Clinical outcomes of dual fixation of femoral shaft fracture nonunion: synchronous nailing and plate augmentation

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Background
The key to success in femoral shaft nonunion cases is the achievement of mechanical stability. We aimed to provide the clinical outcome of dual-fixation femoral shaft fracture nonunion using intramedullary nailing and plate augmentation in the same setting.
Patients and methods
This was a retrospective study of 12 patients with femoral shaft fracture aseptic nonunion operated at our university hospital between January 2017 and June 2021. All patients underwent revision surgery with synchronous nailing and plate augmentation. Demographics, comorbidities, history of previous trauma, fracture healing, and complications were recorded. We also reviewed radiological images.
Results
Twelve patients (nine males and three females) with a mean age of 31.1±9.8 years were included. Six patients had a previous fixation with an intramedullary nail, five with a plate, and one with an external fixator. Ten patients had atrophic nonunion, and two patients had hypertrophic nonunion. Patients achieved fracture healing after the surgical intervention, except two patients required another surgical intervention for delayed union as bone grafting (at 6 and 8 months, respectively). At the end of the study, they achieved fracture healing in all patients. The mean healing time was 6.1±2.4 months.
Conclusion
Good mechanical stability and hence union can be achieved with synchronous nailing and plate augmentation as a treatment option for femoral shaft fracture aseptic nonunion.

Keywords:
clinical outcome, femoral shaft fracture nonunion, nailing, plate augmentation

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Introduction

Femoral shaft fractures are commonly seen in young adults and occur after high-energy injuries, such as vehicle accidents and falling from a height. The intramedullary nail is considered the standard option for femoral shaft fractures, which provides stability and a high union rate (up to 99.1%) even with complex femoral shaft fractures (e.g. AO/OTA 32-B) [1–3]. With the extension of its use, the number of technical problems and complications increased, one of which is nonunion. The incidence of femoral shaft nonunion varied from 0.9 to 7.5% after primary nail treatment [4,5]. A secondary nail exchange is advocated because a high success rate is usually [1,2,6] femoral shaft nonunion that is the key to success in the treatment of such fractures and is the restoration of potential for healing, both mechanical stability and restart of biological process [4,7–11]. Nail dynamization, conversion of the nail to plate with/without bone grafting, and reamed-exchange nailing has been applied, but with a failure rate as high as 20–50% because of mechanical instability, leading to additional surgical procedures [1,2,6,7,9,10,12–15]. A more stable construct to consider is dual plating and/or exchange nailing with plate augmentation with or without cancellous bone graft, depending on the type of nonunion. Evidence shows that most patients achieved fracture healing when received either surgical procedure [7,9,11,15,16].

This study aims to evaluate patients with femoral shaft fractures presented with aseptic nonunion who had been treated with intramedullary nailing and plate augmentation at the same setting regarding fracture characteristics, complications, and fracture healing.

Patients and methods

This retrospective study was approved by the ethics committee of our university. An informed consent was obtained from all patients. Twelve patients with

femoral shaft fracture aseptic nonunion who underwent surgery between January 2017 and June 2021 were analyzed. All patients underwent revision surgery with synchronous nailing and plate augmentation.

Demographic data, comorbidities, history of previous trauma, fracture geometry, fracture healing, and complications were recorded. Nonunion was diagnosed as failure to observe fracture healing within 6 months after surgery and no radiological change as regards the healing progression for three consecutive months or patients was presented by metal failure. According to the AO/OTA Classification of Fractures, the femoral shaft is the segment from the proximal end at the lower level of the lesser trochanter to the distal end exact location that is determined by the norm of a square. The maximum width of the distal condyle determines the proximal extent of the metaphysis. Patients with femoral shaft nonunion defects less than 4 cm, treated with intramedullary nail (either de novo or exchange) and plate augmentation at the same setting, were included in the study. Those with infected nonunion, pathological fractures, diaphyseal fracture extending to the proximal or distal metaphysis, patients received another method of revision, and patients who received similar reconstruction but in two separate surgical settings were excluded from the study.

