Augmentation plates and bone grafting for treatment of nonunited long bones fractures fixed by intramedullary nails

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Background
A delayed union was defined as when the fracture fails to unite within the expected time. Delayed union becomes nonunion when the fracture healing stops (at least 6 months). Intramedullary nailing has proven to be a good treatment option in the management of long bones fracture. The aim of this study is to obtain union in nonunited long bones fractures fixed previously by intramedullary nails by using of augmentation plating and bone grafting to obtain the best outcome.

Patients and methods
The study included 18 patients of nonunited long bones fractures fixed previously by intramedullary nails treated with augmentation plating and bone grafting with maintaining the nail in situ. Full history, clinical and radiological examination were performed. All subjects gave their informed consent prior to their inclusion in the study. Eight cases with femoral fracture nonunion were performed through the lateral approach of the femur. Seven cases of tibial fracture nonunion were performed through the anterior approach of the tibia, Three cases of humeral nonunion was performed using the posterior approach of the humerus. In the postoperatively follow-up, function was assessed using Dash score and Lower extremity functional score.

Results
There was an excellent improvement for bone union occurred to 94.4% of studied patients. Furthermore lower extremities function percent ranged between 92.5-100 with mean±SD 98.1 ± 2.56, and humerus Dash score ranged between 4.16-6.66 with mean±SD 5.41 ± 1.77. There was statistically insignificant difference between the period of nonunion bone per months and fracture bone criteria of studied patients $P>0.05$. Also, there is statistically insignificant difference between lower extremities function score percent after implant procedure and fracture bone criteria of studied patients $P > 0.05$.

Conclusion
Augmentation plating is an excellent solution for the management of nonunited nailed long bones fractures with maintaining the nail in situ, especially with instability at nonunion site and comminution or gap nonunion.

Keywords:
augmentation plating, delayed union, fractures, intramedullary nailing

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Introduction

The fracture union is one of the most outstanding healing processes of the body as it results not in a scar, but in actual repair of the injured tissue resulting in something very like the original form, it's not easy to predict its outcome, therefore this mechanism contains a lot of problems [1]. Intramedullary nails used frequently in the management of long bones fractures, especially with the advancement of new techniques of nailing and locking mechanisms. However, still nonunion occurs, depending on the type of fracture, mechanism of injury, soft tissue damage, osteoporosis in addition to inadequate reduction of the fragments and instability of the fixation [2]. Stimulating fracture healing and union is one of the common goals among orthopedic surgeons, 5–10% of all long bone fractures end in delayed union or nonunion at all [3]. Currently, several options are presented for the treatment of nonunion after intramedullary nailing, such as dynamization, reamed exchange of the nail, nail extraction followed by plate fixation, with or without use of bone graft or external fixation with compression of fracture ends. Reamed exchange of the nail is known for fewer complications and offering the benefit of early rehabilitation. However the rate of bony union reports varies, hence a better insight of fracture stabilization mechanism and biological requirements for healing has been always improving to ensure a good outcome

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in such difficult cases [4]. Augmentation plating with bone graft leaving the nail in situ as a management of nonunited long bone is an effective technique providing additional rotational stability at the site of nonunion and leaving the nail in situ adds to protect against bending forces. It can be done with minimal invasive technique allowing early rehabilitation and less morbidity [5]. Another major advantage to this process is the good surgical exposure of nonunion site to remove the fibrous tissue and refreshening fracture ends, stimulating healing and there is also the possibility for direct bone grafting [6]. Therefore, this study aimed to achieving union in nonunited long bone fractures fixed previously by intramedullary nails by use of augmentation plating and bone grafting with maintaining the intramedullary nail in situ to reach the best outcome.

Patients and methods

The study was done on 18 cases of nonunited long bones fractures previously fixed by intramedullary nails as a comperhensive study, patients were treated by augmentation plating and bone grafting in Zagazig University Hospitals during the period between June 2019 and June 2021.

Written consent was obtained from all participants.

