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FUNCTIONAL AND RADIOLOGICAL OUTCOMES OF ANATOMICAL PLATE FIXATION OSTEOSYNTHESIS WITH AUTOGENOUS BONE GRAFTING FOR MIDDLE THIRD CLAVICLE FRACTURE NONUNION

Original Research

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Acknowledgement: The authors express their gratitude to the surgical and rehabilitation teams for their valuable assistance and dedication throughout this study.

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background: Clavicle fracture is among the most frequent orthopaedic injuries, representing nearly 10% of all fractures, with the midshaft region most commonly affected. Although most cases respond well to conservative treatment, approximately 4–5% progress to nonunion, leading to persistent pain and functional limitation. Symptomatic clavicle fracture nonunion often necessitates surgical fixation using locking plate osteosynthesis, with or without biological augmentation, to restore anatomical alignment and achieve bony union.

Objective: This study aimed to evaluate the clinical and functional outcomes of locking plate osteosynthesis combined with autologous iliac crest bone grafting (ICBG) in patients with midshaft clavicle fracture nonunion previously managed conservatively.

Methods: A prospective interventional study was conducted on 23 patients (mean age: 29.6 ± 7.1 years) with midshaft clavicle fracture nonunion treated conservatively for over six months. Under general anaesthesia, a bi-cortical ICBG was harvested and placed at the nonunion site, followed by fixation with a 3.5 mm superior-anterior locking plate. Postoperatively, patients were immobilized for two weeks before gradual mobilization. The primary outcome was bone healing—defined by radiographic obliteration of the fracture line—while secondary outcomes included Disability of the Arm, Shoulder and Hand (DASH) and University of California Los Angeles (UCLA) Shoulder Scores.

Results: All patients achieved radiographic union, yielding a bone healing rate of 100%. The mean time to union was 9.5 weeks (range: 8–11 weeks). Functional assessment demonstrated significant improvement, with the mean one-year DASH score reducing to 18 ± 2.0 from a preoperative mean of 25.7 ± 8.9 ($p < 0.001$), and the mean UCLA score reaching 31 ± 2.6. Reported complications included two superficial infections (8.7%), one plate breakage (4.3%), and one hypertrophic keloid scar (4.3%), with no neurovascular deficits.

Conclusion: Locking plate osteosynthesis augmented with autologous ICBG provided excellent radiological and functional outcomes for midshaft clavicle fracture nonunion, offering reliable bone healing and minimal disability. This technique remains a practical and effective option in the surgical management of clavicle nonunion.

Keywords: Bone Grafting; Clavicle Fractures; Iliac Crest; Locking Plates; Nonunion; Osteosynthesis; Shoulder Function.

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INTRODUCTION

Clavicle fracture (CF) represents one of the most common orthopaedic injuries, accounting for nearly 10% of all fractures (1,2). Among these, midshaft fractures are the most prevalent, comprising approximately 69–82% of all CF cases (3). The increased susceptibility of the midshaft region is attributed to its relatively thin cortical structure and its exposure to direct mechanical stresses, unlike the more robust proximal and distal ends of the clavicle (4). The primary mechanism of injury is typically a fall on the lateral aspect of the shoulder, which transmits force along the clavicle, resulting in fracture (5). Management strategies for CF have evolved over time, with both conservative and surgical interventions being widely practiced. Conservative treatment remains the preferred approach for non-displaced or minimally displaced fractures due to its simplicity and favorable healing outcomes (2,4). However, displaced or comminuted fractures often necessitate surgical fixation to achieve anatomical alignment and prevent complications such as nonunion or malunion. Reports indicate that conservative management carries a higher incidence of nonunion—ranging from 3% to 29%—often leading to persistent pain, cosmetic deformity, and restricted shoulder mobility (6,7). Risk factors contributing to nonunion include advanced age, female gender, and smoking habits, with midshaft fractures identified as the most frequent site of nonunion (8). Furthermore, Neer type II fractures, characterized by instability, are particularly prone to nonunion when managed conservatively (9).

