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# Plate Fixation for Atypical Fractures of the Femoral Diaphysis

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**Background:** Plate fixation for atypical femoral fractures has shown high failure rates compared to intramedullary nail fixation. The aim of this study was to evaluate the radiological results of patients treated with a plate and screws for atypical fractures of the femoral diaphysis.

**Methods:** This study was conducted retrospectively on 16 patients who had undergone internal fixation using plates for treatment of atypical femoral complete fractures from 2007 to 2015. Nine patients were treated with lag screws and short plates while 7 patients were treated with position screws and long plates, which covered the whole femur. Radiologic evaluation was performed on all patients. Complications were also evaluated.

**Results:** Bone union was achieved in all patients and the average bone union time was 17.7 weeks (range, 14–28 weeks). There was no correlation between the preoperative use of a bisphosphonate, plate length, postoperative teriparatide use, and the time to bone union. Regarding complications, 2 cases of complete fractures and 1 impending fracture occurred at the end of short plates.

**Conclusions:** Satisfactory results were obtained with use of plates for patients with atypical femoral complete diaphyseal fractures, in whom intramedullary nails could not be applied due to severe bowing. In particular, it seemed advantageous compared with intramedullary nail fixation in that it could maintain the leg length through anatomical reduction and prevent iatrogenic fracture.

**Keywords:** *Atypical femoral fracture, Diaphysis, Plate fixation*

Bisphosphonates (BPs) are the most common drugs used for the treatment of osteoporosis. BPs are effective in improving bone mineral density and decreasing the incidence of fracture.[1-4] However, since the report of Odvina et al.[5] about severe suppression of bone turnover, many clinicians have started to pay attention to the negative aspects of BPs such as atypical femoral fractures (AFF) and osteonecrosis of the jaw.[6] Although BPs have been associated with the occurrence of AFF, Yoo et al.[7] reported there was a relationship between the occurrence of AFF and the curvature of the femur regardless of the use of BPs.

In a scoping review, Toro et al found that intramedullary (IM) nailing was the treatment of choice among most surgeons for both complete and incomplete AFF.[8] The preference towards IM nailing is explained by the fact that endochondral repair is usually not achievable with a plate. Also, several surgical methods have been proposed to overcome excessive femoral bowing.[9,10] Despite these efforts to use IM nails, iatrogenic fracture during the insertion of IM nails and leg length discrepancy due to straightening of the bowed femur are expected complications.

IM nail insertion is extremely hard in the case of severe femoral bowing and narrow medullary canal. The purpose of this study was to evaluate the radiological results of patients treated with a plate and screws for atypical fractures of the femoral diaphysis.

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## METHODS

This study was approved by the Institutional Review Board of Daegu Fatima Hospital (IRB No. DFE21ORIO109-R1), which waived informed consent.

The study was conducted retrospectively on 16 patients who had undergone internal fixation using plates for treatment of atypical femoral complete diaphyseal fractures from 2007 to 2015. During the same period, IM nails were used for 40 patients who had complete diaphyseal AFF. According to the femoral bowing grade of Park et al.,[11] patients with grade II or III were fixed using a plate and screws. Patients who had an anterior bowing angle greater than 15° according to Yau et al.[12] were also fixed with a plate and screws because of the risk of anterior cortical perforation. All cases included in the study showed major features such as minimal or no comminution with a medial spike, transverse or short oblique fracture orientation, and localized thickening of the lateral cortex according to American Society for Bone and Mineral Research definition released in 2014.[13] Patients with atypical femoral incomplete fractures or atypical femoral subtrochanteric fractures, patients who had not been regularly followed up until bone union, patients with typical femoral trochanteric or subtrochanteric fractures, and patients with fractures caused by high-energy injury mechanisms were excluded from the study. All patients were women and injured by a simple fall. Table 1 presents basic demographics and preoperative data of all patients. Nine patients were treated with lag screws and short plates while 7 patients were treated with position screws and long plates, which covered the whole length of the femur.

