RESEARCH PAPER

The Outcome of Plate Over an Intramedullary Nail in Treating Non-United Femoral Fractures

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Abstract

Background: Femoral shaft nonunion remains challenging, influenced by patient, biological, and mechanical factors, and is associated with variable outcomes despite available treatment options. This work aimed to evaluate union rate, as well as radiological and clinical outcomes, after plate augmentation (PA) with the remaining nail in cases of femoral non-unions, and to identify possible complications of the technique.

Methods: This retrospective study was carried out on 20 patients with non-union fractures treated with PA over an intramedullary nail (IMN), and included completed medical and radiological documentation. All patients were subjected to fracture level and fracture pattern, and type of non-union (Non-union was classified as oligotrophic, hypertrophic, or atrophic).

Results: Fracture Union was achieved in all patients (100%) with a mean time to union of 5.5 ± 1.14 months. The mean operative time was 103.9 ± 16.78 minutes, with a mean intraoperative blood loss of 381 ± 132.7 mL. According to Wu's criteria, radiological and clinical outcomes were excellent in 60% of patients and good in 35%. The mean follow-up duration was 29.8 ± 14.97 months.

Conclusions: PA over a retained IMN with iliac crest bone grafting achieved reliable union and good functional outcomes in aseptic femoral shaft non-union. The approach was safe, provided mechanical and biological support, and avoided the morbidity of nail removal or exchange.

Keywords: Plate Augmentation, Intramedullary Nail, Femoral Shaft Non-union, Bone Graft

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Introduction:

One of the most frequent fractures seen in orthopaedic practice is a femur shaft fracture. If treatment is not received, a fracture of the femur, the largest bone in the body and one of the main load-bearing bones in the lower extremities, can result in significant impairment [1]. Current approaches to treating femoral fractures involve stabilization with an intramedullary nail (IMN) to allow early ambulation and rapid fixation via closed reduction. Intramedullary nail (IMN) is the gold standard for treating femoral fractures and is very effective, with few side effects, when patients are carefully selected [2]. Femoral non-union is commonly defined as a fracture that does not show full healing within six months or that does not show healing progress on serial radiographs within three months. clinically defined by movement or discomfort at the fracture site. Sclerotic fracture edges, no bone across the fracture site, and persistent fracture lines are frequently seen on radiographs [3]. Depending on fracture type, surgical method, and patient-related variables such as smoking, infection, and comorbidities, the rate of femoral shaft nonunion following IMN might range from 1% to 11% [4]. Two primary categories of causes contribute to femoral shaft fracture non-union: biological factors, such as soft tissue injury and severe bone injuries, and patient-related factors, such as diabetes, smoking, and other comorbidities or fracture-related biomechanical problems, such as nail size, fracture distraction, implant breakage or comminution, position (proximal or distal), and rotational instability at the fracture site [5]. Exchange existing nail, dynamization of static interlocking nails, nail removal, plate over nail (PON) with or without bone grafting, nail replacement with a larger diameter, plate fixation with or without bone transplant, and nail removal with an external fixator are among the treatment options for femoral fractures that do not heal following IMN [6]. Despite their effectiveness, these techniques have certain drawbacks regarding mobility, surgical site morbidity, and failure risk. With union rates ranging from 96% to 100%, early reports clearly showed that reamed exchange nailing was the best treatment option for diaphyseal femoral non-union. Nevertheless, additional research on exchange nailing has revealed worse outcomes than previous studies, prompting further investigation into the best way to manage femoral shaft nonunion [7].

This work aimed to evaluate union rate, as well as radiological and clinical outcomes, after plate augmentation (PA) with the remaining nail in cases of femoral non-unions, and to identify possible complications of the technique.

Patients and Methods:

This retrospective study was carried out on 20 patients aged 18 to 70 years old, both sexes, with non-united femoral fractures, treated with PA over IMN. The study was conducted on cases operated from January 2018 to December 2024, with approval from the Ethical Committee of the Faculty of Medicine, October 6 University, Giza, Egypt (code: O6U-ERC-0069). Informed consent was obtained.

