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ORIGINAL STUDY

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The effect of single plate and double plate application on union and functional results in humeral diaphyseal nonunions

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In this study, we assessed and compared the outcomes of two different fixation techniques for humeral diaphyseal fracture nonunions. A retrospective evaluation of 22 patients who underwent single-plate and double-plate fixation due to humeral diaphyseal nonunions was conducted. Union rates, union times, and functional outcomes of the patients were assessed. There was no significant difference between single-plate and double-plate fixation in terms of union rates or union times. The double-plate fixation group achieved significantly better functional outcomes. Nerve damage or surgical site infection were not encountered in either group.Due to its considerable effect on stability, double-plate fixation, offers both patients and surgeons confidence in terms of early adaptation to daily life in the postoperative period.

Keywords: Humeral nonunions; single plate; double plate; functional results.

INTRODUCTION

Humeral diaphyseal fractures account for about 30% of humeral fractures *(1)*. While the majority of these fractures are treated conservatively, surgical treatment is preferred in cases such as open fractures, vascular-nerve injuries, and polytrauma *(2)*. Although both conservative and surgical treatment can provide successful results, nonunions may occur in up to 15% of cases *(3,4)*.

Nonunions that occur after fractures of long bones can affect the patient's daily life and cause psychological problems due to the inadequate use of the limb *(5)*. In order to increase the patient's quality of life, the appropriate treatment modality should be determined and applied. Although treatment with intramedullary nailing, external fixators, and single-plate or double-plate fixation have demonstrated successful results in the treatment of

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humeral diaphyseal nonunion, treatment with plates is regarded as the most popular method *(6,7)*.

Studies have shown that stability has a major impact on fracture healing *(8)*. It is thought that deteriorated bone quality due to non-use in humeral pseudarthrosis reduces stability of fixation material in revision surgery *(9)*.

This retrospective study aims to investigate the effect of double-plate fixation, applied in our clinic to increase fixation stability in humeral pseudoarthrosis, on union time and functional outcomes compared to single-plate fixation.

MATERIAL AND METHODS

This retrospective study was conducted after receiving approval from the local institutional review board. A total of 22 patients diagnosed with humeral diaphyseal fracture nonunion between 2015-2020 were retrospectively evaluated. Group 1 consisted of 11 patients who were applied single-plate fixation and Group 2 consisted of 11 patients who were applied double-plate fixation to treat nonunion. Patients with infected nonunions, brachial plexus injury, patients treated with intramedullary nailing and Ilizarov external fixator, and patients with diseases that disrupted bone mineralization such as chronic renal failure were excluded from the study. Infections were determined according to wound site discharge and blood parameters. Nonunion was considered as nonunion within the first nine months after initial treatment, no progression in union for three months during monthly follow-up, and failure of implants. In Group 1, initial treatment was conservative in two patients, intramedullary nailing in one patient, and with external fixator in one patient. The other seven patients were initially treated with 4.5 mm low-contact dynamic compression plate(LCDCP). Two patients in Group 1 had radial nerve damage before nonunion surgery. Six patients had atrophic nonunion, in whom five had hypertrophic nonunion. In Group 2, ten patients were initially treated with plate fixation and one patient with intramedullary nailing. One patient in Group 2 had preoperative radial nerve damage, while seven patients had hypertrophic nonunion and four patients atrophic nonunion.

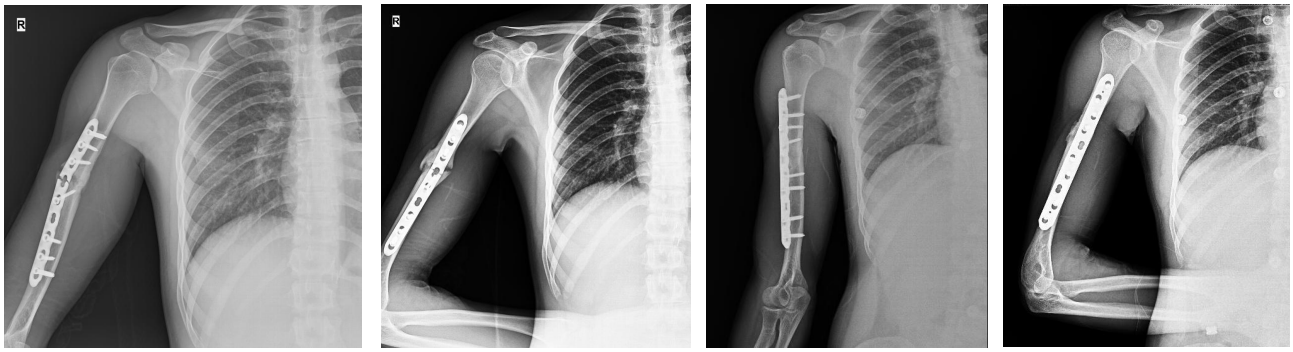
All patients were operated under general anesthesia. Iliac crests of the patients were preoperatively prepared for bone grafting. The old incision site (anterolateral) was used in patients who were previously operated on and the anterolateral approach was applied in unoperated patients. The radial nerve was identified, explored, and suspended. Implants were removed in previously operated patients. After gaining access to the fracture line, the necessary debridement was performed. Cancellous bone graft harvested from the iliac crest was placed in the fracture line after proximal and distal canal drilling. In Group 1, in which one-plate fixation was applied, 4.5 mm LCDCP were fixed proximally and distally with screws to hold eight cortexes (Fig. 1). In Group 2, in which double-plate fixation was applied, in addition to these procedures, a 3.5 mm LCDCP was fixed proximal to the fracture and perpendicular to the first plate with screws that would hold six cortexes (Fig. 2). The wound was closed and a simple arm sling was applied.