**Table 1.** Basic Demographic and Preoperative Data

| Variable | Result |
|---|---|
| Sex (female : male) | 16 : 0 |
| Age (yr) | 75.9 ± 6.9 (63–89) |
| BMD (T-score) | –3.2 ± 0.9 |
| BMI (kg/m$^2$) | 21.9 ± 3.9 |
| Follow-up (mo) | 33.9 ± 26.5 (15–118) |
| Prodromal symptom (yes : no) | 9 : 7 |
| Period of prodromal symptom (mo) | 4.1 ± 3.6 |
| Taking bisphosphonate before surgery (yes : no) | 8 : 8 |
| Duration of bisphosphonate (mo) | 47.1 ± 30.1 |
| Plate length (short : long) | 9 : 7 |
| Teriparatide injection after surgery (yes : no) | 6 : 10 |

Values are presented as mean ± standard deviation (range) or mean ± standard deviation.
BMD: bone mineral density, BMI: body mass index.

### Operative Procedure

Two different fixation methods were applied. In the early stages of surgery, interfragmentary lag screws, which could provide absolute stability, were fixed after exposure of the fracture site and then a short locking compression plate (LCP), which did not cover the whole femur, was applied (Fig. 1). The role of the plate was neutralization. While exposing the fracture site, efforts were made to minimize medial and posterior soft-tissue damage. At least 6 cortices were fixed at each part of the fracture site.

The other fixation method was as follow: a small incision was made over the fracture site then the fracture was fixed with a position screw under direct visualization. This screw only maintained the fracture reduction. A long large fragment LCP covering the entire femur was inserted in the submuscular extra-periosteal layer from the proximal trochanteric area to the distal part of the femur, using a small incision, so called the minimally invasive plate osteosynthesis technique (Fig. 2). An 18-hole LCP was applied in 6 patients and 1 patient was fixed with a 16-hole plate. The working length of plate construction was from 4 holes to 6 holes. Plate screw density varied from 0.43 to 0.5. We intended to achieve relative stability with this fixation method. An image intensifier was used to check the proper length and location of plates. Also, 3 or more

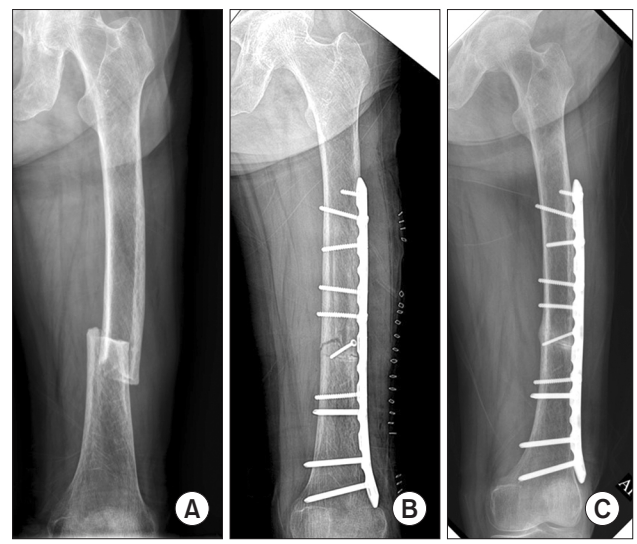


**Fig. 1.** Preoperative (A), immediate postoperative (B), and 4-month follow-up (C) anteroposterior radiographs of an 89-year-old female patient showing an atypical femoral fracture fixed with interfragmentary screws and a short protection plate.