Under regional anesthesia (combined spinal–epidural) with sedation to avoid the emotional stress of the surgery, all patients were positioned in lateral decubitus, and one-stage revision surgery was performed. The antibiotic coverage was postponed after exposure of the fracture and specimens were obtained for microbiological and sensitivity study. The femoral fracture nonunion site was fully exposed with removal of all previously implanted metal plates, or intramedullary nail (except for the patient who underwent external fixator that was removed in a separate session), debridement, and refreshment of the fracture site to remove the fibrous tissue and unhealthy callous, and evaluation of the defect after thorough debridement. In patients with previous intramedullary nailing, the correct entry point of the greater trochanter was determined or adjusted, and the canal was overreamed to allow bigger-size nails. A new nail was inserted to maintain correct angular and rotational alignment. The distal-locking screw was fixed. Then, the proximal locking screws were fixed to maintain the alignment. Then, the plate was applied to the lateral side of the femur, screws passed obliquely to reach the opposite cortex to provide bicortical purchase. In the case of previous plate fixation, a plate was applied on the anterolateral aspect of the femur to achieve the better purchase of the screws. The position and deformity correction were confirmed throughout the procedure using intraoperative fluoroscopy. All patients received autologous iliac-crest bone grafting, except two patients with a hypertrophic nonunion.

Patients were allowed to perform nonweight-bearing exercises immediately to avoid knee stiffness. No weight-bearing on the affected limb was allowed for the first 3 months after surgery. Partial weight-bearing with a crutch was allowed 3 months after surgery, until full fracture healing. The patients were allowed to initiate full weight-bearing activities without a crutch after fracture healing was confirmed. The follow-up period was every 4 weeks to confirm clinical and radiological criteria of bone healing (full weight-bearing on the affected limb without pain, radiograph show a fuzzy fracture line, and callus continuity can be observed on three sides of the bone cortex). Perioperative data, including [operative time (min), incision length (cm)], fracture healing, healing time, and postoperative complications, were recorded and analyzed.

IBM SPSS version 25.0 (SPSS Inc., Armonk, New York, USA) was used for the statistical analysis of data. Categorical variables were compared using the χ^2 or Fisher's exact tests, when appropriate. Continuous variables were compared using the Student's t test or one-way analysis of variance, when appropriate. Statistical significance was set at a P value of less than 0.05.

Results

The study included 12 patients (nine males and three females) with a mean age of 31.1±9.8 years (range, 16–45), all patients were older than 16 years at the time of the secondary intervention (nailing and plating), four patients were smokers, and two patients had controlled diabetes. Ten patients presented atrophic nonunion, while two patients presented with a hypertrophic type of nonunion.

Six patients had a previous fixation with an intramedullary nail, five with a plate, and one with an external fixator. In total, five patients showed previous implant failure (three was fixed by intramedullary nails with distal-locking screw/s breakage and two with plate breakage), six patients had preoperative angular deformities (range, 10°–30°),

six patients had leg-length discrepancy (range, 2–3 cm), and two patients had bone defects [one with a medial bone defect and one with a segmental defect (10 mm)].

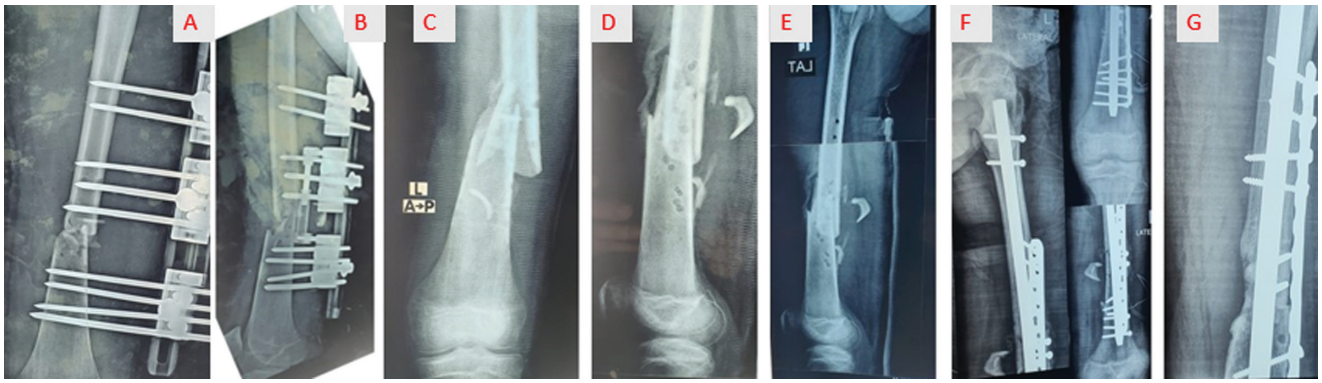
The time elapsed from the primary surgery ranged from 4 to 9 months. The time of hospital stay was 6.4±5.7 days (3–24 days). Except for one patient, all stitches were removed by the third week, and no wound infection was observed upon discharge. Till the last follow-up, no major limb deformity or malunions were noted (deformity was defined as angulation ≥10°, rotation ≥10°, or shortening ≥2 cm).

