

Case Report

Successful Treatment of Atypical Femoral Fracture with Bowed Femur Using Contralateral Intramedullary Nail Combined with Early Daily Teriparatide

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We report a case of atypical femoral fracture achieving early fracture union with combination therapy comprising contralateral nail and immediate teriparatide injection. Fracture union of atypical fractures is often delayed due to bowing deformity and bone metabolic disorders. Combination treatment that takes both problems into consideration represents a useful treatment option for atypical femoral fracture.

Key words: atypical femoral fracture, bowing deformity, intramedullary nail, teriparatide, cephalomedullary screw

Bisphosphonates are now the mainstay of osteoporosis treatment. However, the correlation between long-term bisphosphonate use and so-called atypical femoral fracture (AFF) has been noted [1]. In recent years, many factors have been thought to be involved in the development of AFF, such as severely suppressed bone turnover, bisphosphonate use, denosumab use [2], steroid use, low serum levels of 25-(OH) D [3, 4], and bowing deformity of the femur [4, 5].

Compared to ordinary or osteoporotic femoral fractures, AFF has been reported to have high rates of complications including implant failure, iatrogenic fracture during operation, and delayed union or non-union [6, 7]. Because of the high percentage of implant failure with plate fixation, intramedullary nails are recommended as the first-line treatment of AFF [8]. However, we sometimes encounter complications with intramedullary nails due to bowing deformities such as

iatrogenic fractures, straightening of the femur, medial gap opening and leg-length discrepancy [9, 10]. Even if an intramedullary nail is inserted successfully, concomitant bone metabolic disorders take longer to achieve fracture union, with intervals reported at 5.2-23.5 months [11-13].

Here, we report a case with successful treatment of AFF using combination therapy with contralateral intramedullary nail and teriparatide (TPTD) injection.

Case Report

Report of the case. A 79-year-old woman was transported to the emergency room for left femoral shaft fracture occurring after a fall from a standing height. The fracture was identified as a complete, non-comminuted transverse fracture with medial spike (Fig. 1), satisfying all the major criteria of the American Society for Bone and Mineral Research task force defi-

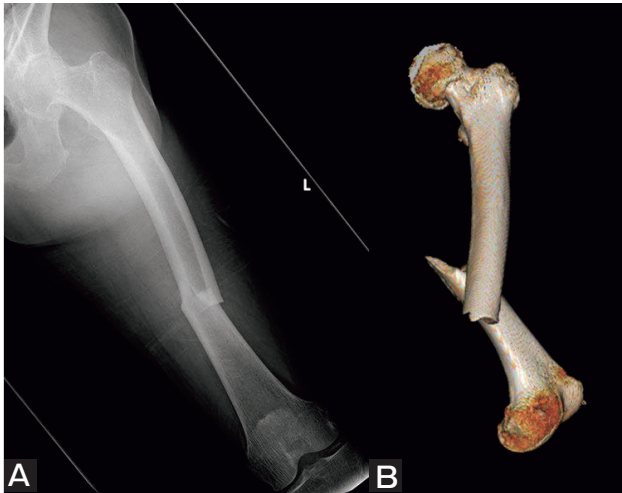


Fig. 1 Anteroposterior radiography (A) and 3D computed tomography (B) of the left femur. The fracture is a complete, non-comminuted transverse fracture with a medial spike, satisfying all major criteria of the ASBMR task force definition of AFF.

nition of AFF [14]. She had taken risedronate for over 8 years to treat osteoporosis identified in another hospital, and treatment was switched to denosumab about 1 year earlier. She had no history of steroid use, or endocrine or bone metabolic disease except for osteoporosis. T-scores for bone mineral density were -1.1 in the femoral neck, and -2.0 in the total lumbar vertebrae. On the day of injury, total type 1 procollagen-N-propeptide (P1NP) was $7.4 \mu\text{g/L}$ and tartrate-resistant acid phosphatase 5b (TRACP5b) was 150 mU/dL , meaning that both bone formation and resorption were severely suppressed. Long-leg X-ray of the lower limbs two years before injury showed incomplete AFF of the left femur. Femoral curvature calculated according to a previous report was 14.5° (Fig. 2) [15], and the degree of anterolateral femoral bowing was considered moderate according to a previously reported grading system [16].