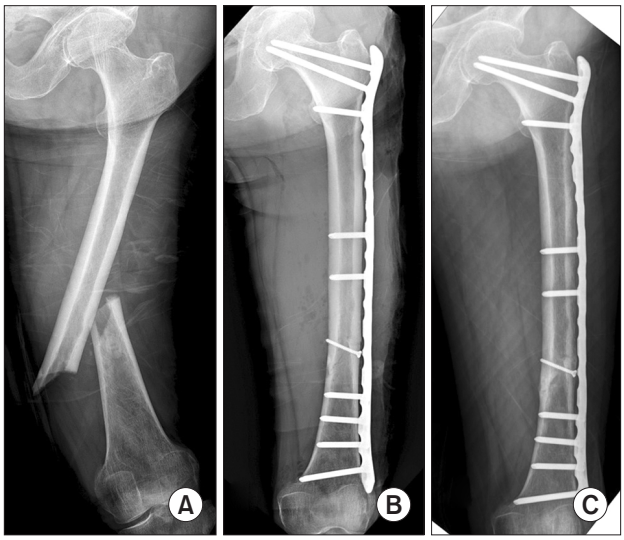


**Fig. 2.** Preoperative (A), immediate postoperative (B), and 6-month follow-up (C) anteroposterior radiographs of a 75-year-old female patient showing an atypical femoral fracture fixed with a position screw and a long plate, which covered the entire femur.

**Table 2.** Bone Union Time According to Plate Length, Use of Bisphosphonate, and Teriparatide Use

| Variable | Bone union time | *p*-value |
|---|---|---|
| Plate length | | 0.606 |
| Short (n = 9) | 17.33 ± 4.47 | |
| Long (n = 7) | 17.71 ± 3.15 | |
| Taking bisphosphonate | | 0.878 |
| Yes (n = 8) | 17.75 ± 4.71 | |
| No (n = 8) | 17.25 ± 3.01 | |
| Teriparatide use | | 0.918 |
| Yes (n = 7) | 18.00 ± 4.90 | |
| No (n = 9) | 17.11 ± 3.02 | |

Values are presented as mean ± standard deviation.

screws were fixed on each fragment of fracture.

**Postoperative Management**

BP administration was stopped in all patients who had taken it preoperatively and a calcium and vitamin D complex was given to the patients. In some patients, teriparatide was injected for 3 months after surgery. Sitting and wheelchair ambulation were encouraged immediately after surgery. Patients were followed up every month after surgery until obtaining bone union. Weight-bearing was not allowed until bone union was confirmed on radiographs.

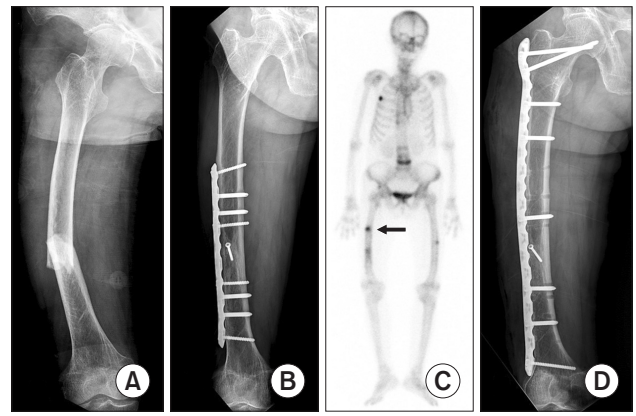


**Fig. 3.** Preoperative (A) and 27-month postoperative (B) anteroposterior radiographs of a 71-year-old female patient. (C) Hot uptake around the proximal end of the plate on the bone scan (black arrow). (D) Anteroposterior radiograph after revision surgery with long plate fixation.

Corrales et al.[14] described bone union as follows: clinical absence of pain at the fracture site on both palpation and weight-bearing and radiological evidence of bridging of 3 or more cortices on 2 different views. We used this definition for our study. Radiologic evaluation was performed on all patients. Complications were also evaluated. Mann-Whitney *U*-test was used for continuous variables. Statistical significance was accepted if the *p*-value was < 0.05. Data analysis was performed using IBM SPSS ver. 21.0 (IBM Corp., Armonk, NY, USA).

