Middle Black Sea Journal of Health Science /
Mid Blac Sea J Health Sci

August 2022; 8(3): 393-402

RESEARCH ARTICLE

DOI: 10.19127/mbsjohs.1093040

Functional Outcomes of Patients Treated with Fibula Strut Graft and Double Plate in the Treatment of Recalcitrant Humerus Nonunions

Selami Karadeniz[1](ID), Murat Bolukbasi[2](ID)

[1]School of Medicine, Department of Orthopaedics and Traumatology, Amasya University, Amasya, Turkey.
[2]Department of Orthopaedics and Traumatology, Medicalpark Samsun Hospital, Samsun, Turkey.

Received: 28 March 2022, Accepted: 15 June 2022, Published online: 31 August 2022

Abstract

Objective: Recalcitrant humerus nonunion is challenging to treat, and plate fixation is a common treatment choice. This study aimed to determine the efficiency of double plating combined with nonvascularized autologous fibular strut allograft in the treatment of atrophic and defective humerus nonunions.

Methods: Fourteen patients were surgically treated for recalcitrant humerus nonunions. Demographic data (age, gender, dominant side), clinical features, and previous surgical records of the patients were recorded preoperatively. Preoperative Visual Analogous Scale (VAS) and Constant-Murley scores of the patients were recorded before the surgery.

Results: 10 (71.4%) of the patients were female, and 4 (28.5%) were male. The mean age was 53.07±9.69 (range, 39-67). 9 (64.3%) of the patients had nonunions on the dominant side. The mean follow-up was 11.14±1.9 months. The complete union was observed in all patients, and the mean union time was 5.1±0.63 months (range, 4.2-6.0). The mean preoperative VAS score was 7.29 ± 0.91 (range, 6-9), and the mean postoperative VAS score was 0.93 ± 0.92 (range, 0-3). VAS scores improved after the surgery (p<0.001). The mean preoperative Constant-Murley score was 53.57 ± 12.17 (range 34-72), and the mean postoperative Constant-Murley score was 86.00 ± 9.21. Constant-Murley scores improved after the surgery (p<0.001). Gender (p=0.635), dominant side involvement (p=0.112), and age (p=0.925) did not correlate with union time.

Conclusion: Double plating with autologous nonvascularized fibular grafts is a successful treatment option for recalcitrant humerus atrophic nonunions, especially with bony defects.

Key words: Recalcitrant humerus nonunion, Double plating, nonvascularized fibular grafts

Suggested Citation: Karadeniz S, Bolukbasi M. Functional Outcomes of Patients Treated with Fibula Strut Graft and Double Plate in the Treatment of Recalcitrant Humerus Nonunions. Mid Blac Sea Journal of Health Sci, 2022;8(3):393-402

Address for correspondence/reprints:

Selami Karadeniz

Telephone number: + 90 (506) 599 35 38

E-mail: drskaradeniz@hotmail.com

INTRODUCTION

Humerus fractures are common, accounting for 5-8% of all fractures. Several surgical and conservative methods for treating humerus fractures are well-defined in the literature. Nonunion rates after conservative treatment of the humerus fractures are 2-10%, which is reported as 30% after surgical management (1-3). Most of these fractures occur in the proximal one-third portion or have a proximal butterfly fragment (4). Complex fractures, inadequate fixation, smoking and alcohol consumption, infections, diabetes mellitus, malnutrition, and early brace removal are reported etiological factors for humerus nonunion (5). Implanted implants and infections after multiple surgeries lead to bony defects, osteopenia, necrotic bone, scars in the connective tissue, metallosis, and instability, which are the obstacles to surgical treatment (6).

Humerus nonunions can be successfully treated with osteosynthesis with single or double plates, intramedullary nailing, Ilizarov fixators, and bone grafting. Success rates with these methods or combinations are reported as 82-95% in the literature (7). Compression plating combined with intramedullary fibular strut allografts is a previously defined surgical technique for treating atrophic and osteopenic humerus nonunions (8, 9). The aim of this study is to determine the efficiency of double plating combined with nonvascularized autologous fibular strut allograft in the treatment of atrophic and defective humerus nonunions after failed surgeries.