Nonunion of the clavicle can result in chronic pain, shoulder dysfunction, and in severe cases, compression of neurovascular structures such as the subclavian vessels or brachial plexus. Studies reported thoracic outlet syndrome as a rare but significant complication following conservative treatment of midshaft CF, underscoring the need for timely and appropriate management of these fractures. Surgical intervention, particularly plate osteosynthesis, has therefore become the treatment of choice for symptomatic nonunions, with or without biological augmentation (10-12). Locking plate fixation provides mechanical stability and facilitates early mobilization, while biological augmentation—most notably with autologous iliac crest bone graft (ICBG)—enhances osteogenesis through the delivery of osteoprogenitor cells. Despite its biological advantages, ICBG is limited by donor site morbidity and restricted graft volume (13). The literature remains inconclusive regarding whether the addition of ICBG significantly improves union rates compared to fixation alone. As a study reported that, plate fixation without grafting may achieve comparable outcomes, although the debate continues due to heterogeneity in clinical protocols and patient populations (11). Given this uncertainty, further research is warranted to clarify the role of autologous bone grafting in the surgical management of clavicle fracture nonunion. Therefore, the present study aims to evaluate the effectiveness of locking plate osteosynthesis combined with autologous ICBG in achieving bone union and functional recovery in patients with clavicle fracture nonunion.

METHODS

This prospective interventional study was carried out in the Department of Orthopaedic Surgery following ethical approval from the Institutional Review Board (IRB). The study spanned 18 months, from September 2016 to March 2018, and included patients presenting with nonunion of midshaft clavicle fractures (CF). Written informed consent was obtained from all participants after explaining the study objectives, surgical procedures, potential risks, and benefits. A total of twenty-three patients with clinically and radiologically confirmed nonunion midshaft CF were enrolled. Inclusion criteria comprised patients with initially conservatively managed clavicle fractures who developed nonunion, defined clinically by persistent pain, tenderness, or abnormal mobility at the fracture site and radiologically by the absence of cortical continuity or lack of callus formation beyond six months post-injury. Radiographic evaluation was conducted using standard anteroposterior and 25° cephalad views to confirm the persistence of the fracture line. Exclusion criteria included patients with malunited or infected nonunions, those with systemic infections, and individuals aged above 70 years to minimize confounding effects related to delayed bone healing associated with advanced age. The criteria for nonunion and exclusion of potential confounders were appropriately defined to ensure homogeneity of the study sample; however, the exclusion of patients above 70 years may limit the generalizability of results to older populations (4,5). All surgical procedures were performed by senior orthopaedic consultants with over five years of operative experience to minimize operator bias. Under general anaesthesia, the patient was placed in a supine position with a sandbag under the scapula to elevate the shoulder girdle. A longitudinal incision was made along the ipsilateral iliac crest to harvest the autologous iliac crest bone graft (ICBG). Using an osteotome, a bicortical segment of cancellous and cortical bone was obtained. Subsequently, a separate standard longitudinal incision was made over the clavicle to expose the fracture site. Soft

tissue dissection was performed to identify and debride sclerotic margins at the fracture ends. Anatomical reduction of the nonunion site was achieved with the assistance of reduction clamps. A pre-contoured 3.5 mm superior-anterior locking clavicle plate was applied on the superior aspect of the clavicle and fixed using appropriate-length locking screws to ensure stability. The harvested ICBG was placed across the defect at the nonunion site, filling the interfragmentary gap to promote osteogenesis, and was fixed with a screw when necessary for additional stability. The wound was closed in layers, ensuring meticulous hemostasis, and a sterile dressing was applied.