## RESULTS

Bone union was achieved in all patients and the average bone union time was 17.7 weeks (range, 14–28 weeks). Of all the patients, only 1 patient had bone union at 28 weeks and was judged as delayed union. There was no statistically significant difference in bone union time according to the plate length, use of BPs, and teriparatide use (Table 2). Two patients who were fixed with short plates experienced complete fractures at the end of plate at 7 months and 42 months after index surgery, respectively. These two patients were treated with position screw and longer plate fixation after removal of all previous implants. Another patient suffered from thigh pain 27 months after the initial surgery. Plain radiographs showed no specific finding but hot uptake at the proximal end of the plate was observed in bone scintigraphy. We thought this was an impending fracture and re-fixed it using a long plate covering the full length of the femur (Fig. 3). There were no other major

complications such as postoperative infection, iatrogenic fracture, malalignment of the lower limb, and leg length increment.

## DISCUSSION

BPs have been the most commonly prescribed medication for osteoporosis in the last two decades. The U.S. Food and Drug Administration first approved alendronate in 1995, and three other BPs (risedronate, ibandronate, and zoledronate) were later approved for osteoporosis treatment. However, in 2005, Odvina et al.[5] reported 9 cases of atraumatic non-spinal fractures (sacrum, rib, ischium, pubic rami, and femoral shaft) during alendronate therapy. Since then, many clinicians have paid attention to the diagnosis and treatment of AFF.

Das De et al.[15] reported that 3 of 14 patients (21.4%) who were fixed with a plate and screws for subtrochanteric AFF experienced fixation failure. Teo et al.[16] stated that 8 of 23 patients (34.7%) needed revision surgery due to fixation failure and nonunion after plate fixation for subtrochanteric AFF. Prasarn et al.[17] reported that plate fixation resulted in higher fixation failure than IM nail fixation after operative treatment for BP-associated femur fractures (30% vs. 0%). As revealed in these papers, IM nailing became the preferred fixation method as plate fixation resulted in more cases of nonunion and metal failure.

Among various treatments for AFF, IM nailing fixation is mostly recommended regardless of the fracture location.[18-20] IM nailing is considered the first-line treatment for complete fractures, although the risk of delayed healing and revision surgery seems to be higher than that in typical femoral fractures. Using cephalomedullary nails rather than standard IM nails in the fixation of AFF might prevent future fragility fractures in the proximal femur.[21] However, IM nail insertion is challenging in severely bowed or narrow femurs due to increased risk of iatrogenic fracture.[17] Several modified operation techniques including far lateral entry point, use of the opposite site nail, overreaming more than 2.5 mm have been introduced to overcome excessive anterolateral bowing of the femur.[9,10,22] Even if an IM nail is inserted after addressing these difficulties, leg-length discrepancy caused by femoral straightening and lengthening is inevitable.

In the current study, the authors used plates and screws on patients with severe anterolateral bowing of the femoral shaft, in whom inserting IM nails was judged difficult because of the risk of iatrogenic fracture or cortical perforation. The rationale for plate fixation on the femur is the tension band principle: applying a plate on the lateral cortex of the femur without comminution to the medial side can promote fracture healing by converting tensile force to compressive force. Plate screws are a load-bearing device, so difficulty in early weight-bearing is considered a disadvantage compared to IM nail fixation.

In the earlier stages of the study, all fractures were fixed with the short protection plate after interfragmentary lag screw fixation. We could obtain bone union in 8 cases within 6 months, but in 1 case, bone union was achieved at 28 weeks. Although the fracture was fixed with a lag screw to obtain absolute stability, slight instability occurred during follow-up after surgery in some cases. However, these cases were healed with small amount of external callus formation. We thought that this instability was caused by using a 3.5-mm screw, which was usually used for small bone fixation. Two patients experienced complete fracture at the end of plate in 7 and 42 months after index surgery, respectively. Another patient experienced thigh pain 27 months after initial surgery, which was determined to be an incomplete fracture at the proximal end of the screw hole. Overall complication rate was 33% (3/9) in the short plate fixation group. After experiencing such peri-plate fractures, short plate fixation was replaced with a long plate, which covered the entire femur. A long plate fixation with position screw fixation was also successful although it was more challenging because it required precise plate contouring. We recommend fixation with a long bridging plate that has shown more favorable results and less complications.

