Effectiveness of plate augmentation for femoral shaft nonunion after nailing

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Abstract

**Background:** Treatment options for nonunion of the femoral shaft fracture after intramedullary nail fixation are controversial. The methods of exchanging an existing nail with a larger-sized nail, dynamization, removal of the nail followed by plating, and bone grafting have all been reported. From those options, exchange nailing seems to be the most popular choice. In our study, we used plate augmentation and bone grafting with retention of the nail. The purpose of our study was to evaluate the effectiveness of this method in treating femoral shaft nonunion after open reduction and internal fixation with intramedullary nail fixation.

**Methods:** Between January 2003 and December 2009, 22 patients who had nonunion after open reduction and internal fixation with intramedullary nail for femoral shaft fracture were included in our study. There were 13 men and nine women participants, with a mean age of 34.3 years (range, 17–77 years). The mean period of nonunion after surgery was 20.0 months (range, 7–63 months). The patients were classified into three groups, atrophic, oligotrophic, and hypertrophic. We retained the nail and performed plate augmentation for all patients, with simultaneous autologous bone grafting as indicated. We followed up on all patients with plain film examination, and to assess functional recovery status to determine osseous union condition.

**Results:** All 22 of the patients achieved postoperative bony union uneventfully at a mean time of 22.1 weeks (range, 12–40 weeks). The mean operative time was 105 minutes (range, 60–150 minutes), and the mean blood loss was 340 ml (range, 150–700 ml). All of the patients could walk bearing full weight without pain within 3 months. There were no significant complications such as broken hardware, implant back-out, axial or rotational malalignment, or deep infections.

**Conclusion:** Plate augmentation with retention of the nail with autologous bone grafting may be an effective and reliable alternative in treating nonunion of the femoral shaft fracture after open reduction and internal fixation with intramedullary nail.

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**Keywords:** autologous bone grafting; intramedullary nail; nonunion of femoral shaft fracture; plate augmentation; rotational malalignment

1. Introduction

Femoral shaft fractures occur most frequently in young men after high-impact trauma, and in elderly women after a low energy fall. The standard treatment is closed reduction with intramedullary nailing, which can achieve a high union rate of almost 99%. Another method, open reduction with plate fixation has also led to high union rates. However, there was a high complication rate of 24%, including failure of plates and screws, refracture after plate removal, fracture near the end of the plates, nonunion, and infection.

Femoral shaft nonunion after intramedullary nailing is not common. There are several strategies used to treat such a condition, depending on the nature of the nonunion. Exchange nailing with a larger-sized intramedullary nail,
dynamization, removal of nail followed by plating, bone grafting, and plate augmentation have all been reported.\textsuperscript{1–10} For patients who had open reduction and nailing treatment, or those who had prior multiple surgeries, femoral shaft nonunion may be more difficult to manage. Herein, we report our surgical technique used to remediate nonunion that resulted in high union rates through a combination of plate augmentation and autogenous bone grafting while the nail was left in situ.

2. Methods

There were 22 patients included in our study, which extended from January 2003 to December 2009. We obtained informed consent from each patient, and our institutional ethics committee approved the study. All patients had sustained unilateral femoral shaft fracture, and they presented with a nonunion fracture site after initial stabilization surgery. Thereafter, all patients had received open reduction for the fracture site and internal fixation with intramedullary nail before visiting our facility. There were 13 men and nine women in our study, with a mean age of 34.3 years (range, 17–77 years). Femoral shaft fractures in 21 of the patients resulted from traffic accidents, and all of the fractures were closed fractures. The different types of comminution were graded using the Winquist-Hansen classification, which revealed eight cases of type 1, four of type 2, five of type 3, and four of type 4. The other case involved periprosthetic fracture of the femoral shaft after long Gamma nailing treatment. Fracture site locations included five patients with fracture in the upper one-third of the shaft, 12 patients with a middle-third fracture, and five patients with fracture in the lower one-third of the femoral shaft. Of those 22 fractures, nine were hypertrophic nonunion, seven were oligotrophic, and six had atrophic fracture nonunion. Sixteen patients had undergone intramedullary nailing with proximal and distal screws locked (Fig. 1). Six patients had unlocked intramedullary-nailing fixation; of those six patients, three had undergone distal or proximal dynamized intramedullary nailing, and the other three had Kuntscher nailing. Four patients had undergone a second operation for nonunion of the femoral shaft fracture. The mean period of nonunion was 20.0 months (range, 7–63 months), extending from the time the initial injury was treated with intramedullary nailing until the time of presentation. The patient profiles are shown in Table 1.

