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Clinical and radiological assessment of iliac crest autograft augmentation in three-and four-part proximal humerus fractures

Eralp Erdoğan, Zafer Güneş

Department of Orthopedics and Traumatology, Ankara Training and Research Hospital, University of Health Sciences, Ankara, Turkiye

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ABSTRACT

Aims: To evaluate the clinical and radiological outcomes of locking plate fixation with versus without intramedullary iliac crest cortical autograft augmentation in patients with three- and four-part proximal humerus fractures or fracture-dislocations, particularly in the context of osteoporotic bone and medial calcar insufficiency.

Methods: This retrospective study included 65 patients aged between 18 and 65 years treated for complex proximal humerus fractures at a single tertiary institution between 2015 and 2023. Patients were divided into two groups: those treated with locking plate fixation alone (n=47) and those treated with locking plate fixation combined with intramedullary iliac crest autograft augmentation (n=18). Functional outcomes were evaluated using range of motion (ROM), Constant-Murley shoulder outcome score, and Visual Analog Scale (VAS) for pain at 12 months postoperatively. Radiological healing was assessed by time to union. Statistical analyses included t-tests, ANOVA, and Fisher's exact test, with a p-value <0.05 considered statistically significant.

Results: Patients receiving iliac crest grafts (plate+graft group) demonstrated significantly improved union time and greater ROM in flexion, extension, and abduction compared to the Plate-only group (all p<0.001). However, there were no statistically significant differences between the groups in adduction, internal rotation, external rotation, Constant-Murley scores, or VAS pain scores (p>0.05). The mean age of patients was higher in the graft group (49.2 vs. 42.5 years; p<0.001), but this did not alter the functional outcome trends.

Conclusion: Iliac crest cortical autograft augmentation in locking plate fixation of complex proximal humerus fractures offers significant biomechanical advantages, including shorter union time and enhanced shoulder mobility in specific planes. Despite these radiological and kinematic benefits, the absence of significant differences in patient-reported outcomes suggests a functional ceiling effect, where improvements in structural stability do not necessarily correlate with perceived clinical benefit. These findings support the selective use of autografts, particularly in fractures with medial calcar deficiency, while also emphasizing the need for individualized rehabilitation protocols and longer-term follow-up to determine the full clinical value of graft augmentation.

Keywords: Proximal humerus fracture, Constant-Murley shoulder outcome score, iliac crest autograft, plate fixation

INTRODUCTION

Fractures of the proximal humerus account for 5% of all bone fractures and are more common in individuals with osteoporosis.[1,2] The highest incidence of injuries was seen in active people over 60 years old, especially women aged 80 to 89, who had the greatest frequency.[3,4] As society ages, minor injuries are causing more cases of proximal humerus fractures, which are becoming more fragmented, displaced, and complex. Consequently, this group of people experiences reduced shoulder function.[5]

Although proximal humerus fractures are often associated with osteoporotic bone, the present study focused on the biomechanical role of medial calcar support rather than bone mineral density. The patient population consisted primarily of middle-aged adults, reflecting a clinical scenario in which medial column instability and comminution—not osteoporosis—represent the principal challenges for fixation.

Treatment options for proximal humerus fractures vary depending on the fracture classification and the severity of the injury.[6] Common treatments include closed reduction with sling immobilization, open reduction with internal fixation, or shoulder arthroplasty.[7,8] When fixation is required, locking plates offer superior stability compared to standard plates.[9] Proper stabilization and creating a healthy biological environment are crucial for healing and achieving optimal functional outcomes.[10,11] In osteoporotic fractures, the upper arm bone can break into pieces, lose some of its intramedullary bone, and become crushed, making fixation more difficult because there is less bone to hold onto.[12,13]

Corresponding Author: Eralp Erdoğan, eralperdogan85@hotmail.com

Medial calcar support is crucial for stable fixation and prevention of varus collapse in proximal humerus fractures.[14,15] Without adequate medial support, fixation failures such as screw cut-out and humeral head collapse may occur.[16,17] Structural grafting has been proposed to reinforce medial stability and improve outcomes.[15] Among bone graft options, fibular strut grafts have been widely used, but harvesting the fibula carries increased morbidity and technical complexity. Iliac crest autografts, in contrast, provide cortical bone with easier access and lower donor-site risk, though they require additional operative steps.[18,19]

Previous studies have shown that intramedullary grafts enhance stability and reduce fracture micromotion.[20,21] Kim et al.[22] reported that iliac crest autografting provided improved medial support and fixation strength in proximal humerus fractures.

