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EFFECTIVENESS OF AUGMENTATION PLATING AND BONE GRAFTING IN MANAGEMENT OF FEMUR AND TIBIA SHAFT NON-UNION FOLLOWING INTRAMEDULLARY NAIL FIXATION

Orthopaedics

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ABSTRACT

Background And Aims: Nonunion of femoral and tibial shaft fractures is a challenging complication that significantly impacts patient recovery and quality of life. Augmentation plating combined with bone grafting has shown promise in enhancing fracture healing, particularly in nonunion cases after failed intramedullary nailing. This study evaluates the effectiveness of this technique in achieving radiological and clinical union. **Methods:** This prospective case series included 20 patients with femoral or tibial shaft nonunion managed surgically using augmentation plating with or without exchange nailing and bone grafting. Patients were treated at the Department of Orthopaedics, BIRRD Hospital, Tirupati, between October 2020 and June 2022. Inclusion criteria comprised patients aged ≥18 years with hypertrophic or atrophic nonunion following intramedullary nailing. Radiographic and clinical outcomes were assessed at 1, 3, and 6 months using the Radiographic Union Scale for Tibia (RUST) and Goldberg scoring systems. Statistical significance was determined using paired t-tests ($p < 0.05$). **Results:** All 20 patients achieved complete radiological union within six months. The mean RUST score improved significantly from 7.25 ± 0.78 preoperatively to 11.50 ± 0.76 at six months ($p < 0.0001$). The mean Goldberg score also demonstrated progressive improvement, from 1.65 ± 0.48 at 1 month to 6.55 ± 0.60 at 6 months ($p < 0.0001$). Hypertrophic nonunion accounted for 90% of cases, highlighting the mechanical instability corrected by augmentation plating. **Conclusion:** Augmentation plating with bone grafting is an effective technique for managing femoral and tibial shaft nonunions. This method ensures mechanical stability, promotes biological healing, and achieves consistent fracture union, making it a reliable option for challenging nonunion cases.

KEYWORDS

Augmentation plating, Femoral shaft, Tibial shaft, Nonunion, Bone grafting

INTRODUCTION

Fracture nonunion is a challenging complication in orthopaedic practice, causing considerable physical, emotional, and financial distress to patients. (1) It occurs when a fracture fails to heal within the expected timeframe despite appropriate treatment, often due to a combination of biological, mechanical, and host-related factors. (2,3) Nonunion rates vary widely, influenced by fracture type, location, and treatment methods. For tibial shaft fractures, the incidence can range from 16% in Gustilo-Anderson type II fractures to as high as 80% in type IIIB fractures. Among the surgical options available for long bone fractures, intramedullary nailing is the standard of care, boasting union rates of up to 99% in uncomplicated cases. However, certain fractures fail to heal due to issues such as inadequate vascularity, mechanical instability, or infection, resulting in either atrophic or hypertrophic nonunion. (4,5,6)

Atrophic nonunion, characterized by minimal callus formation and compromised biological factors, presents unique challenges. In contrast, hypertrophic nonunion often results from inadequate stability at the fracture site, highlighting the importance of mechanical factors in fracture healing. Host-related variables, such as smoking and age, further complicate outcomes. Smokers face a significantly higher risk of nonunion, with delayed healing and a doubled likelihood of nonunion compared to non-smokers. (7,8)

Surgical management of long bone shaft nonunions includes various interventions, such as reamed exchange nailing (REN), dynamization, and external fixation. Among these, augmentation plating combined with bone grafting has emerged as a promising approach. This technique, which involves compressive plating and bone grafting to stimulate osteogenesis and improve mechanical stability, has shown encouraging results in tibial and femoral shaft nonunions, particularly after failed intramedullary nailing. Despite evidence supporting high union rates with reamed exchange nailing (76%–96%), a growing body of research advocates for augmentative methods, including osteoperiosteal decortication and compressive plating. (9,10)

This study aims to evaluate the effectiveness of augmentation plating with bone grafting in managing femoral and tibial shaft nonunion after intramedullary nail fixation. By addressing a critical gap in the literature, this research intends to provide evidence on the utility of augmentation plating in enhancing fracture healing, improving outcomes, and offering a reliable alternative for refractory cases.

MATERIAL AND METHODS

This prospective hospital-based case series was conducted at the Department of Orthopaedics, BIRRD Hospital, Tirupati, from October 2020 to June 2022. Twenty patients with femoral or tibial shaft non-union following intramedullary nail fixation were surgically treated with augmentation plating (with or without exchange nailing) and bone grafting.