Inclusion criteria

Patients with nonunited long bones fractures with nonunion after fixation by intramedullary nail for 6–8 months and surgically fit.

Exclusion criteria

Surgically unfit patients and patients with infection at the nonunion site.

Full history, clinical and radiological examination were performed for all studied patients. The routine laboratory investigations were performed to assess the fitness of the patient for surgical intervention.

Augmentation platting approach

Spinal anesthesia was used for 15 lower limb cases and general anesthesia was used for 3 upper limb cases. Implants were 4.5 mm Broad DCP for 7 cases, 4.5 mm Narrow DCP for 10 cases and T-plate for 1 case. The patient positioning was on a radio-lucent table to allow visualization of the fracture site by the C arm in both AP and lateral views. The used technique was fixation of fracture nonunion site by augmentation plate and bone grafting without extraction of previously installed intra-medullary nail.

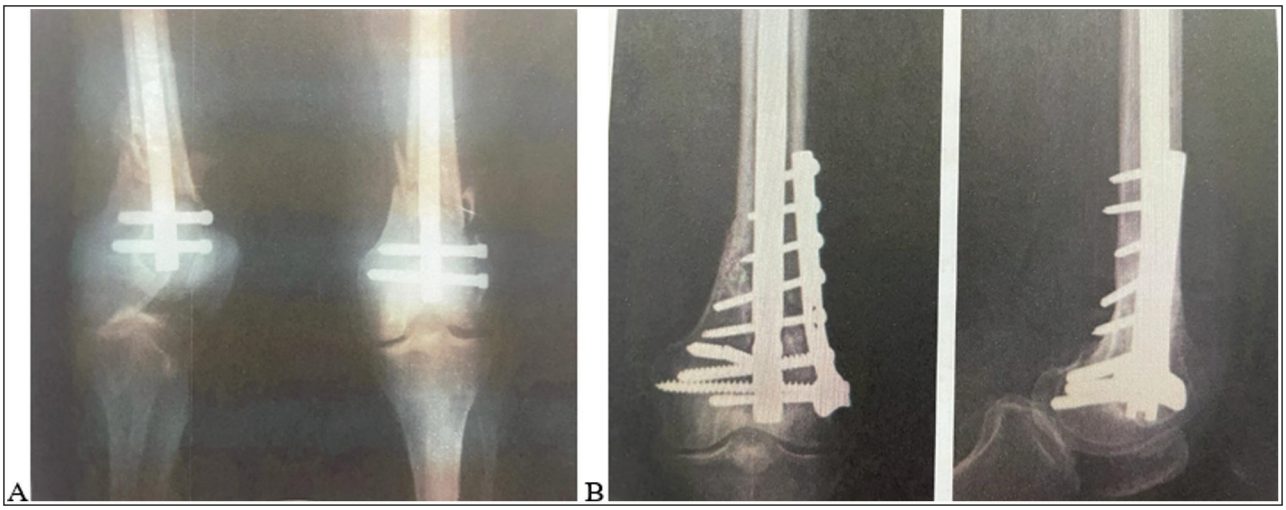
Femoral fracture nonunion

Eight cases with femoral fracture nonunion were performed through the lateral approach of the femur. A longitudinal lateral incision was done on the thigh. Ilio-tibial band was incised carefully in the same line with the skin and subcutaneous planes till the vastus lateralis muscle. A Hohmann was inserted through the muscle running the tip over the anterior aspect of the femoral shaft, then inserted a second Hohmann through the same gap and down to the femoral shaft underneath the femur. Splitting of the vastus lateralis was revealed the underlying lateral surface of the femur. Preparing of the nonunited bone ends by refreshening and removal of fibrous tissues then filling the gap with bone grafting. The plate was then placed over the lateral aspect of the femur then screws were drilled around the intramedullary nail (Fig. 1a-b)