This study aimed to evaluate whether locking plate fixation combined with intramedullary placement of cortical bone autografts harvested from the iliac crest provides better anatomic reduction, increased stability, and improved clinical-functional outcomes in 3- or 4-part proximal humerus fractures and fracture dislocations compared to locking plate fixation without graft use.

METHODS

Ethics

The study has been approved by the Clinical Researches Ethics Committee of Ankara Training and Research Hospital (Date: 02.05.2024, Decision No: 106/2024), and was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. Participants were provided with comprehensive information about the research, and each patient signed an informed consent form prior to participation. The study received no financial support from any institution or organization; the researchers personally funded all expenses.

Patient Selection

Patients treated with locking plate fixation for 3- or 4-part proximal humerus fractures and fracture dislocations between 2015 and 2023 were identified from institutional records. Inclusion criteria were:

- Age between 18 and 65 years;
- Three- or four-part proximal humerus fractures or fracture dislocations (Neer classification);
- Varus or valgus angulation deformity;
- No glenoid bone loss or previous shoulder surgery.

Exclusion criteria included severe glenohumeral arthritis, frozen shoulder, neuromuscular disorders, or systemic comorbidities affecting bone healing (e.g., diabetes, chronic renal disease, long-term corticosteroid use).

Patients were divided into two groups:

- Plate group–locking plate fixation only;
- Plate+graft group–locking plate fixation combined with intramedullary iliac crest cortical autograft.

Radiologic and Functional Evaluation

Postoperative follow-up visits were scheduled at 1, 3, 6, and 12 months, and annually thereafter. Radiologic union was defined as bridging callus formation across at least three cortices on anteroposterior and lateral radiographs, accompanied by the absence of pain or motion at the fracture site during clinical assessment.

Functional outcomes included the Constant–Murley and VAS scores, recorded at the 12-month follow-up. Range of motion (ROM) (flexion, abduction, internal and external rotation) was evaluated by the same investigator and re-assessed by a second author to minimize observer bias.

Statistical Analysis and Power Calculation

The data analyses were performed using SPSS v30. Normality was assessed with the Shapiro–Wilk test. Categorical variables were compared using Fisher's exact test, while quantitative data were analyzed using the unpaired t-test or one-way ANOVA as appropriate. Significance was defined as $p<0.05$.

A post-hoc power analysis was conducted for the primary outcome variable (union time). Based on the observed means (27.15±1.46 weeks in the plate group vs 24.10±1.46 weeks in the plate+graft group), the calculated effect size (Cohen's d=2.09) provided a power of >0.99 at $\alpha=0.05$, indicating that the study was adequately powered to detect differences between groups.

RESULTS

Sixty-five patients were included: 47 in the plate group and 18 in the plate+graft group. The mean age was 42.5 years in the plate group and 49.2 years in the plate+graft group (overall mean: 44.4 years, $p<0.001$). There were 24 females and 41 males. The right shoulder was affected in 39 cases and the left in 26 (Table 1, Figure 1, 2, 3).

Table 1. Demographic information of patients

Treatment Characteristic		Plate n=47 (72.3%)	Plate+graft n=18 (27.7%)	Total n=65 (100%)
Age (mean)		42.51	49.22	44.37
Gender	Female	18 (38.3%)	6 (33.3%)	24 (36.9%)
	Male	29 (61.7%)	12 (66.7%)	41 (63.1%)
Side	Right	27 (57.4%)	12 (66.7%)	39 (60.00%)
	Left	20 (42.6%)	6 (33.3%)	26 (40.00%)

Functionally, the plate+graft group achieved significantly better flexion, extension, and abduction than the plate-only group (all $p<0.001$). No significant differences were observed for adduction, internal or external rotation, Constant–Murley, or VAS scores (p=0.674, 0.057, 0.326, 0.106, and 0.672, respectively) (Table 2, Figure 4, 5, 6).

The mean union time was 27.15±1.46 weeks for the plate group and 24.10±1.46 weeks for the plate+graft group. The difference was statistically significant (95% CI:–7.57 to –3.44, $p<0.001$). The post-hoc power analysis demonstrated a power >0.99 (Cohen's d=2.09), confirming adequate sample strength for this outcome.