Exclusion criteria were patients with pathological fractures, active infections at the fracture site, and incomplete medical records.

Preoperatively, all patients underwent full history taking, fracture level, fracture pattern, and type of non-union (oligotrophic, hypertrophic, or atrophic). A fracture line that lasts longer than expected and has varied quantities of callus surrounding the fracture site on radiographic examination was referred to as hypertrophic non-union. Conversely, atrophic non-union was defined as increased sclerosis of the fracture edges and persistent fracture lines that did not show any callus on radiographic inspection and persisted beyond the anticipated period of union [8].Infected non-union was excluded through clinical and laboratory investigations,such as (ESR and CRP). Mechanism of injury, such as road traffic accidents (RTAs) and falling from a height (FFH). Classification of fracture according to Arbeit gemeinschaft für Osteosynthesefragen (AO) classification. Affected knee range of motion (ROM). A standard protocol was used for all patients after admission. It consisted of Proper analgesia, taking into consideration hepatic and renal function. Correction of any fluid and electrolytes imbalance after laboratory investigations by the aid of internal medicine consultations, proper control of blood sugar in diabetic patients by the use of short acting insulin [regular insulin] with detection of regular random blood sugar level every 8 hours, cardiology consultation to cardiac patient to assess their cardiac condition and their fitness for surgery, control of any other comorbidities especially chest infection and urinary tract infection, anesthesia consultation to determine patient fitness for surgery, some adjust measures were used to improve outcome. These include medical consultation if required, proper nutrition, and smoking cessation. Preoperative patient optimization was considered a priority, and the preoperative antibiotic was a 1st-generation cephalosporin, cefazolin (Zinol) 1 gram.

Intraoperatively:

Spinal or general anesthesia was used as the anesthetic approach for all patients. All patients were positioned supine on a radiolucent table. After proper incision and lateral approach in relation to the non-union site at the femur, the vastus lateralis was bluntly split to expose the site of non-union. The non-united site was then debrided with curettage as a refresh method. A drill with a thin osteotome was used to create thin layers by decortication at the different edges of the bone [posterior, lateral, and anterior edges]. The ipsilateral iliac crest was used to obtain an autogenous graft, which was placed at the site of non-union. Conventional plate of dynamic compression [DCP] type, locking plates, or low-profile plates were used in the fixation of the lateral surface of the femur. Screws of a unicortical type were used, or conventional screws were placed around IMN. Plates were used to induce axial stability at the site of non-union. Any slight motion at the fracture site disappeared completely after the fixation of the plate. Plates were used with variable holes, according to fracture pattern, location, and plate availability.

Postoperatively:

After surgery, all patients were transferred to the internal ward, with application of the following procedures: administration of antibiotic for one week in most of the cases, LMWH [40 IU enoxaparin] subcutaneously, was started 12-24 hours after surgery and continued for 14 days to protect against thromboembolic events [such as DVT and PE], determination of postoperative haemoglobin, mobilization was started one to three days after surgery to promote active movement of the hips and knees.

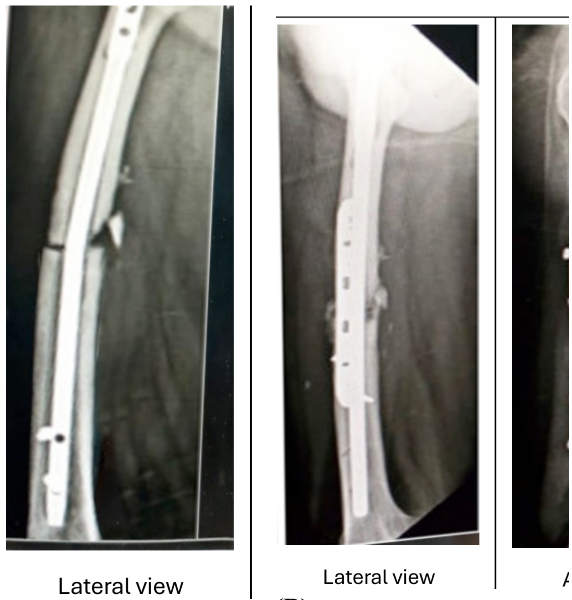
Clinical and radiological follow-up:

In the outpatient clinic, all follow-up visits were performed as follows: 2 days after postoperative removal of the surgical drain, and dressing changes every 4 days. Two weeks after surgery, the wound was re-examined, the sutures were removed, and PXR, AP, and lateral views were obtained for all patients. Partial weight bearing was advised for most patients. Six weeks after surgery, an X-ray was performed, and mobilization was encouraged. Three months after surgery, an X-ray was repeated to assess healing. In addition, weight-bearing ability was evaluated, ROM was examined, and the results were recorded. Six months after surgery, another X-ray was performed to re-check for union and the presence of any complications such as infection, implant failure, and ROM. The union was determined by the formation of a bridging callus, with resolution of the persistent fracture lines, as shown in **Figure 1 and Figure 2.** Wu's scoring system was used to assess the clinical and radiological signs of healing at the non-union site for all patients at the last recorded plain X-ray (PXR) time for each case [9]. Clinical assessment was performed to determine for any complications at the end of follow-up. Validated Arabic version of the lower extremity functional scale (LEFS), a questionnaire containing 20 questions about a person's ability to perform everyday tasks [10]. The LEFS was used to measure patients' initial function and ongoing progress at the end of follow-up [11].

(A) **(B)**

(C) **(D)**

Figure 1: A 23-year-old male developed non-union of a left femoral shaft fracture 15 months after IMN fixation and underwent revision with bone grafting and screw removal. Recovery progressed from partial to full weight bearing by 1.5 months, with radiographic union at 4.5 months. At 43 months follow-up, he had full motion and excellent function (LEFS 74/80). (A) Preoperative, (B) 2 weeks postoperative, (C) 1.5 months postoperative, and (D) At time of union



