



# Plate Augmentation for Nonunion of Femoral Shaft Fractures

Ali Yeganeh<sup>1,2</sup>, Mehdi Abbasi<sup>1</sup>, Habib-o-lah Gorgani<sup>1,2</sup> and Mehdi Moghtadaei<sup>1,2,\*</sup>

<sup>1</sup>Department of Orthopedic Surgery, Rasool-e-Akram Hospital, Iran University of Medical Sciences, Tehran, Iran

<sup>2</sup>Bone and Joint Reconstruction Research Center, Shafa Orthopedic Hospital, Iran University of Medical Sciences, Tehran, Iran

\*Corresponding author: Department of Orthopedic Surgery, Rasool-e-Akram Hospital, Iran university of Medical Sciences, Tehran, Iran. Email: moghtadaei.m@iums.ac.ir

Received 2019 January 04; Revised 2019 January 07; Accepted 2019 January 25.

## Abstract

**Background:** Femoral nonunion is an important complication, which can occur after intramedullary nailing and it requires surgical intervention. Plate augmentation over intramedullary nail is emerging as an acceptable option with satisfactory results for femoral nonunion.

**Objectives:** The aim of the present study was to determine whether plate augmentation over retained intramedullary nail is an effective treatment for nonunion of femoral shaft fracture.

**Methods:** Overall, 35 cases of femoral nonunion, initially treated with intramedullary nailing, were managed with plating augmentation. Patients with oligotrophic or atrophic nonunion also received iliac cancellous auto graft. The outcome was evaluated by the rate and duration of union and complications were recorded.

**Results:** All patients achieved bony union during an average time of 21 weeks ( $\pm 3.94$ ) and no union occurred later than 35 weeks. In plain radiography, evidence of callus formation was seen at mean time of 10 weeks. There was no statistically significant difference in union time among different types of nonunion ( $P: 0.466$ ) while a significant difference was noticed in the time for callus formation ( $P < 0.01$ ). Also, no complications were observed.

**Conclusions:** Plating augmentation is an effective and safe treatment option for nonunion of femoral shaft fractures.

**Keywords:** Plate Augmentation, Intramedullary Nail, Femoral Nonunion, Bone Graft

## 1. Background

Intramedullary nailing with its minimally invasive nature is considered the standard treatment for the majority of patients with femoral shaft fractures and it has shown excellent union outcome with reported high union rates (1, 2). Femoral nonunion is an important complication, which can occur in up to 57% of patients after intramedullary nailing and it requires a surgical intervention (3, 4). Several treatment options exist for femoral nonunion after intramedullary nailing, including reamed re-nailing (5, 6), dynamization (7), nail removal followed by plating (8), stable fixation with or without bone grafting (9, 10), and external fixation (11).

Currently, exchange nailing with or without bone graft is the standard of care for femoral nonunion. Some studies have reported secondary union rates as low as 53% after exchange nailing, which questions the efficacy of this treatment paradigm (12).

Plate augmentation over intramedullary nail is emerging as an acceptable option with satisfactory results for femoral nonunion. Many studies have indicated high

union rates of this method (13-15).

## 2. Objectives

This study sought to evaluate the efficacy of plating augmentation over retained intramedullary nail in achieving bony union in patients with nonunion of femoral shaft fracture.

## 3. Methods

### 3.1. Study Design and Patients

This was a prospective interventional study conducted between 2015 and 2018. Patients with current unilateral femoral nonunion, initially treated by intramedullary nailing, were recruited in the study. Patients were included if they had clinical manifestation of non-union and also depicted no sign of bony union on X-ray for at least six months, postoperatively. Patients with nonunion due to infection were excluded. The outcome parameters were rate and time to union. Patients were also categorized to

three groups, according to their non-union type, including hypertrophic, atrophic, and oligotrophic. The mean weeks to obtain cross-bridge or solid union was reported in the study population and compared between groups.

Femoral shaft was defined as a part of femoral diaphysis between 5 cm distal to lesser trochanter and 5 cm proximal to adductor tubercle (15). Non-union was defined as the lack of radiographic union at least for six months combined with persistent pain at the fracture site (16). Patients were evaluated at the scheduled intervals to investigate for evidence of clinical and radiographic bony union. Union was defined as the absence of clinical symptoms in addition to visualized bridging callus over three-fourths of the diameter of the fracture site of femur on both anteroposterior and lateral view (15).