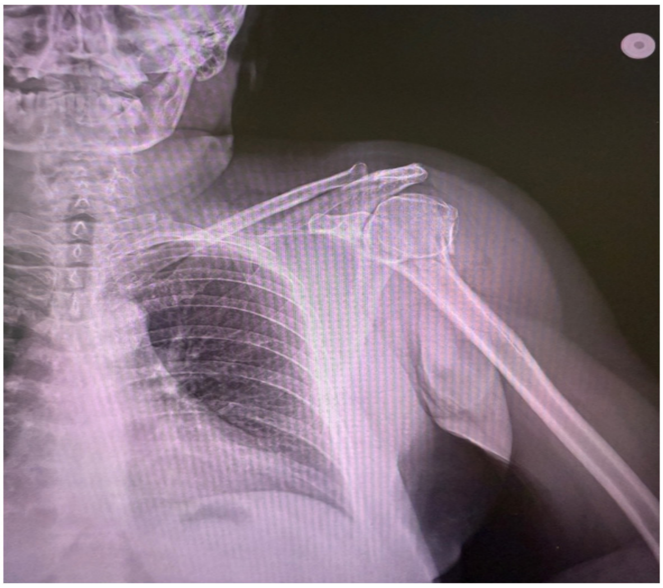

Figure 1. Preoperative image of a 60-year-old female patient with a complex humerus fracture

Table 2. Evaluation of functional outcomes across the study groups

	Plate n=47	Plate+graft n=18	p value	SED	95% CI of the differance	
					Upper	Lower
Union time (week)	24.1	27.15	.000	1.456	-7.567	-3.442
Flexion (°)	139.72	152.67	.000	2.337	-17.614	-8.273
Extension (°)	32.68	38.89	.000	1.206	-8.617	-3.799
Abduction (°)	129.23	137.56	.000	1.919	-12.156	-4.487
Adduction (°)	31.83	31.17	.674	1.569	-2.473	3.799
Internal rotation (°)	47.51	51.44	.057	2.028	-7.986	.119
External rotation (°)	43.09	45.72	.326	2.665	-7.963	2.689
Constant score	74.00	76.44	.106	1.489	-5.420	.531
VAS score	19.89	20.44	.672	1.294	-3.137	2.035

CI: Confidence interval, VAS: Visual Analog Scale

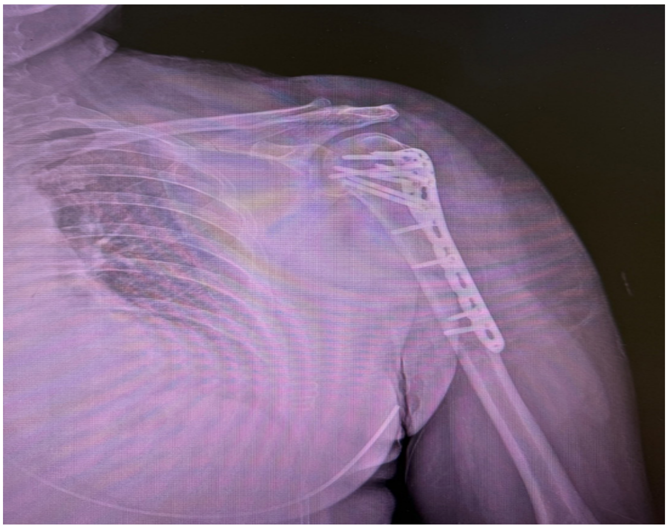

Figure 2. Postoperative AP image of the patient in Figure 1 after graftless plate and screw application

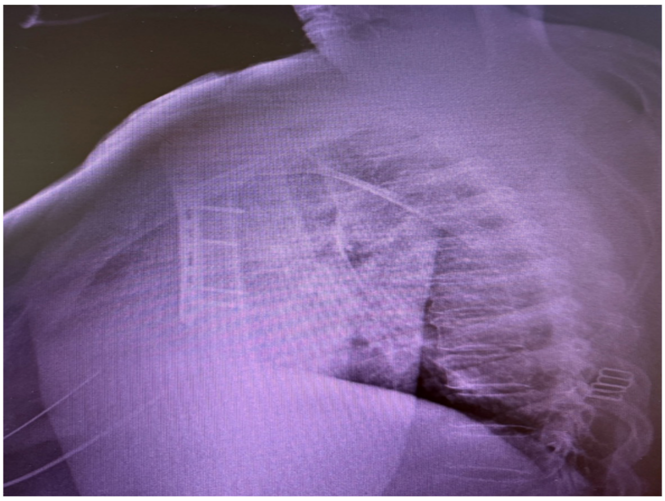

Figure 3. Postoperative LAT image of the patient in Figure 1 after graftless plate and screw application

