was not met. Tukey post hoc tests were used, followed by one-way ANOVA analysis for comparisons between more than 2 groups. The agreement between pre- and postoperative anteversion measurements was evaluated with Blant-Altman plots. Statistical significance level was accepted as $P < .005$.

Figure 2. A supracondylar femur fracture operated with an anteromedial incision and dual plates, preoperative and postoperative images.

Before the research commenced, a priori power analysis was conducted for testing the primary hypothesis, based on expert opinion, with an alpha value of 0.05 and Cohen d effect size of 0.8 for the Student *t* test. This analysis indicated that including a total of 50 patients (25 in each group) would provide 80% power for the study. However, considering the potential participant attrition during the research process, the sample size was increased by 10%. As a result, a total of 56 patients were included in the study.

4. Results

The average age of patients was 71 (62–88) in Group A and 75 (63–91) in Group B. Group A consisted of 12 males and 17 females, while Group B consisted of 11 males and 16 females. The mean follow-up period was 29 months (24–38 months) in Group A and 31 months (24–40 months) in Group B. The bone mineral density of the study group was measured as T-score, with an average of −3.32 (ranging from −2.3 to −4.9) in Group A and −3.2 (ranging from −2.5 to −4.7) in Group B (Table 1). There were 5 cases of 33-A2 and 4 cases of 33-A3 in Group A, while Group B had 3 cases of 33-A2 and 5 cases of 33-A3; type C fractures were those with complete involvement of the joint surface, with a total of 20 cases in Group A (33-C1: 6, 33-C2: 9, 33-C3: 5) and 19 cases in Group B (33-C1: 7, 33-C2: 7, 33-C3: 5).

The average age of patients was 71 (62–88) in Group A and 75 (63–91) in Group B. Group A consisted of 12 men and 17 women, while Group B consisted of 11 men and 16 women. The mean follow-up time was 29 months (24–38 months) in Group A and 31 months (24–40 months) in Group B. The bone mineral density of the study group was measured as T-score, which was −3.32 (−2.3 to −4.9) in Group A and −3.2 (−2.5 to −4.7) in Group B (Table 1).

Table 1

Characteristics of the patients included in the study.

	Single plate N = 29	Double plate N = 27	*P* value
Age	71 ± 7.5 (62–88)	75 ± 8.7 (63–91)	.084*
Gender			
Male	12	11	.817‡
Female	17	16	
Follow-up (weeks)	24 ± 6 (12–38)	22 ± 3.8 (12–27)	**.09***
Z score	−3.32 ± 0.86(−4.9/−1.2)	−3.2 ± 0.6 (−4.7/−1.8)	.46†
Body mass index	28 ± 2.4 (24–32)	29 ± 1.5 (26–32.5)	**.047***
Fracture types			
A2/A3	5/4	3/5	.456‡
C1/C2/C3	6/9/5	7/7/5	.876‡
Revision fracture types			
A2/A3	1/2	2/4	.89‡
C1/C2/C3	2/5/4	3/4/5	.82‡
Smoking	13	12	.988‡
DM	8	10	
Chronic obstructive lung disease	3	5	
Chronic kidney failure	2	2	

Bold values denote statistically significant at $P < 0.05$.

* Student *t* test.

† Mann–Whitney U test.

‡ Chi-square test.

Table 2

Time to union, modified RUST score, time to operation, length of hospital stay and follow-up.

	Single plate	Double plate	*P* value
Union time (weeks)	14.9 ± 2.1 (11–21)	13.5 ± 2.6 (9–19)	**.038***
Modified RUST score	11 ± 2.4 (7–15)	12 ± 1.6 (9–15)	.089*
Time to operation	3 ± 1.1 (1–5)	3 ± 1.15 (1–5)	.85*
Hospital stay (days)	7 ± 1.3 (4–9)	7 ± 1.3 (4–9)	.17*
Follow-up (months)	24 ± 5.9 (12–38)	22 ± 3.8 (12–27)	**.09***

Bold values denote statistically significant at $P < 0.05$.