Inclusion Criteria:

- Medically fit patients with postoperative non-union (hypertrophic, atrophic, or oligotrophic) of femoral or tibial diaphyseal fractures following intramedullary nailing.
- Patients aged 18 years and above.
- Non-union after previous stabilization surgery.

Exclusion Criteria:

- Cases with infection or unhealed wounds.
- Patients with distal neurovascular compromise.
- Pathological or metastatic fractures.
- Non-union following extramedullary fixation.

Preoperative Evaluation:

All patients underwent clinical evaluation, including history of trauma, time since initial surgery, and systemic health assessment. Radiographic evaluation was performed with anteroposterior, lateral, and oblique X-rays; CT scans were obtained if necessary. Non-union was classified according to the Weber and Cech classification.

Surgical Technique:

- **Exchange Nailing:** For 14 patients, the previous intramedullary nail was removed, and the medullary canal was reamed. A larger-diameter nail was inserted to enhance stability.
- **Augmentation Plating:** Locking compression plates were used in 15 cases, dynamic compression plates in 4, and limited contact dynamic compression plates in 1. The plate was applied laterally, with screws positioned to avoid the nail.
- **Bone Grafting:** Cortico-cancellous grafts harvested from the ipsilateral iliac crest were packed circumferentially at the non-union site to stimulate osteogenesis.

Procedure

The procedure began with the patient under either spinal or general anaesthesia, positioned supine with the contralateral leg on a holder and the ipsilateral leg elevated and adducted. The area from the

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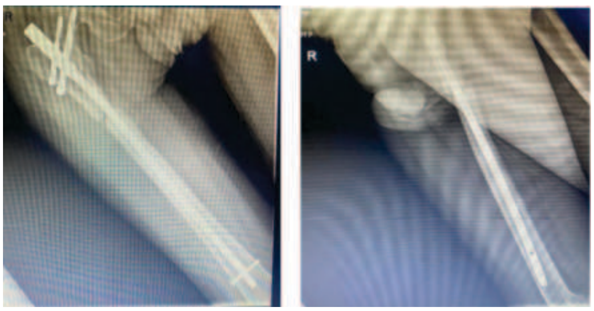
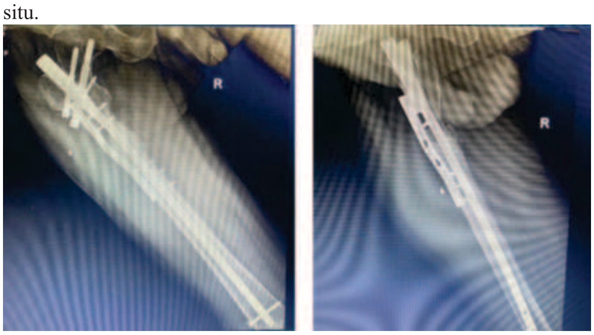
umbilicus to the foot of the ipsilateral leg was sterilized with betadine and draped with sterile linen. Exchange nailing was performed by removing the previous intramedullary nail with an extraction device, followed by insertion of a guide wire into the medullary canal. The canal was reamed with progressively increasing-sized reamers to accommodate a new nail, 1 mm larger in diameter or at least 11 mm. Distal interlocking screws were inserted first, followed by compression of the fracture ends with a back hammering device. Proximal interlocking screws were then locked, and rotational stability of the nail was checked by applying external rotation force at the distal thigh. A standard lateral approach was used to expose the non-union site. A 4.5 mm locking compression plate or dynamic compression plate was applied for plate augmentation, with 3–4 screws placed proximally and distally to the fracture. Pre-contoured or, when necessary, contoured plates were used, ensuring stability. Cortico-cancellous bone graft was harvested from the iliac crest of the same side and used to pack the fracture site. The fixation was checked for stability under fluoroscopy, and the muscle, fascia lata, subcutaneous tissue, and skin were repaired sequentially with suction drainage in place.

Postoperative Management:

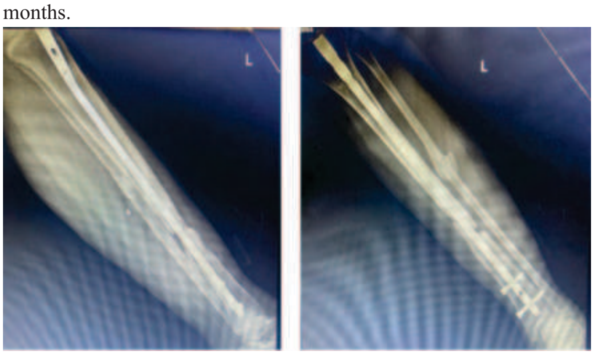
- IV antibiotics for three days, followed by oral antibiotics for seven days.
- Early mobilization with weight-bearing as tolerated after two weeks.
- Thromboprophylaxis with low molecular weight heparin for four weeks.
- Follow-up at 1, 3, and 6 months with clinical and radiographic evaluation.