Tibial fracture nonunion

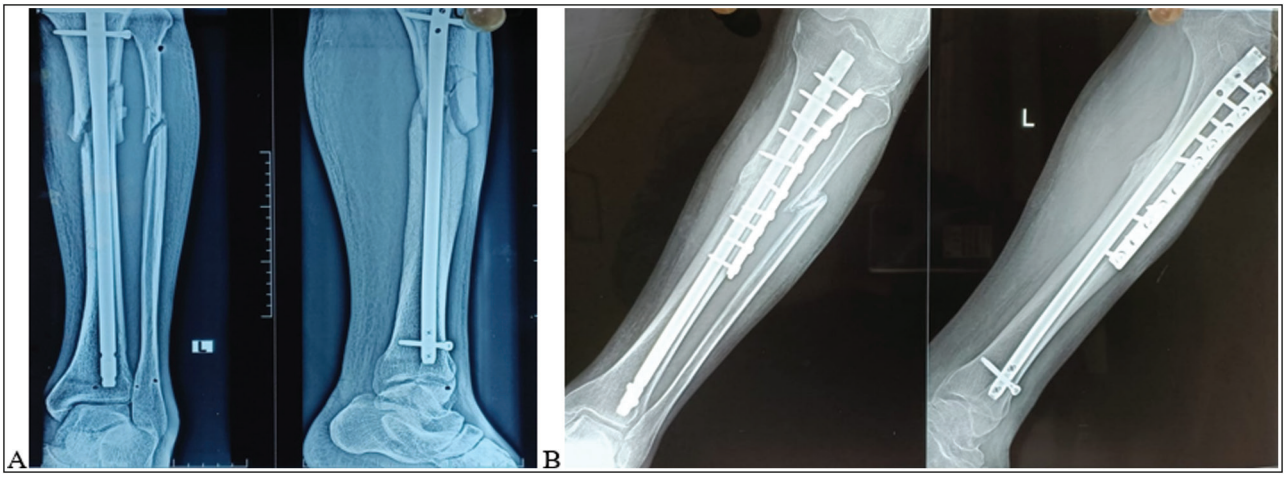
Seven cases of tibial fracture nonunion were performed through anterior approach of the tibia. Longitudinal

Figure 1



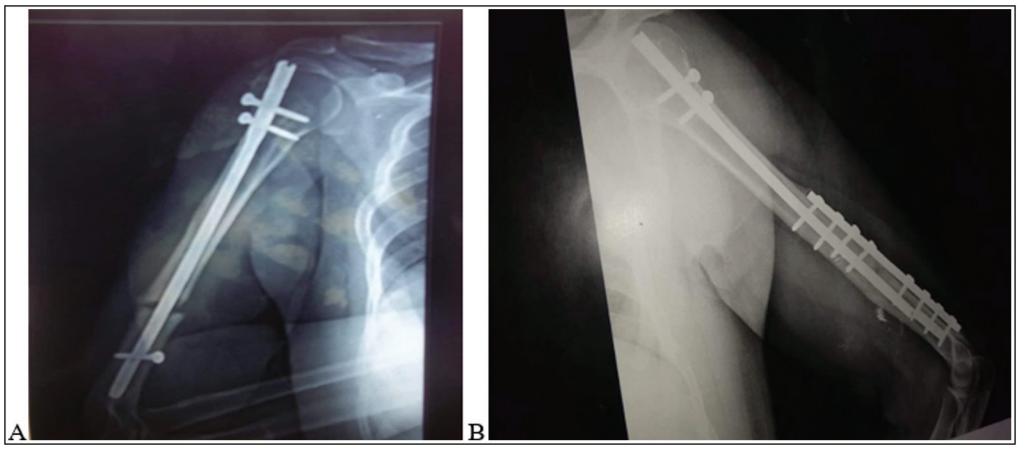
a-showing ununited supracondylar fracture fixed with supranail. b-showing united fracture after augmentation of the fracture with plate and bone graft.

Figure 2



a-showing nonunited fracture proximal tibia fixed with inter medullary nail. b-Follow-up X-ray after 1-year showing complete union of the fracture.