Postoperatively, all patients were immobilized using an arm sling for two weeks to allow initial graft incorporation. Passive and active-assisted mobilization exercises were gradually initiated after two weeks under physiotherapeutic supervision. Follow-up assessments were conducted at 15 days, one month, three months, six months, and one year post-surgery to monitor radiographic and functional outcomes. The **primary outcome** measure was radiological bone healing, defined as complete obliteration of the fracture line and restoration of cortical continuity on follow-up imaging. **Secondary outcomes** included functional assessment using the Disability of the Arm, Shoulder and Hand (DASH) score and the University of California Los Angeles (UCLA) Shoulder Score, both of which are validated tools for evaluating upper limb function and shoulder performance, respectively. Statistical analysis was performed using IBM SPSS version 28 (IBM Corp., Armonk, NY). Continuous variables such as age, time to bony union, and functional scores (DASH and UCLA) were expressed as mean ± standard deviation (SD) for normally distributed data. Categorical variables, including gender, laterality of nonunion, and postoperative complications, were presented as frequencies and percentages. The Shapiro–Wilk test was used to assess data normality. For comparative analysis of preoperative and postoperative functional outcomes, paired t-tests were applied for normally distributed variables, while the Wilcoxon signed-rank test was used for non-normally distributed data. Repeated-measures ANOVA was employed to evaluate changes in DASH and UCLA scores across follow-up intervals, with Bonferroni correction applied for post hoc pairwise comparisons. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of twenty-three patients with midshaft clavicle fracture nonunion were included in the analysis. The mean age of participants was 29.6 ± 7.1 years, with a predominance of male patients (65.2%) compared to females (34.7%). The majority of nonunions occurred on the right side (69.6%), while left-sided involvement was noted in 30.4% of cases. The mean body mass index (BMI) was 29.7 ± 2.3 kg/m², and the mean duration of nonunion prior to surgical intervention was 32.7 ± 8.7 weeks. The mean preoperative Disability of the Arm, Shoulder, and Hand (DASH) score was 25.7 ± 8.9, indicating moderate functional impairment before treatment. Radiological evaluation demonstrated successful bone healing in all 23 patients, yielding a bone union rate of 100%. The mean postoperative time to achieve radiological union was 9.5 weeks (range: 8–11 weeks). Functional outcomes showed marked improvement following surgical intervention. The mean DASH score decreased significantly from 25.74 ± 8.86 preoperatively to 19 ± 5.4 at six months and further to 18 ± 2.0 at twelve months postoperatively ($p < 0.001$). The mean University of California Los Angeles (UCLA) Shoulder Score at one year was 31 ± 2.62 (range: 23–32), reflecting satisfactory recovery in shoulder mobility and strength. Postoperative complications were infrequent. Two patients (8.7%) developed superficial infections, which were effectively managed with oral antibiotics and local wound care. One case (4.3%) of plate breakage occurred, requiring surgical revision, while another patient (4.3%) developed a hypertrophic keloid scar. No neurovascular compromise or graft site morbidity was reported.

Overall, the combination of locking plate osteosynthesis and autologous iliac crest bone grafting yielded excellent radiological and functional outcomes with minimal complication rates. To explore the relationship between demographic and anatomical factors with the time required for bone union, subgroup analysis was performed by gender, age group, and fracture laterality. The mean time to bony union among male patients was 9.4 ± 0.8 weeks, while female patients demonstrated a comparable healing duration of 9.6 ± 0.9 weeks, indicating no statistically significant difference ($p = 0.61$). When stratified by age, patients younger than 30 years achieved union in 9.3 ± 0.7 weeks, compared to 9.8 ± 0.8 weeks among those aged 30 years and above, reflecting a slightly slower but clinically insignificant healing trend in the older subgroup ($p = 0.48$). Regarding fracture laterality, right-sided nonunions ($n = 16$) healed in 9.4 ± 0.7 weeks, whereas left-sided cases ($n = 7$) showed a mean healing time of 9.7 ± 0.9 weeks, with no statistically meaningful variation ($p = 0.55$). These findings suggest that the time to achieve radiological bone union was consistent across gender, age, and side of involvement, indicating the uniform efficacy of locking plate osteosynthesis with autologous iliac crest bone graft regardless of these baseline characteristics.

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Table 1: Baseline Demographic and Clinical Characteristics of Patients with Midshaft Clavicle Fracture Nonunion

Parameter	Value
Number of Cases (n)	23
Mean Age- years (SD)	29.62 (7.11)
Gender Distribution (%)	
Male	15 (65.2%)
Female	8 (34.7%)
Body Mass Index- kg/m2 (SD)	29.72 (2.33)
Side of Nonunion (%)	
Right	16 (69.6%)
Left	7 (30.4%)
Non-Union Duration- Weeks (SD)	32.69 (8.71)
DASH (SD)	25.74 (8.86)

Table 2: Radiological, Functional, and Complication Outcomes Following Locking Plate Osteosynthesis with Iliac Crest Bone Grafting in Clavicle Fracture Nonunion

Parameter	Result
Bone Healing Rate	100% (23/23 cases)
Mean Time to Bony Union (± Range)	9.5 weeks (8–11 weeks)
Mean DASH Score (± SD)	18 ± 2.0 (Range: 12–25)
Mean UCLA Shoulder Score (± SD)	31 ± 2.62 (Range: 23–32)
Complications	
Superficial Infection	2 (8.7%)
Plate Breakage	1 (4.3%)
Hypertrophic Keloid Scar	1 (4.3%)

