

# Augmented Plating and Bone Grafting in Treatment of Tibial and Femoral Shaft Nonunion

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## Abstract

**Background:** Tibial and femoral nonunion is not unusual after intramedullary fixation and might lead to multiple surgical procedures and long-term disabilities. Different surgical techniques have been described for management of lower limb long bone nonunion primarily treated with intramedullary nailing. Despite the use of various procedures, the success rate of most of them are suboptimal, increases the risk of related complications and costs.

**Objectives:** Augmented plating concomitant with autologous bone grafting technique make it possible to improve healing in a single operation.

**Methods:** In this study, 19 patients with lower limb long bone nonunion were primarily fixed with intramedullary nails, were treated with augmented plating and autologous bone grafting and followed for one year.

**Results:** The union rate was 94.7% with a mean union time of 4.75 months, 18 patients healed completely with solid union and only one case of femoral shaft nonunion remained. Infection and other surgical-related complications were not detected. After one year follow up, Visual Analog Scale was  $31 \pm 18.8$ , and decrement in active knee range of motion was more than 20% compared with opposite side in 47.4% of the patients.

**Conclusion:** According to the results, the single stage augmented plating with locking plates combined with autologous bone grafting can be used as a useful method in treatment of femoral or tibial nonunion.

**Keywords:** Fractures, Ununited, Bone Plates, Intramedullary Nailing, Bone Grafting.

## Introduction

According to Food and Drug Administration (FDA), nonunion was defined as lack of fracture site healing within nine months or no progression of fracture union in serial x-rays during a 90day period.

In fact, nonunion diagnosis is corroborated with radiographic and clinical criteria including absence of bony trabeculation on X-ray and persistent pain in the fracture site.<sup>1</sup>

Nonunion has been classified into atrophic nonunion (due to the biologic failure), hypertrophic nonunion (due to mechanical failure) and oligotrophic nonunion (due to biological failure, mechanical failure or both).<sup>2</sup>

Based on previous studies, the rate of nonunion after intramedullary nailing was reported between 0 and 10% in femoral shaft fractures and 15-19% in tibial diaphysis fractures.<sup>1,3</sup> Some risk factors of nonunion consist of open injuries, infection, severe bone defect, cigarette smoking, corticosteroid consumption, extended soft tissue dissection

during surgery and inappropriate fixation technique.<sup>4</sup>

Long-term morbidity, disability and the relevant socioeconomic problems highlight the need for appropriate and definitive treatment of femoral or tibial fracture nonunion.<sup>3</sup>

Until now, different surgical techniques have been described for management of lower limb long bone nonunion treated primarily with intramedullary nailing (IMN) such as bone grafting, conversion of nail to plate, exchange nailing, external fixation and augmented plating.<sup>1,5</sup> Despite of variety, these procedures may require several surgical steps, which increase the risk of related complications and costs.

## Objectives

The present study aimed at evaluating the efficacy of one stage surgery including augment plating and bone grafting for the treatment of femoral and tibial nonunion following IMN.

## Materials and Methods

In a retrospective case series, all femoral and tibial nonunion fractures treated with IMN in two centers of orthopedic surgery (Taleghani hospital and Shohada Tajrish hospital, Tehran, Iran) from 2017 to 2019 were enrolled in the study. Patients with age range of 18-60 years were included, and patients younger than 18 and older than 60 years were excluded.

Moreover, cases which primarily fixed with plate and also patients with IMN or screw breakage, infected nonunion, pathological fractures, severe osteoporosis and floating knee injuries were excluded from the study.

The patients were categorized based on the type of nonunion in three groups of hypertrophic, oligotrophic and atrophic nonunion. Hypertrophic nonunion cases with more than 70% bony contact were not enrolled in the study. Other patients went under the same surgical treatment method.

### Surgical Technique

All the remained and qualified cases were planned for augmented plating and bone grafting. After debridement, refreshing and decortication of the nonunion site, augmented plating was done.

The selected device for augment fixation in mid diaphyseal zone was 4.5 mm narrow locking plate. However, in more distal or proximal regions anatomical locking plates were used. Corticocancellous auto-graft was harvested from ipsilateral iliac crest and placed in the nonunion site.