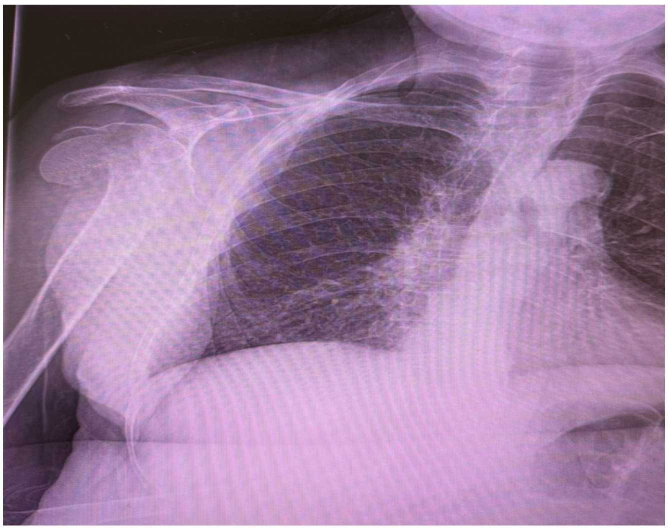

Figure 4. Preoperative image of a 64-year-old female patient with a complex humerus fracture

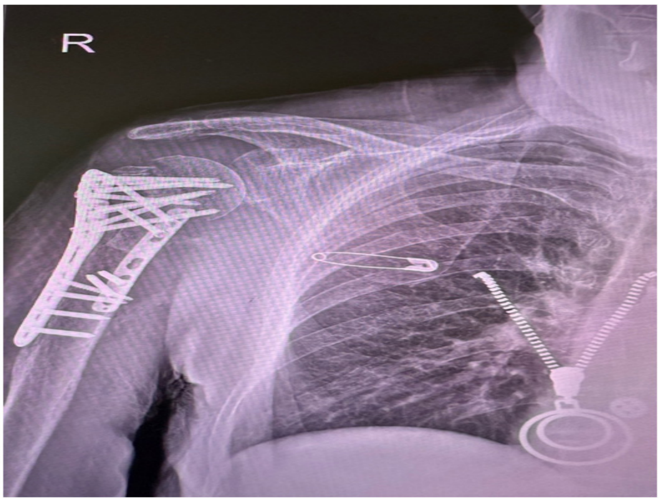

Figure 5. Postoperative AP view of the patient in Figure 4 after iliac crest graft+plate screw application

Figure 6. Postoperative LAT image of the patient in Figure 4 after iliac crest graft+plate screw application

DISCUSSION

This study investigated whether iliac crest cortical autograft augmentation provides superior outcomes compared to plate fixation alone in complex proximal humerus fractures. Our results demonstrated that patients in the plate+graft group achieved significantly faster union times and greater terminal ROM in flexion, extension, and abduction. However, these improvements did not translate into better Constant-Murley or VAS scores at one year.

Biomechanical Rationale and Alignment with Previous Research

The use of autografts to reinforce medial calcar support is grounded in biomechanical principles. Intramedullary cortical grafts provide additional load-sharing capacity, prevent varus collapse, and decrease micromotion at the fracture site.[23] Prior biomechanical studies have shown that fibular strut grafts significantly improve construct stability.[19] Our findings support these principles, demonstrating faster radiological healing and improved shoulder motion in the grafted cohort. Importantly, Kim et al.[22] found that iliac crest autografts provide reliable medial buttress and enhance fixation quality in proximal humerus fractures. Our study adds to this evidence by confirming their effectiveness in a larger retrospective cohort.

Functional Ceiling Effect and Clinical Relevance

The lack of improvement in Constant and VAS scores despite mechanical gains highlights the concept of a functional ceiling. Once patients reach the ROM and pain thresholds required for basic activity daily living scores (ADLs), further biomechanical improvements may not yield proportional clinical benefits. Several authors, including Spross et al.,[28] have reported that radiological union or improved reduction does not necessarily correlate with superior clinical scores at early follow-up. Our results echo these observations, suggesting that achieving biomechanical perfection does not always translate to improved patient-perceived function.

Donor Site Considerations and Rehabilitation

Although no complications were observed, donor-site morbidity remains a relevant concern with iliac crest grafting. Pain, gait disturbance, and cosmetic deformity have been described in other series but were not systematically evaluated in our study. This omission is an important limitation and highlights the need for future trials incorporating validated donor-site morbidity scales. Similarly, while the graft may theoretically allow earlier or more aggressive mobilization due to enhanced stability, our standardized rehabilitation protocol may have prevented these potential benefits from manifesting. Future prospective trials with tailored physiotherapy schedules for graft patients may provide more accurate insights.