We performed surgery 6 days after injury. A contralateral Zimmer Natural Nail[®] GT femoral (ZNN) (Zimmer Biomet, Warsaw, IN, USA) was used. We inserted the nail in an externally rotated position in order to fit the proximal bend and anterior curvature of the nail to the anterolateral femoral bowing in the patient. The low neck-shaft angle (119.5°) prohibited the standard insertion of two cephalomedullary screws. Instead, we inserted one cephalomedullary screw (reconstruction screw), one descending screw proxi-



Fig. 2 Long-leg X-ray taken 2 years before injury. Femoral curvature calculated according to a previous report was 14.5° on anteroposterior radiography.

mally, and three distal screws (Fig. 3A, B). We allowed immediate weight-bearing as tolerated, together with daily TPTD (Forteo[®]; Eli Lilly Japan, Kobe, Japan) injection. Eight weeks postoperatively, the patient was able to walk unaided without a cane, and by 16 weeks post-surgery, fracture union was obtained with a modified radiographic union scale score of 13, with scores of 13 or over considered to indicate fracture union [17] (Fig. 3C, D). Suppressed markers of bone metabolism were improved (total P1NP, $279.4 \mu\text{g/L}$; TRACP5b, $1,271 \text{ mU/dL}$ with normal ranges of $26.4\text{--}98.2 \mu\text{g/L}$ and $120\text{--}420 \text{ mU/dL}$, respectively), reflecting both TPTD injection and the process of fracture healing. The patient and her family were informed that data from the case would be submitted for publication, and they provided consent. This study was approved by the ethics committee of our institute (permit no. 21-008).

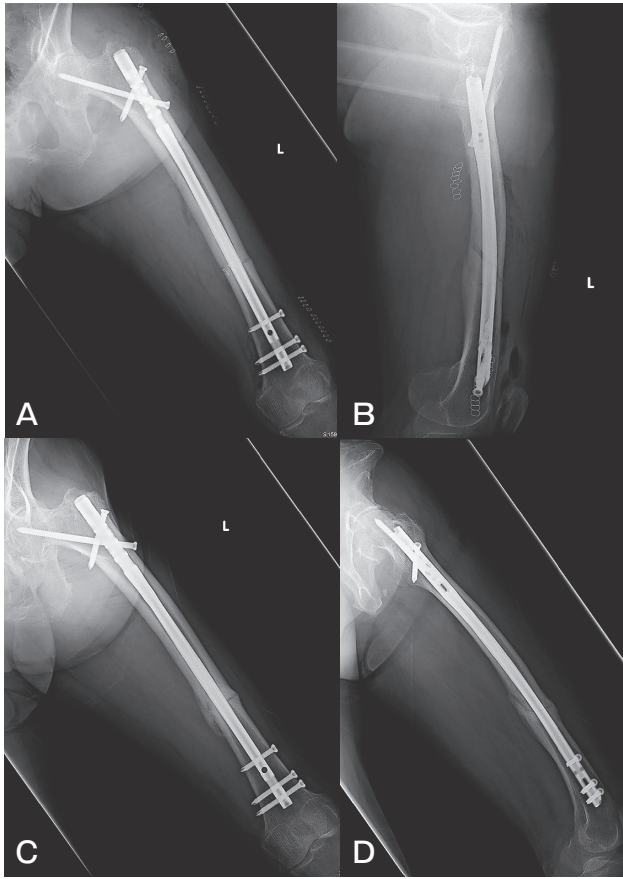


Fig. 3 Anteroposterior and lateral radiography of the left femur immediately (**A,B**) and 16 weeks after surgery (**C,D**). Fracture was fixed by a contralateral nail with a cephalomedullary screw and no medial fracture gap. Fracture union was obtained within 16 weeks.

Discussion

Recent analyses have shown that the biological activity of mid-shaft AFF is not always suppressed, and that femoral bowing is greater than with subtrochanteric AFF, suggesting that tensile stress is highly involved [18,19]. Another histological analysis of AFF patients also revealed that the lateral fracture gap was devoid of living cells, but the adjacent bone contained living cells, including active osteoclasts [20]. This implies that the local strain applied to the lateral cortex due to the bowing deformity inhibits fracture union in mid-shaft AFF [21], but remodeling remains active [20]. Correction of the bowing deformity is thus ideal in mid-shaft AFF. In fact, several reports have described valgus osteotomy to correct bowing deformity in AFF