We could achieve bone union in all 16 patients and the average bone union time was 17.7 weeks. A systematic review showed that the mean time to healing postoperatively was 7.3 months (range, 2–31 months) for complete fractures.[20] It is thought that the relatively short healing time of our cases compared to other studies was due to anatomical reduction performed while preserving blood supply as much as possible and minimizing fracture gaps.

BPs used to treat osteoporosis acts on osteoclasts. Therefore, BPs are expected to affect fracture healing by inhibiting osteoclasts that play an important role in the fracture healing process. However, in patients with non-atypical fractures, administration of BPs did not delay callus formation or healing.[23] This is true in indirect bone healing, which promotes external callus formation. Savaridas et al.[24] performed an animal study and reported BP administration before an acute fracture had an inhibitory effect on direct bone healing, which does not make external callus. They proposed that BP therapy not be commenced until after the fracture has united if the fracture has been rigidly fixed and is undergoing direct osteonal healing.

However, our study showed that preoperative use of BP had no negative effect on direct bone healing. We could not explain the reason why our patients obtained bone union uneventfully unlike the animal study. However, it should be taken into account that results from animal studies are not always applicable to humans. We believe that there are two different fracture patterns of AFF: insufficiency fracture around the anterolateral aspect and fresh fracture at the posteromedial cortex of the femur. Accurate reduction with a minimal fracture gap in the anterolateral insufficiency fracture area will give a better chance to unite bone. We tried to preserve fracture biology by minimizing periosteal dissection during surgery. We thought that these two efforts–accurate fracture reduction and minimal fracture gap, and preservation of blood supply around the fracture site–resulted in satisfactory union of all fractures in an acceptable period.

Our study has several limitations. This is a retrospective study, so there is a possibility of selection bias. The number of patients is small, but it should be considered that the absolute incidence of AFF is low. Also, our study was based on one surgeon's experience. It cannot be assumed that plate fixation would provide superior results compared to IM nail fixation because we did not compare with the results of IM nail fixation. This is also an important limitation of our study and it needs to be clarified through further studies in the future. However, to the best of our knowledge, our study is the first report about plate fixation for atypical complete fractures of the femoral diaphysis.

In conclusion, satisfactory results were obtained with use of plates for patients with atypical femoral complete diaphyseal fractures, in whom IM nails could not be applied due to severe bowing. In particular, it can be advantageous over IM nail fixation in maintaining the leg length through anatomical reduction and preventing iatrogenic fracture.

## CONFLICT OF INTEREST

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

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## REFERENCES

1. Black DM, Cummings SR, Karpf DB, et al. Randomised trial of effect of alendronate on risk of fracture in women with existing vertebral fractures. Fracture Intervention Trial Research Group. Lancet. 1996;348(9041):1535-41.
2. McClung MR, Geusens P, Miller PD, et al. Effect of risedronate on the risk of hip fracture in elderly women. N Engl J Med. 2001;344(5):333-40.
3. Black DM, Delmas PD, Eastell R, et al. Once-yearly zoledronic acid for treatment of postmenopausal osteoporosis. N Engl J Med. 2007;356(18):1809-22.
4. Chesnut CH 3rd, Skag A, Christiansen C, et al. Effects of oral ibandronate administered daily or intermittently on fracture risk in postmenopausal osteoporosis. J Bone Miner Res. 2004;19(8):1241-9.
5. Odvina CV, Zerwekh JE, Rao DS, Maalouf N, Gottschalk FA, Pak CY. Severely suppressed bone turnover: a potential complication of alendronate therapy. J Clin Endocrinol Metab. 2005;90(3):1294-301.
6. Borromeo GL, Brand C, Clement JG, et al. A large case-control study reveals a positive association between bisphosphonate use and delayed dental healing and osteonecrosis of the jaw. J Bone Miner Res. 2014;29(6):1363-8.
7. Yoo H, Cho Y, Park Y, Ha S. Lateral femoral bowing and the location of atypical femoral fractures. Hip Pelvis. 2017;29(2):127-32.
8. Toro G, Ojeda-Thies C, Calabro G, et al. Management of atypical femoral fracture: a scoping review and comprehensive algorithm. BMC Musculoskelet Disord. 2016;17:227.
9. Kim JW, Kim H, Oh CW, et al. Surgical outcomes of intramedullary nailing for diaphyseal atypical femur fractures: is it safe to modify a nail entry in bowed femur? Arch Orthop Trauma Surg. 2017;137(11):1515-22.
10. Shon OJ, Yoon JY, Kim JW. Clinical outcomes of using contralateral-side laterally bent intramedullary nails in atypical femur fractures with femoral bowing. Arch Orthop Trauma Surg. 2021;141(8):1291-6.
11. Park YC, Song HK, Zheng XL, Yang KH. Intramedullary nailing for atypical femoral fracture with excessive anterolateral bowing. J Bone Joint Surg Am. 2017;99(9):726-35.
12. Yau WP, Chiu KY, Tang WM, Ng TP. Coronal bowing of the femur and tibia in Chinese: its incidence and effects on total