The mean follow-up period of the patients was 22±7.5 months (range, 12–36 months). By the last follow-up, all patients achieved fracture union, with the mean healing time of 6.1±2.4 months (range, 4–12 months). No patients had nonunion at the last follow-up (Figs 1 and 2) As regards the complications, there were no severe complications encountered. One patient had a superficial wound infection that responded to intravenous antibiotics for 3 weeks, this patient had the longest hospital stay (24 days). Two patients required another surgical intervention for delayed union in the form of bone grafting (at 6 and 8 months, respectively), both achieved full union at 4 months after the intervention. Two patients received hardware removal, one at 26 months postoperatively removed all the hardware, while the other removed one of the distal-locking screws due to iliotibial band friction.

Discussion

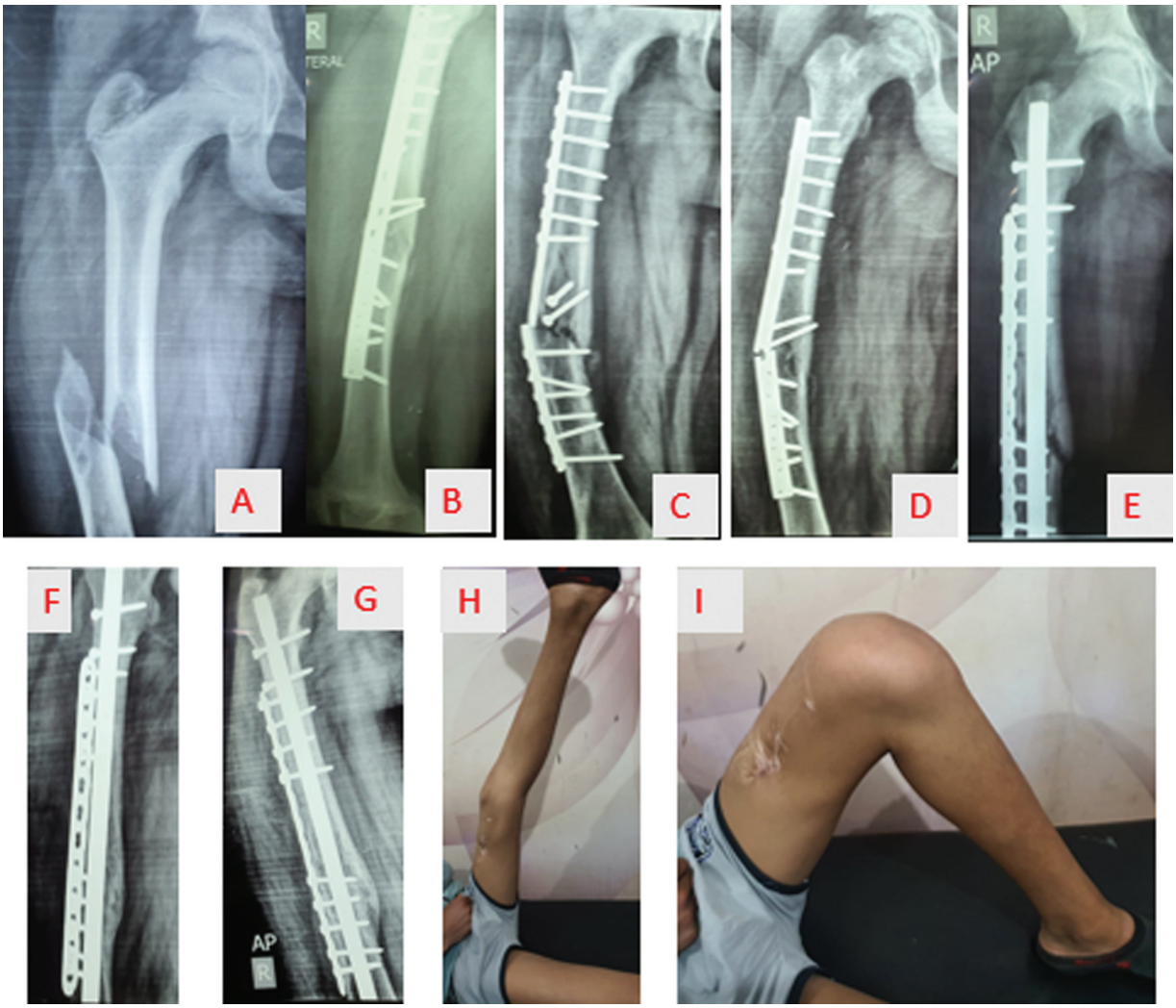
Mechanical stability achievement in femoral shaft nonunion treatment is essential. Nail dynamization may lead to rotational instability and hence failure and nonunion in up to 40–60% [17,18]. The intractability of rotational and bending instability remains unresolved, even with exchange nailing, with a larger nail, higher rotational and bending forces are there, which may lead to 20–50% failure to achieve the [13,19] nailing and plate osteosynthesis can solve the problem of axial and rotational stability with a more stable construct that helps to maintain the bone graft at the nonunion site [20]. The stability of this construct is multiplanar stability, with the healing rate up to 90% in femoral shaft fracture nonunion [1,9,11]. In this study, 12 (100%) patients achieved fracture union, which is comparable to previous reports. In previous reports, they have reported the fracture-healing time with this construct to be 6–13 [1,9]. This may be different in this study, with a shorter mean healing time than reported (5.9±1.9 months), which supports that synchronous nailing and plating achieves better stability and earlier union. This may be attributed to the autologous bone