### Post Operation Care

Patients were encouraged to walk as tolerated weight bearing and early range of motion of related joints as soon as possible after surgery.

At the end of the second week, healing of the wound was assessed and stitches were removed. Further post operation assessments including radiographic studies and clinical exams were conducted at 6<sup>th</sup> week, 3<sup>rd</sup>, 6<sup>th</sup> and 12<sup>th</sup> months after the surgery to evaluate healing of the nonunion site. After one year follow up, pain assessment was conducted using Visual Analog Scale (VAS).<sup>6</sup> Furthermore, active knee range of motion stitches was measured by standard goniometry.<sup>7</sup>

### Data Collection

Demographic data such as age and sex, past medical and social history including underlying diseases and history of smoking were collected. In addition, bone fracture data such characteristics of primary fracture and the interval between

primary surgery and surgery for nonunion were recorded. Furthermore, post-operative patient data such as evidence of infection and range of motion of related joints were recorded. Final result was described as "union" or "failure to union" at the last follow up. All collected data were analyzed using SPSS software (version 22).

### Ethical Statement

All stages of the study were conducted after obtaining the permission from the Ethics Committee of Shahid Beheshti University of Medical Sciences. Written informed consent was obtained from the patients before the intervention. The participants were assured that their information would be protected by the researchers. This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (No. IR.SBMU.MSP.REC.1397.816).

## Results

Regarding the exclusion criteria, totally 23 patients with confirmed diagnosis of tibial or femoral fracture nonunion were enrolled in this study. All of the included cases were fixed with intramedullary nailing devices primarily. Four patients did not complete the follow-up. Finally, nineteen patients remained in the study and were followed for one year. The mean age of them was  $42.8 \pm 15.3$  with range between 21 and 59 years. Of them, 16 patients were male (84.2%) and 3 were female (15.8%). Three patients were smoker (15.8%). Other demographic data and related comorbidities are summarized in (Table-1).

The numbers of patients with femoral or tibial diaphysis fractures sequentially were 13 and 6, respectively. Based on the morphology of fractures, 13 cases had transverse or oblique pattern and 6 cases were comminuted or segmented fractures.

Moreover, 3 cases had open injuries and 16 other cases had closed injuries. Atrophic nonunion was the most common nonunion pattern (13 cases), followed by oligotrophic and hypertrophic nonunion (Table-2).

The average of interval time between primary surgery and augmented plating was  $15.7 \pm 5.68$  months (ranged 6 to 31 months).

Complete union was achieved in 18 patients (94.7%) with mean union time of 4.75 months (ranged 1.5 to 12 months) (Figure-1, Figure-2, Figure-3, Figure-4). In one case of

atrophic femoral nonunion, complete healing of the fracture site did not occur during the one year follow up.

This case was a 32 years-old smoker man with an open femoral fracture due to gun-shot injury, which had been treated with external fixation primarily, then converted to intramedullary fixation and finally, augmented plating and bone grafting was done. In general, no infection was detected

among patients during one year follow up period among the patients. The range of motion of ipsilateral knee joint after one year follow up was evaluated and compared with the opposite normal limb. In 9 patients, decrement of knee range of motion were more than 20% compared with the opposite side (Table-3).



**Figure-1.** Anteroposterior radiograph of right femur revealed nonunion, 7 months after first surgery.



**Figure-2.** Lateral radiograph of right femur revealed nonunion, 7 months after first surgery.



**Figure-3.** Anteroposterior radiograph of right femur revealed complete union 2 months after augmented plating and bone grafting.



**Figure-4.** Lateral radiograph of right femur revealed complete union 2 months after augmented plating and bone grafting.