Patients were permitted to use their extremities as much as they could tolerate during the postoperative period. Patients were summoned to monthly follow-ups. Fracture union was considered as union of at least three cortexes in anteroposterior and lateral radiography. Functional outcomes of the patients were evaluated according to the Stewart functional scale (Table I).

All analyses were performed using SPSS 21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). Continuous variables were expressed as median (minimum-maximum) and mean ± standard deviation values, and categorical variables were expressed as frequency (percent) values. The results were reported with the 95% confidence intervals (CIs) and related p values. Normal distribution of continuous data was tested using the Shapiro-Wilk test, skewness, and kurtosis. Mann-Whitney U test and Independent samples t-test were used for comparisons between two groups. The value of $p < 0.05$ was considered statistically significant.

RESULTS

Demographic data of the patients are presented in Table II. Except for one patient, union was achieved



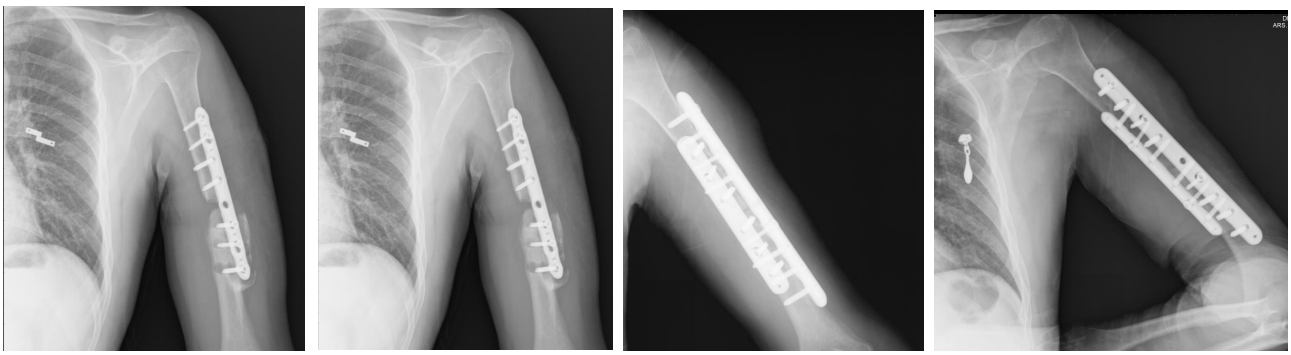
A: Pre-operative anteroposterior (AP) radiography.

B: Pre-operative lateral radiography.

C: Post-operative anteroposterior (AP) radiography.

D: Post-operative lateral radiography.

Figure 1. — Radiographs after revision of humerus nonunion with single-plate fixation.



A: Pre-operative anteroposterior (AP) radiography.

B: Pre-operative lateral radiography.

C: Post-operative anteroposterior (AP) radiography.

D: Post-operative lateral radiography.

Figure 2. — Radiographs after revision of humerus nonunion with double-plate fixation.

Table I. — Stewart and Hundley classification of functional results

	Pain	Range of motion	Alignment and complications
Excellent	No	Full	Good
Good	Occasional	<20° limitation	<10° angulation
Fair	After effort	20° to 40° limitation	>10° angulation
Poor	Permanent	>40° limitation	Nonunion ,iatrogenic radial nerve palsy

Table II. — Patients' demographics data

	Group 1 Single plate	Group 2 Double plate
Age (Year)	39 (19-56)	43,5(23-64)
Sex (Female/Male)	3/8	3/8
Nonunion type (Atrophic-Hypertrophic)	6/5	4/7
Injured side (Left/Right)	4/7	5/6
Follow-up time(month)	23,2 (6-96)	13 (6-36)

in ten patients in Group 1 and in all patients in Group 2. It was determined that the patient who did not achieve union had underwent revision with single-plate fixation due to pseudoarthrosis at an external institution, and had still not achieved union as observed in last follow-up radiography. Mean union time was 19.2 (8-44) weeks in Group 1 and 15.4 (7-32) weeks in Group 2. Despite shorter union time in Group 2, there was no statistically significant

difference between the groups in terms of union time ($p>0.05$). When both groups were evaluated according to the Stewart functional scale, functional scores were 3.6 ± 0.5 in Group 1 and 2.7 ± 1.4 in Group 2. The functional results of the patients in Group 2 were statistically better than the function results of the patients in Group 1 ($p <0.05$).