grafting resulting from reaming that settled at the nonunion [9,21]. Also, reaming can increase the periosteal blood supply together with less periosteal striping during plating and [9,21,22] as deformity correction is the main surgical technical difficulty in femoral nonunion [9,16], nail with improper nail entry must be corrected and adequate exposure of nonunion site throughout the procedure and maintaining of the fracture alignment during the nailing and plating, that is why deformity correction must be achieved during nailing and maintained during plate application. Adequate exposure of the nonunion site, debridement, good fracture contact, deformity correction, and stable fixation can be achieved with the nail-plate construct simultaneously [16]. Intramedullary nailing should have the key role in

Figure 1



Male patient 18 years old presented with femoral shaft fracture with grade-2 open fracture, the patient underwent external fixator (a, b), after complete healing of soft tissue, removal of external fixator nonunion was achieved by the fourth month (c, d, e). Intramedullary nail augmented by plate was applied, follow-up at 1 month (f), and complete consolidation of the fracture site at 1-year follow-up (g).

Figure 2



Male patient 17 years old presented with femoral shaft fracture (a), was fixed by plate (b), which failed and broke 4 months postoperatively (c, d). Intramedullary nail augmented by plate was applied, early postoperative follow-up (e). Follow-up at 18 months with full consolidation (f, g). Range of motion at the final follow-up.

the correction of the rotational and angular deformity, which is maintained by an augmentation plate [9,23]. Some surgeons have proposed this construct to treat femoral shaft nonunion with severe deformities.

In this study, plate augmentation eliminates torsional forces, which is the main reason for mechanical failure. Also, it increases strength and stiffness when combined with an intramedullary nail. Then, the cancellous bone graft improves the biological environment for healing. All patients regained painless, unsupported walk and bone healing.