a) Radiographs showing anteroposterior (AP) and Lateral view of proximal femur hypertrophic non-union with an intramedullary nail in situ.



b) Radiographs showing AP and lateral view of proximal shaft femur showing Union with augmentation plating and bone grafting at 6 months.



a)Radiograph showing Antero-posterior (AP) and lateral view of the shaft of tibia showing non-union with an intramedullary nail in situ.

b) Radiograph showing AP and lateral view of shaft of tibia showing Union with augmentation plating and bone grafting at 6 months

Outcome Assessment:

Union was defined clinically by absence of pain at the non-union site and radiographically by bridging callus across three cortices in two views.

- **Radiographic Union Scale for Tibia (RUST):** Assessed callus formation and fracture line visibility. Scores ranged from 4 (not healed) to 12 (healed).

Radiographic Union Scale for Tibia fractures (RUST) [46] score:

Radiographic criteria		
Score per cortex	**Callus**	**Fracture line**
1	Absent	Visible
2	Present	Visible
3	Present	Invisible
The individual cortical scores (anterior, posterior, medial and lateral) are added to provide an overall RUST value ranging from 4 (i.e definitely not healed) to 12 (i.e. definitely healed) for a set of radiographs		

- **Goldberg Scoring System:** Evaluated bone graft integration and union, with a maximum score of 7.

Goldberg Radiographic scoring system [47]	
Appearance of graft	
Resorbed	0
Mostly resorbed	1
Largely intact	2
Reorganizing	3
Union (proximal and distal evaluated separately)	
Nonunion	0
Possible union	1
Radiographic union	2
Total points possible per category	
Graft	3
Proximal union	2
Distal union	2
Maximum score	7

This approach was aimed at enhancing mechanical stability and biological healing to achieve fracture union in cases of non-union after intramedullary nail fixation.

RESULTS

Table 1 shows that the study included 20 participants with a mean age of 57.40 ± 12.21 years (range 28–74). Most patients were aged 41–60 years (45%) or 61–80 years (45%), with only 10% in the 25–40 age group. Males constituted 65% of the population, while females accounted for 35%, highlighting a higher prevalence of non-union in males.

Table: 1 Demographic characteristics:

Category	Group	Frequency	Percentage (%)
Age Group	25 – 40	2	10

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	41 – 60	9	45
	61 – 80	9	45
Mean ± SD	-	57.40 ± 12.21	-
Age Range	-	28 – 74	-
Gender	Male	13	65
	Female	7	35

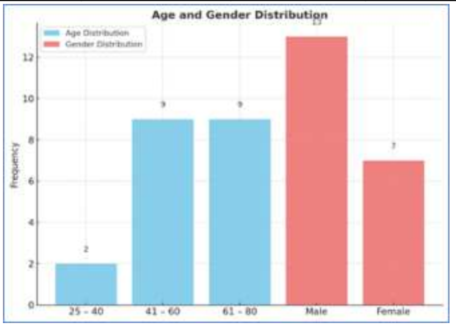

Figure: 1 Demographic characteristic:

Table 2 shows the majority of patients (75%) had duration of 12–18 months since primary intramedullary nail fixation, with a mean duration of 16.85 ± 2.68 months. Hypertrophic non-union was observed in 90% of cases, while atrophic non-union accounted for only 10%, highlighting the predominance of mechanical instability-related non-unions.

Table: 2. Duration of primary surgery and type of non-union.

Category	Group	Frequency	Percentage (%)
Duration (Months)	12 – 18	15	75
	19 – 22	5	25
Type of Non-Union	Atrophic	2	10
	Hypertrophic	18	90
Mean ± SD	16.85 ± 2.68	-	-
Range	12 – 22	-	-

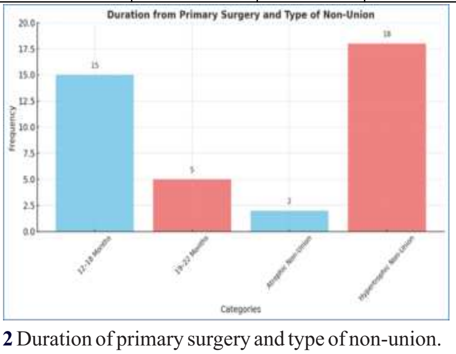

Figure: 2 Duration of primary surgery and type of non-union.