METHODS

Fourteen patients surgically treated for recalcitrant humerus nonunions in our clinic between 2009 and 2018 were retrospectively evaluated. Institutional Review Board approval from Amasya University was obtained. Written and verbal informed consent of the patients was taken.

Demographic data, clinical features, and previous surgical records of the patients were recorded preoperatively. CBC, ESR, and serum CRP values of the patients were tested to diagnose probable infection. Patients with a history of previous surgery for humerus fractures, having bony defects, and no infection are included in this study. Patients with infection, pathological fractures, malunions too distal for intramedullary fibular graft usage, and patients without bony defects were excluded from the study. Preoperative Visual Analogous Scale (VAS) and Constant-Murley scores of the patients were recorded before the surgery (10).

Surgical Technique:

All the patients were operated under general anesthesia and in the supine position. The same surgeon operated all of the patients. Previous surgical scars and nonunion lines were considered for the skin incision. The radial and musculocutaneous nerves were identified and protected during the soft tissue dissection. Existing implants were removed, and the nonunion line was exposed. All of the fibrous and bony necrotic tissues in the nonunion line were removed. Samples from the nonunion line were taken for culture. Obstructed medullary canals, both proximal and distal to the nonunion line, were curetted and drilled. Two two-cm skin incisions were done in the distal and proximal ends of the 10-cm middle portion of the fibula. Soft tissue was dissected, and fibular osteotomy was performed from these incisions. Neighboring soft tissue was dissected, and 10-cm long autologous fibular strut graft was harvested.

Soft tissue on the graft was removed, and the graft was decorticated to fit the intramedullary canal of the humerus. The graft was positioned as the middle point of the graft will be in the nonunion line. Bony alignment was carefully evaluated to prevent rotation. One 3.5-mm LC-DCP plate was applied from the lateral aspect of the humerus, and another plate was applied from the anterior aspect after that. Both plates were implanted in a manner as at least four screws were implanted in the proximal part and at least four in the distal part of the humerus. The longest possible plate was implanted according to the site of the nonunion. The periosteum was protected as far as possible.

No splints were utilized in the postoperative period. Passive shoulder and elbow movements were started on the first postoperative day. Active range-of-motion exercises were started after the radiological union.reached

Statistical Analysis

Power analysis was performed with the G*Power version 3.1.9.7 software (11). According to the power calculations for the study performed by Feng et al. (12), only four patients were needed to compare the mean Constant-Murley scores between the groups.

Statistical analysis was performed using SPSS version 27.0 (SPSS, Inc., Chicago, IL). Frequency distributions were expressed as number and percentage, continuous variables as mean ± standard deviation. Normality of the data was tested with the Kolmogorov-Smirnov test, and since all the distributions of the variables were normal, parametric tests were used. The p-value of less than 0.05 was considered significant.

RESULTS

Ten (71.4%) of the patients were female, and four (28.5%) were male. The mean age was 53.07±9.69 (range, 39-67). Nine (64.3%) of the patients had nonunions on the dominant side. The mean follow-up was 11.1±1.9 months. A complete union was observed in all patients, and the mean union time was 5.1±0.63 months (range, 4.2-6.0) (Figures 1, 2). Patients' data are summarized in Table 1.

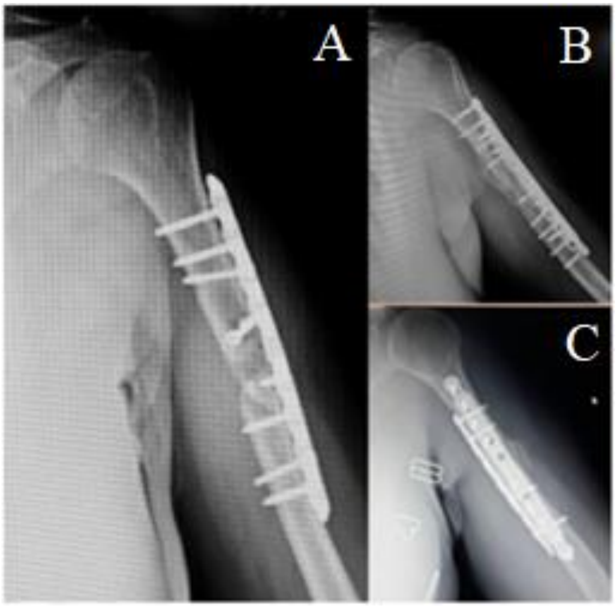


Figure-1. 49 years old women A-B) preoperative, C) postoperative 60th days D) postoperative 100th days

Nine of the patients were operated once, and five of them were operated twice in another center, and these surgeries failed. Four of them had intramedullary nailing, and ten of them had plate-screw osteosynthesis.