patients [22,23]. Deformity correction represents a useful treatment option, particularly for incomplete AFF, but in patients with complete, displaced AFF, osteosynthesis and deformity correction are technically difficult to perform at the same time. In addition, osteotomy in the diaphysis is disadvantageous for bone union [24]. We therefore still consider simple intramedullary nailing as the gold standard for AFF surgery. A past report emphasized the importance of avoiding a medial fracture gap to maintaining a healthy biological environment at the medial fracture site [16]. However, another report identified a large mismatch between the curvature of antegrade intramedullary nails and the average normal femoral curvature [9]. This mismatch causes straightening of the bowed femur, resulting in a medial fracture gap. In AFF patients, who often show a severely bowed femur, the mismatch is highly important. To overcome this mismatch, a new technique that rotates the nail externally and matches the anterior curvature of the femoral nail with the anterolateral bowing of the femur has been reported [16]. Although this is an excellent technique, cephalomedullary screws often cannot be inserted because of excessive external rotation of the nail. In addition, ipsilateral femoral neck fractures sometimes occur after treatment of femoral shaft fractures [25,26]. Therefore, in nailing femoral shaft fractures, cephalomedullary screws are recommended as the standard proximal fixtures [27]. A previous study using finite-element methods revealed that AFF patients showed marked concentration of diffuse stress on the anterolateral surface throughout the femur, including the femoral neck [28]. If an intramedullary nail is inserted without cephalomedullary screws in an AFF patient, stress can become concentrated in the femoral neck owing to the stress shielding of the femoral shaft. We therefore think that inserting cephalomedullary screws is mandatory in AFF patients.

In the present case, using contralateral nail, we were able to insert cephalomedullary screw without creating a medial fracture gap. ZNN showed 3 degrees of lateral bending proximally, and an anterior curvature with a 1270-mm radius. Inserting the contralateral nail with slight external rotation, the lateral bend is converted to a medial bend, and, in combination with the anterior curvature, we could match the nail and bowed femur with a smaller angle of external rotation compared to the ipsilateral nail, resulting in cephalomedullary screw insertion (Fig.4). A previous three-dimensional (3D)



Fig. 4 Comparison of ipsilateral (A) and contralateral (B) nail curvatures. Using the contralateral nail, the lateral bend can be converted to a medial bend, which facilitates matching the nail and bowed femur with a smaller external rotation angle compared to the ipsilateral nail.

printed model simulation study of AFF patients with severely bowed femur also revealed that, of nine commercially available intramedullary nail systems, contralateral ZNN provided the smallest gap and translation of the fracture fragment in both the coronal and sagittal planes, and a case with bilateral AFF treated with contralateral ZNN surgery was introduced. However, the importance of cephalomedullary screws was not discussed, and one leg was treated without a cephalomedullary screw [10]. We therefore reviewed the utility of this surgical technique from the perspective of cephalomedullary screw insertion. This technique enabled restoration of the bowing deformity and preserved the biological environment of the medial side of the fracture, while allowing insertion of cephalomedullary screws. A recent report also suggested that using a contralateral nail enabled the insertion of a cephalomedullary screw [29]. However, because the neck-shaft angle in AFF patients is often low [30], and the degree of bowing deformity varies among patients, it may some-

times be difficult to avoid creating a medial gap or insertion of cephalomedullary screws even when using contralateral nails. Although this technique is one option to obtain fracture union, a detailed explanation to the patient during provision of informed consent is important because data about the mechanical strength and longevity of implants with the use of a contralateral nail remain insufficient.

Another difficulty in this case was the location of the fracture in the infra-isthmal area. Infra-isthmal fracture is a risk factor for nonunion [31], and stability of the distal fracture fragment is important. When using intramedullary nails with an interlock mechanism, factors that contribute to the improvement of fixation are longer nail-cortical contact, increased distance between the fracture and distal screws, and a combination of distal screws [32,33]. Insertion of the distal screws in a different plane (*e.g.*, antero-posterior and lateral-medial) is considered effective to improve stability, but surprisingly and counterintuitively, a past report showed that stability in this situation remained unimproved [33]. Although the necessity of an antero-posterior screw is still controversial, we typically insert 3 distal medial-lateral screws with an interlock mechanism when the distance between the fracture line and distal screws are sufficient, considering the risk of vascular injury, longer operation time and radiation exposure with the insertion of antero-posterior screw.

In the present case, the surgery was combined with TPTD injection. Although past systematic reviews have not reached definitive conclusions regarding the efficacy of TPTD treatment for AFF patients due to the absence of randomized, placebo-controlled trials [34,35], many clinical studies have demonstrated the positive effects of TPTD on fracture healing in patients with AFF [36-38]. As a physiological rationale for these results, a recent study revealed that TPTD treatment causes "rejuvenation" of bone marrow mononuclear cells, increasing the number of osteoblast precursors in AFF patients [39]. Another study showed that using TPTD immediately postoperatively was more beneficial than delayed use [40]. In the present case, we used TPTD immediately after surgery for accelerated fracture healing and indeed achieved early fracture union. Although further evidence is awaited, use of TPTD to accelerate fracture union in AFF appears clinically reasonable.

In conclusion, using a contralateral nail enabled insertion of cephalomedullary screws without opening

a medial fracture gap, and the combination of immediate TPTD use was beneficial for early fracture union. This may offer a very useful treatment option for AFF patients, who are likely to encounter many difficulties in treatment due to bowing deformity and problems with bone metabolism.

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