Two patients in Group 1 and one patient in Group 2 had preoperative radial nerve damage. No new nerve damage occurred during the postoperative period. None of the patients developed infection during the postoperative period.

DISCUSSION

Nonunions of long bones may cause patients pain and loss of function. When this becomes a chronic condition, it may lead to psychological problems *(10)*. Surgeons must determine the most appropriate treatment method for each nonunion. According to the literature, intramedullary nailing, Ilizarov external fixator, and single-plate and double-plate methods are widely used methods in the treatment of humeral nonunion *(11-14)*. A method with short union time, fewer complications, and an early adaptation to daily life should be preferred.

When comparing methods to treat humeral non-union, similar union rates and union times have been reported. Union rates from 40% up to 100% have been achieved in treatments with intramedullary nailing *(15-17)*, with union times ranging between 4.2 to 6 months *(15,17,18)*. Successful results of up to 100% and union times ranging from 5.5-7.2 months have been reported with treatment using the Ilizarov external fixator *(13,19-21)*. When using plates to treat nonunion, single-plate and double-plate methods are performed. Like other treatment methods, both methods have yielded union rates of over 90% with union times usually ranging between 4-5 months *(14,22,23)*. Our study was consistent with the literature in terms of union rates. Union was achieved in all patients, except for one patient in whom single-plate was applied. Although the union time was shorter in patients who were applied the double-plate method, our union times were shorter compared to the literature.

All of these methods used to treat nonunion have demonstrated successful results. Therefore, the treatment method should be selected according to the method's complications and the patient's comfort. One of the most feared complications is nerve damage. Rates of postoperative nerve damage have been reported as 3% after intramedullary nailing *(24,25)*, 8% after external fixator *(13,20)*, and 5% after plate application, however it is reported that nerve damage is usually temporary *(4,26)*. We did not encounter nerve damage in any of our patients during the postoperative period. Although the radial nerve is very susceptible to injury in the surgical site, these injuries are mostly temporary. Care should be taken when accessing the fracture line and during debridement.

In order to increase functional outcomes of patients undergoing treatment of nonunion, early mobilization during the postoperative period may be beneficial. Although early mobilization is permitted in the postoperative period after intramedullary nailing, injury to the rotator cuff during surgery causing subacromial impingement may result in poor functional outcomes *(4-6,8,22,23)*. Treatment with the Ilizarov external fixator, on the other hand, restricts joint movements due to close proximity of its frames to the joint, and may lead to undesired functional outcomes due to patient discomfort *(27)*. The double-plate method has demonstrated better functional results due to its significant contribution to axial and torsional stability and also because it allows early mobilization without the need for any assistive apparatus *(14,22)*.

The double-plate method is used in humeral nonunions to increase fixation stability for reasons such as the humeral structure not allowing a sufficient number of screws to be fixed distally and decreased bone quality *(28)*. Murray et al., who popularized the use of the double-plate method in nonunion treatment, indicated that the double-plate method provides a stable fixation and has positive effects on fracture union *(29)*. Biomechanical studies have shown that double-plate fixation provides more stable fixation than single-plate fixation and intramedullary nailing *(30,31)*. One biomechanical study, which evaluated plate placement and plate length, found that the most stable fixation method for

osteoporotic bones was the method that used eight lateral screws and six anterior screws for fixation *(31)*. Therefore, in our study, this plate configuration was applied in patients who underwent double-plate fixation and early postoperative mobilization was initiated. The double-plate method involves more soft tissue dissection than the single-plate method, resulting in concerns that it may disrupt circulation. Studies have shown that these concerns may be valid for acute fractures; as for nonunions, it has been shown that no additional interventions are required for exposure for the necessary debridement when applying the second plate *(22)*. Decreased bone quality and osteoporosis may develop due to non-use of the extremity. Decreased bone quality may lead to negative outcomes in fracture union by decreasing fixation stability *(25)*. It has been observed that the double-plate method applied to increase stability does not increase the risk of complications, while also positively contributing to functional results by allowing early mobilization and return to daily life, due to both the patient and the surgeon's confidence in the procedure.

CONCLUSIONS

Although several methods provide successful results in humeral nonunions, the aim is to enable patients to return to their daily activities in the postoperative period as soon as possible, rather than bone union alone. We believe that the doule-plate fixation method, which increases the confidence of both surgeons and patients, significantly contributes to the stabilization of the deteriorated bone after nonunion compared to the single-plate fixation method.

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