*Student's *t* test

The average time for bone healing confirmed by radiography and computed tomography was 14.9 weeks (11–21 weeks) in Group A, but in Group B, the average time from bone fracture to healing was 13.5 weeks (9–19 weeks). When the modified radiographic union scale for tibial fractures score was used to objectively evaluate bone healing, the score was 11 points (7–15 points) in Group A and 12 points (9–15 points) in Group B ($P = .089$) (Table 2).

After bone healing, the mean ROM of the examined knee joint was 112° (90°–130°) in Group A with a flexion contracture of 4° and 108° (90°–125°) with a flexion contracture of 6.7° in Group B ($P = .0069$). There was a statistically significant difference between the 2 groups in the aLDFA, with a value of 85 (79–89) in Group A and 83 (77–88) in Group B ($P = .0232$), as well as the aPDFA, with a value of 86 (79–99) in Group A and 83 (79–88) in Group B ($P = .051$). The mean Knee Society Score was 84.3 points (68–98 points) in Group A and 81.3 points (66–96 points) in Group B ($P = .1445$). The mean WOMAC score was 85.6 points (71–98 points) in Group A and 83.5 points (64–94 points) in Group B ($P = .2278$) (Table 3). There were 5 cases of loosening and collapse resulting in nonunion in Group A and 2 cases in group B, with no significant difference between the groups ($P = .0928$). In Group A, the cases of nonunion were treated by refreshing the fracture line through a lateral incision and applying a new lateral plate, followed by medial incision and fixation with allograft and medial plate in the same session. One patient in Group B developed a superficial wound infection, which was treated with antibiotics and daily dressings for 2 weeks, and the condition improved without the need for surgical intervention. Two patients in Group A were treated by wound irrigation and debridement. All patients achieved bone healing, and no periprosthetic fractures were observed.

Postoperative anteversion measurements in group A with supracondylar femur fractures ranged from −15 to 19 degrees. The mean anteversion degree was 6.3 with a standard deviation of 8.1. In group B, postoperative anteversion measurements in the injured extremity ranged from 5 to 18 degrees, with a mean anteversion degree of 11.8 and a standard deviation of 4.2 (Table 4). When comparing anteversion degrees between the injured and uninjured extremities in the postoperative period, significant differences were observed within Group A ($P = .0018$), but not within Group B ($P = .2492$) (Table 5).

The Bland-Altman graph showing the agreement between pre- and postoperative anteversion measurements of Group A is given in Figure 3. According to the Bland-Altman plot, only 2 of the preoperative and postoperative anteversion measurements in group A were outside the confidence limits.

The Bland–Altman graph showing the agreement between pre- and postoperative anteversion measurements of Group B is given in Figure 4. According to the Bland–Altman plot, it was determined that only one of the preoperative and postoperative anteversion measurement values in Group B was outside the confidence limits.