The mean preoperative VAS score was 7.29 ± 0.91 (range, 6-9), and the mean postoperative VAS score was 0.93 ± 0.92 (range, 0-3). VAS scores improved after the surgery (the paired samples t-test, $p<0.001$).

The mean preoperative Constant-Murley score was 53.57 ± 12.17 (range 34-72), and the mean postoperative Constant-Murley score was 86.00 ± 9.21. Constant-Murley scores improved after the surgery (the paired samples t-test, p<0.001).

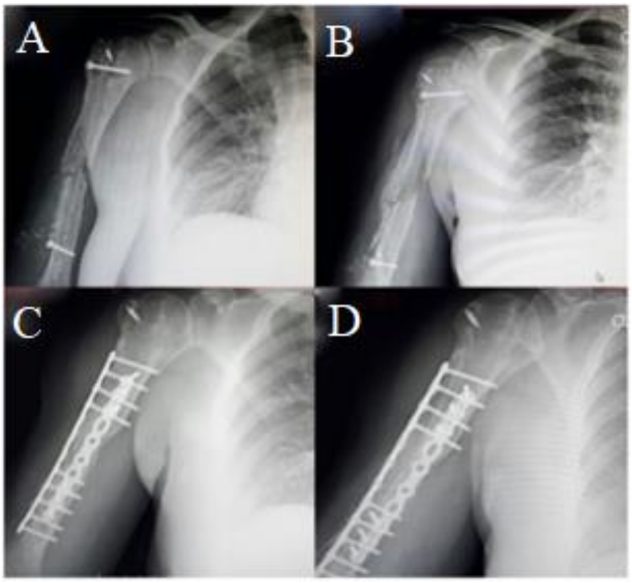


Figure-2: 47 years old women, A) preoperative, B) postoperative 60th days and C) postoperative 90th days

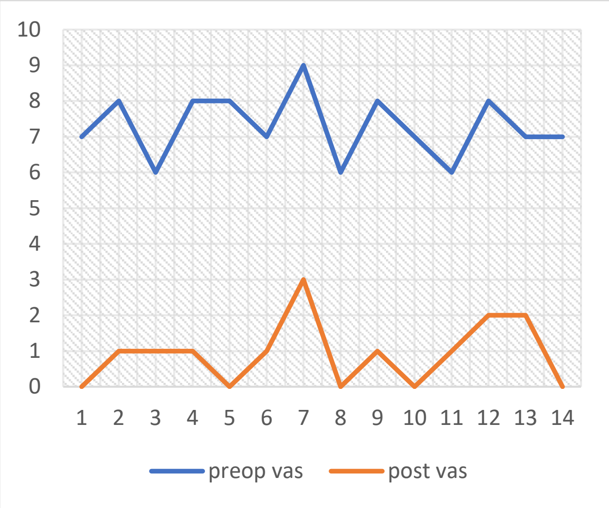
Gender did not affect the postoperative VAS score (Independent-Samples t-test, p=0.428), union time (Independent-Samples t-test, p=0.679), or postoperative Constant-Murley score (Independent-Samples t-test, p=0.999).

Dominant side involvement did not affect the postoperative VAS score (Independent-Samples t-test, p=0.055), union time (Independent-Samples t-test, p=0.068), or postoperative Constant-Murley score (Independent-Samples t-test, p=0.366).