(A) **(B)**

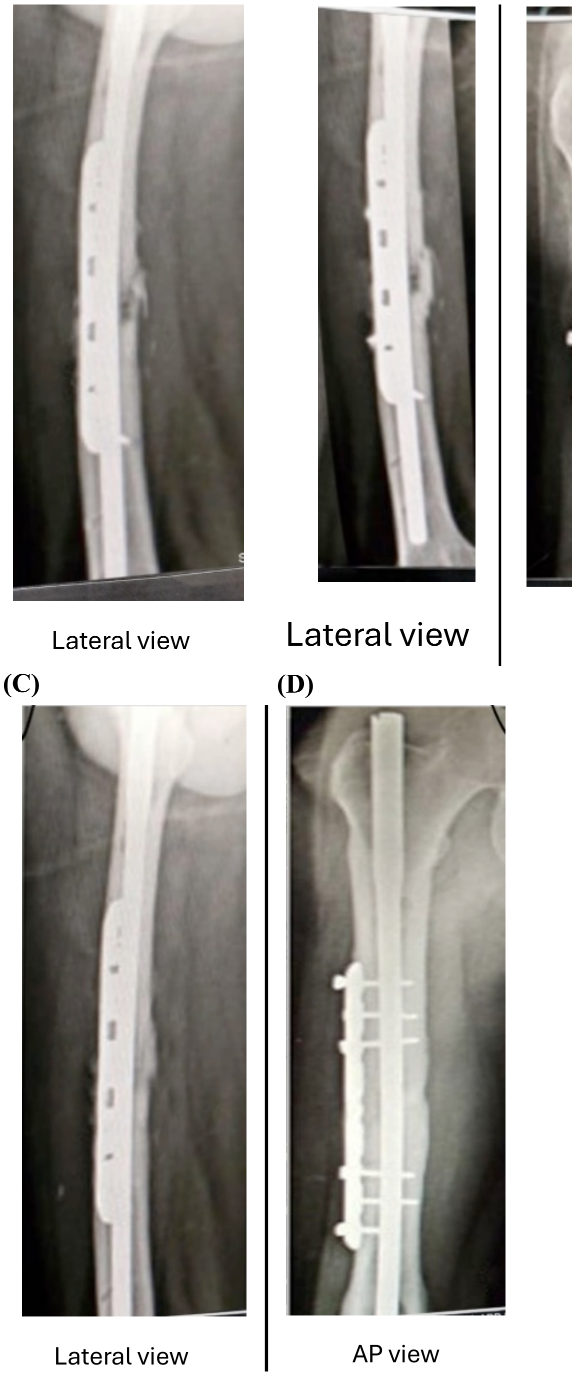


Figure 2: A 52-year-old female developed non-union of a right femoral shaft fracture 6 months after IMN fixation and underwent revision with iliac crest bone grafting and screw removal under general anesthesia. Recovery progressed from partial to full weight bearing by 1.5 months, with radiographic union at 6 months. At 48 months follow-up, she had full motion and a good functional outcome (LEFS 71/80) with only mild limitation. (A) Preoperative, (B) 2 weeks postoperative, (C) 1.5 months postoperative, (D) 3 months postoperative, and (E) 6 months postoperative

Statistical analysis:

Statistical analysis was performed using SPSS v27 (IBM©, Chicago, IL, USA). The Shapiro-Wilk test and histograms were used to assess the normality of the data distribution. Quantitative parametric data were presented as mean and standard deviation (SD) and were analyzed between two groups by unpaired t test and were analyzed among three groups or more by ANOVA (F) test with post hoc test (Tukey). Qualitative variables were presented as frequencies (%) and analyzed using the Chi-square test. A two-tailed P value ≤ 0.05 was considered statistically significant.

Results:

Demographic data, AO code, comorbidities, risk factors, non-union data and the mechanism of injury of the studied patients were enumerated at **Table 1**

Table 1: Demographic data, AO code, comorbidities, risk factors, non-union data, the mechanism of injury and type of the used nail of the studied patients

		N=20
Age (years)		38±12.98
Sex	**Male**	15(75%)
	Female	5(25%)
Weight (kg)		85.8±6.88
Length(cm)		176.1±4.8
BMI (kg/m^2)		27.3±2.19
AO code		
32-A2		2(10%)
32-A3		2(10%)
32-B2		8(40%)
32-B3		1(5%)
32-C2		7(35%)
Comorbidities and risk factors		
Smoking		6(30%)
Hypertension and smoking		3(15%)
Diabetes mellites (Type 2)		1(5%)
Non-union data		
Oligotrophic		5(25%)
Atrophic		9(45%)
Hypertrophic		6(30%)
Mechanism of injury		
RTA		16(80%)
FFH		4(20%)
Type of the used nail		
IMN		14(70%)
Retrograde nail		4(20%)
Long gamma nail		1(5%)

Short gamma nail	1(5%)

Data are presented as mean ± SD or frequency (%). BMI: Body mass index, AO: Arbeit gemeinschaft für Osteosynthesefragen, RTAs: Road Traffic Accidents, FFH: Falling from a Height, IMN: Intra medullary nail.

Fracture level, fracture pattern and time of radiological union were not significantly different related to complications. **Table 2**

Table 2: Relation between (fracture level, fracture pattern and time of radiological union) and complications

		No (n=14)	Infection (n=1)	Limited ROM (n=6)	P
Fracture level	**Middle 1/3**	12(85.71%)	0 (0%)	3 (50%)	0.426^{x2}
	Proximal 1/3	1 (7.14%)	0 (0%)	0 (0%)	
	Distal 1/3	1 (7.14%)	1 (100%)	3 (50%)	
Fracture pattern	**Butterfly segment**	6 (42.86%)	1 (100%)	2 (33.33%)	0.058^{x2}
	Commination fragments	3 (21.43%)	0 (0%)	4 (66.67%)	
	Short oblique	2 (14.29%)	0 (0%)	0 (0%)	
	Transverse	2 (14.29%)	0 (0%)	0 (0%)	
	Butterfly segment +Small fragments	1 (7.14%)	0 (0%)	0 (0%)	
Union time		5.5 ± 1.22	6 ± 0	5.5 ± 1.05	0.908^{F}