### 3.2. Intervention

All the procedures were performed by the senior author (AY). Blood tests were obtained from patients to exclude infectious causes of non-union, preoperatively. Direct lateral approach was used by splitting the tensor fasciae latae and vastus lateralis muscles to expose the nonunion site. Following incision on the previous scar, all the fibrotic tissues were resected and the bone edges were completely freshened with curettage, drilling, and rongeur while osteotome was applied to perform thin layers decortication on the posterior, lateral, and anterior edges of the bone. Samples were taken for laboratory analysis of infection then the researchers applied a 4.5-mm Dynamic Compression Plate (DCP) or anatomical locking plate for the distal part of the shaft. The plates were between 8 to 14 holes and at least three cortical screws were implanted on each side of the fracture based on the type of fracture to gain rigid fixation over the retained intramedullary nail. Following plate fixation, 6 to 10 cc of iliac cancellous auto graft was harvested and injected to the nonunion sites in patients with oligotrophic or atrophic nonunion while the non-union gap was closed rigidly (Figure 1). Patients were discharged after 48 hours of empirical antibiotic therapy and allowed protected partial weight bearing gait. Partial weight bearing with the aid of crouches was allowed immediately after surgery whereas full weight bearing began after satisfactory bony union and clinical improvement. Also, nutritional supplement of vitamin D and calcium for three months and oral antibiotics for one week were prescribed.

### 3.3. Statistical Analysis

All statistical analysis was performed using SPSS 18.0. Descriptive data were reported as a mean  $\pm$  standard deviation

for continuous values and frequency for categorical values. Repeated measure analysis was used to compare the outcome between subgroups. Spearman correlation was also conducted to evaluate the relationship between baseline characteristics of patients and union time. P values below 0.5 were considered statistically significant.

## 4. Results

The mean  $\pm$  SD age of patients was  $34.31 \pm 14.59$ , including 25 (71.4%) males. Motor vehicle accidents was the major mechanism of fractures and 13 cases initially presented open fractures. Diabetes mellitus occurred in 10 patients as a comorbidity disorder. In 9 patients, fractures were located at the distal part of shaft and the rest of patients had fractures located at either proximal or middle third of femoral bone. In terms of non-union typing, 10 fractures revealed hypertrophic non-union, 15 patients depicted oligotrophic and 10 cases had atrophic nonunion. Among these 35 non-union circumstances, 28 patients had ineffective nonunion treatment; 12 cases underwent dynamization followed by weight bearing exercise, 14 cases sustained re-nailing with replacement of a larger nail and in two patients bone marrow injection was done. The mean time of nonunion between primary surgery of intramedullary nailing and the plate augmentation was  $20.03 (\pm 6.37)$ . Mean surgical time was 90 minutes (with a range of 70 to 150 minutes).

All patients achieved solid bony union in a mean time of 21 weeks ( $\pm 3.94$ ) and no union occurred later than 35 weeks. The mean time of follow-up was  $21.09 (\pm 6.22)$ . Table 1 summarizes patients' profile. In the radiographic study, evidence of callus formation was seen at mean time of 10 weeks. In the hypertrophic non-union group, radiographic callus formation was earlier than other nonunion types. There was no statistically significant difference in union time among different types of nonunion ( $P: 0.466$ ) while a significant difference was noticed in time to visualize callus formation ( $P < 0.01$ ) (Table 2).

Statistical evaluation demonstrated that there was no significant relationship between union time and gender ( $P: 0.986$ ), and primary fracture type ( $P: 0.193$ ). There was a significant negative relationship between age and union time ( $P: 0.005$ , correlation coefficient:  $-0.493$ ).

The average blood loss during the surgery was 300 mL ( $\pm 124.85$ ). No complications, including infection, discharge, pain, malalignments, and device failure, were observed. The range of motion in the hip and knee in addition to the limb length did not change postoperatively.