5. Discussion

In our series, there were no significant differences between the 2 groups in terms of patient numbers, age, gender ratio, and follow-up durations. There was no difference in the distribution of fracture types between the single plate and double plate groups, and Group C had a higher utilization of bone grafts. The distribution of comorbidities was equal in both groups. Except for a higher incidence of flexion contracture in the double plate group, there were no significant differences observed in joint range of motion in both groups. There were significant differences in aLDFA and aPDFA between the double plate and single plate groups. Postoperative measurements of anteversion did not show significant differences in the double plate group, but significant differences were observed in the single plate group. Rotational malalignment accounts for 10% of distal femur fractures and the unique geometry of distal femoral condyles with 25° medial and 10° lateral tilt increases the risk associated with minimal invasive percutaneous plate osteosynthesis (MIPPO) approaches. This malrotation primarily affects the patellofemoral articulation, leading to anterior knee pain and exacerbation of osteoarthritic changes.[16,17] Despite the current anatomical plate position, malreduction of supracondylar fractures is possible, and the "golf club" deformity arises from both medial translation and external rotation of the distal femur.[18] The anterior parapatellar median approach was used for fracture reduction. In terms of better visualization of the fracture configuration, the same incision can be used for later total knee arthroplasty when partial fracture develops as a late sequela of osteoarthritis, with malrotational alignment prevented by intra-articular extension associated particularly with the MIPPO technique.[19,20] Restoration of limb alignment is critically important during fracture stabilization. Misalignment of the femur or tibia in any plane can lead to abnormal load transmission across adjacent joints and subsequently result in cartilage damage.[21–23] Buckley et al found that femur fractures had an average malrotation of 11.5 degrees, with the most significant malrotation observed in C1 and C2 tibia fractures and A1 and A2 femur fractures, each showing malrotation >20 degrees.[24] There was no relationship between fracture severity and degree of malrotation. Regarding anteversion measurements, in the double plate group, there was no significant difference between preoperative and postoperative

Table 3

Clinical and radiological follow-up data of the patients included in the study.

	Single plate	Double plate	*P* value
Range of motion	112 ± 11 (90–130)	108 ± 9.4 (90–125)	.15*
Flexion contracture	4 ± 2.77 (0–10)	6.7 ± 4.38 (0–20)	**.007***
The aLDFA (lateral distal femoral angle)	85 ± 5.2 (79–99)	83 ± 2.8 (77–88)	**.023***
The aPDFA (posterior distal femoral angle)	86 ± 4.9 (79–99)	83 ± 2.3 (79–88)	.051*
WOMAC (Western Ontario and McMaster Universities Arthritis Index)	85.5 ± 6.5 (71–98)	83.5 ± 5.5 (66–96)	.227*
Knee Society Score	84.3 ± 7.2 (68–98)	81.2 ± 7.6 (66–96)	.144*

Bold values denote statistically significant at $P < 0.05$.
*Student's *t* test

Table 4

Anteversion measurements in the single plate and double plate groups.

	Non-operated extremity	Operated extremity	*P* value
Single plate	12.2 ± 4.9 (6–27)	6.3 ± 8.1 (–15–19)	**.002***
Double plate	13.3 ± 4.7 (6–27)	11.8 ± 4.2 (5–18)	.249*

Bold value denote statistically significant at $P < 0.05$.
*Student *t* test.

Table 5

Comparison of anteversion measurements of operated and non-operated extremities in single plate and double plate patients

	P value	Post hoc *P* values
Group I-A (1)	**.002***	**1–2: .002†**
Group I-B (2)		1–3: .9†
Group II-A (3)		1–4: .9†
Group II-B (4)		**2–3: .001†**
		2–4: .025†
		3–4: .8†

Bold values denote statistically significant at $P < 0.05$.
Group I-A: non-operated extremity in single plate group.
Group I-B: operated extremity in single plate group.
Group II-A: non-operated extremity in single plate group.
Group II-B: operated extremity in double plate group.
* One-way ANOVA.
† Tukey post hoc tests.

measurements. In the single plate group, however, the preoperative anteversion was 12.2 ± 4.9 degrees (range: 6–27), and the postoperative anteversion was 6.3 ± 8.1 degrees (range: –15–19), showing a significant difference ($P < .0018$). Inclusion of intra-articular fracture reduction and visualization, including open reduction of the joint surface, before fixation of the metaphyseal block to the diaphyseal segment, can provide a broader anatomical view of the fracture. Buckley et al found rotational alignment abnormalities in 38.5% of distal femur fractures and 50% of proximal tibia fractures. Certain injury patterns appear to be more prone to indirect methods of malreduction compared to other fracture patterns.[24] Malrotation can have cosmetic and functional effects, and complaints such as difficulty in running, climbing stairs, and walking on uneven surfaces start to arise when femoral malrotation exceeds 15 degrees. It is believed that these biomechanical changes associated with femoral malrotation can lead to functional impairments and contribute to an increased incidence of hip and knee osteoarthritis.[22,25,26]

