Plate augmentation leaving the nail in situ and bone grafting for the treatment of nonunited diaphyseal fractures

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Background
Intramedullary nailing (IMN) is now the standard treatment for diaphyseal fractures. Despite recent advances in nailing techniques and designs, some cases of nonunion are still encountered. There are different lines of treatment for nonunion over IMN such as nail conversion to plate, exchange nailing, augmentation plating with bone grafting, and external fixation with nail retention. The aim of our study is to evaluate augmentation plating and bone grafting as a method of treatment for nonunited diaphyseal fractures over IMN.
Patients and methods
Eleven patients were included in this study. They were nine men and two women; their ages averaged 41 (18–54) years. The femur was affected in three cases, the tibia in six cases, and the humerus in two cases; all of them were treated by augmentation plating and bone graft.
Results
The follow-up duration averaged 14 (range: 9–24) months; union was achieved in all cases without complications of infection, implant failure, nonunion, or joint stiffness.
Conclusion
Augmentation plating and bone graft represents a good solution for the treatment of nonunited diaphyseal fractures over IMN

Keywords:
augmentation plating, intramedullary nails, nonunion

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Introduction

Intramedullary nails (IMN) are now the standard treatment for diaphyseal fractures of long bones; despite recent advances in techniques and designs of nails, some cases of nonunion are still encountered. The causes of nonunion following IMN as summarized by Said *et al.* [1] are unstable fixation because of undersized nails, comminution, or poor reduction or devitalization of the soft tissue envelope by trauma or surgery. Choi and Kim [2] concluded that the most important factor of the nonunion over IMN was instability at the fracture site. Many lines of treatment have been described for the treatment of nonunited diaphyseal fractures over IMN. Conversion of nail to plate with grafting was first described for excision of nonunion, closure of gaps, and rigid fixation [3]. Exchange nailing is the most accepted line of treatment; it obviates the need for graft, and the retained nail maintains alignment and stability of the fracture [4–7]. Augmentation plating with grafting combines the advantage of retaining the nail with its role in intramedullary stability and alignment and the rigidity of fixation with plates [8–12]. Park *et al.* [13], in their cadaveric study on a fracture model of the femur fixed with IMN in one group and IMN and an augmentation plate in the other group, found a 2.5-fold increase in bending stiffness and a 3.3-fold increase in torsional stiffness in plate augmentation, leaving the nail *in situ* compared with an interlocking nail only in the distal third fracture of the femur. Augmentative Ilizarov external fixation is retained for resistant cases of nonunion for closure of large gaps from without and in the presence of excessive scarring [14]. In our study, we used augmentation plating with bone grafting for the treatment of nonunited diaphyseal fractures over IMN.

Patients and methods

Eleven cases with nonunited diaphyseal fractures fixed with IMN were included in this study (Table 1); all of them were operated by augmentation plates and bone graft between January 2010 and January 2012 in the Orthopedic Surgery Department, Zagazig University. In three of these patients, the first operation of IMN was performed in our department and the remaining eight cases were referred from other hospitals. The

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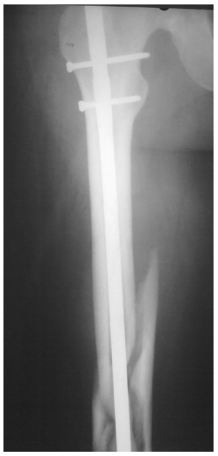
average age of the patients was 41 (range: 18–54) years; there were nine men and two women. The femur was affected in three cases, the tibia in six cases, and the humerus in three cases. A nonunion was defined by persistent pain at the fracture site combined with the absence of progressive healing on three consecutive radiographs taken at 1-month intervals or failure to unite at 6 months after surgery. The presence of infection was excluded by preoperative laboratory investigations (erythrocyte sedimentation rate and C-reactive protein). The nonunion was hypertrophic in one case and oligotrophic in 10 cases. The mean time from primary nailing to plate augmentation and bone grafting averaged 8 (range: 5–14) months. All our cases were operated by plating and corticocancellous bone grafts. Dynamic compression plates (DCP) were used in 10 cases and a locked plate in one case.