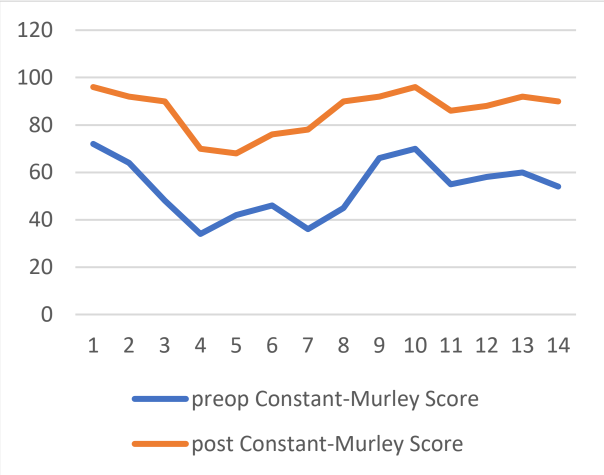
Age did not correlate with union time (Pearson correlation test, r=0.0584, p=0.842), postoperative VAS score (Pearson correlation test, r=0.147, p=0.614) or postoperative Constant-Murley score (Pearson correlation test, r=0.4944, p=0.072).

Table 1. Patients' data

Patient No	Gender	Age (Years)	Affected Side	Union Time (Months)	Follow Up Time (Months)
1	Female	49	R-dominant	5,50	11
2	Female	47	R-dominant	4,20	13
3	Male	54	L-nondominant	5,50	12
4	Female	67	L-nondominant	6,50	14
5	Female	48	R-dominant	4,60	10
6	Female	65	R-dominant	5,00	9
7	Male	62	L-dominant	4,80	10
8	Male	43	L-nondominant	6,00	8
9	Female	57	R-dominant	5,20	12
10	Female	42	L-nondominant	5,00	11
11	Male	65	L-dominant	4,60	10
12	Female	39	R-dominant	5,50	9
13	Female	44	R-dominant	4,50	13
14	Female	61	L-nondominant	4,60	14



Graphic-1. Preoperative and Postoperative VAS Scores



Graphic-2. Preoperative and Postoperative Constant-Murley Scores

DISCUSSION

Recalcitrant humerus nonunions are hard-to-treat for both the patients and the surgeons. Patients generally complain about pain and inability to move. Co-existing problems such as obesity, diabetes mellitus, osteoporosis, alcoholism, and smoking habit may complicate the treatment (13, 14). Dissection may be more complex with previous unsuccessful surgical attempts and previous implants. Neurovascular structures are more prone to injuries.

Various techniques for managing humerus nonunions are well-defined in the literature, but the old standard technique is still debatable (8, 9, 15). Several studies showed that plate-screw systems and bone grafts can achieve union in more than 90% of the patients (16-18). The main disadvantage of this technique is the necessity for comprehensive dissections. Especially the radial nerve is at risk of injury with this technique, having an incidence of 5%, which are mostly transient (19, 20).

Results of intramedullary nailing are also a matter of debate. Siedel nails have a success rate of 30-60% (21) and using unreamed nails with bone grafts yields a 100% success rate (22). Martinez et al. compared plates and intramedullary nails in 50 patients, and with the combination of iliac crest autografts, they observed union in all patients (22).

Ilizarov external fixator is another option for the treatment of humeral nonunions. Some studies reported fewer complication rates with this technique (23, 24). This fixator is especially reasonable for patients having active infections and skin problems. Disadvantages of this technique are pin-tract infections, long treatment durations, and discomfort.

We achieved union in all the patients with plate-screw osteosynthesis. An extended anterolateral approach was used in all the patients, considering the previous incision scars. We dissected and preserved the radial nerve in all the surgeries despite the adhesions resulting from previous surgeries, and none of our patients experienced radial nerve injury (Figure-1).

Osteoporosis and osteopenia may complicate the treatment of recalcitrant humerus nonunions. These can be seen because of elderly age, previous surgeries, and disuse. Overlapping the bone erosions of previous plates, previous screw holes, and bone loss because of the loose screws with osteopenia may make a stable fixation with plate-screws impossible (23). Utilization of 6.5 mm cancellous screws instead of 4.5 mm cortical screws and poly-methyl methacrylate (PMMA) usage are described to increase stability. On the other hand, PMMA may end up with foreign body reactions, infections, and deteriorated blood circulation of the bone, probably due to increased local temperature (24). Extramedullary or intramedullary fibular grafts are described as a means of increasing the stability of fixation. Wright et al. was the first author who described the usage of intramedullary fibular strut grafts to treat humerus malunions. They reported that intramedullary fibular grafts are intramedullary splints and the quadricortical usage of screws are biomechanically equivalent to PMMA and bicortical screws (9). While extramedullary grafts result with extended dissections, intramedullary applications do not disturb the vasculature of the bone with dissections (9, 18). Fibula may be used as allografts, vascularised or non-vascularised autografts. Vascularised fibular grafts are good choices, especially when the bony defect is wide and segmental (17, 25-27).

