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Research / Araştırma

Single-Stage Treatment of Aseptic Nonunion of the Humerus with Locking Plate Fixation and Autograft

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ABSTRACT

Background: Locking and non-locking compression plates are widely used in different long bone fractures. Biomechanical and controlled studies have reported a higher stability and rate of union with the use of locking plates. Locking plates are safely used also in the treatment of humeral nonunions with varying rates of success.

Aims: The aim of this study was to evaluate the radiological and clinical results of a single-stage surgical treatment with locking compression plates (LCPs) and autologous bone grafting in patients with aseptic nonunion of the humerus.

Study Design: Level of Evidence IV, case control study.

Methods: Twenty-four patients (17 males; mean age: 43.5 years) treated with LCPs and autologous bone grafts due to nonunion following humeral fractures were included in this study. Twelve patients had earlier been treated surgically while the remaining 12 had received non-surgical (conservative) treatment. Six patients had atrophic and 18 had oligotrophic nonunions. Functional evaluation was made using the Constant-Murley scoring system.

Results: The mean follow-up period was 43.6 months. Radiological union was observed in all patients except one (95.8%) in an average period of 18.8 weeks. A mean shortening of 1.8 cm was performed on six patients with atrophic nonunion. Preoperative infection markers and intraoperative cultures were negative for infection. Four patients experienced delayed unions and one patient had transient radial nerve palsy. Ten patients had excellent, 12 had good, and two had fair scores.

Conclusion: The management of humeral nonunions with single-stage surgical intervention performed using LCPs and autologous bone grafts, following adequate debridement, is an effective method with satisfactory radiological and clinical outcomes.

Keywords: Autografts, humerus, plating, diaphyseal, fixation

ÖZ

Aseptik humerus kaynamaması olan hastalarin tedavisinde internal tespit ve otogreftleme ile tek aşamali cerrahi

Arkaplan: Kilitleme ve kilitlenmeyen kompresyon plakaları, farklı uzun kemik kırıklarında yaygın olarak kullanılmaktadır. Biyomekanik ve kontrollü çalışmalar kilitleme plakalarının kullanımıyla daha yüksek stabilite ve kaynama hızı bildirilmiştir. Kilitleme plakaları, değişen oranlarda başarı gösteren humeral kaynamamaların tedavisinde de güvenle kullanılmaktadır.

Amaç: Bu çalışmada humerus cisminde aseptik kaynamama gelişen hastaların tedavisinde debridman, kilitli kompresyon plağı (LCP) ile internal tespit ve otolog kemik grefti kombinasyonu ile yapılan tek aşamalı cerrahinin radyolojik ve klinik sonuçlarının değerlendirilmesi amaçlandı.

Hastalar ve Yöntem: Humerus kırığı sonrası kaynamama gelişen ve klinimizde LCP ve otolog kemik grefti ile tedavi edilen 24 hasta (17 erkek, 6 kadın; ortalama yaş 43.5 yıl) çalışmaya dahil edildi. 12 hasta daha önce en az bir kez cerrahi tedavi edilmişken 12 hasta cerrahi dışı (konservatif) yöntemle tedavi edilmişti. Altı hastada atrofik ve 18 hastada oligotrofik kaynamama vardı. Tüm hastalara geniş debridman, plak ile internal tespit ve otogreftleme uygulandı. Fonksiyonel değerlendirme Constant ve Murley skorlama sistemine göre yapıldı.

Bulgular: Ortalama takip süresi 43.6 aydı. Bir hasta dışında tüm hastalarda (%95.8) ortalama 18.8 haftada radyolojik kaynama sağlandı. Atrofik kaynamama olan altı hastada ortalama 1.8 cm kısaltma uygulandı. İlave cerrahi gereken hasta olmadı. Preoperatif enfeksiyon belirteçleri ve cerrahi sırasında alınan kültürler sonucu enfeksiyon gözlenmedi. Dört hastada kaynama gecikmesi, bir hastada geçici radial sinir hasarı gözlendi. On hastada mükemmel sonuç, 12 hastada iyi sonuç ve 2 hastada orta sonuç elde edildi.

Sonuç: LCP'ler ve otolog kemik greftleri kullanılarak yapılan tek aşamalı cerrahi girişim ile humeral kaynamamaların yönetimi, yeterli debridmanın ardından, tatmin edici radyolojik ve klinik sonuçlar ile etkili bir yöntemdir.

Anahtar kelimeler: Otogreftler, kol kemiği, plak, diyafiz, tespit

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INTRODUCTION

Despite usually positive response to treatment, nonunions following humeral shaft fractures are not uncommon; their prevalence ranges between 5% and 15%, independent of the treatment method (1,2). Nonunions of the humeral shaft may develop following conservative or surgical treatment of the primary fracture. As in other long bones, reasons related to the fracture, the patient or the initial treatment method may play a role in the development of nonunions.

The aim in the treatment of nonunions is to achieve union and to restore the alignment and functionality of the bone. Dynamic compression plates (DCPs), locking compression plates (LCPs), nails and fixators are the most commonly used fixation materials. Based on the type of the nonunion, these materials may be used in combination with autografts or allografts (3,4). Although researchers have tried various implants and reported successful results with the treatment of humeral nonunions, the type of implant to be used and the requirement for grafting are still matters of debate (3-6).

The aim of this study was to evaluate retrospectively the effect of single-stage surgical treatment of humeral shaft nonunions with debridement, LCPs and autologous bone grafting on radiological and clinical healing.

