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Effect of bone grafting on bone union in exchange nailing for the treatment of femoral shaft nonunions

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ABSTRACT

OBJECTIVE: This study aims to investigate the effect of bone grafting on the bone union in exchange nailing (EN) for the treatment of femoral shaft nonunions.

METHODS: A total of 26 patients (16 male) were included in this study. The mean age of the patients was 36.1±9.3. Bone grafts were used in 8 patients (bone graft group), and EN was performed without bone grafting (no bone graft group) in 18 patients. Etiology, fracture type, location, and classification of the fractures at the time of initial injury were evaluated. The reduction type (open or closed) and locking status of the nails were also noted. Nonunion types were recorded. In the bone grafting group, iliac bone autografts were used in seven patients and a synthetic bone graft was used in one patient. Following EN, the presence and duration of bone union, and the increase in the nails' diameter were analyzed for each group and compared.

RESULTS: Union rates were 100% and 94.4% in bone grafting and no bone grafting groups, respectively. The mean union period was not significant between the groups (22.5 and 16.5 months, respectively). The mean increase in the nail diameter was 1.88 mm in the bone graft group and 2.00 mm in the no bone graft group ($p>0.05$).

CONCLUSION: This study demonstrated that high union rates can be achieved with EN by means of using larger diameter nails with or without bone grafting in the management of femoral shaft nonunions, and bone grafting had no significant effect on union rates and periods.

Keywords: Bone grafting; exchange nailing; femoral shaft nonunion; intramedullary nailing.

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Intramedullary nailing (IMN) with reaming has been known as an efficient treatment method for fractures of the femoral shaft [1, 2]. Fractures of the subtrochanteric region, open fractures, fractures due to high energy trauma, transverse fracture pattern, using small diameter nails, nailing without reaming, improper insertion of the nail, and inadequate reduction of the fracture were associated with increased nonunion rates [3]. Studies have shown that exchange nailing (EN) is a successful procedure for nonunion of the femoral shaft fractures treated with IMN previously [4–6]. Although bone grafting with EN has been reported to induce fracture healing and has a positive effect on healing [7–9], there is no consensus yet and indications of bone grafting during EN still remain unclear [10, 11].

Autografts and allografts both can be viable options for bone grafting in the management of nonunion. Using the iliac bone autograft for external grafting in

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nonunion of long bones is still considered the gold standard and has a positive effect on fracture union. However, it has certain disadvantages such as time consumption and associated complications such as donor site morbidity and increased bleeding [12]. The risk of donor site morbidity can be eliminated by using allografts, however, they may lead to disease transmission [13]. On the other hand, the lack of both osteoinductive and osteogenic activities, and the high costs of synthetic bones remain a big concern [14].

The placement method of bone graft is also an issue that has come to the fore in recent years. Intramedullary autografting is a newly described method. The most important advantage of it is that it does not cause donor site morbidity, however, special apparatus is required for the procedure, and the amount of grafts obtained is limited and costly. Furthermore, it was associated with some serious complications albeit at a low rate [15]. In the treatment of femoral nonunion, graft-free procedures should be preferred as much as possible to avoid the negative effects of all kinds of bone grafting methods. The controversy of bone grafting in the treatment of femoral nonunion with EN reveals that this is a treasured matter.

To the best of our knowledge, there is no comparative study in the literature for bone grafting during the treatment of femoral shaft nonunions with EN. In this study, we aimed to investigate the union rates and periods with or without bone grafting in the treatment of femoral shaft nonunions managed with EN. We hypothesized that bone grafting has a significant effect on union rates and periods.

MATERIALS AND METHODS

Clinical and radiological records of the patients who underwent EN with the diagnosis of femoral shaft nonunion between 2012 and 2019 were retrospectively analyzed. The patients who were >17 years old, and had more than 12 months follow-up period with aseptic nonunion were included in the study. The patients diagnosed with septic nonunion and treated for pathological fractures were excluded. The femoral shaft fracture was considered as nonunion in the absence of radiologic evidence of fracture union at less than two cortexes after the 6th month of follow-up postoperatively. Before the EN procedure, infection was determined by using laboratory markers and clinical examination. Preoperative white blood cell count (WBC), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) levels were evaluated. Clinical considerations for infection were the presence of a sinus tract and signs of local inflammation at the surgical site such as redness, heat, and swelling.