On the other hand, it is technically demanding. Non-vascularised fibular grafts are easier to harvest and lead to less donor site morbidity. Some authors reported successful results with non-vascularized fibular grafts (9, 28-30). Using plates with intramedullary grafts may damage both the endosteal and periosteal blood flow, and some authors advocated grafts shorter than 6 cm because of this (25). Iatrogenic fracture is another risk of intramedullary grafts especially with osteoporotic bones. We used 10-cm long non-vascularised fibular autografts, regardless of the size of the bony defect. After the stripping of the soft tissue, the graft was attentively decorticated according to the width of the humeral medulla. In order to protect stability after decortication, we did not let the fibular medulla open. We adjusted the graft in a manner that the graft did not make the humerus crack while maintaining stability. None of the patients complained about the donor side morbidity (Figure-2).

Plate-screw systems were reported to have an 83-100% success rate in the treatment of humerus nonunions either alone or with the combination of several grafts (31). Hierholzer et al. conducted a study with 78 patients and treated them with several graft combinations and locking compression plates. They used autologous iliac crest grafts in 45 patients and demineralised bone matrix (DBM) in 33 patients. They reported 100% union rate with iliac crest grafts and 97% union rate with DBM. Twenty of the patients treated with iliac crest grafts complained about prolonged pain at the donor site and superficial infections and irrigation and debridement was necessary in one patient (32). Reed et al. analysed the specimens taken from the nonunion lines in 22 nonunion patients. They reported that the vasculature of the 11 atrophic nonunions and 11 hypertrophic nonunions were same (33). Willis et al. reported 95% union rates with locked compression plates and intramedullary strut allografts in a study performed with 20 patients. They also reported that the biological status of the nonunion site is more important than the type of the graft. They advocated that stable fixation with an allograft which does not cause additional morbidity is sufficient for the treatment of nonunions of the humerus (34). While single plating is reported to have good or excellent results, double plating is shown to increase compressive and torsional forces (34-36). We applied double LC-DCP plating with autologous non-vascularised fibular grafts. All our patients were operated before at least once and had atrophic nonunions with bony defects. Their bone qualities were poor. They were excluded from social life and work for long durations. Because of this, our main aim was to acquire perfect stability. We thoroughly debrided the nonunion line, removed all the necrotic bone and soft tissue. We applied the longest possible plate to maximise the stability. We used autologous fibular grafts and even if its osteoinductive effect is less than autologous cancellous bone grafts have, we did not add extra grafts. We made minimal incisions to harvest the graft and did our best to protect the soft tissue. We did not have any complications except the prolonged donor site pain in two patients. We could start early rehabilitation with the help of stable fixation. We achieved full union in all our patients. Feng et al also reported a 100% union rate and better Constant-Murley scores with this method (12). They reported the mean union time as 6.4 ± 1.8 months, which is slightly longer than reported in our study, 5.1±0.63 months.

The limitations of this study are its retrospective nature and limited number of the patients. Recalcitrant humerus nonunions are not common in daily practice. Because of the limited number of the cases, we could not have a control group. On the other hand, previous reports about humerus nonunions have similar sizes. It is possible to compare graft types and fixation methods with sufficient number of cases.

As a result, double LC-DCP plating with autologous nonvascularised fibular grafts is a successful treatment option for recalcitrant humerus atrophic nonunions, especially with bony defects. Autologous fibular grafts are important because they increase stability, quadricortical course of the screws enhance mechanical power of the plate fixation and they have osteoinductive property. 90°double plating increases the tensile and compressive forces in the nonunion line and diminishes the failure rates.