Data are presented as mean ± SD or frequency (%). X^2: Chi-square test, F: one-way Anova test. ROM: Range of Motion

Operative, clinical, preoperative, intra operative data, types of augmentation plates used, and blood transfusion were enumerated at **Table 3**

Table 3: Operative, preoperative, intra operative data, types of augmentation plates used and blood transfusion of the studied patients

		N=20
Preoperative and clinical data		
Fracture reduction during first surgery	**Closed**	18(90%)
	Open	2(10%)
Infection		0(0%)
Deformities		0(0%)
Pre-operative ROM	**Full ROM**	18(90%)
	Limited ROM	2(10%)
Time from first surgery (months)		9.8±3.25
Operative data		
Surgical drain		12(60%)
Fracture reduction		9(45%)
Intra operative complications		0(0%)
Anesthesia	**General**	15(75%)
	Spinal	5(25%)
Approach	**Direct lateral + iliac window**	20(100%)
Position	**Supine**	20(100%)
Preoperative antibiotics	**1 gram cefazolin**	20(100%)
Operative time (min)		103.9±16.78
Type of plate used	**Broad DCP**	8(40%)
	Small locked	5(25%)
	Small DCP	1(5%)
	Low profile plates	1(5%)
	Broad locked	5(25%)
Amount of blood loss(ml)		381±132.7
Blood transfusion		9(45%)

Data are presented as mean ± SD or frequency (%). ROM: Range of motion, DCP: Dynamic Compression Plate.

Post operative data, radiological and functional outcome were enumerated at **Table 4**

Table 4: Post operative data, radiological and functional outcome of studied patients

		N=20
Post operative antibiotics	**2 weeks**	1 (5%)
	1 week	19 (95%)
Dressing	**Day 2 remove drain**	12 (60%)
Suture removal	**After 2 weeks**	20 (100%)
Weight bearing	**Immediate Partial weight-bearing as tolerated, progressing to full weight-bearing**	19(95%)
Reduction quality on PXR	**Good**	20(100%)
Physiotherapy needing		15(75%)
Time of radiological union (months)		5.5±1.14
Knee ROM	**Full ROM**	14(70%)
	Limited	6(30%)
Time of follow-up (month)		29.8±14.97
Early complications		0(0%)
Late complications	**Limited ROM**	6 (30%)
	Infection	1(5%)
Radiological and clinical criteria WU's criteria from 50		
Mean ± SD		41.9 ± 4.42
Excellent		12(60%)
Good		7(35%)
Fair		1(5%)
LEFS		
Mean ± SD		72.6 ± 6.72
Mild functional limitation		12 (60%)
Moderate functional limitation		1 (5%)
Mild to moderate function limitation		2 (10%)
Full function		5 (25%)

Data are presented as mean ± SD or frequency (%). PXR: Plain X-ray, ROM: Range of Motions, LEFS: Lower Extremity Functional Scale.

Time of radiological union was not significantly different related to comorbidities, radiological, clinical criteria and non-union data. **Table 5**

Table 5: Relation between time of radiological union and co- morbidities, radiological, clinical criteria and non-union data

Co-morbidities	**HTN and smoking (n=3)**	**DM Type 2 (n=1)**	**Smoking (n=6)**	**Free (n=10)**	**P**
Time of radiological union (months)	5.5 ± 0.87	6 ± 0	5.9 ± 1	5.2 ± 1.27	0.624[F]
Radiological and clinical criteria	**Excellent (n=12)**	**Good (n=7)**		**Fair (n=1)**	**P**
Time of radiological union (months)	5.3 ± 1.23	5.6 ± 1.11		6±0	0.798[F]
Non-union data	**Oligotrophic (n=5)**	**Atrophic (n=9)**		**Hypertrophic (n=6)**	**P**
Time of radiological union (months)	5.2 ± 1.68	5.6 ± 1.08		5.5 ± 0.84	0.826[F]

Data are presented as mean ± SD. F: one-way Anova test. HTN: Hypertension, DM: Diabetes Mellitus

Time of radiological union was not significantly different related to radiological and smoking, age, mechanism of injury, non-union data. **Table 6**