Table 3 shows the mean pre-operative RUST score was 7.25 ± 0.78, progressively improving to 11.50 ± 0.76 at six months, with statistically significant differences observed at each follow-up (p < 0.0001). Radiological union was achieved in 7 patients by 3 months and in all 20 patients by 6 months.

Table: 3. Mean pre-operative RUST score.

Time Point	RUST Score Distribution	RUST Score Mean ± SD	Radiological Union (n)	Not United (n)	Statistical Significance (p-value)
Pre-operative	6 (4), 7 (7), 8 (9)	7.25 ± 0.78	-	20	-
1 Month	6 (3), 7 (9), 8 (5), 9 (3)	7.40 ± 0.94	0	20	p < 0.0001 (vs. 3 Months)
3 Months	9 (7), 10 (9), 11 (4)	9.20 ± 0.89	7	13	p < 0.0001 (vs. 6 Months)
6 Months	10 (3), 11 (4), 12 (13)	11.50 ± 0.76	20	0	p < 0.0001 (vs. 1 Month)

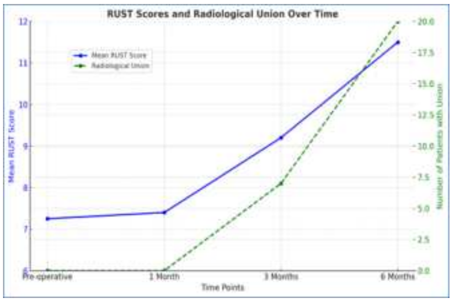

Figure: 3. Mean pre-operative RUST score and Radiological union over time.

Table 4 shows the mean Goldberg score improved from 1.65 ± 0.48 at 1 month to 3.75 ± 0.85 at 3 months and 6.55 ± 0.60 at 6 months, reflecting significant healing over time. Statistical analysis revealed significant differences between all time points (p < 0.0001), emphasizing the progressive effectiveness of the intervention.

Table: 4 Mean Goldberg Radiologic score

Time Point	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Total	Mean ± SD	Paired t-test (p-value)
1 Month	7	13	0	0	0	0	0	20	1.65 ± 0.48	-
3 Months	0	1	7	8	4	0	0	20	3.75 ± 0.85	13.07 (p < 0.0001)*
6 Months	0	0	0	0	1	7	12	20	6.55 ± 0.60	15.02 (p < 0.0001)*
1 Month vs 6 Months	-	-	-	-	-	-	-	-	-	34.20 (p < 0.0001)*

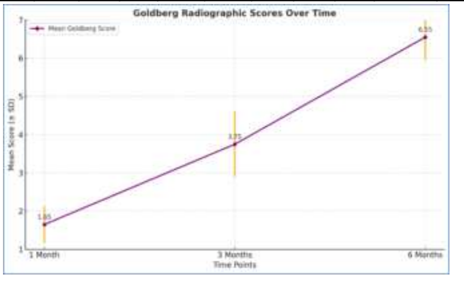

Figure: 4. Mean Goldberg Radiologic score

Table 5: Comparison of Universal VAS score - pre-operative, 1 month, 3 months and 6 months

Score	Pre-operative	1 Month	3 Month	6 Month
0	-	3	7	16
1	-	4	10	3
2	-	8	2	1
3	-	3	1	-
4	-	2	-	-
5	3	-	-	-
6	6	-	-	-
7	4	-	-	-
8	4	-	-	-
9	3	-	-	-
10	-	-	-	-
Total	20	20	20	20
Mean ± SD	6.80 ± 1.32	1.85 ± 1.18	0.85 ± 0.81	0.25 ± 0.55
1 Month vs 3 month = Paired t test = 4.873, p= <0.0001*, Statistically significant				
3-month vs 6 month = Paired t test = 2.734, p= <0.0001*, Statistically significant				
1 month vs 6 month = Paired t test = 5.488, p= <0.0001*, Statistically significant				

Pre-operative vs 6 month = Paired t test = 20.613, p= <0.001, statistically significant

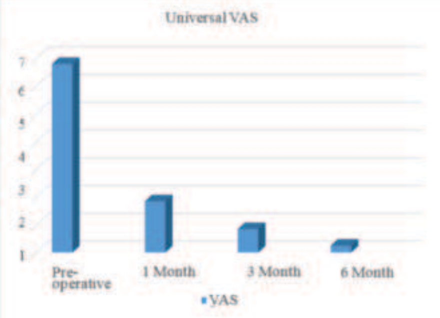

Figure: 5. Comparison of Universal VAS score - pre-operative, 1 month, 3 months and 6 months.