Ethics Committee Approval: Ethical approval was obtained from the local ethics committee at Amasya University with file number 2021/133

Author Contributions: Concept: SK Design: SK, MB. Literature search: SK, MB, Data Collection and Processing: SK, MB Analysis or Interpretation: SK, MB, Writing: SK, MB.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study hasn’t received no financial support.

REFERENCES

1. Borus TA, Yian EH, Karunakar MA. A case series and review of salvage surgery for refractory humeral shaft nonunion following two or more prior surgical procedures. The IOWA Orthopaedic journal. 2005;25:194.
2. Volgas DA, Stannard JP, Alonso JE. Nonunions of the humerus. Clinical Orthopaedics and Related Research (1976-2007). 2004;419:46-50.
3. Rupp M, Biehl C, Budak M, Thormann U, Heiss C, Alt V. Diaphyseal long bone nonunions—types, aetiology, economics, and treatment

recommendations. International orthopaedics. 2018;42(2):247-58.

4. Mast JW, Spiegel PG, Harvey Jr JP, Harrison C. Fractures of the humeral shaft: a retrospective study of 240 adult fractures. Clinical orthopaedics and related research. 1975(112):254-62.

5. Babhulkar S, Babhulkar S, Vasudev A. Recalcitrant aseptic atrophic non-union of the shaft of the humerus after failure of surgical treatment: management by excision of non-union, bone grafting and stabilization by LCP in different modes. Injury. 2017;48:S33-S43.

6. Rubel IF, Kloen P, Campbell D, Schwartz M, Liew A, Myers E, et al. Open reduction and internal fixation of humeral nonunions: a biomechanical and clinical study. JBJS. 2002;84(8):1315-22.

7. Muramatsu K, Doi K, Ihara K, Shigetomi M, Kawai S. Recalcitrant posttraumatic nonunion of the humerus: 23 patients reconstructed with vascularized bone graft: 23 patients reconstructed with vascularized bone graft. Acta Orthopaedica Scandinavica. 2003;74(1):95-7.

8. Badman BL, Mighell M, Kalandiak SP, Prasarn M. Proximal humeral nonunions treated with fixed-angle locked plating and an intramedullary strut allograft. Journal of orthopaedic trauma. 2009;23(3):173-9.

9. Wright TW, Miller GJ, Vander Griend RA, Wheeler D, Dell PC. Reconstruction of the humerus with an intramedullary fibular graft. A clinical and biomechanical study. The Journal of Bone and Joint Surgery British volume. 1993;75(5):804-7.

10. Celik D. Turkish version of the modified Constant-Murley score and standardized test protocol: reliability and validity. Acta Orthop Traumatol Turc. 2016;50(1):69-75.

11. Faul F, Erdfelder E, Lang A-G, Buchner A. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior research methods. 2007;39(2):175-91.

12. Feng D, Wang X, Sun L, Cai X, Zhang K, Wang Z, et al. Double plating with autogenous bone grafting as a salvage procedure for recalcitrant humeral shaft nonunion. BMC Musculoskeletal Disorders. 2020;21(1):1-8.

13. Castellá FB, Garcia FB, Berry EM, Perelló EB, Sánchez-Alepuz E, Gabarda R. Nonunion of the humeral shaft: long lateral butterfly fracture–a nonunion predictive pattern? Clinical Orthopaedics and Related Research®. 2004;424:227-30.

14. Coventry MB, Laurnen EL. 16 Ununited Fractures of the Middle and Upper Humerus Special Problems in Treatment. Clinical Orthopaedics and Related Research®. 1970;69:192-8.

15. Wallny T, Westermann K, Sagebiel C, Reimer M, Wagner U. Functional treatment of humeral shaft fractures: indications and results. Journal of orthopaedic trauma. 1997;11(4):283-7.

16. Barquet A, Fernandez A, Luvizio J, Masliah R. A combined therapeutic protocol for aseptic nonunion of the humeral shaft: a report of 25 cases. The Journal of trauma. 1989;29(1):95-8.