Table 6: Relation between time of radiological union and smoking, age, mechanism of injury, non-union data

	Smokers (n=9)	**Not smokers (n=11)**	**P**
Time of radiological union (months)	5.8 ± 1	5.2 ± 1.23	0.295[t]

Age			
	<45 (n=14)	>45 (n=6)	P
Time of radiological union (months)	5.3 ± 1.19	5.8 ± 1.03	0.372^{t}
Mechanism of injury			
	RTA (n=16)	FFH (n=4)	P
Time of radiological union (months)	5.4 ± 1.14	5.8 ± 1.26	0.604^{t}

Data are presented as mean ± SD. t: unpaired t test. RTA: Road Traffic Accident. FFH: Fall From Height.

Time of radiological union was not significantly different related to type of plate used. **Table7**

Table 7: Relation between time of radiological union and type of plate used

	Broad locked (n=5)	Broad DCP (n=8)	Small locked (n=5)	Small DCP (n=1)	Low profile plate (n=1)	P
Time of radiological union (months)	6.1±1.34	5 ± 1.04	5.6 ±1.19	6 ± 0	5 ± 0	0.545^{F}

Data are presented as mean ± SD. F: one-way Anova test. DCP: Dynamic Compression Plate

There was no correlation between time of radiological union and (age, smoking and type of plate used). There was no correlation between time of follow-up and functional outcome. **Table 8**

Table 8: Correlation between time of radiological union, (age, smoking and type of plate used), time of follow-up and LEFS

	r	P
Time of radiological union (months)		
Age	0.297	0.204
Smoking	0.234	0.321
Type of plate used	-0.137	0.565
Time of follow-up (month)		
LEFS	0.326	0.161

r: Pearson correlation coefficient. LEFS: Lower extremity functional scale.

Discussion:

Femoral shaft fractures (FSFs) are a frequent injury in traumatology, often caused by either high-energy trauma, such as road traffic accidents (RTAs), or low-energy trauma, such as fractures in the elderly due to osteoporosis [12].

In our study, 9 (45%) patients were smokers and out of them, 3 (15%) patients were hypertensive. One (5%) patient had diabetes mellites type 2. These findings were comparable to previously reported by Cho et al. [13] who stated that there were 20 smokers (39.2%) and 7 patients (13.7%) on diabetic medication.

In the present study, RTAs constituted the principal mechanism of injury (80%), with falls from height accounting for the remainder (20%), a pattern consistent with Sonbol et al. [14] conducted a study on 591 patients and reported that the most common site for femoral fractures was the mid-shaft, and mainly was a result of RTA.

Non-union following initial IMN remains a challenging complication. In this cohort, atrophic non-unions predominated (45%), followed by hypertrophic (30%) and oligotrophic (25%), which reflected differences in biological activity and mechanical stability at the fracture site [15]. Atrophic non-unions indicate poor biology, hypertrophic non-unions indicate instability despite good biology, and oligotrophic non-unions show both mild biological and mechanical issues [16]. In contrast, hypertrophic non-union is generally considered a mechanical problem; bone grafting was used consistently in this series to maintain a uniform revision strategy and to support the local biological environment after surgical exposure and decortication.

According to Çimen et al. [17], predominantly atrophic (65%) and oligotrophic (35%) non-unions were reported following plate-over-IMN, whereas Wu et al. [18] observed mainly oligotrophic (81.3%) and fewer hypertrophic non-unions. Such discrepancies likely relate to differences in patient selection, surgical technique, sample size, and follow-up timing.

In this study, IMN was the most frequently retained implant (70%), reflecting its established role as the gold standard for FSFs due to its favourable biomechanical stability and preservation of the fracture biology [19]. Retrograde nails were preferentially used for distal fractures, while short and long gamma nails (each 5%) were reserved for proximal or subtrochanteric involvement [20]. This implant distribution underscores the use of individualised fixation strategies based on fracture location and morphology to optimise alignment and stability.

According to Daher et al. [21], intra-medullary nailing was the gold standard for the treatment of femoral shaft fractures.

