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Evaluation of Treatment Outcomes for Femoral Shaft Nonunion Fixed with Intramedullary Nail, with Addition of Plate and Bone Graft

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ABSTRACT

Introduction:
Femoral shaft nonunion is a serious and challenging complication following intramedullary nailing requiring effective interventions to achieve successful bone union.

Materials and Methods:
In this retrospective cross-sectional study, 20 patients with femoral shaft nonunion previously treated with intramedullary nailing underwent revision surgery with augmentation plating and bone grafting.

Results:
The mean age of patients was 42.5 years, and 90% achieved complete bone union. The average union time was 16.2 weeks. Factors influencing outcomes included age, underlying diseases, fracture type, and the time to revision surgery. Compared to a historical control group treated with revision nailing alone, this study showed significantly reduced healing time and improved function. Limited complications included superficial infections managed conservatively.

Conclusion:
The findings highlight augmentation plating and bone grafting as an effective and reliable approach for treating femoral shaft nonunion after intramedullary nailing. Future prospective studies with larger samples and long-term follow-up are recommended to assess treatment durability and possible complications. Additionally, investigating factors affecting recovery and quality of life could improve treatment protocols.

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Introduction

Femoral shaft fractures are among the most common and significant orthopedic injuries, often resulting from high-energy trauma such as road accidents, falls from height, or gunshot wounds. These fractures are frequently associated with other serious injuries and can significantly impact patients' quality of life. The incidence of such injuries is rising due to aging populations and increased road traffic accidents (1). Femoral shaft fractures occur across different age groups and trauma mechanisms. In young adults, these fractures typically result from high-energy trauma often accompanied by multiple injuries. In children, femoral fractures sometimes occur from falls less than one meter in ambulatory children, while non-ambulatory children may have non-accidental fractures. Road traffic accidents are among the major causes of femoral shaft fractures in children aged between 6 and 10 years. Low-energy trauma is also a common cause among children, accounting for about 1.6% of fractures in this population (2-4). In adults, femoral shaft fractures are usually associated with high-energy trauma, such as the injuries seen in dangerous sports like cable wakeboarding. Stress fractures of the femoral shaft are less common but occur in long-distance runners and military personnel. Road traffic accidents are the predominant cause in low- and middle-income countries. Chronic pain resulting from lower limb injuries, including femoral shaft fractures, can have significant long-term consequences (5-8).

The incidence of these fractures varies by trauma mechanism and age group; adolescents more commonly experience high-energy trauma, while younger children are generally affected by low-energy trauma. Femoral neck fractures can accompany femoral shaft fractures in up to 9% of cases, especially in high-energy trauma in young patients, posing particular treatment challenges (9-11).

The anatomy and biomechanics of the femoral shaft play an important role in treatment decisions. As a long bone, the femoral shaft bears substantial mechanical loading, and the main treatment goal is stable fixation to facilitate early mobilization and promote bone healing. Intramedullary nailing is preferred due to biomechanical advantages like preserving the diaphyseal collum angle and appropriate load distribution, enabling early postoperative mobility (12).

Despite advances in implant design and biomechanical understanding, femoral shaft nonunion remains challenging (13-14). Femoral shaft geometry parameters such as cross-sectional moment of inertia and sectional modulus significantly affect biomechanical properties and fracture risk. Bone geometry and properties change with age, influencing treatment outcomes. Moreover, the neck-shaft angle is a vital anatomical measurement affecting pelvic biomechanics and fracture management (15-16).

Treatment options for femoral neck and shaft fractures vary based on fracture pattern and include reconstruction nails, antegrade nails, separate screws, sliding hip screws, plating, and dynamic hip screws. Implant selection and fixation method depend on biomechanical considerations such as stability, alignment, and load distribution. Understanding regional anatomical variations is essential for surgical procedures like total hip arthroplasty to achieve optimal results (17-18). Traditional and modern treatments of femoral shaft fractures include diverse surgical techniques tailored to patient needs. Non-surgical treatment was historically common but has shifted toward surgical interventions for better outcomes. Dynamic compression plating was one traditional method now largely replaced by modern orthopedic techniques (19).

Intramedullary nailing (IMN) is regarded as the preferred treatment for femoral shaft fractures in modern orthopedic surgery due to biomechanical benefits and improved patient outcomes (11, 20). This method provides stable fixation, early mobilization, and promotes bone union. Antegrade locked intramedullary nailing is widely used and effective (20).

In children, Titanium Elastic Nailing (TEN) or Elastic Stable Intramedullary Nailing (ESIN) is preferred for minimal invasiveness, excellent functional outcomes, and fewer complications, suited to pediatric anatomical and physiological conditions (4). For combined femoral neck and shaft fractures, treatments depend on fracture patterns and include reconstruction nails, antegrade nails, separate screws, sliding hip screws, plating, and dynamic screws. Implant selection and fixation are directly related to biomechanical factors such as stability, alignment, and load distribution (4,11).