**Table-1.** Demographic data of patients

| Parameter                     | Frequency                            |
|-------------------------------|--------------------------------------|
| <b>Gender</b>                 | 16 (84.2%) Male,<br>3 (15.8%) Female |
| <b>Smoking</b>                | 16 (84.2%)                           |
| <b>Diabetes Mellitus</b>      | 1 (5.3%)                             |
| <b>Cardiovascular Disease</b> | 2 (10.5%)                            |
| <b>Hypertension</b>           | 7 (36.8%)                            |
| <b>Immune Deficiency</b>      | 0                                    |

**Table-2.** Characteristics of Injury

| Parameter                      | Frequency (Percent)   |
|--------------------------------|---|
| <b>Involved Bone</b>           | Femur: 13 (68.4)<br>Tibia: 6 (31.6)                                     |
| <b>Open/Closed Injury</b>      | Closed: 16 (84.2)<br>Open: 3 (15.8)                                     |
| <b>Nonunion Type</b>           | Atrophic: 13 (68.4)<br>Oligotrophic: 4 (21.1)<br>Hypertrophic: 2 (10.5) |
| <b>Fracture Pattern</b>        | Transverse/Oblique: 13 (68.4)<br>Comminuted/Segmented: 6 (31.6)         |
| <b>Vascular Injury/ Repair</b> | 0   |

**Table-3.** Outcomes

| Parameter  | Measurement   |
|--|---|
| <b>Union Status</b>  | Union: 18 (94.7%)<br>Nonunion: 1 (5.3%)                   |
| <b>Visual Analog Scale (VAS)</b>                                     | 31±18.8 (Range: 0-70)                                     |
| <b>Infection</b>   | 0   |
| <b>Active Knee Joint Range of Motion<br/>Decrement more than 20%</b> | 9 (47.4%)<br>(Tibial nonunion: 2 and Femoral nonunion: 7) |

## Discussion

The intramedullary nailing is an accepted method for fixation of acute tibial and femoral shaft fractures.<sup>8,9</sup> The union rate after intramedullary nailing was reported to be 87.5-100% in femoral shaft fractures and 81-97.5% in tibial diaphysis fractures.<sup>1,3,10-12</sup>

Nevertheless, nonunion might lead to socioeconomic concerns such as long term morbidity and requirement of multiple surgical procedures.<sup>3</sup> The nonunion rate would be enhanced 5-7 folds in open fractures with considerable soft tissue injury and contamination.<sup>12</sup> Furthermore, the risk of nonunion might be increased by smoking and taking nonsteroidal anti-inflammatory drugs, delayed weight bearing, complexity of fracture pattern and inadequate reduction of fracture site.<sup>4</sup>

There were some surgical methods introduced for treatment of femoral and tibial fractures nonunion which primarily fixed with IMN. Dynamization of the nail is a common procedure among these methods. It includes removing distal or proximal static screws to stimulate osteogenesis process during weight bearing. The union rate was reported to be 33.3-90% after dynamization procedure.<sup>5</sup> Another common method is exchange nailing consists of extracting the previous inserted nail, reaming of the medullary canal and putting a larger intramedullary nail.

According to the previous studies, the union rate ranged from 28.6% to 100% for exchange nailing.<sup>5</sup> However, some studies reported lower success rate (58-73%) of closed exchange nailing in atrophic or oligotrophic nonunion cases, and also patients with non-isthmic femoral shaft nonunion.<sup>13-16</sup> The augmented plating technique was first described in 1997 for management of femoral shaft nonunion.<sup>17</sup> While the retained intramedullary nail neutralizes shearing forces as a load sharing device and preserves alignment of fracture site, the plate enhances stability of fixation and provides possibility of immediate full weight bearing and rehabilitation.<sup>18</sup> Although augmented plating with dynamic compressive plates needs bicortical screws to achieve proper stability, using bicortical screws is technically difficult while the nail is retained and occupies the medullary canal. This is more problematic when the surgeon confronts with nonunion around isthmus. Locking plates make it possible to fix the plate with unicortical locking screws, which provide stable fixation even in patients with poor bone quality.<sup>18,19</sup> On the other side, plate screws act as blocking screws around the retained nail and cause additional stability of the nail and fracture site.<sup>20</sup> The use of low-contact locking plates preserves the periosteal blood supply, which plays an essential role in the healing process.<sup>18</sup> Otherwise, considering biological etiologies of nonunion,

augmented plating provides possibility of debridement of fibrotic tissues, refreshing of fracture edges, decortication and using bone graft for stimulation and acceleration of union process. Disregarding underlying biologic causes of nonunion even in hypertrophic nonunion cases is not feasible especially in hypertrophic nonunion cases with bone defect. Therefore, augmented plating with simultaneous bone grafting could provide biological improvement of union process besides improving stability of fixation.