In the current study, femoral shaft fractures were mostly mid-shaft (75%), with proximal (5%) and distal (20%) involvement. Fracture patterns included butterfly (40%), comminuted (35%), short oblique/transverse (20%), and combined (5%), with AO types 32-B2 (40%) and 32-C2 (35%) predominating. These complex, high-energy fractures, often from RTAs, are prone to non-union [22, 23], whereas simpler 32-A2/A3 fractures (20%) likely stemmed from lower-energy trauma [24]. Understanding fracture location, pattern, and AO classification aids surgical planning, fixation strategy, and the potential need for augmentation to optimise healing.

These findings align with Sonbol et al. [14], who reported mid-shaft predominance following RTAs, and Nikolaou et al. [25], who observed AO 32-B (32%), 32-C (23%), and 32-A (45%), highlighting variability in fracture complexity and mechanism across populations.

In the current study, 90% of fractures underwent closed reduction and 10% open reduction, all presenting as aseptic non-unions with pain as the main symptom. No infections or deformities occurred, with time from initial surgery ranging from 6–18 months (mean 9.8 ± 3.25 months). According to Cho et al. [13], open fractures were diagnosed in 7 patients (13.7%). While Mohamed et al. [5] observed 25% open fractures with no complications and 75% closed fractures, supporting technique safety, similarly, Ghouri et al. [26] reported 91% closed fractures.

In our study, operative time averaged 103.9 ± 16.78 minutes (range 80–150). Similar durations were reported by Lin et al. [27], who reported a mean operative time for femoral shaft fracture of 105 minutes (range, 60-150 minutes), as well as Jin et al. [28], who found that operation time (min) was 112.13 ± 23.49 in the PA-group.

In this study, surgical drains were used in 60% of patients as a precaution against postoperative hematoma or seroma, particularly during extensive soft-tissue dissection [29]. Fracture reduction was required in 45% through the removal of stabilising nail screws from one side to restore proper alignment and stability, which is essential for optimal healing in non-union cases [30].

The absence of intraoperative complications demonstrates that PA over a retained IMN can be performed safely and effectively, reflecting both the technique's reliability and the surgeons' expertise in managing complex femoral nonunions. Supporting our findings, Mohamed et al. [5] reported augmentation plating with iliac grafting as a safe, effective treatment for previously nailed, non-united FSFs, while Fadel et al. [31] observed minimal complications, including one postoperative hematoma requiring drainage.

According to the current findings, various plates were used, including broad DCP (40%), small locked (25%), broad locked (25%), small DCP (5%), and low-profile plates (5%). Intraoperative blood loss ranged from 190–750 ml (mean 381 ± 132.7 ml), with 45% requiring blood transfusion. This finding is likely attributable to the revision nature of the procedure, which necessitates extensive exposure, decortication, and autologous bone graft harvesting. Importantly, no transfusion-related complications were observed; this was consistent with Amr [32], who similarly reported a mean blood loss of 400 ml.

Radiological union occurred between 3 and 7.5 months (mean 5.5 ± 1.14), with full hip ROM in all patients (100%) and full knee motion in 70%; 30% had some limitation. Follow-up ranged 9–50 months (mean 29.8 ± 14.97). Consistently, Kook et al. [33] reported union at 5.4 months and follow-up of 28.6 months, while Çimen et al. [17] observed a mean follow-up of 23.8±20.4 (range, 12 to 96) months in the plate over an IMN group and 34.7±27.4 (range, 12 to 90) months in the exchange nailing group.

El Zahlawy et al. [34] similarly demonstrated that full hip and knee motion and independent full weight-bearing were achieved by eight months. Also, Mohamed et al. [5] observed complete radiographic union in atrophic non-union FSFs following PA and iliac grafting without nail removal.

No early complications occurred in our cohort, while late complications affected six patients (30%), mainly limited joint motion. One diabetic female patient developed a late infection 11 months after PA requiring debridement and metal removal, and another patient had heterotopic ossification managed with low-profile plates, indicating PA over IMN is generally safe, with rare, manageable late complications. In contrast, infection and heterotopic ossification are rare and manageable.