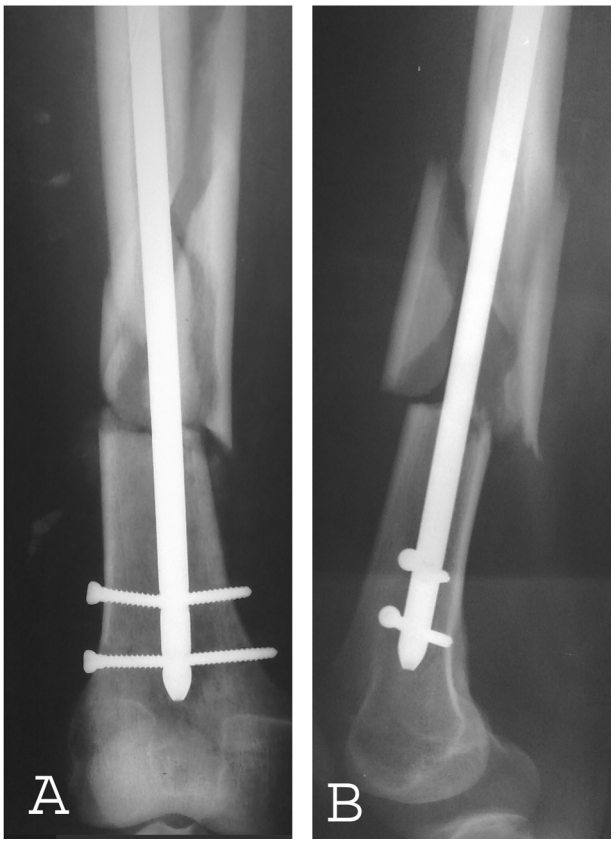
Operative technique: the fracture was exposed, surfaces rawed, bone ends were curetted, and intervening soft tissues were removed. Plates were applied over the retained IMN. On exposure of the fracture, visible motion was noted at the fracture site that disappeared after application of the plate. In femoral cases, broad DCP 6–10 holes were used and the eccentric position of holes enabled the placement of screws on both sides of the nail, especially in the undersized nail (Figs. 1–5). In the tibia, narrow DCP 6–8 was used in all cases, except in one case, where a long anatomical locked plate was used (Figs. 6–11). In the case of a locked plate when the screw heads are locked in the threaded holes, the purchase of screws in the bone cannot be

Figure 1



Comminuted fracture femur fixed with an undersized interlocking nail.

Figure 2



Three months after the operation, with delayed union and implant failure. (A&B) Three months after the operation, with delayed union and implant failure.

Table 1 Table of our cases

Number of cases	Age	Sex	Bone	Time from injury/month	Procedure	Union after surgery/month	Follow-up/month
1	47	Male	Femur	11	Plate +bone graft	4	12
2	42	Male	Femur	12	Plate +bone graft	5	24
3	53	Female	Humerus	6	Plate +bone graft	4	12
4	54	Male	Tibia	6	Plate +bone graft	6	15
5	18	Male	Tibia	5	Plate +bone graft	4	18
6	37	Male	Tibia	7	Plate +bone graft	4	12
7	38	Male	Tibia	6	Locked plate +bone graft	5	18
8	33	Male	Femur	14	Plate +bone graft	4	12
9	48	Female	Humerus	8	Plate +bone graft	5	9
10	45	Male	Tibia	6	Plate +bone graft	6	12
11	38	Male	Tibia	8	Plate +bone graft	5	12

Figure 3

Twelve months after the operative, with hypertrophic nonunion and implant failure.