Figure 3



a-distal humeral ununited fracture fixed with intramedullary nail. b-showing united fracture humerus after augmentation plate and bone graft.

incision was done parallel to the anterior border of the tibia. Periosteal stripping and the tibialis anterior muscle was reflected from the periosteum and retracted to expose the lateral surface of the bone. The nonunion site of fracture edges were refreshed using the decortication technique by osteotome and hammer and removal of all fibrous tissue, the fracture gap was filled with bone graft. The plate was then placed over the lateral aspect of the tibia then screws were drilled around the intramedullary nail (Fig. 2a,b).

Humerus fracture nonunion

Three cases of nonunited humerus were performed using posterior approach of the humerus. The plate was placed over the posterior aspect of the humerus then screws were applied and drilled around the intramedullary nail after refreshening of the bone ends and filling the gap with bone graft. (Fig. 3a,b)

In all cases, iliac bone graft in the nonunion gap were implanted within the nonunion site, and then intraoperative x-ray using fluoroscopy was done to ensure good position of the plate and screws. Tightening of the screws over the graft was reassured before closure of the wound in layers.

Postoperative care

Immediate postoperative x-ray was done in both AP and lateral views to check the position of the plate, screws, and bone graft and ensure good fixation of nonunion site. Patients were discharged from the hospital after removal of the suction and improvement of the wound. IV antibiotics and analgesics were given for seven days postoperatively.

Follow-up

On each follow-up visit the patient was asked about suggestive symptoms of union as pain, weight bearing, walking distance, and return of daily activity, then the patient was examined for range of motion as well as shortening and rotational instability or deformity, radiological examination to assess union at fracture site was performed.

Statistical analysis

Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi-square test ($\chi 2$) and Fisher exact were used to calculate the difference between qualitative variables as indicated. Quantitative data were expressed as mean±SD (Standard deviation). Independent samples t-test was used to compare between two independent groups of normally distributed variables (parametric data), while Mann Whitney U test was used for nonnormally distributed Data (nonparametric data).

Results

The current study showed that, the studied age of patients ranged between 22-54 years with mean±SD 34.17 ± 9.91, 15 of them males and 3 females, 66.7% of the studied group was smokers, Lastly, 22.2% of the studied group had diabetes (Table 1).

In this study,the femoral nonunion was the most common(44.4%), followed by the tibia (38.9%), then the humerus (16.7%). Two-thirds (66.7%) of patients complained from left side fracture. Other fractures were existing among (16.7%) of patients, three quarters of fracture were Simple Type A (75%), also the level of nonunion was nonisthmic among (66.7%). Nonunion period ranged between 8 and 14 months with mean±SD 10.33 ± 2.06 (Table 2).

The attainable results showed that implant was 4.5 mm Broad DCP for (38.9%) followed by 4.5 mm Narrow DCP for(55.6%), then 5.6% 4.5 mm T plate for studied patients. The patients were followed to detect radiological union which occurred within period from 2.5 to 4.5 months with mean±SD 3.46 ± 0.58. months (Fig. 4).

Regarding postoperative complication, 1 case(5.6%) of postimplant complication was transient neuropraxia of the radial nerve and 2 cases (11.1%) donner site (iliac) superficial infection and 1femoral case had infected nonunion (5.6%) (Fig. 5).

There was an excellent improvement for bone union occurred to 94.4% of studied patients. Furthermore lower extremities function percent ranged between 92.5-100 with mean±SD 98.1 ± 2.56, and humorous Dash score ranged between 4.16-6.66 with mean±SD 5.41 ± 1.77 (Table 3).