Some injury patterns appear to be more prone to indirect methods of malreduction compared to others. Long-term outcome studies examining the development of joint disease associated with poorly rotated limbs should be conducted.[24] In the literature, various surgical approaches have been adopted, including both medial and lateral approaches, anterior medial/lateral parapatellar approaches, and modifications of the extensile approach.[1,5,7,9,15,19,20,27–32]

They emphasized that early rehabilitation of joint injuries in the extremities is limited, and excessive damage to the suprapatellar tissue contributes to stiffness, highlighting the need for meticulous repair of the suprapatellar tendon to prevent adhesions between the quadriceps and the bone surface.[28] Intra-articular fracture patterns may require extensile approaches to expose the joint surface.[33,34]

Campana et al demonstrate that Variable Angle Locking Compression Plate Contoured Condylar Plates provide good functional outcomes and fracture healing. Avoiding fragmented or osteoporotic bone fragments from the joint surfaces potentially increases the overall stability of the construct and provides greater versatility in the internal fixation of fractures, regardless of plate design.[35]

In osteoporotic femur fractures, it is preferred to use plates that are as long as possible and cover the entire femur. The number and configuration of screws are also subject to debate. Stoffel et al have suggested placing oblique screws at the ends of the plates to enhance fixation strength.[36] We prefer using as many locking screws as possible in the distal fragment and bending the proximal end screw.

In severe osteoporosis, the main area of fixation failure is the bone-implant interface, therefore devices with larger interface areas cause less stress and are preferred.[37,38] Biomechanical studies have suggested that a titanium locking compression plate with sufficient working length on the lateral side (three times the longitudinal displacement of the fracture and 8 times the transverse fracture dimension) and sufficient screws in the proximal and distal regions provide stable fixation.[39,40] Severe comminution, short distal femoral bone block, and weak bone stock require increased rigidity and may necessitate dual plating.[19,20] Retrograde nails or medial side plates can be added to lateral LISS plating. Additionally, augmentation with intramedullary bone grafts helps improve screw purchase and fracture healing in these cases.[41,42] Rajasekaran et al reported 50 cases of inadequate fixation, including insufficient plate length in 16 cases, inappropriate fixation in 6 cases, screw or implant failure in 5 cases, and a combination of these factors in the remaining 23 cases.[43] The use of longer plates increases the working length and the number of cycles it can withstand before failure.[44]

In our elderly population, this fixation principle allows for early mobilization without subsequent implant failure or screw loosening, even in the presence of delayed union (>12 weeks). Early mobilization is particularly important in preventing complications such as deep vein thrombosis, pneumonia, urinary tract infections, and pressure ulcers. It also helps prevent joint contractures due to prolonged immobilization.

Ziran et al evaluated 35 patients with AO type C3 distal femur fractures.[32] The patients were treated using an anterior approach, and 2 orthogonal plates were placed with minimal medial dissection, providing excellent exposure.

An orthogonal dual-plate configuration provides more stable fixation and is biomechanically superior to single-plating with standard compression or locking plates.[45] In their study on dual plating to prevent nonunion of the distal femur, Holzman et al utilized a single-stage medial approach if the previous lateral distal femur plate was intact. In cases of failure of the lateral plate, the authors performed a two-stage procedure, involving plate removal and fixation of the lateral plate in the first stage, followed by a second stage with medial plating, including the use of bone grafting.[30]

The primary concerns regarding dual plating include potential disruption of periosteal blood flow, which can lead to increased soft tissue stripping and a higher risk of infection.[46] A cadaver study demonstrated that medial plating did not result in significant devascularization of the distal femur.[47] Additional medial plating only caused a 4.2% reduction in