Figure 4

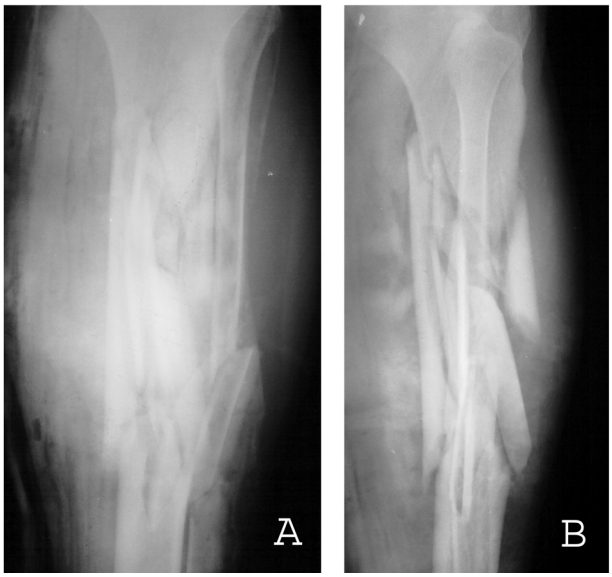
Augmentation plate with a bone graft – 6 months after the operation.

guaranteed. In the case of two humeral nonunions, narrow DCP 4 and 6 holes were used; in one case, oblique position of the plate facilitated the placement of screws to one side of the nail proximal to the fracture and on the other side distally. All cases were followed up monthly until complete union; the average follow-up period was 14 (range: 9–24) months.

Figure 5

Solid union – 1 year after the operation.

Figure 6



Open comminuted fracture tibia.

Results

For augmentation plating and grafting, the operative time averaged 75, (range: 50–120) min, and blood loss averaged 300 (range: 200–500) ml. There were no intraoperative complications of drill or tape

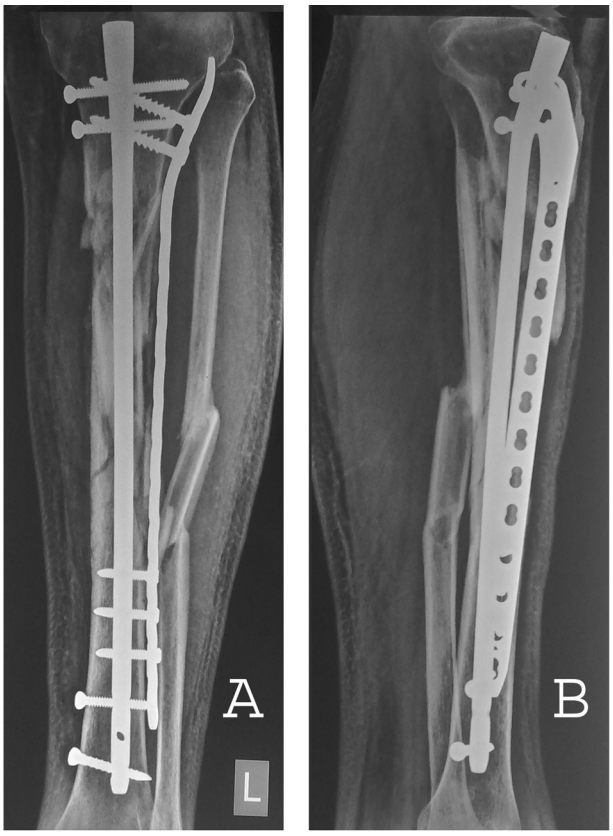
Figure 7

Fixation with interlocking nail and circulage – 6 months after the operation.

Figure 8

Atrophic nonunion – 6 months after the operation.

Figure 9



Augmentation with a lock plate and a bone graft – 6 weeks after the operation.

breakage. Follow-up duration averaged 14 (range: 9–24) months. Union occurred in all 11 (100%) cases without any further surgical intervention. Pain and tenderness around the fracture site improved within an average of 2 (average: 2–3 months), callus appeared within an average of 2.5 (range: 2–4) months, and solid union occurred within an average of 4.7 (range 4–6) months. No cases of infection, implant failure, nonunion, or joint stiffness were encountered in our study.