**Figure 1.** A, Femoral shaft fracture; B, Primary Intramedullary nailing; C and D, 6 months postoperative nonunion of femoral fracture; E and F, 9 months postoperative nonunion of femoral fracture; G, 4 months post-plate augmentation; H, 6 months post-plate augmentation

## 5. Discussion

Femoral nonunion is a rare yet difficult to treat complication of fractures, in which standard treatment, such as re-nailing has failed to produce consistent results in different studies. In the recent years, plate augmentation has emerged as a promising treatment option. The current results indicated that the combination of plate augmentation and bone auto graft over retained intramedullary nail is an effective and safe treatment option for femoral nonunion with union rate of 100%. In a meta-analysis by Somford et al. applying a plate over existing intramedullary nail had more union rate compared with other techniques, including re-nailing (17). Reports of results of augmentation plating over retained intramedullary nailing in femoral nonunion are limited. The number of patients in these studies are generally less than 50 cases and favorable outcome in all cases were reported (15, 18, 19). The findings are aligned with the results of previous studies. In the study of Hakeos et al. using a plate over intramedullary nailing associated with bone graft, particularly for complex fractures around the metadiaphyseal region, resulted in satisfactory outcome and they concluded that this procedure appears to be effective in reducing pain and improving function, and predictably leads to radiographic consolidation of the nonunion (20). In a retrospective study by Vaishya et al., this method was performed in 16 cases. All patients had bony union and bone graft was applied in four cases. The average surgical time was acceptable and no major complication occurred

yet they had some cases of limb shortening (21). Ueng et al. as in the current study reported successful bony union after augmentation plating over intramedullary nailing. However, this study additionally applied bone autograft to nonunion sites in atrophic and oligotrophic nonunion patients to stimulate further callus formation (13).

This surgical technique has benefits over other available treatments for femoral shaft nonunion, including shorter time of surgery because of no need for nail removal, independence of this method from fracture reduction and alignment or direct approach to fracture site, less blood loss due to minimal incision and localized surgery, early weight bearing and walking, and less pain because of smaller incision and retaining of nailing. There is no need for new alignment and limb length correction unlike nailing exchange and solitary plating. This method makes surgery much easier and more comfortable for patients. Lower rate of infection and complications and complete range of motion after surgery in patients, who may have undergone several failed surgical treatments and may not bear another failed trial are other benefits of this method. Other important findings of this study, including no effect of gender or nonunion type or primary fracture type on outcome, point out the effectiveness of this method in patients with different profiles. There were some limitations in the current study. Lack of a control group and nature of the study, clinical score sheets, and the small population of the study are drawbacks of the study. More studies with an RCT design, larger number of patients and longer du-