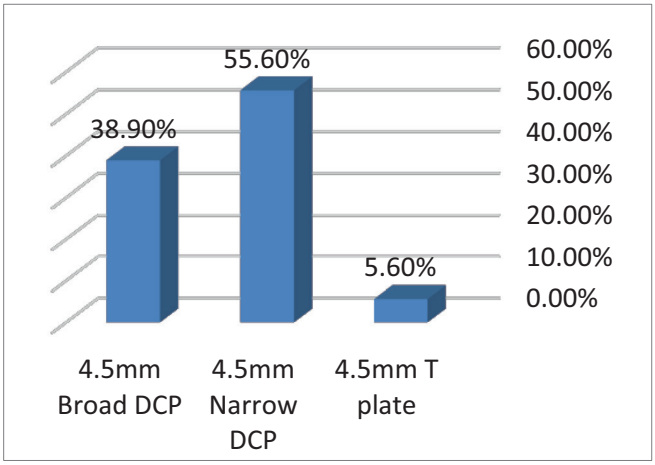
Table 1 Sociodemographic of studied group (*n* = 18)

Items	No. (%)
Age	
≥35	9 (50.0)
<35	9 (50.0)
Mean±SD	34.17 ± 9.91
Median(range)	33.5 (22–54)
Sex	
Males	15 (83.3)
Females	3 (16.7)
Smoking	
Yes	12 (66.7)
No	6 (33.3)
Associated comorbidity	
DM	4 (22.2)

Table 2 Fracture criteria of studied patients (*n* = 18)

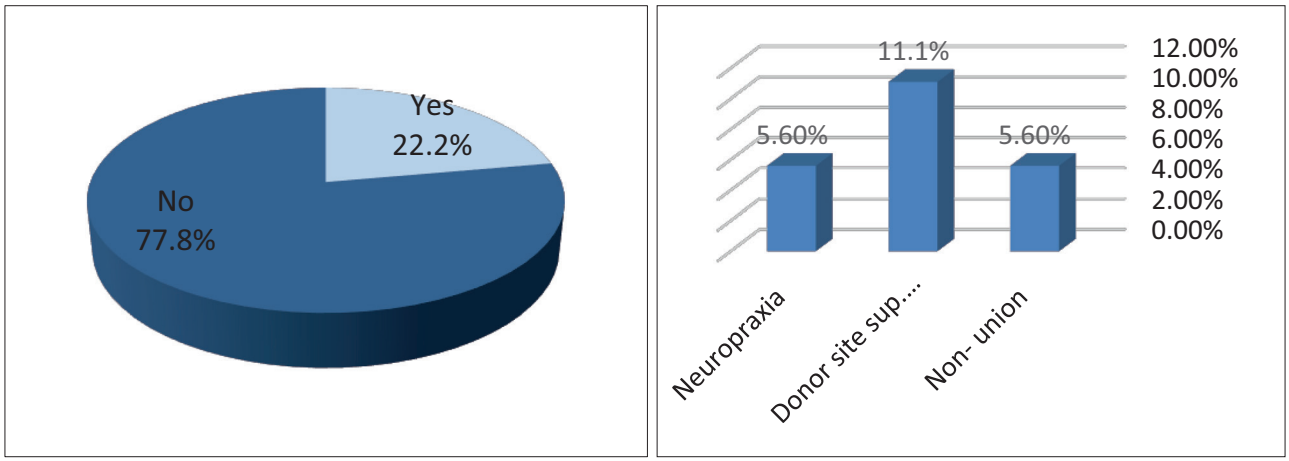
Items	No. (%)
Fractured	**bone**
Tibia	7 (38.9)
Femur	8 (44.4)
Humerus	3 (16.7)
Side of Fractured bone	
Right	6 (33.3)
Left	12 (66.7)
Other fractures	
Yes	6 (33.3)
No	12 (66.7)
Site of other fracture	
Distal radius	3 (16.7)
Femur	1 (5.6)
Clavicle	2 (11.1)
BG	
Yes	18 (100.0)
Fracture classification	
Simple Type A	14 (77.8)
Wedged B	3 (16.7)
Multi fragmentary type C	1 (5.6)
Level nonunion	
Isthmic	6 (33.3)
Nonisthmic	12 (66.7)
Nonunion period (months)	
Mean±SD	10.33 ± 2.06
Median(range)	10 (8–14)

Figure 4



Percent of implant used for bone union of studied patients.

Figure 5



Percent of postoperative complication and its types among studied patients.