Highlight key points

- Reamed intramedullary nailing (IMN) is highly effective for treating femoral shaft fractures and promoting union.
- Certain factors like poor fracture patterns, small diameter nails, lack of reaming, and improper nail insertion may lead to nonunion (NU) after poor reduction.
- Exchange nailing (EN) alone has proven successful for femoral shaft fractures without prior IMN treatment.
- While using grafts with EN can positively impact fracture healing, there is still no consensus on their combined use, particularly in treating femoral NU with EN, and limited comparative studies exist in the literature.

The cases were divided into two groups "grafting group" (GG) and "no grafting group" (NGG). In GG graft augmentation was performed, while in NGG no graft was used during EN. Fractures were classified according to the AO classification system, according to which there were one A3, one B2, one C1, one C2, and four C3 type femoral shaft fractures in the grafted group, while the non-grafted group had four A1, four A2, one A3, three B1, three B2, one B3, and two C1 type fractures.

EN procedure was performed by different surgeons. The cases were operated under either spinal or general anesthesia on the standard operating table in lateral decubitus position. After removing the previously implanted nails, a five- to ten-mm lateral longitudinal incision was made over the nonunion site on the femur. Fibrous tissues from the nonunion site were removed, and decortication of the fracture sites was performed. At least five specimens were obtained around the nonunion site, from the extracted nail and reaming materials for both aerobic and anaerobic cultures in order to determine any infection. One specimen was sent for frozen section analysis intraoperatively. Infection was considered if equal or more than 5 polymorphonuclear leukocytes were seen per high-power field in the frozen specimen. If the infection was detected during nonunion surgery, the EN procedure did not proceed with the new nail. After removing the old nail, an external fixator was performed in order to achieve fracture stability. Aggressive debridement was performed and antibiotic handmade spacers were applied to the nonunion site.

When the infection was ruled out, reduction of the fracture was performed and the femoral canal was reamed two to four mm more than the extracted nail diameter according to its condition. A femoral nail that had a 1-mm smaller diameter than the diameter of the last reamer was inserted into the femoral canal, and static locking screws were inserted in all cases. Bone grafting was performed in the presence of a bone defect of more than 2 mm regardless of the nonunion type. An autograft that was obtained from the ipsilateral iliac bone was used in seven cases and a synthetic allograft graft was used in only one case. Grafts were inserted into the defective area on the femur.

The patients were examined at the 2nd and 6th weeks, and at the 3rd, 6th, and 12th months postoperatively. Partial weight bearing was allowed after the postoperative 2nd week as tolerated. Full weight bearing was allowed when the union of the femoral fracture was confirmed radiologically.

Union after EN was defined as the absence of pain with full weight-bearing, and the presence of the contact of three cortexes at the fracture site in anteroposterior and lateral radiographs. The presence and duration of the union in both groups were statistically compared. The Helsinki principles were followed, and the study was approved by the Izmir Katip Celebi University Ethics Committee (approval no/date: 741/18.06.2020).

Statistical Method

The SPSS 22.0 program was used in statistical analysis (SPSS, Chicago, IL, USA). Differences between the two groups were analyzed using descriptive data analysis, the average, standard deviation, median, lowest, highest, frequency, and ratio were obtained. The Kolmogorov-Smirnov test was used to measure variable distributions. The Mann–Whitney U test was used for quantitative analysis of independent data, which were then assessed using the chi-square test. The Fisher's test was used when the chi-square test conditions were not provided. Survival analysis was performed using the log-rank test for univariate analysis and Cox model for multivariate analysis. A p-value of <0.05 was considered statistically significant.

RESULTS

Based on the inclusion and exclusion criteria, this study included a total of 26 patients (18 men). The mean age of the patients was 36.1±9.3 (range, 18–54) years. All cases were followed up for an average of 19.1±3.1 (range, 9–36) months. Clinicodemographic information of the patients is given in Table 1.

Table 1. Clinicodemographic information of the patients regarding the initial surgery

	Graft group (n=8)	No graftgroup (n=18)	p
Mean age	34.2±11.4	37.1±9.3	0.531
Gender, n			0.671
Male	6	12	
Female	2	6	
Side, n			0.395
Right	3	10	
Left	5	8	
Fracture location, n (%)			0.597
Isthmic	4 (50)	12 (67)	
Nonisthmic	4 (50)	6 (33)	
Etiology of the fracture, n			
MVA	5	14	
Fall	0	2	
Gunshot	3	2	
Fracture type, n			**0.006**
Open	5	2	
Closed	3	16	
Reduction type, n (%)			**0.049**
Open	6 (75)	6 (33)	
Closed	2 (25)	12 (67)	

Statistically significant results are given in bold. MVA: Motor Vehicle Accident.