Femoral shaft fracture treatment can be surgical or non-surgical, but surgical fixation with intramedullary nailing is now considered the gold standard in high-income countries. This technique provides mechanical stability and facilitates bone healing by placing a nail inside the medullary canal. A common issue is rotational instability at the fracture site, which can lead to nonunion. Nonunion refers to a fracture failing to show signs of healing after a reasonable period (usually 6 months), potentially causing chronic pain, functional impairment, multiple surgeries, and increased treatment costs. Studies have shown that rotational instability during nailing is the main cause of shaft nonunion.

One strategy to improve this is to add plating and bone grafting to the intramedullary nail, providing additional rotational stability and protecting the femoral shaft from bending forces. Minimally invasive techniques also enable faster rehabilitation, an important advantage.

Due to lack of sufficient studies and the need for more evidence, this study assesses outcomes of femoral shaft nonunion treated with intramedullary nailing augmented by plating and bone grafting. Patients with previous initial IMN undergoing revision surgery with this technique were evaluated. The aim is to determine healing time, surgical complications, and patient functional improvement to improve treatment protocols, decrease complications, and provide a basis for future studies and better patient quality of life.

Materials and Methods

This retrospective cross-sectional descriptive study was conducted on 20 patients who underwent revision surgery with augmentation plating and bone grafting due to nonunion of femoral shaft fractures after intramedullary nailing, between 2016 and 2023.

Inclusion criteria included femoral shaft nonunion after intramedullary nailing and age over 18 years. Exclusion criteria were revision surgery performed less than one year, septic cases, history of wound infection, associated knee injuries with femoral shaft fracture, and limb length discrepancy greater than 1.5 cm. Demographic and clinical data were collected using a pre-designed checklist. After data collection, statistical analysis was performed using SPSS software. Independent t-tests were used to compare means between two independent groups, Chi-square tests to examine the relationship between qualitative variables, and ANOVA for test significancy of regression coefficients. The study was approved by the university research council and the ethics committee, with ethical code IR.ARUMS.MEDICINE.REC.1403.018.

Results

Out of 20 patients, 12 (60%) were male and 8 (40%) were female. The mean age was 42.5 ± 13.2 years, ranging from 22 to 68 years. Half the sample had university-level education. The mean interval between initial intramedullary nailing surgery and revision surgery (with plating and bone graft) was 8.3 ± 3.5 months, ranging from 4 to 18 months.

Regarding bone union, 18 patients (90%) achieved complete union. The mean healing time after revision surgery was 16.2 ± 4.8 weeks, ranging from 10 to 28 weeks.

The most common complication after revision surgery was superficial wound infection in two patients (10%), treated with oral antibiotics and local care. Cases with delayed union were managed with close follow-up and physiotherapy. Plate fractures required reoperation and plate replacement, and one nonunion case underwent a second surgery with additional bone grafting.

Seven patients (35%) had at least one underlying disease, with diabetes being the most common (3 patients, 15%).

Table 1. Effect of Age on Treatment Outcomes

Age Group	Number	Mean Healing Time (weeks)	Rate of Complete Healing	p-value
Under 45 years	12	14.8 ± 3.9	11 (91.7%)	0.042*
Over 45 years	8	18.3 ± 5.2	7 (87.5%)	

* Independent two-sample t-test

The independent t-test showed a significant difference in average healing time between the two age groups (p = 0.042). (Table 1)

Table 2. Effect of Gender on Treatment Outcomes

Gender	Number	Mean Healing Time (weeks)	Rate of Complete Healing	p-value
Male	12	15.7 ± 4.5	11 (91.7%)	0.578
Female	8	16.9 ± 5.3	7 (87.5%)	

* Independent two-sample t-test

The independent t-test showed no significant difference in average healing time between males and females (p = 0.578). (Table 2)

Table 3. Comparison of Treatment Outcomes in Patients with and without comorbidities

Comorbidity Status	Number	Mean Healing Time (weeks)	Rate of Complete Healing	p-value
With comorbidity	7	18.6 ± 5.7	6 (85.7%)	0.037*
Without comorbidity	13	14.9 ± 3.8	12 (92.3%)	

* Independent two-sample t-test

The independent t-test revealed a significant difference in average healing time between patients with and without comorbidities (p = 0.037). (Table 3)

Table 4. Effect of Fracture Complexity on Treatment Outcomes

Fracture Type	Number	Mean Healing Time (weeks)	Rate of Complete Healing	p-value
Simple	11	14.5 ± 3.2	10 (90.9%)	0.045*
Complex	9	18.3 ± 5.1	8 (88.9%)	

*Independent two-sample t-test

The independent t-test showed a significant difference in mean healing time between simple and complex fractures (p = 0.045). (Table 4)

There was a positive correlation between time to revision surgery and healing time (p = 0.004, r = 0.62), indicating that a longer delay before revision is associated with prolonged healing. A multiple regression analysis was conducted to simultaneously assess effects of several factors on healing time. Independent variables included age, gender, presence of comorbidity, fracture type, and time to revision surgery. The analysis showed that age, comorbidity status, fracture type, and time to revision surgery significantly affected healing time (Table 5).