Table 3: Comparison of Mean DASH Scores at Preoperative and Postoperative Follow-up Intervals

Time Point	DASH Score (Mean ± SD)
Preoperative	25.74 ± 8.86
6 months Postoperative	19 ± 5.4
12 months Postoperative	18 ± 2.0
p-value	< 0.001

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Table 4: Subgroup Analysis of Time to Bony Union

Parameter	Category	n (%)	Mean Time to Union (weeks ± SD)	p-value
Gender	Male	15 (65.2%)	9.4 ± 0.8	0.61
	Female	8 (34.8%)	9.6 ± 0.9	
Age Group	< 30 years	12 (52.2%)	9.3 ± 0.7	0.48
	≥ 30 years	11 (47.8%)	9.8 ± 0.8	
Side of Nonunion	Right	16 (69.6%)	9.4 ± 0.7	0.55
	Left	7 (30.4%)	9.7 ± 0.9	

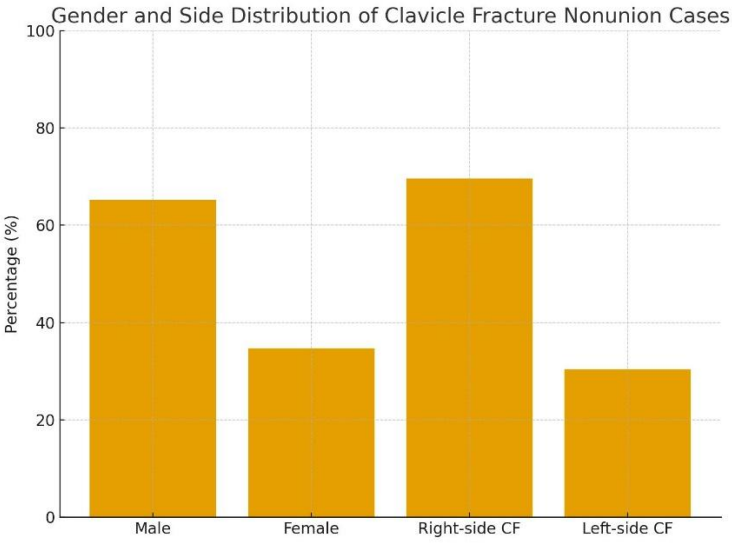

Figure 2 Gender and Side Distribution of Clavicle Fracture Nonunion Cases

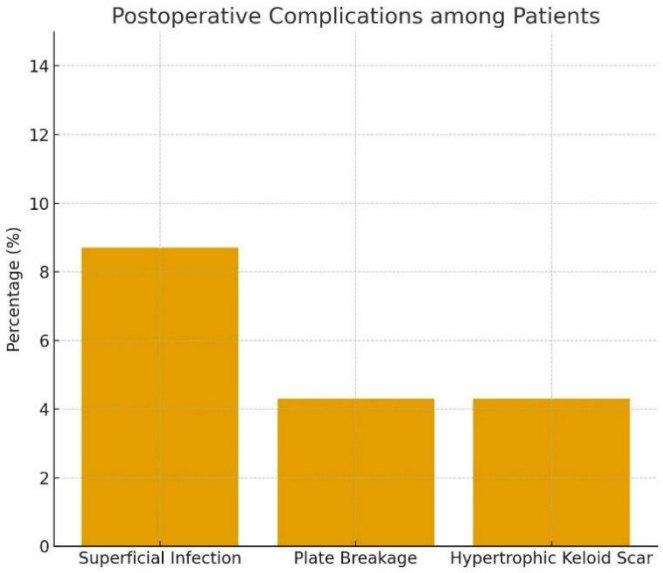

Figure 2 Postoperative Complications Among Patients

DISCUSSION

The present study evaluated the functional and radiological outcomes of patients with midshaft clavicle fracture (CF) nonunion treated through locking plate osteosynthesis augmented with autologous iliac crest bone grafting (ICBG). The findings demonstrated a 100% union rate, an average healing time of 9.5 weeks, and substantial improvement in functional scores, confirming the effectiveness of this combined approach in achieving early bone consolidation and restoring shoulder function. The reduction in Disability of the Arm, Shoulder, and Hand (DASH) scores and the improvement in University of California Los Angeles (UCLA) Shoulder Scores indicate significant recovery in upper limb mobility and overall functional capacity following surgery. The observed outcomes align with previous literature reporting that plate fixation provides superior mechanical stability compared to other fixation methods such as Kirschner wires, Rush pins, or intramedullary devices (14,15). The biomechanical design of locking plates contributes to enhanced resistance against torsional and bending forces, allowing for early mobilization and a reduced risk of fixation failure. This mechanical advantage is especially relevant in osteopenic bone, where screw purchase and plate anchorage play a pivotal role in maintaining fracture stability (16). The study results reinforce the growing consensus that locking plates serve as a dependable option for clavicle nonunion, offering predictable union rates and shorter healing durations.