The femoral shaft was defined as the portion of the femoral diaphysis between 5 cm distal to the lesser trochanter and 5 cm proximal to the adductor tubercle. Nonunion was defined as failure of the fracture site to unite at least 6 months after the last surgery.\textsuperscript{10} The intramedullary nail was retained for all patients. We used a direct lateral approach to explore the nonunion site of the femoral shaft. The incision wound follows the previous surgical scar should the patient have had open reduction in the initial surgery. One 4.5-mm, AO broad dynamic compression plate was applied to augment the fracture site, followed by routine decortication procedure. We inserted at least four cortical screws on each side of the fracture, in an eccentric way to avoid the retained intramedullary nail. They were inserted bicortically if possible. Furthermore, dynamic compression is not required in plate application, since we planned to fill the fracture gap by autogenous bone graft. In patients with hypertrophic nonunions, the hyperplastic callus was shaved to flatten the cortical surface, and we recycled them to fill the nonunion defect site. For patients with atrophic or oligotrophic nonunion, we harvested autologous bone graft from the anterior superior iliac crest to fill in the fracture site. All patients were allowed to partially bear weight on the operated leg immediately after surgery. We followed all patients on an outpatient basis, at an interval of 6 weeks. We evaluated the bony union status according to the femur bone roentgenogram. Bony union was defined as the callus bridging of the fracture site of more than three-fourths on both views of the plain radiograph (anteroposterior and lateral views).\textsuperscript{10} Full weight bearing was permitted after bony union was evident.

3. Results

These patients achieved bony union in a mean time of 22.1 weeks (range, 12–40 weeks), and evident callus formation was seen roentgenographically at a mean time of 10.5 weeks (range, 6–24 weeks). The mean operative time was 105 minutes (range, 60–150 minutes), and the mean blood loss was 340 ml (range, 150–700 ml).

Significant callus formation was noticed at a mean time of 8.2 ± 0.8 weeks (range, 6–12 weeks) in patients with hypertrophic nonunions compared with 10.0 ± 0.7 weeks (range, 8–12 weeks) in those with atrophic nonunions and 13.7 ± 3.0 weeks (range, 6–24 weeks) in those with oligotrophic nonunions (\(p = 0.0013\)). Solid union was achieved at a mean time of 20.2 ± 1.9 weeks (range, 16–32 weeks) in those with hypertrophic nonunions compared with 21.7 ± 3.9 weeks (range, 12–40 weeks) in those with atrophic nonunions and 24.9 ± 3.8 weeks (range, 12–40 weeks) in those with oligotrophic nonunions. Time to union was not statistically different among the three groups, while time to callus formation was statistically different (Table 2).

The AO broad dynamic compression plate (at least an 8-hole) was used for fixation to the fractures, and the mean number of fixed cortical screws was 9.0 (range, 8–11). Bone graft material harvested from the anterior superior iliac crest was required, to fill the nonunion sites in 13 patients with atrophic or oligotrophic nonunion types, but was not required in the other nine patients with hypertrophic nonunion, instead the nonunion sites were filled with the scraped hyperplastic callus.

There were no significant postoperative complications such as infection, broken hardware, implant back-out, or axial or rotational malalignment more than 5°. The range of knee and hip motion was not limited in any of the patients postoperatively. All patients were able to walk bearing full weight without pain within 3 months postoperatively.
Fig. 1. (A) A 77-year-old man with atrophic nonunion and broken distal screws at 36 months after treatment with an intramedullary locking nail; (B) significant callus formation was noted at 10 weeks after plate augmentation and bone grafting; (C) bony union was achieved at 40 weeks after the surgery.
Solid union (wk) 20.2 ± 1.9 21.7 ± 3.9 24.9 ± 3.8 0.3146

4. Discussion

Smith and Morgan\textsuperscript{11} reported that aseptic nonunions are categorized as hypertrophic, normotrophic (oligotrophic), and atrophic nonunions. Hypertrophic nonunion is a form that is characterized by abundant callus and a persistent radiolucent line at the fracture site, which results from a lack of mechanical stability (such as a small-sized nail) but sufficient blood supply and new bone formation. Atrophic or oligotrophic nonunion is characterized by the absence of callus and resorption of the bone ends because of impaired vascularity (such as poor blood supply and loss of stem cells due to damage of periosteum and endosseum). Currently, there are various strategies used to manage the nonunion of the femoral shaft.

To enhance fixation stability, exchange nailing with a larger-sized nail to achieve adequate stability is the treatment of choice for hypertrophic nonunion of femoral shaft fracture. This method can result in high union rates of 78\% to 96\%, as reported by Forlong and colleagues and Hak and coauthors.\textsuperscript{4,5} Pihlajamaki and others\textsuperscript{12} claimed that exchange nailing without extracortical bone grafting seems to be the most effective method of treating nonunion of femoral shaft fractures after intramedullary nailing. However, Weresh and colleagues\textsuperscript{6} reported only a 53\% union rate in patients who underwent reamed exchange nailing, and a significant number of their patients required additional procedures to achieve fracture healing. Niedzwiedzki and coauthors\textsuperscript{13} concluded that despite the fact that exchanging nailing is an acknowledged treatment method for delayed union of long-bone shafts, intramedullary nailing after reaming of the medullary cavity does not result in bone healing in all patients, and additional procedures are often required. Therefore, although exchange nailing is an effective treatment, variable healing rates occur and additional procedures may be needed, especially in patients with failure of union after other procedures. In addition, exchange nailing seems to be an ill-advised choice of treatment in patients with atrophic nonunion, because the bone graft cannot be effectively placed at the fracture site.