17. Jupiter JB. Complex non-union of the humeral diaphysis. Treatment with a medial approach, an anterior plate, and a vascularized fibular graft. The Journal of Bone and Joint surgery American

Volume. 1990;72(5):701-7.
18. Van Houwelingen AP, McKee MD. Treatment of osteopenic humeral shaft nonunion with compression plating, humeral cortical allograft struts, and bone grafting. Journal of orthopaedic trauma. 2005;19(1):36-42.
19. Hornicek FJ, Zych GA, Hutson JJ, Malinin TI. Salvage of humeral nonunions with onlay bone plate allograft augmentation. Clinical Orthopaedics and Related Research®. 2001;386:203-9.
20. Kumar A, Sadiq S. Non-union of the humeral shaft treated by internal fixation. International orthopaedics. 2002;26(4):214-6.
21. Pietu G, Raynaud G, Letenneur J. Treatment of delayed and nonunions of the humeral shaft using the Seidel locking nail: a preliminary report of five cases. Journal of orthopaedic trauma. 1994;8(3):240-4.
22. Martínez ÁA, Cuenca J, Herrera A. Treatment of humeral shaft nonunions: nailing versus plating. Archives of orthopaedic and trauma surgery. 2004;124(2):92-5.
23. Ansell R, Scales JT. A study of some factors which affect the strength of screws and their insertion and holding power in bone. Journal of biomechanics. 1968;1(4):279-302.
24. Trotter DH, Dobozi W. Nonunion of the humerus: rigid fixation, bone grafting, and adjunctive bone cement. Clinical orthopaedics and related research. 1986(204):162-8.
25. Kerfant N, Valenti P, Kilinc A, Falcone M. Free vascularised fibular graft in multi-operated patients for an aseptic non-union of the humerus with segmental defect: Surgical technique and results. Orthopaedics & Traumatology: Surgery & Research. 2012;98(5):603-7.
26. Taylor GI, Miller G, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular techniques. Plastic and reconstructive surgery. 1975;55(5):533-44.
27. Liaw F, Teoh SH, Stevens-Harris I, Maamoun W. Outcomes of free vascularised fibular graft reconstruction in upper limb trauma—a systematic review. European Journal of Orthopaedic Surgery & Traumatology. 2022:1-17.
28. Humerus YOHKO, Fibula ŞKN, GPBÇ. Fibular Non-Vascularized Graft Might be a Practical Solution for Treatment of Osteopenic Humeral Shaft Non-union in Elderly Obese Patients. 2011.
29. Erden ER, Arda C, Mesut SM, Adnan K, Bulent OI, Irfan O. Implementation of locking compression plate together with intramedullary fibular graft in atrophic type humeral nonunions. European Journal of Orthopaedic Surgery & Traumatology. 2012;22(8):661-5.
30. Padhye KP, Kulkarni VS, Kulkarni G, Kulkarni MG, Kulkarni S, Kulkarni R, et al. Plating, nailing, external fixation, and fibular strut grafting for non-union of humeral shaft fractures. Journal of Orthopaedic Surgery. 2013;21(3):327-31.
31. Pugh DM, McKee MD. Advances in the management of humeral nonunion. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2003;11(1):48-59.
32. Hierholzer C, Sama D, Toro JB, Peterson M, Helfet DL. Plate fixation of ununited humeral shaft fractures: effect of type of bone graft on healing. JBJS. 2006;88(7):1442-7.
33. Willis MP, Brooks JP, Badman BL, Gaines RJ,

Mighell MA, Sanders RW. Treatment of atrophic diaphyseal humeral nonunions with compressive locked plating and augmented with an intramedullary strut allograft. Journal of orthopaedic trauma. 2013;27(2):77-81.

34. Kosmopoulos V, Nana AD. Dual plating of humeral shaft fractures: orthogonal plates biomechanically outperform side-by-side plates. Clinical Orthopaedics and Related Research®. 2014;472(4):1310-7.

35. Martinez AA, Cuenca J, Herrera A. Two-plate fixation for humeral shaft nonunions. Journal of Orthopaedic Surgery. 2009;17(2):135-8.

36. Akdemir M, Bicen Ç, Ozkan M. Comparison of single-and double-plate fixation techniques in the treatment of nonunions of the humeral shaft. Acta Ortopédica Brasileira. 2022;30.