The GG included eight patients, while the NGG consisted of 18 patients. There was no significant difference in the time from the first surgery to nail replacement in both groups. Bone union was achieved in all eight patients in the GG, while out of one patient, 17 were in the NGG (100% vs. 94.4%, p=0.497). The patient with nonunion in the NGG had an open fracture in the infra-isthmic region as a result of a gunshot wound before the initial surgery (Fig. 1, 2). Mean union time was 22.5±10.23 (range 9–36) weeks in the GG. In NGG, it was 16.5±5.36 (10–28) weeks (p=0.196). The mean increase in nail diameter in EN surgery was similar between both groups (Table 2). Any complication related to the donor site was not observed in GG after EN surgery.

DISCUSSION

The most important factors that influence the development of nonunion are the type of the first damage location and type of the fracture, the medical condition of the patient, and the treatment method of the fracture.

TABLE 2. Datum regarding the exchange nailing surgery

	Graft group (n=8)	No graftgroup (n=18)	p
Nonunion type, n (%)			0.540
Hypertrofic	7 (88)	17 (94)	
Atrofic	1 (12)	1 (6)	
Period between initial surgery and EN (month)	10.5±5.7	13.0±13.3	0.160
Mean increase in nail diameter (mm)	2.0 (1–3)	1.9 (1–3)	0.330
Number of patients withbone union n (%)	8 (100)	17 (94.4)	0.126

EN: Exchange nailing.

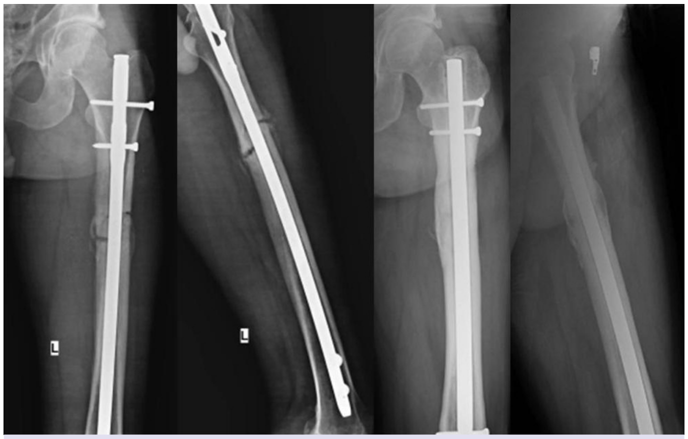

FIGURE 1. A 24-year-old man sustained a left open femoral 32B2 fracture in the supra isthmic region. Nonunion was observed in the ninth month after intramedullary nailing. Bone union was achieved at postoperative 11th month by means of EN using 2 mm larger diameter nail and iliac bone grafting.

FIGURE 2. A 39-year-old man sustained from left 32B3 closed femoral shaft fracture in isthmic- an infra-isthmic region. Nonunion was observed after initial intramedullary nailing at the 11th month postoperatively. Bone union was achieved after EN by using 2 mm larger diameter nail without bone grafting.

The first three are the factors that are not surgeon-dependent. If there is no large bone defect in both hypertrophic and atrophic aseptic nonunion, treatment with EN seems to be the most appropriate method with a success rate from 72% to 100% [4, 16, 17]. Especially in diaphyseal hypertrophic nonunions, the lack of bone loss increases success rates. However, there are also studies in the literature stating that this method alone is not very successful [10, 18]. Hierholzer et al. [4] underlined that the key step to success is not opening the fracture site. They also emphasized the importance of correcting the axis and rotation of the extremity, performing a larger diameter nail after reaming and inserting the dynamic locking screw in the treatment of aseptic femoral shaft nonunions [4]. In our patients, the union was achieved in 25 (96.1%) of 26 patients through EN. In contrast, in our series, static locking screws were applied after the reduction of the fracture in all patients. Although static locking provides better stabilization and allows early load bearing, it may lead to delayed union or nonunion if the screws are left in place for a long period, and dynamization may become necessary. Nevertheless, we believe that allowing early load bearing to our patients by means of static locking had a positive effect on fracture healing, by providing sufficient compression at the fracture site.

Bone grafting alone has been reported to be ineffective in the treatment of femoral shaft nonunions [9, 19]. In the literature, there are some hesitations about the use of bone grafts while performing EN. It is advocated that grafting should be included in EN procedure in cases where there is bone loss and the gap between the fragments is more than two centimeters or 50% of the cortical diameter [16, 20]. Apart from this, there are opinions stating that autologous bone grafting (ABG) is necessary to manage atrophic nonunions due to the low osteogenic activity [12, 19]. Osteogenic and osteoinductive effects are encountered as a result of autografting with the transfer of stem cells and growth factors; along with its scaffold-like structure, an osteoconductive effect occurs and all of these contribute positively to the union. The negative aspect of ABG is donor site morbidity. On the other hand, allografts carry the risk of disease transmission. The disadvantages of synthetic bone grafts are the lack of osteogenic and osteoinductive effects and high cost [19].