Table 3 Mean, standard deviation and range lower extremities function percent, humerus dash score of studied patients after implant (*n* = 18)

Items	No. (%)
Improvement	
Bad	1 (5.6)
Excellent	17 (94.4)
Humerus Dash score(*n* = 3)	
Mean±SD	5.41 ± 1.77
Median(range)	5.41 (4.16–6.66)
Lower extremities function percent(*n* = 15)	
Mean±SD	98.1 ± 2.56
Median(range)	99.4 (92.5–100)

There was statistically insignificant difference between period of nonunion bone per months and fracture bone criteria of studied patients $P > 0.05$ (Table 4).

There is statistically insignificant difference between lower extremities function score percent after implant procedure and fracture bone criteria of studied patients $P > 0.05$ (Table 5).

Discussions

Several methods have been documented for the treatment of nonunion of long bones fractures fixed previously by intramedullary nails. Exchange nailing is one of the mostly accepted methods of treatment, but it doesn't promise more stability and it's not favorable for comminution or gap nonunion, exchange of the nail with plate is more extensive approach and with more blood loss and soft tissue injury with loss of stability of the previous nail, external fixators have the advantages in cases of infection, poor soft tissue status and in cases of large bone defects with the possibility of bone transport to compensate the defect. Augmentation plating and bone grafting is a suitable choice [7,8].

This study presented the clinical study of surgical treatment of 18 nonunited long bone fractures previously fixed by intramedullary nails and treated by augmentation plating and bone grafting without extraction of the previously installed intramedullary nail. The analysis of the results was made in the terms of age of the patients, sex, special habits, chronic illnesses, locality, laterality, level of nonunion, associated injuries, fracture classification, nonunion period, duration of treatment, results and complications.

This study, on 18 cases, the age of the patients ranged from 22 to 54 years with 9 of the patients were under 35 years and the other 9 patients were over 35 years making the mean age of 34.17 ± 9.91.

The studied patients were 15 males (83.3%) and 3 females (16.7%), 12 patients (66.7%) had the habit of smoking, 4 of the studied patients (22.2%) diabetes. Fourteen patients were classified as simple type A fracture (77.8%), 3 cases were simple type B fracture (16.7%) and 1case was Multi fragmentary type C (5.6%), The level of nonunion was either isthmic or nonisthmic, In 6 patients the nonunion level was isthmic (33.3%) and the other 12 patients (66.7%) were nonisthmic. Two patients (33.4%) had associated fractures as in three patient having distal radius fracture, the other femur fracture in one patient and fracture clavicle in two patients.

In this study, 4.5 mm Broad DCP was used in 7 patients, 10 of the patients were treated using 4.5 mm narrow DCP and 4.5 mm T plate was used in one patient. Nonunited long bones varied as 7 nonunited tibia fractures, 8 femoral nonunion and 3 humeral nonunions. All patients were previously treated by intramedullary nails and complicated by s nonunion without infection. Nonunion period ranged between

Table 4 Comparison period of nonunion bone per months regard fracture bone criteria of studied patients (*n* = 18)

Period of nonunion	No.	Period of nonunion bone per months		*U* test	*P* value
		Mean±SD	Median (range)		
Fractured bone					
Tibia	7	12±1.89	10 (8–12)	3.79	0.15
Femur	8	13.75±2.06	11.5 (10–14)		
Humerus	3	8.5±0.71	8.5 (8–9)		
Side of nonunion					
Right	6	11±2.58	11 (8–14)	0.68	0.492
Left	12	10.0±1.85	9.5 (8–13)		
Level nonunion					
Isthmic	6	9.25±1.89	8.5 (8–12)	1.37	0.17
Nonisthmic	12	10.87±2.03	10.5 (8–14)		
Others fracture					
Yes	6	13±1.41	13 (12–14)	1.85	0.064
No	12	9.8±1.75	9.5 (8–13)		
Fracture classification					
Simple type A	14	9.78±1.86	9 (8–13)	KW=2.535	0.28
Wedged B	3	12±2.83	12 (10–14)		
Multi fragmentary type C	1	12	12 (12–12)		

U Mann-Whitney u Test Kruskal-Wallis Test.