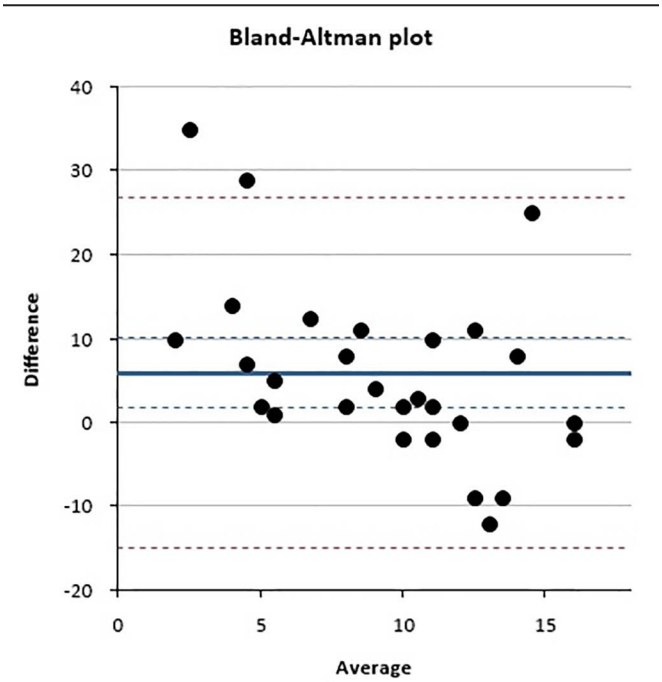

Figure 3. The differences between preoperative and postoperative anteversion measurements in Group A.

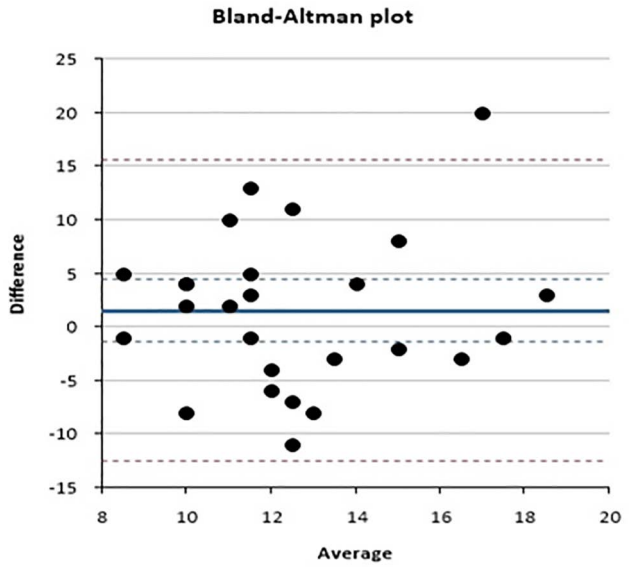

Figure 4. The differences between preoperative and postoperative anteversion measurements in Group B.

arterial supply, compared to a 21.2% reduction achieved with a single lateral plate.[48] Another significant concern with dual plating is that excessive structural rigidity may contribute to delayed healing or nonunion.[49,50] Potential vascular injury can be expected in the distal part of the medial thigh. CT angiography studies have shown that this area is supplied by 2 vessels: the medial superior genicular artery and the third perforating artery that supplies the vastus medialis muscle. However, none of these arteries are directly adjacent to the bone, so careful dissection can help prevent vascular injury.[20] When approximately 60% of the femur length, from the greater trochanter to the lateral joint line of the knee, is operated on, no reported impairment of superficial or deep femoral arteries has been observed. The proximal 16 cm of the medial adductor tubercle is considered safe for plating in terms of the femoral artery and its branches, as well as the femoral nerve and its branches.[17,48,51]