Supporting this, Amr [32] reported a ~24% complication rate, including one wound infection following PA after IMN for femoral shaft non-union. Similarly, Mohamed et al. [5] observed no early complications with PA and bone grafting without nail removal. Moreover, Birjandinejad et al. [35] reported no serious complications at 1-year follow-up. In contrast, Bansal et al. [36] , noted full union and range of motion, with patients walking independently by three months and radiological union by six months. Differences in outcomes likely reflect variations in patient characteristics, fracture patterns, comorbidities, sample size, and rehabilitation protocols.

In the present study, radiological healing was assessed using Wu's criteria, while functional recovery was evaluated with the validated Arabic LEFS, providing a comprehensive outcome assessment. Wu's criteria assessed callus formation and cortical continuity, and the LEFS captured patient-reported functional status, thereby strengthening the validity of the outcomes. Radiologically, 60% of patients were excellent, 35% good, and 5% fair; functionally, 60% had mild limitations, 5% moderate, 10% mild to moderate, and 25% achieved full function, reflecting alignment between structural union and functional recovery.

These results align with Metwally et al. [37], who reported 94.4% excellent bone union following augmentation plating and grafting. Likewise, Mohamed et al. [5] reported that PA with bone grafting without nail removal yielded excellent results in 12 and good results in 8 atrophic non-union FSFs. Furthermore, Lin et al. [27] concluded that PA with nail retention and autologous grafting is an effective and reliable alternative for femoral shaft non-union after IMN.

Our results showed that time of radiological union was not significantly different related to comorbidities, radiological, clinical criteria, non-union data, smoking, age, mechanism of injury and type of plate used. There was no correlation between time of radiological union and (age, type of plate used and smoking). There was no correlation between time of follow-up and functional outcome.

Supporting these observations, Factor et al. [38] who found that none of the other assessed parameters, including age, fracture location, involvement of single or both forearm bones, fracture type, or preoperative displacement, demonstrated a significant correlation with the time required for union, and Kaneko et al. [39] who concluded that smoking had statistically no significant impact on distal radius fracture healing.

Further supporting these findings, Zura et al. [40] noted that predicting fracture non-union is challenging, as age, smoking, fracture pattern, and surgical technique show inconsistent effects, supporting uniform radiological union across the cohort. In addition, Taormina et al. [41] found that patient age did not influence union rates or time to union, and older age was not linked to worse outcomes. Regression analysis confirmed no age effect, while smoking and prior non-union surgery were strongly associated with prolonged time to union.

This was in contrast with Ahmed et al. [42], who concluded that smoking status demonstrates a clear gradient of risk for delayed fracture healing, with current smokers experiencing the longest time to union. While Patel et al. [44] reported longer union times and higher delayed or non-union rates in smokers, indicating that smoking can adversely affect bone healing despite overall uniform outcomes across other variables. These variations in findings could be attributed to the differences in sample sizes, geographical and environmental settings.

Limitations of the study:

This study has several limitations. The retrospective design and relatively small sample size may limit the statistical power and generalizability of the findings. In addition, the cohort included heterogeneous fracture types (AO 32-A2 to 32-C2), which may influence healing and functional outcomes. Furthermore, the absence of a control group precluded direct comparison between augmentation plating with iliac bone grafting and other revision techniques.

Conclusions:

PA over a retained IMN, combined with iliac crest bone grafting, resulted in reliable fracture union within an acceptable healing period and satisfactory functional recovery in patients with aseptic femoral shaft non-union. The procedure proved to be safe, with no early postoperative complications and only a small number of manageable late complications. By preserving the existing nail, this strategy offers both mechanical stability and biological support while avoiding the additional morbidity associated with nail removal or exchange nailing.

Financial support and sponsorship: Nil

Conflict of Interest: Nil

Ethical approval:

The study was conducted on cases operated from January 2018 to December 2024, after approval from the Ethical Committee of the Faculty of Medicine, October 6 University, Giza, Egypt (code: O6U-ERC-0069). Informed consent was obtained.

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