In the current study, 19 cases of tibial or femoral shaft nonunion, which were primarily fixed with IMN, treated with augmented plating technique. Autologous iliac crest corticocancellous bone graft was applied in all patients. Complete union was achieved in 94.7% of the patients. In other words, nonunion was persisted in only one case of femoral nonunion during one year follow up after surgery. Lai et al., in a retrospective cohort study showed that the rate of union with augmented plating was significantly higher than exchange nailing in patients with aseptic atrophic femoral nonunion, especially in cases with non-isthmic femoral shaft atrophic nonunion.<sup>21</sup> Furthermore, the operation time of augmented plating was significantly shorter than the exchange nailing procedure.<sup>21</sup> Herein, the results of the current study showed similar outcomes in both femoral and tibial nonunion cases with any type of nonunion. In another study, 25 cases of femoral nonunion and 13 cases of tibial nonunion which primarily fixed with intramedullary nails, were treated with augmented plating with or without bone grafting. All of the femoral nonunion cases and 84.6% of tibial nonunion cases were healed completely with mean union time of 4.78 months.<sup>22</sup> No serious complication was detected during one year follow up, and hence they recommended this technique for treating femoral and tibial nonunion cases.<sup>22</sup> However, in the current study, augmented plating with autologous bone graft used as single procedure for all types of femoral or tibial nonunion with union rate of 94.7%. In a meta-analysis study, Luo et al. reported significantly higher union rate, shorter union time and shorter operation time and less blood loss during surgery for augmented plating compared with exchange nailing in femoral shaft nonunion cases. The rate of infection was not statistically different in both groups. In the mentioned study, primarily open fractures were excluded. Moreover, it was reported that the definite concluding still is not possible due to limited evidences.<sup>11</sup> Gao et al. used augmented locking

plate with bone graft for treatment of 13 cases of femoral shaft nonunion which primarily fixed with intramedullary nail. Bone grafting was done in all cases, autologous iliac crest bone graft was used in 11 patients and autologous non-vascularized fibular strut grafts was applied for two other patients. Only patients with nonisthmic diaphyseal with atrophic/oligotrophic nonunion were included. All the patients were healed with bony union during follow up.<sup>18</sup> In the current study, augmented plating and bone grafting were used for the both femoral and tibial fractures nonunion in any region of the bone and also for all types of nonunion including atrophic, oligotrophic or hypertrophic. Furthermore, this procedure can be applied for both primarily closed and open injuries. This technique seems to be an effective single stage method for the treatment of femoral and tibial nonunion cases with the acceptable union rate and without increasing the infection rate.

In this study, two other parameters that were investigated included Range of Motion (ROM) of knee joint compared with opposite limb and Visual Analog Scale (VAS) after one year follow up. Up to now, too little attention has been paid to knee joint ROM and VAS following augmented plating technique have been less mentioned and discussed in the literature. Jhunjhunwala et al. reported more than 120 degrees arch of motion in adjacent knee joint among 87.5% of femoral nonunion patients after augmented plating.<sup>23</sup> In comparison with the above mentioned study, in the present study, in addition to the assessment of knee range of motion among femoral and tibial nonunion cases, Visual Analog Scale (VAS) was measured. According to the results, VAS was (31±18.8) after one year follow up was (31±18.8). Decrement of active knee range of motion was more than 20% compared with the opposite side in 47.4% of patients. Loss of knee joint ROM among femoral nonunion cases were 53.8% and for tibial nonunion cases were 33.3%. It might be due to the prolonged interval time between the first and second surgeries. Furthermore, adherence and contracture of quadriceps system plays a significant role in causing this complication and makes it more frequent in nonunion of femoral shaft fracture.

## Conclusions

According to the results, single stage augmented plating with locking plates combined with autologous bone grafting can be used as a useful method in the treatment of femoral or

tibial nonunion cases previously fixed with IMN. This technique could also be useful in the management of all types of nonunion with the least risk of infection and other complications.

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None.

### Authors' Contribution

All authors pass the four criteria for authorship contribution based on the International Committee of Medical Journal Editors (ICMJE) recommendations.

### Conflict of Interests

The author(s) declared no potential conflicts of interests with respect to the research, authorship, and/or publication of this article.

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