Dynamization is a simple treatment method and can be performed under local anaesthesia. However, Wu and colleagues\textsuperscript{7} treated nonunion of femoral shaft fractures with dynamization and found a union rate of only 58\%, and 21\% of...
patients had greater than 2 cm of femoral shortening. Therefore, the authors suggested that this method is indicated only for patients without segmental bony defects, and regular follow-up is necessary. Therefore, dynamization is not well adapted for complicated fractures and treatment with smaller nailing, but is the most efficient and effective method for those patients with simple femoral shaft fracture treated with stable fixation but overtraction.

Bellabarba and colleagues\(^8\) adopted the method of removing the nail followed by plating, (AO 95-degree condylar blade plate for the nonunion of distal and proximal one-third and a broad large-fragment dynamic compression plate for the middle one-third of femoral shaft), with selective autologous cancellous bone grafting. Although the union rate reached 91\%, the complication of early hardware breakage needing repeated surgery had occurred. In addition, this method involved more surgical procedures resulting in more operative time, more blood loss and more wounds.

Choi and Kim\(^{10}\) and Ueng and others\(^{9,14}\) reported that plate augmentation, while retaining the nail in situ, resulted in a high union rate. The nail was left in situ to maintain the alignment of the fracture, which could help to maintain stability as a loading-sharing device. Thus, it provides extremely rigid fixation, and provides reason to believe that we can confidently allow patients to bear weight early in the postoperative period. The rehabilitation protocol we suggested is immediate partial weight bearing using one or two crutches after the surgery, with tapered-off use of the crutches thereafter. The patient could bear full weight again when significant callus formation was noticed in plain film. Additionally, bone graft could be precisely placed in the fracture site if necessary. Therefore, this method offers extremely rigid fixation, early mechanical force, and autograft implantation, which promotes bone healing and increases union rate.\(^{15-20}\)

Such a procedure would still be feasible even if the nail was difficult to remove. Especially in those patients with a broken nail or screws, plate augmentation with retaining the nail in situ is an easier, faster, and more effective treatment modality. Ueng and colleagues\(^{14}\) treated five patients with femoral nonunion and broken interlocking nail with the augmentative plating procedure, and bony union was achieved in an average time of 5.4 months after treatment. In our study, there were four patients with broken screws and one patient with a broken nail; all of them successfully were treated with augmentative plating while leaving the broken nail and screws in situ.

The mean nonunion time of our patients was 20.0 months (range, 7–63 months). Every patient experiences a long, uncomfortable postsurgical hearing period, and desires to return to normal daily function sequentially after this surgery. Our study findings indicate that plate augmentation can be a reasonable treatment option for all types of nonunion, and it is more likely to have superior results that can even attain a 100\% rate of union. This enables us to have greater confidence that a successful result from the operation will be obtained. There are two possible explanations that can explain the excellent results that we achieved; first, plate augmentation increased the stability of the fracture site, helping us to avoid endosteum redestruction. Second, bone grafting could be done in the fracture site precisely and effectively through the same earlier surgical wound. Third, we could perform the operation in one wound (nonunion site), but using another wound as necessary for the autograft of the anterior superior iliac crest in atrophic or oligotrophic nonunions.

In addition, the nail was left in situ, so no further reduction was necessary. Also the nail maintained the alignment and stability of the femoral shaft, and served as a useful load-sharing device. As a result, it would be easier to apply the plate to the fracture site. One requirement of screw fixation involved inserting the screws obliquely to side step the nail. Therefore, plate augmentation leaving the nail in situ proved to be a simple procedure, with a short operation time and minimal blood loss. In our series, no patient experienced early hardware breakage or required repeated surgery.

Our study limitations included the fact that it was retrospective in nature with a small cohort of patients and lacked a control group. However, based on our experience from these 22 patients, the combination of plate augmentation and bone grafting while leaving the nail in situ offers the benefits of extremely rigid fixation, the possibility of early-applied load-bearing force, and precise autograft implantation. These elements promote bone healing and can lead to excellent surgical outcomes. All patients achieved solid union without any additional surgeries. Whether the nonunion was atrophic or hypertrophic, this method can be an effective, reliable alternative in treating nonunion of femoral shaft fracture after open reduction and internal fixation with intramedullary nail.

References