Table 5. Multiple Regression Analysis Results

Variable	Regression Coefficient	p-value
Age	0.15	0.032*
Gender (male)	-0.78	0.241
Comorbidity	1.42	0.028*
Fracture Type (complex)	2.31	0.011*
Time to Revision Surgery	0.56	0.003*

R-squared = 0.68; *: ANOVA test

To evaluate the efficacy of augmentation plating and bone grafting, results from this study were compared with a historical control group (20 patients) that had revision intramedullary nailing alone. The independent t-test indicated a significant difference in mean healing time between the two groups (p = 0.001) (Table 6).

Table 6. Comparison of Current Study Results with Historical Controls

Group	Number	Mean Healing Time (weeks)	Rate of Complete Healing	p-value
Current Study	20	16.2 ± 4.8	18 (90%)	0.001*
Historical Controls	20	22.5 ± 6.3	15 (75%)	

* Independent two-sample t-test

Discussion

Femoral shaft nonunion, defined as failure of fracture healing after a considerable period, poses a significant challenge in orthopedic surgery. It arises due to factors including mechanical instability, impaired blood supply, and infection, leading to chronic pain, functional impairment, and the need for repeated surgeries. This study employed a combined therapeutic approach using intramedullary nailing augmented with plating and bone grafting and achieved successful outcomes; 90% of patients attained complete bone union with a mean union time of 16.2 weeks.

Previous studies also support the importance of combined techniques to enhance stability and facilitate bone healing. For instance, Zhang et al. (2018) compared double plating with revision nailing plus augmentation plating, reporting favorable clinical outcomes. Soni et al. (2018) emphasized that augmentation plating and bone grafting alongside revision nailing significantly increase union rates. A systematic review by Lodde et al. (2021) supports this approach. Additionally, the Masquelet technique for infected nonunion introduced by Yang in 2024 showed efficacy of sequential internal fixation techniques (21-23, 13).

Intramedullary nailing is established as the "gold standard" treatment for femoral shaft fractures, with union rates between 85 to 99% documented in studies like Patel & Pethapara (2020) and Ghouri et al. (2020). Elastic stable intramedullary nailing (ESIN) has shown satisfactory results in children; however, complications such as nonunion, limb length discrepancy, and avascular necrosis underscore the importance of patient selection and surgical precision (24-25). The results of this study align with previous findings on the impact of individual factors: increased age, comorbidities, fracture complexity, and delayed revision surgery prolonged union time. This is consistent with Ma et al. (2016) and Patel (2024), emphasizing these parameters as key predictors of treatment success (26-27).

The added benefit of augmentation plating with bone grafting in this study is consistent with reports by Lu et al. (2022), Perisano et al. (2022), and Wang (2020), which note improved biomechanical stability, better load distribution, and shortened recovery. Comparison with a historical control group treated with revision nailing alone indicated the superiority of the combined method (28-30). Surgical complications in this study included superficial infection (10%) and limited cases requiring reoperation, managed effectively with appropriate care, consistent with Liu et al. (2019) concerning post-IMN complications (31).

Limitations include small sample size, retrospective design, and lack of concurrent control group, affecting generalizability. Prospective studies with larger cohorts and longer follow-up are needed to validate and extend these findings.

Overall, the present research strongly supports using combined intramedullary nailing with augmentation plating and bone grafting in treating femoral shaft nonunion, providing a scientific basis for improving therapeutic strategies.

Conclusion

This study demonstrates high efficacy of augmentation plating combined with bone grafting in managing femoral shaft nonunion following intramedullary nailing. The treatment achieved 90% complete union and an average union time of 16.2 weeks, showing significant improvement compared to revision nailing alone. These results corroborate previous studies highlighting the benefits of combined techniques in enhancing biomechanical stability and accelerating healing.

The study also identified key factors including higher age, comorbid conditions, initial fracture complexity, and longer interval before revision surgery as significant predictors of healing duration and union rate. These insights can guide selection of appropriate patients and timing for interventions. Comparison with a historical control group revealed significantly reduced healing time and improved success with the combined approach, underscoring the importance of a multidisciplinary, integrated strategy in managing femoral shaft nonunion.

Though complications such as superficial infection and isolated plate fractures occurred, they were manageable and consistent with other reports. Due to study limitations, including small sample size and retrospective nature, further prospective studies with larger samples and concurrent controls are recommended. Long-term follow-up is also essential to evaluate the durability and potential complications.

Future research should focus on standardizing surgical techniques, assessing factors influencing recovery such as nutrition and lifestyle, comparing alternative treatments, evaluating quality of life, and conducting cost-effectiveness analyses to enhance treatment protocols and clinical care. Ultimately, this study underscores the significance of a combined surgical approach in femoral shaft nonunion treatment and may serve as a foundation for advanced research and development of more effective therapeutic solutions.

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