Both lateral and anterior LCP provide continual fracture compression and reduction during cancellous graft application, ensuring excellent bone contact and preventing graft displacement. If the strut graft gives instant structural continuity at the fracture location, that is a plus [1]. Third, the reaming enhances the osteogenesis, while the debridement excises the fibrous scar prohibiting direct bone contact. This procedure provides stability and a suitable environment. Exchange nailing after reaming is one benefit gained rather than keeping it while revision. It is also the standard procedure for resolving femoral nonunion [24]. Its efficacy and safety have been well documented in many [2,25–27] results that were achieved with union rates ranging from 72% [2,6,25,26,28].

The nonunion remains a serious complication of bone fracture and its treatment is challenging [2]. Because of its minimally invasive nature and superior biologic and mechanical environment for fracture healing, intramedullary nail exchange has become the treatment of choice for the great majority of femoral shaft fracture nonunions [21,29]. Success rates have been reported in many reports [2,6,30], most of which

require additional treatment procedures [14,31]. According to the literature, higher nonunion rates occur in more complex femoral shaft fracture patterns due to displaced bone grafts and a lack of compression at the fracture site [11]. Plate osteosynthesis is also listed as a valid procedure for nonunion treatment. The plate, as opposed to an intramedullary nail, provides constant fracture compression and the possibility of sufficient debridement to eliminate the fibrous scar. Because the majority of nonunion belongs to the AO/OTA 32-B/C [26], a single locking plate positioned laterally is subjected to a localized concentration of bending forces, failing to provide cortical support medially. As a result, the double LCP is gaining traction as a promising advanced approach for treating femoral shaft fracture nonunion. In some cases, a union rate of up to 100% has been observed [11,32]. Plates, on the other hand, have the disadvantage of causing more surgical stress and providing poorer mechanical support than medullary fixation, which needs bone union before weight-bearing. Thus, they achieve the best results. A few studies applied a plate augmentation over a retained intramedullary nail [24]. Plate augmentation [24] has been shown to have a high rate of fracture union because it provides solid fixation, consistent compression, and good bone contact at the nonunion site, all of which are important factors in fracture healing [25,33]. In this report, the bony union was achieved in all cases after an average of 9±1.6 months, which is relatively longer than patients receiving only one or two revision surgeries [30]. The healing is attributed to the combined benefits of the nail, plate, and bone graft offers rigid and stable stability in multiple planes, which creates an excellent mechanical environment with limited micromotion for nonunion repair.The refractory femoral shaft nonunion is extremely difficult to treat [2]. Jiang *et al.* [1] reported a novel alternative surgical procedure (fibular strut graft combined with plate osteosynthesis) that provided excellent results. Lengkong *et al.* [34] evaluated the bone healing after nonunion reconstruction using intramedullary nailing with or without autogenous iliac bone graft for at least 6 months, with a union rate of 95%. Among 22 patients, one patient persisted in nonunion, and two patients experienced delayed union.

Wang *et al.* [35] described 12 patients with femoral shaft nonunion who underwent the same procedure and achieved effective correction of the encountered deformity. In this study, 12 patients had achieved good deformity correction after adequate exposure to the nonunion site.

The main indication for this technique was the aseptic nonunion of femoral shaft fractures that were associated mainly with nonrigid fixation, metal failure, or failed fixation, but this was associated with a longer time of surgery, which needs adequate patient optimization, also was associated with multiple and sometimes longer incision that is required for previous hardware removal, fracture-site debridement, nail and plate application, and bone-graft harvesting.

The limitations of this study were a retrospective study with a relatively small number of cases and the lack of a control group. Further investigation with a larger sample is required. The presentation of patients was heterogeneous, and the surgical technique depends mainly on the patient's presentation and surgeons' preference. In the future study, the number of cases will be extended and a control group for a similar group of cases and treated with another option will be added.

Conclusions

Good mechanical stability and hence union can be achieved with synchronous nailing and plate augmentation as a treatment option of femoral shaft fracture aseptic nonunion.

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Conflicts of interest

There are no conflicts of interest.

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