**Table 1.** Patients' Profile

No.	Sex	Age, y	Site	Type of Nonunion	Nonunion Time, mo	BG from ASIC	Cross Bridge, wk	Solid Union, wk	Op Time, min	Blood Loss, mL	Hospital Stay, d	F/U, mo
1	F	45	M/3	Hypertrophy	9	(-)	8	17	75	200	3	15
2	M	36	M/3	Oligotrophy	12	(+)	10	19	100	350	4	21
3	M	54	L3	Oligotrophy	14	(+)	11	22	70	450	3	13
4	F	25	M3	Atrophy	16	(+)	10	16	140	150	5	17
5	M	26	U/3	Hypertrophy	30	(-)	9	18	80	250	3	30
6	M	33	U/3	Atrophy	18	(+)	12	18	70	350	3	25
7	M	20	M/3	Atrophy	28	(+)	10	24	95	300	7	24
8	M	28	L/3	Oligotrophy	22	(+)	11	26	75	400	4	20
9	F	19	M/3	Hypertrophy	30	(-)	9	25	85	250	4	12
10	M	67	M/3	Oligotrophy	18	(+)	11	17	120	200	3	14
11	F	59	L/3	Oligotrophy	25	(+)	9	16	105	500	4	19
12	M	29	L/3	Hypertrophy	24	(-)	8	19	70	150	4	26
13	F	21	U/3	Hypertrophy	14	(-)	8	20	75	200	5	24
14	M	69	M/3	Oligotrophy	9	(+)	10	21	75	150	3	12
15	M	42	M3	Oligotrophy	29	(+)	8	20	70	250	3	28
16	M	21	U/3	Atrophy	29	(+)	14	19	75	200	4	32
17	M	26	U/3	Oligotrophy	19	(+)	10	23	80	600	5	30
18	F	24	M/3	Hypertrophy	17	(-)	8	35	140	300	4	17
19	M	46	L/3	Atrophy	13	(+)	10	18	80	350	3	30
20	F	41	M/3	Atrophy	19	(+)	12	20	70	250	5	14
21	M	51	M/3	Oligotrophy	25	(+)	8	23	125	600	4	18
22	M	42	M/3	Atrophy	30	(+)	10	20	100	300	5	21
23	F	49	L3	Atrophy	18	(+)	12	19	75	400	4	19
24	M	22	U/3	Oligotrophy	27	(+)	9	16	90	300	4	28
25	M	20	M/3	Atrophy	23	(+)	12	22	70	250	3	27
26	M	20	L/3	Hypertrophy	21	(-)	8	24	150	150	5	13
27	M	24	M/3	Oligotrophy	14	(+)	10	24	85	400	6	19
28	F	22	M/3	Oligotrophy	20	(+)	13	26	115	200	4	25
29	M	34	M/3	Oligotrophy	16	(+)	11	16	70	400	3	25
30	M	54	U/3	Oligotrophy	28	(+)	9	18	75	150	4	21
31	M	21	U/3	Hypertrophy	20	(-)	7	23	75	200	4	12
32	F	18	M/3	Hypertrophy	17	(-)	9	22	90	400	5	30
33	M	35	L/3	Atrophy	12	(+)	14	24	110	150	4	26
34	M	38	M/3	Hypertrophy	23	(-)	9	19	80	450	3	17
35	M	20	L/3	Oligotrophy	12	(+)	11	26	90	300	4	14

**Table 2.** Analysis of Nonunion Type<sup>a</sup>

	Hypertrophic	Oligotrophic	Atrophic	P Value
Callus formation (weeks)	8.30 ± 0.67	10.07 ± 1.33	11.60 ± 1.57	< 001
Solid union (weeks)	22.20 ± 5.22	20.87 ± 3.75	20 ± 2.62	0.466

<sup>a</sup>Values are expressed as mean ± SD.

ration of follow-up are required to establish the definitive outcome of augmentation plating for femoral nonunion.

### 5.1. Conclusions

The current literature and the present study have shown the effectiveness of plate augmentation over re-

tained intramedullary nail for patients with nonunion of femoral shaft fractures, who failed to respond to conventional surgical treatments, including dynamization, reamed re-nailing.

## 5.2. Compliance with Ethical Standards

Ethical approval was obtained from the ethics committee of Iran University of Medical Sciences. This study was also in accordance with the Helsinki Declaration and its later amendments and prior to entering the study, patients gave their informed consent to participate in this study.

## Footnotes

**Authors' Contribution:** Study concept and design: Ali Yeganeh and Mehdi Moghtadaei; acquisition of data: Ali Yeganeh, Mehdi Abbasi, Habib-o-lah Gorgani and Mehdi Moghtadaei; analysis and interpretation of data: Ali Yegan, Mehdi Abbasi and Habib-o-lah Gorgani; drafting of the manuscript: Mehdi Abbasi, Habib-o-lah Gorgani and Mehdi Moghtadaei; critical revision of the manuscript for important intellectual content: Ali Yeganeh, Habib-o-lah Gorgani and Mehdi Moghtadaei; statistical analysis: Mehdi Abbasi, Habib-o-lah Gorgani and Mehdi Moghtadaei.

**Conflict of Interests:** All authors declared that they had no conflict of interests.

**Ethical Considerations:** Ethical approval was obtained from the Ethics Committee of Iran University of Medical Sciences. This study was also in accordance with the Helsinki Declaration and its later amendments and prior entering the study patients gave their informed consent to participate in this study.