Population Characteristics and Real-World Context

The mean age of 44 years indicates that the studied population was primarily composed of middle-aged, high-demand adults rather than osteoporotic patients. Therefore, the study's objective was not to evaluate osteoporotic fractures but to analyze the biomechanical contribution of medial calcar support in complex patterns. The smaller graft group size reflects selective clinical use of autografts in cases with medial comminution or compromised bone stock, mirroring real-world decision-making rather than random allocation.

Biomechanical Considerations and Comparison with Literature

Medial calcar support is fundamental for preventing varus collapse and maintaining fixation stability. Intramedullary cortical autografts enhance load-sharing and minimize micromotion at the fracture site.[15,25,26] Our findings are consistent with Kim et al.,[22] who demonstrated improved fixation strength and medial buttressing with iliac crest autografts. Similarly, Krappinger et al.[27] and Spross et al.[28] emphasized that restoration of medial continuity significantly improves mechanical stability and reduces complications after locking plate fixation.

Clinical and Functional Interpretation

Although the graft group exhibited superior mechanical outcomes, no statistically significant differences were observed in Constant or VAS scores at one year. This may reflect a functional ceiling effect, as patients often achieve sufficient motion for daily activities regardless of small biomechanical advantages. Similar findings have been reported by Spross et al.[28] and Jung et al.,[29] who found that radiologic improvements do not necessarily translate to better patient-reported outcomes at early follow-up.

Long-Term Perspective

Finally, the one-year follow-up in our study is insufficient to assess long-term complications such as humeral head collapse, avascular necrosis, or secondary osteoarthritis. These conditions often emerge beyond the first postoperative year and may reveal more pronounced benefits of graft augmentation. Longer-term prospective investigations are necessary to determine whether the mechanical advantages of grafting translate into improved survivorship of fixation constructs and reduced late complications.

Limitations

This study has several limitations that should be acknowledged. First, the retrospective design inherently carries a risk of selection bias, and the relatively small sample size—particularly in the plate+graft group—reduces the statistical power to detect subtle differences. Moreover, an a priori power analysis was not performed, which further limits the strength of the conclusions. Second, the age distribution differed significantly between the groups, with the plate+graft cohort being older. This imbalance may have influenced both functional outcomes and patients' perception of recovery, since older individuals typically have lower physical demands. Third, while iliac crest autografting is generally safe, donor-site morbidity such as pain, discomfort, or gait disturbance was not systematically assessed using validated tools, thereby restricting the comprehensiveness of our functional evaluation. Fourth, the one-year follow-up period is relatively short and insufficient to capture long-term complications such as humeral head collapse, avascular necrosis, or secondary osteoarthritis, which may alter the long-term benefit-risk profile of grafting. Fifth, both groups followed the same standardized rehabilitation program. Although graft augmentation theoretically permits earlier and more aggressive mobilization, this uniform protocol may have masked potential functional benefits. Finally, we did not assess the additional operative time, blood loss, and costs associated with iliac crest harvesting, which are important practical considerations when evaluating the overall value of grafting. These limitations should be taken into account when interpreting the results, and they highlight the need for larger, prospective studies with longer follow-up and more comprehensive outcome assessments.

CONCLUSION

In summary, iliac crest autograft augmentation in the surgical treatment of three- and four-part proximal humerus fractures enhances medial support, accelerates union, and improves terminal ranges of motion in selected planes. Nevertheless, these biomechanical and radiological advantages did not result in superior patient-reported outcomes within the first postoperative year. This discrepancy highlights the complex relationship between objective surgical improvements and subjective clinical recovery.

The findings of this study suggest that while iliac crest grafting provides measurable mechanical benefits, its clinical utility may be most relevant in younger, high-demand patients or in cases with severe medial comminution where construct failure is more likely. For older or low-demand patients, the additional surgical time, donor-site morbidity, and costs may outweigh the benefits, particularly when standard fixation techniques already achieve acceptable outcomes.

Future research should prioritize prospective, randomized studies with larger cohorts, incorporate standardized donor-site morbidity assessments, and extend follow-up beyond one year. Additionally, the potential synergy between grafting and customized rehabilitation protocols should be explored, as earlier mobilization may reveal hidden functional benefits. Ultimately, individualized treatment strategies that balance biomechanical stability, patient expectations, and resource considerations are essential for optimizing outcomes in proximal humerus fracture management.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study has been approved by the Clinical Researches Ethics Committee of Ankara Training and Research Hospital (Date: 02.05.2024, Decision No: 106/2024).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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