It is recommended to use a lateral plate that is at least 2 cortices longer than the medial cortex.[20] However, utilizing an existing incision method for total knee arthroplasty has the advantage of reducing intraoperative vascular damage. In complex distal femur fractures and nonunions where a lateral plate or retrograde intramedullary nail alone provides insufficient stability required for healing, there is an increased need for dual fixation constructs.[52] Steinberg et al demonstrated higher union rates with dual plating in AO type C3 distal femur fractures.[20] Imam et al treated 16 cases of type C3 distal femur fractures using an anterior approach and a dual plating technique, with an average time to union of 6.0 ± 3.5 months and no cases of reduction loss. Bone grafting was required in ten cases.[7] These findings suggest that facilitating rehabilitation treatment after rigid fixation may prevent systemic disease complications associated with osteoporotic fractures in the elderly.[53]

In fact, distal femur fractures have the lowest survival rate in patients aged 60 and above (35%) compared to periprosthetic fractures (<15%) or young patients with distal femur fractures (<21%), emphasizing the need for early surgical intervention (within 48 hours) in femur fractures in the elderly population to reduce complications associated with prolonged immobilization and mortality rates.[54–56] Surgery should be performed as soon as the patient is medically optimized.[56,57] However, attention should also be given to the treatment of dehydration and inadequate nutrition, which can improve bone healing, wound healing, and walking ability in these patients.

Moloney et al found that early complications were more common in the elderly population after open reduction and internal fixation (ORIF) surgery, with at least one early postoperative complication observed in 37.5% of patients, such as respiratory/urinary tract infections or cardiac problems.[58] Kammerlander et al reported significant mobility decline in the geriatric population following distal femur fractures, where 23% of the study population was completely dependent on others for daily activities, 26% were unable to perform any social activities, and only 18% could engage in unsupervised social activities.[3] Early mobilization and rapid rehabilitation should be allowed to prevent bed rest syndrome. The importance of providing a mechanically stable structure to decrease failure rates in geriatric patients who are unable to comply with partial weight-bearing protocols is emphasized through rigid fixation.[59]

Kammerlander et al reported that the complications observed in their study population included urinary tract infections and pneumonia, which were resolved with treatment.[3] They noted no deaths during the 2-year follow-up period. However, they found mortality rates ranging from 0.05% (1 month) to 20% (12 months) in elderly patients following distal femur fractures. It was emphasized that underlying illnesses, especially in the elderly, can contribute to increased mortality by exacerbating the underlying condition.[60]

Bai et al found that dual plating required bone grafting more frequently (91.7%) compared to single plating (40.4%), but there was no significant difference between the 2 groups in terms of time to bone healing or functional outcomes.[5] Sun et al reported >90% union rates for both treatments without significant differences in healing time or knee function.[49] However, in our series, dual plating resulted in significantly shorter bone healing time and better knee function compared to single plating, particularly in patients with disrupted medial cortex. Rajasekaran et al recommended the use of an additional medial plate with bone grafting to mechanically restore medial continuity after >2 cm revision fixation and alignment correction, specifically for medial defects.[43] Beeres et al performed MIPPO with an additional spiral-shaped plate in the ventromedial direction of the femur in 5 patients with nonunion and hardware failure due to large bone defects. Four patients achieved full weight-bearing at an average of 16 weeks.[51]

Complications associated with internal fixation include metal failure requiring reoperation, which occurs in approximately 5–7% of cases, and rotational malalignment, which occurs in 19–23% of cases.[8,61] Excessive scarring and fibrosis resulting from 2 incisions can lead to reduced range of motion in dual plating fixation. Most case series in the literature have shown decreased range of motion.[19,31,32,62] A comparative study found no difference between single and dual plate fixation groups.[15] Following dual plate fixation in distal femur fractures, there is a decrease in range of motion compared to normal. Sanders et al reported <90° flexion in 33.3% of patients and 5° flexion contracture in 44% of patients.[7,62] Khalil et al found limited range of motion (<110°) in 42% of patients.[31] Metwaly et al reported 3° to 5° less range of motion in geriatric patients after dual plating.[1,19]

Zhang et al compared the range of motion between single and dual plate groups at different time intervals during the postoperative period but did not find a significant difference.[63] They identified a comprehensive surgical approach as a risk factor for knee stiffness.[31] However, our procedure involved a median incision, minimizing soft tissue damage, and no cases of knee stiffness were observed. We believe that early range of motion is crucial to prevent potential knee stiffness in these patients. Rigid and adequate fixation is necessary for these cases.