**Funding/Support:** None.

## References

- Winquist RA, Sigvard J, Clawson DK. Closed intramedullary nailing of femoral fractures. A report of five hundred and twenty cases. *Orthop Trauma Direct*. 2005;**3**(4):29-31. doi: [10.1055/s-2005-919122](https://doi.org/10.1055/s-2005-919122).
- Neumann MV, Sudkamp NP, Strohm PC. Management of femoral shaft fractures. *Acta Chir Orthop Traumatol Cech*. 2015;**82**(1):22-32. [PubMed: [25748658](https://pubmed.ncbi.nlm.nih.gov/25748658/)].
- Taitsman LA, Lynch JR, Agel J, Barei DP, Nork SE. Risk factors for femoral nonunion after femoral shaft fracture. *J Trauma*. 2009;**67**(6):1389-92. doi: [10.1097/TA.0b013e318182afd0](https://doi.org/10.1097/TA.0b013e318182afd0). [PubMed: [19704386](https://pubmed.ncbi.nlm.nih.gov/19704386/)].
- Canadian Orthopaedic Trauma Society. Nonunion following intramedullary nailing of the femur with and without reaming. Results of a multicenter randomized clinical trial. *J Bone Joint Surg Am*. 2003;**85-A**(11):2093-6. doi: [10.2106/00004623-200311000-00005](https://doi.org/10.2106/00004623-200311000-00005). [PubMed: [14630836](https://pubmed.ncbi.nlm.nih.gov/14630836/)].
- Hak DJ, Lee SS, Goulet JA. Success of exchange reamed intramedullary nailing for femoral shaft nonunion or delayed union. *J Orthop Trauma*. 2000;**14**(3):178-82. doi: [10.1097/00005131-200003000-00005](https://doi.org/10.1097/00005131-200003000-00005).
- Weresh MJ, Hakanson R, Stover MD, Sims SH, Kellam JF, Bosse MJ. Failure of exchange reamed intramedullary nails for ununited femoral shaft fractures. *J Orthop Trauma*. 2000;**14**(5):335-8. doi: [10.1097/00005131-200006000-00005](https://doi.org/10.1097/00005131-200006000-00005). [PubMed: [10926240](https://pubmed.ncbi.nlm.nih.gov/10926240/)].
- Meadows TH, Bronk JT, Chao YS, Kelly PJ. Effect of weight-bearing on healing of cortical defects in the canine tibia. *J Bone Joint Surg Am*. 1990;**72**(7):1074-80. doi: [10.2106/00004623-199072070-00018](https://doi.org/10.2106/00004623-199072070-00018). [PubMed: [2384507](https://pubmed.ncbi.nlm.nih.gov/2384507/)].
- Wolinsky PR, McCarty E, Shyr Y, Johnson K. Reamed intramedullary nailing of the femur: 551 cases. *J Trauma*. 1999;**46**(3):392-9. doi: [10.1097/00005373-199903000-00007](https://doi.org/10.1097/00005373-199903000-00007). [PubMed: [10088839](https://pubmed.ncbi.nlm.nih.gov/10088839/)].
- Loomer RL, Meek R, De Sommer F. Plating of femoral shaft fractures: The Vancouver experience. *J Trauma*. 1980;**20**(12):1038-42. doi: [10.1097/00005373-198012000-00005](https://doi.org/10.1097/00005373-198012000-00005). [PubMed: [7452747](https://pubmed.ncbi.nlm.nih.gov/7452747/)].
- Smith WR, Morgan SJ. Failure of internal fixation of the femoral shaft. *Tech Orthop*. 2002;**17**(4):448-57. doi: [10.1097/00013611-200212000-00009](https://doi.org/10.1097/00013611-200212000-00009).
- Menon DK, Dougall TW, Pool RD, Simonis RB. Augmentative Ilizarov external fixation after failure of diaphyseal union with intramedullary nailing. *J Orthop Trauma*. 2002;**16**(7):491-7. doi: [10.1097/00005131-200208000-00007](https://doi.org/10.1097/00005131-200208000-00007). [PubMed: [12172279](https://pubmed.ncbi.nlm.nih.gov/12172279/)].