knee arthroplasty planning. J Orthop Surg (Hong Kong). 2007;15(1):32-6.

13. Shane E, Burr D, Abrahamsen B, et al. Atypical subtrochanteric and diaphyseal femoral fractures: second report of a task force of the American Society for Bone and Mineral Research. J Bone Miner Res. 2014;29(1):1-23.
14. Corrales LA, Morshed S, Bhandari M, Miclau T 3rd. Variability in the assessment of fracture-healing in orthopaedic trauma studies. J Bone Joint Surg Am. 2008;90(9):1862-8.
15. Das De S, Setiobudi T, Shen L, Das De S. A rational approach to management of alendronate-related subtrochanteric fractures. J Bone Joint Surg Br. 2010;92(5):679-86.
16. Teo BJ, Koh JS, Goh SK, Png MA, Chua DT, Howe TS. Postoperative outcomes of atypical femoral subtrochanteric fracture in patients on bisphosphonate therapy. Bone Joint J. 2014;96(5):658-64.
17. Prasarn ML, Ahn J, Helfet DL, Lane JM, Lorich DG. Bisphosphonate-associated femur fractures have high complication rates with operative fixation. Clin Orthop Relat Res. 2012;470(8):2295-301.
18. Egol KA, Park JH, Rosenberg ZS, Peck V, Tejwani NC. Healing delayed but generally reliable after bisphosphonate-associated complete femur fractures treated with IM nails. Clin Orthop Relat Res. 2014;472(9):2728-34.
19. Oh Y, Wakabayashi Y, Kurosa Y, Ishizuki M, Okawa A. Stress fracture of the bowed femoral shaft is another cause of atypical femoral fracture in elderly Japanese: a case series. J Orthop Sci. 2014;19(4):579-86.
20. Koh A, Guerado E, Giannoudis PV. Atypical femoral fractures related to bisphosphonate treatment: issues and controversies related to their surgical management. Bone Joint J. 2017;99(3):295-302.
21. Schilcher J. High revision rate but good healing capacity of atypical femoral fractures: a comparison with common shaft fractures. Injury. 2015;46(12):2468-73.
22. Sahemey R, Nikolaides AP, Bhattacharya S, Simons A, Makrides P. Bisphosphonate-related atypical femoral fractures: a novel strategy to improve patient outcomes. J Orthop Trauma Rehabil. 2020;27(2):192-7.
23. Xue D, Li F, Chen G, Yan S, Pan Z. Do bisphosphonates affect bone healing?: a meta-analysis of randomized controlled trials. J Orthop Surg Res. 2014;9:45.
24. Savaridas T, Wallace RJ, Salter DM, Simpson AH. Do bisphosphonates inhibit direct fracture healing?: a laboratory investigation using an animal model. Bone Joint J. 2013; 95(9):1263-8.