In a retrospective cohort study by Moloney et al, a higher nonunion rate was found in the age group of 60 to 74 years compared to others.[58] Sun et al compared a group treated with dual plating for complex distal femur fractures to a group treated with unilateral locked metal plating. The dual plating group had no cases of nonunion, while the single plating group had 2 cases of nonunion.[49] In a pooled analysis of 3 studies comparing single and dual plating, Tripaty et al reported union rates of 9.2% versus 0%.[64] The average healing time for distal femur fractures using dual plating ranged from 11 weeks to 18 months. Bologna et al found a significant difference in average healing time between the dual plating group (7 weeks) and the 2 treatment groups, but no significant difference in time to full weight-bearing.[27] Bai et al reported an average healing time of 14.3 months compared to 18 months, and Zhang et al reported 17 weeks for both groups.[5,15] A combined analysis of the studies reported earlier healing in the dual plating group compared to single plating fixation. Steinberg et al reported the shortest time for fracture healing, with all except 2 cases radiographically healing in an average of 12 weeks and clinically healing in 11 weeks; however, the study included several noncomplex fractures.[20]

Metwaly and Zakaria demonstrated that single-incision dual plating in osteoporotic distal femur fractures provided fixation stability resulting in an 82.6% union rate and an average healing time of 9 months, enabling early mobility and accelerated rehabilitation.[19] The nonunion rate in the single plating cohort was 46%. The healing time was 7 weeks for the dual plating group and 12.5 weeks for the single plating group, showing a statistically significant difference between the 2 groups in this study.[27,31]

Fixation with plates in cases of particularly fragmented distal femur fractures tends to be prone to failure. During revision surgery, after achieving proper alignment of the fragments, there is often a gap on the medial side due to the opening of the fracture. As emphasized by Sanders and Krettek, restoring medial continuity is biomechanically crucial to prevent failure.[62,65] When fixation is inadequate, alignment loss, often resulting in internal rotation deformity and bone loss, can occur. Wang demonstrated successful healing using allografts for defects larger than 2 cm, which required a medial plate combined with autografts or autograft struts since a defect of this size cannot be mechanically bridged with an autograft alone.[66,67]

Bai et al followed a different strategy based on intraoperative findings. After lateral locking plate fixation, they applied a varus force, and if it was positive, they switched to dual plating.[5] The lateral locking plate and screws all act as a single unit and are typically rigid enough to resist any movement.

Bottlang et al evaluated the fixation strength of a lateral locking plate in a fracture model with approximately 1 cm bone defect. They recorded cortical displacements of <0.3 mm with an axial force of 400 N, within an acceptable range of micro-motion (0.2–1 mm). Therefore, intraoperative bone grafting is recommended for defects larger than 1 cm.[68] Fontenot et al reported a significant 70% increase in stiffness when a medial plate was added to a single lateral plate in a 33C fracture model under axial load.[69] The torsional stiffness of a dual-plated construct is 2.6 times greater than that of a single lateral plate and 5.4% higher than that of an retrograde intramedullary nail. The average load to failure and survival rate until failure were significantly higher for dual-plated constructs compared to single lateral plates.[69] Sanders et al applied a medial plate with a support plate in addition to the lateral condyles when observing motion during intraoperative testing with knee flexion and extension and varus and valgus stresses.[62,69] Athar et al reported knee stiffness as the most common complication, but it was often impossible to determine whether the stiffness was preexisting or related to the injury or treatment.[54] Regardless of the choice of fixation, perioperative complications associated with supracondylar femur fractures include delayed or nonunion requiring revision surgery, deep infection, proximal implant failure, and malunion.[26,70,71] Knee stiffness is prevalent in approximately 48% of cases, and other complications such as reduction loss (7%), fracture of locking screws (8%), and anterior knee pain (22%) have been reported.[16,19] Reduction loss, malunion, rotational malposition, and nonunion can lead to revision surgeries ranging from 19% to 23%.[8,61,70]