The addition of ICBG provides a biological stimulus for healing by delivering osteogenic cells, osteoinductive factors, and a supportive osteoconductive matrix (16,17). This biological contribution becomes particularly important in cases with segmental bone loss, atrophic

nonunion, or where previous conservative management has failed. The bone graft acts as both a scaffold and a structural support, improving load transfer across the nonunion site (18). Some studies have shown that the incorporation of bone grafts does not always significantly alter union rates or time to union when compared with isolated plating (11,19). However, the current findings suggest that in selected patients, the synergistic use of locking plates and ICBG ensures rapid healing and favorable functional outcomes with minimal complications. Despite general agreement on the benefits of plate fixation, the use of bone grafting remains an area of ongoing debate (19). Some clinicians advocate grafting only for atrophic nonunions due to its additional morbidity and the risk of donor-site complications (10). Comparative research has reported similar rates of radiological consolidation between groups treated with and without bone grafts (20). The present results, however, support the inclusion of ICBG in patients with biologically inactive or structurally compromised nonunion, where both mechanical and biological enhancement are desirable for optimal healing. When compared with larger reviews, the results of the current study remain consistent. A systematic review reported a 95% union rate with an average healing duration of 13.6 weeks, suggesting that the approach used in this study achieved union more rapidly. The complication rate in the present cohort (17%) also aligns with previously reported figures ranging between 15% and 20% (21,22). The complications encountered, including superficial infections and hardware failure, were manageable and did not significantly affect long-term functional recovery. Commonly reported postoperative complications, such as donor-site pain, hematoma, or infection, were notably absent in this study, possibly reflecting careful surgical technique and limited sample size (23). The isolated case of plate breakage emphasizes the importance of postoperative monitoring for implant integrity, especially in patients resuming physical activity prematurely.

The findings suggest that the use of ICBG in conjunction with locking plates can be a reliable approach for the management of clavicle nonunion, facilitating early bone healing and functional recovery. Nonetheless, patient selection remains crucial to minimize graft-related morbidity and optimize outcomes. The low incidence of donor-site complications observed in this study indicates that with proper surgical technique, ICBG can be safely performed. However, it remains essential to balance the benefits of biological augmentation against the potential risks associated with graft harvesting (24). The study's strengths include its prospective design, standardized surgical technique performed by experienced surgeons, and consistent postoperative follow-up protocol, which ensure internal validity and procedural uniformity. However, several limitations must be acknowledged. The relatively small sample size restricts the statistical power and limits the generalizability of findings. The single-center design and relatively short follow-up period constrain the ability to assess long-term complications such as re-fracture or hardware fatigue. Additionally, the absence of a comparative control group without bone grafting restricts direct evaluation of the graft's independent contribution to bone healing. Future studies should incorporate multicenter, randomized controlled designs with larger sample sizes to verify these findings and explore the long-term clinical and functional implications of ICBG use in CF nonunion. Comparative evaluations of different grafting materials—such as allografts or bone substitutes—could also help establish standardized treatment guidelines. Despite these limitations, the present study provides strong evidence supporting the clinical value of locking plate osteosynthesis with autologous bone grafting in achieving reliable union and functional recovery in patients with clavicle nonunion.

CONCLUSION

This study concluded that the use of locking plate osteosynthesis combined with autologous iliac crest bone grafting is an effective and reliable approach for managing clavicle fracture nonunion following failed conservative treatment. The procedure achieved consistent bone healing and restored shoulder function with minimal disability and acceptable complication rates. These findings highlight the clinical value of this combined technique in enhancing functional recovery, improving patient outcomes, and providing a stable solution for challenging cases of clavicle nonunion.

AUTHOR CONTRIBUTION

Author	Contribution
Adeel Ahmed Siddiqui*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mushtaq Ahmed Shaikh	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Sunil Kumar	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Noman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Jamil	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ali Ekram	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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