In EN, it has been reported that ABG with reamed femoral canal material without opening the nonunion site was found to be superior to open bone grafting. However, using this method for large bone defects may be insufficient [21, 22]. A large butterfly fragment can lead to soft tissue interposition and cause nonunion due to interruption of the endosteal blood supply. In these cases, stimulation of the fracture healing by grafting during EN has been recommended [9]. Furlong et al. [7] believed that the effect of internal bone grafting with reaming is insufficient because intact fibrous tissue in the nonunion region prevents the grafts from reaching the periosteal area. The authors stated that external autografting might be more effective. Although they were unable to demonstrate statistical evidence, they reported that the union was faster in cases where autograft was applied by linking it to the advanced stimulation of the periosteal healing process. Finally, the authors stated that ABG should be performed in the management of femoral shaft nonunions, and dynamization should also be performed when necessary in follow-ups [7]. Wu [6] performed open ABG during EN in 16 of 19 cases, Weresh et al. [10] in three-quarters of the cases, and Harper [8] in five of eight cases. However, these authors did not define detailed indications for open ABG. Therefore, certain indications for open ABG remain unclear in this regard. In the present study, although it was not statistically significant, the union time was longer in GG. This finding may mean that opening of the nonunion site may negatively affect fracture healing.

In our study, similar union rates and the period between the two groups have led to the conclusion that EN alone may be sufficient in the treatment of femoral nonunions. The presence of one atrophic nonunion in each group may prevent a reliable comparison. However, fracture healing was achieved in both cases. Our mean 19.1 months union period may seem to be long. However, if the final goal is to achieve the union, we believe that it should wait for a sufficiently long time before additional interventions.

Although EN alone can show high success rates, when there is inadequate stability, particularly in nonisthmic diaphyseal fractures, fracture healing may be negatively affected. [23, 24]. In our study, since a good union rate was obtained with EN in the nonisthmic region in both groups, we believe that EN may also be used for nonunions in this region with stable fixation.

The nail diameter that should be increased during EN nailing is unclear. Although some authors believe that it is sufficient to insert one mm larger diameter nail, many argue that the increase in diameter should not be less than 2 mm [4, 6, 17, 25]. A larger diameter nail increases the strength of the nail, and better stability can be achieved with a reduced risk of bending and breaking. Another positive aspect of a larger diameter nail application is thought to be the increase in periosteal blood supply with the increase in the amount of reaming, and the formation of large amounts of bone grafts [11, 25]. During EN procedure, Shroeder et al. [25] implanted at least 2 mm larger nails than the previous nail (an average of 2.65 mm), reaming the femoral canal at least 1 mm more than the diameter of the nail. With this approach, the authors achieved 91% union rates. Similarly, Swanson et al. [17] reported that the union rate was 100% with the use of 2 mm larger nails than the initial nails. Apart from our cases, 28% of their patients underwent dynamization. Wu and Chen [21] stated that increased nail diameter is more effective than using bone graft in the management of femoral shaft nonunions [6]. Using a 2 mm larger nail for the nonunions of the isthmic area, reaming one mm more than the inserted nail diameter, and changing the location of the locking screws by means of using different nails from different manufacturers would increase the stability [11]. In our cases, an average of 1.88 mm larger nails were used in GG, and 2 mm larger nails were used in NGG by means of reaming the femoral canal 1 mm larger than the diameter of the inserted nail.

The limitations of our study were its retrospective design, a relatively small number of cases, and the lack of a balanced number of compared groups. In addition, regarding the initial surgery, the distribution of the patients was heterogeneous in terms of fracture type and fracture reduction (open or closed). Another shortcoming is that the issue of atrophic nonunions could not be properly evaluated, since there were only two cases.

Conclusion

This study demonstrated that high union rates can be achieved with EN by means of using larger diameter nails with or without bone grafting in the management of femoral shaft nonunions, and bone grafting had no significant effect on union rates and periods. However, further prospective randomized controlled studies with a larger number of cases are needed in this regard.

Ethics Committee Approval: The Izmir Katip Celebi University Non-interventional Clinical Research Ethics Committee granted approval for this study (date: 18.06.2020, number: 741).

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