Considering the frequent occurrence of metal failure or varus collapse, in this study, we evaluated and compared the treatment options of single-plate technology, which involves the medial and lateral edges of the fracture site, and dual-plate technology for femoral supracondylar fractures. It is argued that dual plating reduces the distance between stress centers (lever arms) that affect the femoral axis, thereby reducing the magnitude of stress on the fracture site. In this study, all fractures in Group B, where the dual-plate method was applied, except for 2 cases requiring bone grafting due to nonunion, achieved confirmed healing on imaging at an average of 14 weeks. One case had a wound infection postoperatively and was treated with dressing and antibiotics. Bai et al mentioned that wound infection is one of the possible complications after surgical treatment, particularly in open fractures associated with open reduction techniques and in the presence of risk factors such as diabetes and obesity. They also emphasized that a history of smoking can increase the risk of post-injury wound infection. In this comparative study, no significant difference was observed between the single-plate and dual-plate groups regarding infection.[5]

Bologna et al reported a significant difference between the single-plate and dual-plate groups in terms of nonunion and delayed union. They highlighted that 4 patients in the single-plate group required revision ORIF, whereas no patients in the dual-plate group needed revision ORIF.[27]

Zhang et al did not find a significant difference in complication rates between single-plate and dual-plate fixation for distal femur fractures.[63] Tripathy et al stated in this systematic review that dual plating has an excellent fusion rate in cases of comminuted distal femur fractures, significant metaphyseal comminution, and periprosthetic fractures categorized as C2, C3, A2, and A3. The current limited evidence supports that there is no significant difference between single-plate and dual-plate fixation in terms of fusion rate, functional outcomes, intraoperative blood loss, and complications.[64]

In this study, postoperative wound infections occurred in 2 cases with single-plate fixation, while 1 case in the dual-plate group experienced a surgical site infection. For the treatment of all cases, wound irrigation, debridement, dressing, and antibiotic therapy were sufficient. This finding suggests that factors other

than surgical technique can contribute to wound infections in patients at risk of postoperative infection. Therefore, close monitoring of postoperative wounds is necessary for patients with risk factors for infection. Additionally, encouraging smoking cessation in patients with a history of smoking may help prevent wound infections.

The dual plating technique utilizing a medial parapatellar approach provides excellent visualization and minimizes medial stripping while allowing controlled access to the distal femur. The anterior approach facilitates the application of reduction and fixation devices and prevents medial dissection. Additionally, the plates can be placed parallel to each other to provide enhanced structural stability.

This study had several limitations and shortcomings, including its retrospective design, short follow-up period preventing long-term evaluation, and relatively small sample size that hinders generalizability of the results. While none of our patients required revision due to clinical malrotation in fracture fixation, no clinical correlation was established between malrotation limbs and postoperative patient satisfaction using any outcome score. According to our study findings, there was no statistically significant difference in clinical and radiological outcomes when comparing single plating via a lateral incision with dual plating via an anterior incision. However, unilateral fixation with single plating has disadvantages such as difficulties in securing fracture fragments and grafts, particularly in elderly patients or cases with significant metaphyseal comminution. In such cases, dual plating via a single incision is a useful surgical option that allows for anatomical reduction and stable fixation, facilitating early knee manipulation.

6. Conclusion

Double plating is a useful surgical treatment method for severe distal femur supracondylar fractures in elderly patients due to its relatively easy exposure of the surgical site and the possibility of early knee manipulation through anatomical reduction and stable medial and lateral fixation. Further studies and clinical trials are needed to investigate the importance of this method in more detail.

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