- Birjandinejad A, Ebrahimzadeh MH, Ahmadzadeh-Chabock H. Augmentation plate fixation for the treatment of femoral and tibial nonunion after intramedullary nailing. *Orthopedics*. 2009;**32**(6):409. doi: [10.3928/01477447-20090511-12](https://doi.org/10.3928/01477447-20090511-12). [PubMed: [19634823](https://pubmed.ncbi.nlm.nih.gov/19634823/)].
- Ueng SW, Chao EK, Lee SS, Shih CH. Augmentative plate fixation for the management of femoral nonunion after intramedullary nailing. *J Trauma*. 1997;**43**(4):640-4. doi: [10.1097/00005373-199710000-00013](https://doi.org/10.1097/00005373-199710000-00013). [PubMed: [9356061](https://pubmed.ncbi.nlm.nih.gov/9356061/)].
- Chiang JC, Johnson JE, Tarkin IS, Siska PA, Farrell DJ, Mormino MA. Plate augmentation for femoral nonunion: More than just a salvage tool? *Arch Orthop Trauma Surg*. 2016;**136**(2):149-56. doi: [10.1007/s00402-015-2365-9](https://doi.org/10.1007/s00402-015-2365-9). [PubMed: [26646845](https://pubmed.ncbi.nlm.nih.gov/26646845/)].
- Choi YS, Kim KS. Plate augmentation leaving the nail in situ and bone grafting for non-union of femoral shaft fractures. *Int Orthop*. 2005;**29**(5):287-90. doi: [10.1007/s00264-005-0668-0](https://doi.org/10.1007/s00264-005-0668-0). [PubMed: [16132986](https://pubmed.ncbi.nlm.nih.gov/16132986/)]. [PubMed Central: [PMC3456636](https://pubmed.ncbi.nlm.nih.gov/PMC3456636/)].
- Lin CJ, Chiang CC, Wu PK, Chen CF, Huang CK, Su AW, et al. Effectiveness of plate augmentation for femoral shaft nonunion after nailing. *J Chin Med Assoc*. 2012;**75**(8):396-401. doi: [10.1016/j.jcma.2012.06.008](https://doi.org/10.1016/j.jcma.2012.06.008). [PubMed: [22901724](https://pubmed.ncbi.nlm.nih.gov/22901724/)].
- Somford MP, van den Bekerom MP, Kloen P. Operative treatment for femoral shaft nonunions, a systematic review of the literature. *Strategies Trauma Limb Reconstr*. 2013;**8**(2):77-88. doi: [10.1007/s11751-013-0168-5](https://doi.org/10.1007/s11751-013-0168-5). [PubMed: [23892497](https://pubmed.ncbi.nlm.nih.gov/23892497/)]. [PubMed Central: [PMC3732674](https://pubmed.ncbi.nlm.nih.gov/PMC3732674/)].
- Jung HG, Kim DJ, Kim BH, Chung YY. Treatment of the femoral shaft nonunion occurred after intramedullary nailing. *J Korean Orthop Assoc*. 2007;**42**(5):653-8.
- Nadkarni B, Srivastav S, Mittal V, Agarwal S. Use of locking compression plates for long bone nonunions without removing existing intramedullary nail: Review of literature and our experience. *J Trauma*. 2008;**65**(2):482-6. doi: [10.1097/TA.0b013e31817c9905](https://doi.org/10.1097/TA.0b013e31817c9905). [PubMed: [18695487](https://pubmed.ncbi.nlm.nih.gov/18695487/)].
- Hakeos WM, Richards JE, Obremskey WT. Plate fixation of femoral nonunions over an intramedullary nail with autogenous bone grafting. *J Orthop Trauma*. 2011;**25**(2):84-9. doi: [10.1097/BOT.0b013e3181dfbb33](https://doi.org/10.1097/BOT.0b013e3181dfbb33). [PubMed: [21245710](https://pubmed.ncbi.nlm.nih.gov/21245710/)].
- Vaishya R, Agarwal AK, Gupta N, Vijay V. Plate augmentation with retention of intramedullary nail is effective for resistant femoral shaft non-union. *J Orthop*. 2016;**13**(4):242-5. doi: [10.1016/j.jor.2016.06.003](https://doi.org/10.1016/j.jor.2016.06.003). [PubMed: [27408496](https://pubmed.ncbi.nlm.nih.gov/27408496/)]. [PubMed Central: [PMC4925908](https://pubmed.ncbi.nlm.nih.gov/PMC4925908/)].