Table 5 Comparison Lower extremities function score percent regard fracture criteria of studied patients (*n* = 15)

Items	No.	Lower extremities function score percent		*U* test	*P* value
		Mean±SD	Median (range)		
Fractured bone					
Tibia	7	99.37±1.04	100 (97.5–100)	3.33	0.068
Femur	8	96.12±3.06	96 (92.5–100)		
Site of lesion					
Right	4	99±2	100 (96–100)	1.03	0.304
Left	11	97.46±2.87	98.13 (92.5–100)		
Level nonunion					
Isthmic	6	99.58±0.72	100 (98.75–100)	1.098	0.27
Nonisthmic	9	97.43±2.83	97.5 (92.5–100)		
Others fracture					
Yes	5	100±0	100 (100–100)	1.39	0.16
No	10	97.59±2.66	98.13 (92.5–100)		
Others fracture					
Distal radius	3	100	100 (100–100)	-	-
Femur	1	100	100 (100–100)		
Fracture classification					
Simple Type A	11	98.32±1.83	98.75 (96-100)	1.036	0.59
Wedged B	3	96.25±5.3	96.25 (92.5–100)		
Multifragmentary type C	1	100	100 (100-100)		
Implant					
4.5 mm Broad DCP	6	97.87±3.06	99.38 (92.5–100)	1.641	0.44
4.5 mm Narrow DCP	8	99.17±1.44	100 (97.5–100)		
4.5 mm T plate	1	96	96 (96–96)		

Mann-Whitney u Test Kruskal-Wallis Test $P > 0.05$ insignificant.

8-14 months with mean of 10.33. All patients (100%) were treated using iliac bone graft implanted in the nonunion site after fixation to promote healing. 17 patients (94.4%) had excellent union, which occurred within the period from 2.5 to 4.5 months with mean 3.46 and 1 femoral case had infected nonunion (5.6%).

These results are in agreement with Park *et al.*, [9] who showed the result of 100% radiographic consolidation in 17 patients with long bones nonunion at a mean 22.7 weeks (range 14–25 weeks) after the procedure. El Zahlawy *et al.*, [10] who revealed 100% solid union on plain radiographs (mean 6.3 months) for 34 patients.

Also, Khairy, [11] had the same result of 100% radiological union within 2-4 months with the average of 2.5 months for 11 patients with nonunited nailed long bones.

Ateschrang *et al.*, [12] who reported union in 24 out of 25 patients of nonunited nailed tibia fracture within a mean of 29 weeks of plating and patients were able to resume full previous activities. Ueng *et al.*, [13] was also able to achieve union in 100% of patients with aseptic tibial nonunion all of which were able to regain full weight bearing without pain at the fracture site within the period of average 3 months. Mohamed A *et al.*, [14] reported 100% union of 20 patients at a mean time 4.9 months (3–8 months).

Studies of augmentation plates had generally demonstrated favorable results with lower complication rates than the other available treatment options. The rotational instability has proven to be a major factor in the occurrence of nonunion, which is addressable by the additional stability of the augmentation plate with the nail remaining in situ provides a useful load-sharing tool neutralizing shear forces at nonunion site and maintaining alignment of the fracture, with the published articles showing very high success rates with or without use of autologous bone graft with low complication rates and early rehabilitation [15].

In this study, there is some points of strengths as it was a prospective study and it was done on all long bones of the body, which was liable to be fractured and be fixed with interamedullary nails.

But this study has some limitations: sample size in this study was small, and in future studies, a larger number of patients will be needed in order to increase the confidence in the final conclusions. Also, a longer follow-up will help identify remote complications that may not appear earlier. Finally, the lack of randomization is also another weak point of this clinical study.

Conclusion

Augmentation plating is an excellent solution for the management of nonunited nailed long bones fractures with the nail remaining in situ, especially with instability at nonunion site and comminution or gap nonunion.

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Nil.

Conflicts of interest

The authors have no conflict of interest regarding this manuscript.

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