Discussion

Nonunion over IMN is a challenge; many factors have been considered to cause nonunion such as lack of stability because of comminution or a wide medullary canal around an undersized nail or devitalization of soft tissue envelope in high-velocity trauma. In our study, both factors were encountered: lack of stability with visible motion at the fracture site in all cases (Figs. 1–5) and soft tissue devitalization in some cases (Figs. 6–11).

Many lines of treatment have been described for the treatment of nonunion over IMN. Exchange nailing is the most accepted line of treatment; it obviates the

Figure 10

Union 3 months after the operation.

Figure 11

Solid union 6 months after the operation.

need for grafting, there is less blood loss, less extensive dissection, and rapid rehabilitation, but it is not suitable when there is comminution or gap nonunion. Conversion of a nail to a plate is more extensive, there is more blood loss, and lost previous stability by nail.. External fixation with Ilizarov with the nail *in situ* is suitable in large defects and poor soft tissue envelope. The use of an augmentation plate has the advantage of conferring more interfragmentary stability as the retained nail maintains axial stability and alignment of the bone and there are less dissection and blood loss as in ordinary planting. Also, the presence of a team, composed of two surgeons for exposure of the fracture and obtaining the iliac graft, shortens the operative time and reduces blood loss.

All of our cases achieved radiological union on an average of 4.7 months and this is nearly comparable with the results obtained by Said *et al.* [1] in their study of 14 cases of nonunited femoral fractures over IMN and union occurred on average at 4.3 months; the difference may be related to the fact that our study included not only femoral cases but also tibial and humeral cases, and the tibia is famous of delayed union.

Choi and Kim [10], in their study on 15 cases of nonunited femoral fractures over IMN, reported achievement of radiological union in their patients on average at 7.2 months; this longer duration may be related to difficulty in the cases included in their study. Patients included in their study had undergone about 1–3 previous operations and had been operated on average 10 months after the primary nailing.

In our study and studies carried out by Said *et al.* [1], Nadkarni *et al.* [8], and Choi and Kim [10], healing occurred in all cases (100%) without any further surgical intervention, with some difference in the duration of healing, but in studies carried out on exchange nailing by Hak *et al.* [4], Furlong *et al.* [5], and Weresh *et al.* [15], nonunion ranged from 4 to 53% and all of these patients required further surgical intervention. This finding confirms the superiority of augmentation plating and grafting over exchange nailing only.

Nadkarni *et al.* [8], in their study of 11 cases of nonunion over IMN in femoral tibial and femoral fractures, used locked plates and bone grafting, leaving the nail *in situ* with union in all cases on an average of 6.2 months. We used a locked plate in one

tibial fracture case and we found that a locked plate has the advantage of unicortical fixation, especially in the presence of a medullary fitting nail, but has one disadvantage that when the screw locks into the plate, the purchase of the screw in the bone cannot be guaranteed; we preferred the bone use of DCP.

In some fractures with marked comminution, healing was not anticipated after nailing, but the aim was to splint the fracture until an improvement in soft tissue condition and transformation of a multifragmentary fracture into two or three fragments; then, the procedure of augmentation plating and grafting is performed. In these situations, we can consider primary nailing and secondary plating and grafting as a two-stage operation.

There was controversy in terms of plating and periosteal stripping following IMN. According to the study by Cole [16], the blood supply recovered within 2 weeks in all cortical areas, including the periosteal and endosteal area, after the insertion of a reamed or an undreamed nail. Wolnisky *et al.* [17] reported that blood supply would be recovered by 6–12 weeks. Thus, problems related to insufficient blood supply will not arise if sufficient time is allowed to pass between two procedures.

Conclusion

Argumentation plating and bone graft is a good solution for the treatment of nonunited diaphyseal fractures over IMN, especially in the presence of instability at the fracture site because of an undersized nail in a wide medullary segment or the presence of comminution or gap nonunion, a situation in which exchange nailing is not sufficient.

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Conflicts of interest
There are no conflicts of interest.

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