DISCUSSION

The study investigated the outcomes of augmentation plating combined with bone grafting in 20 patients with femoral and tibial shaft nonunion. This approach was implemented to enhance fracture stability and promote healing in cases where primary intramedullary nailing had failed.

Participants' ages ranged from 28 to 74 years, with a mean age of 57.40 ± 12.21 years. Most patients (90%) were aged above 40 years, contrasting with studies by **Chin-Jung-Lin et al. (2012) (11)** and **Thanh HV et al. (2020) (12)**, where the mean ages were 34.3 and 32 years, respectively. In this study, males constituted 65% of the participants, similar to Thanh HV et al.'s findings of 71.9% males. Smoking history was present in 45% of participants, aligning with the review by **Smolle MA et al. (2021) (13)**, which found significantly higher nonunion rates among smokers. Additionally, 55% of participants had diabetes mellitus, a known contributor to delayed healing due to heightened inflammation and impaired bone coupling.

The mean pre-operative RUST score was 7.25 ± 0.78, improving to 11.50 ± 0.76 by six months, showing statistically significant improvement across all follow-ups (p < 0.0001). These findings are consistent with **Panchoo P et al. (2021) (15)**, who observed mean RUST scores ranging from 4 to 12, with a strong interobserver agreement. Radiological union was achieved in all patients by six months, similar to **Thanh HV et al. (2020) (12)**, where 96% of cases had union by six months. In the study by **Chin-Jung-Lin et al. (2012) (11)**, mean union times were 20.2 ± 1.9 weeks for hypertrophic nonunion and 21.7 ± 3.9 weeks for atrophic nonunion, closely aligning with the current study's findings.

The mean Goldberg score in this study was 1.65 ± 0.48 at one month, improving to 6.55 ± 0.60 at six months, demonstrating significant healing over time. This progression aligns with radiographic healing patterns reported in similar studies, emphasizing the utility of this scoring system in assessing fracture union.

Hypertrophic nonunion was present in 90% of cases, while 10% were atrophic. This distribution aligns with **Thanh et al. (2020) (12)**, who reported hypertrophic nonunion in 95% of cases. Hypertrophic nonunions have excellent healing potential due to good vascularity but require mechanical stability, which augmentation plating provides effectively.

The mean time from primary surgery to augmentation plating was 16.85 ± 2.68 months. In comparison, **Chin-Jung-Lin et al. (2012) (11)** reported a mean duration of 20 months. **Megas P et al. (2009) (16)** observed a mean interval of 10.9 ± 7 months between plating and revision surgery, slightly shorter than this study.

Augmentation plating combined with bone grafting demonstrated a 100% union rate in this study. **Choi et al. (2015) (17)** and **Ueng et al. (1997) (18)** also reported high union rates with augmentation plating, highlighting its effectiveness in achieving rigid fixation and early weight-bearing. While exchange nailing is commonly employed, **Weresh et al. (2000) (19)** found a lower union rate of 53% with reamed exchange nailing, suggesting the need for additional stabilization methods like plating.

Dynamization, although a simpler procedure, is less effective in complex fractures. **Wu et al. (1997) (14)** reported only a 58% union rate with dynamization, reinforcing the limitations of this approach for challenging cases.

Strengths of Augmentation Plating

Augmentation plating offers several advantages:

1. **Improved Stability:** Plate augmentation increases rotational stability, crucial for hypertrophic nonunion.
2. **Precise Grafting:** Autologous bone grafting enhances biological healing potential.
3. **Minimally Invasive:** Retaining the nail minimizes disruption, allowing faster recovery and earlier weight-bearing.

These benefits align with findings by **Ueng et al.**, who achieved bony union within 5.4 months using this method, and **Bellabarba et al.**, who reported a 91% union rate with plating.

Augmentation plating combined with bone grafting is a highly effective treatment for femoral and tibial shaft nonunion following intramedullary nailing. This study reaffirms its advantages, including superior union rates, enhanced stability, and reduced complications, consistent with findings from exisiting studies.

CONCLUSION

This study concluded that augmentation plating combined with bone grafting is a highly effective technique for managing femoral and tibial shaft nonunions following intramedullary nail fixation. The procedure proved reliable in achieving complete fracture healing by enhancing mechanical stability and promoting biological healing. The outcomes highlight the effectiveness of this approach, particularly in cases of hypertrophic nonunion, which benefit from its ability to provide rotational stability and support early weight-bearing. This method ensures consistent healing and offers a dependable solution for addressing the challenges of nonunion, making it a valuable tool in orthopaedic practice.

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Ethical Approval: Ethical approval was obtained and documented as per institutional guidelines.

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