PATIENTS AND METHODS

Twenty-four patients (17 males, 7 females; mean age: 43.5 years, range: 24 to 74 years) who developed nonunions following humeral fractures and were treated in our clinic with LCPs and autologous bone grafts harvested from the iliac wing between 2005 and 2011 were included in this study. The dominant arm was involved in 14 patients. Reasons for the treatment included nonunion accompanied by pain and loss in range of motion (ROM) and strength. Patients with less than two years of follow-up and those operated due to active infection were excluded.

The patients' medical history revealed that 12 patients had earlier been treated conservatively with closed reduction and plaster (Figure 1) while the remaining 12 had received surgical treatment using various implants (plate-screw in 6, external fixator in 2, multiple screws in 2, and intramedullary implant in 2 patients) (Figure 2). None of the patients had suffered infection or permanent nerve damage in the postoperative period. Seven patients had a history of smoking and three had diabetes mellitus.

Upon evaluation of the radiographs, atrophic nonunion was detected in 6 and oligotrophic nonunion in 18 patients. Implant failures were observed in 9 patients. The screws were broken in 4 patients while loosening around the plate and screws was evident in 4 patients.

Full blood count, sedimentation rate and C-reactive protein (CRP) level were preoperatively investigated for infection in all patients. The line of nonunion was reached by anterolateral incision. Following extensive debridement of the devitalized tissue, the fracture ends were treated and the medullary canal was reopened. Culture sampling from

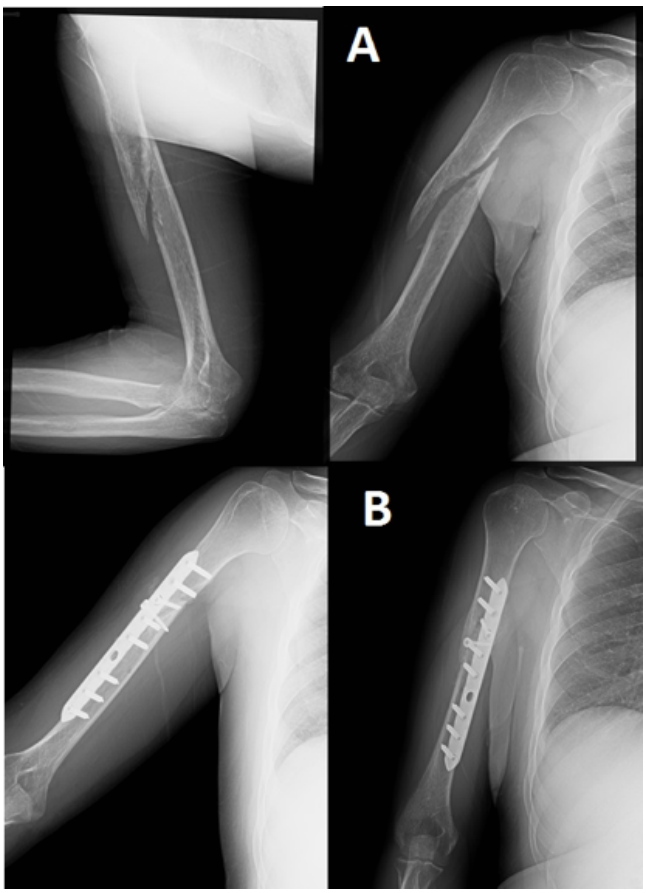

Figure 1: Images of a 48-year-old male patient whose closed fracture of the humerus had been treated conservatively. **(A)** Anteroposterior and lateral radiographs taken seven months after the primary intervention showing the nonunion. **(B)** Radiological union was achieved 15 weeks after our surgical intervention with LCP fixation and autografting.

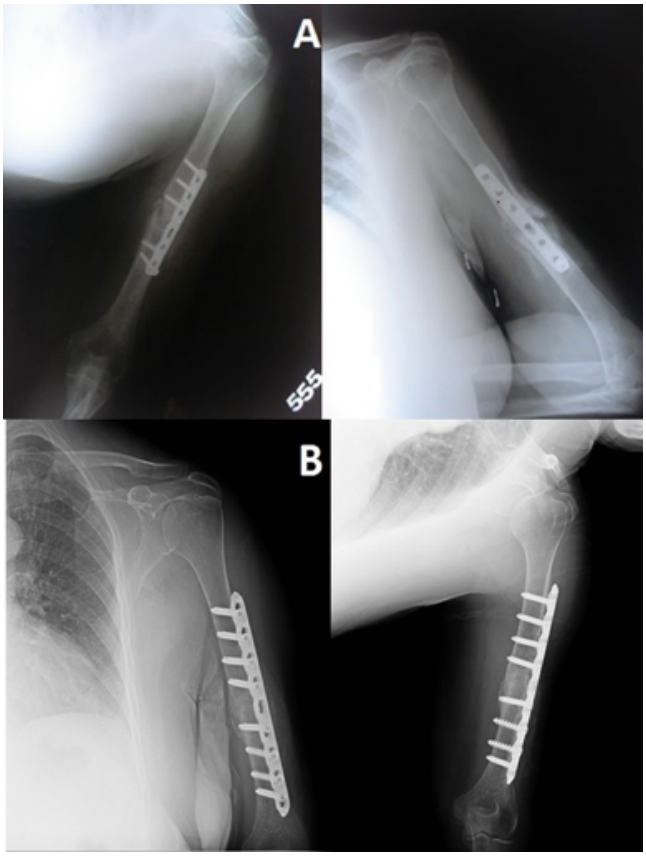

Figure 2: Images of a 69-year-old female patient who had undergone surgical intervention using the plate-screw system. **(A)** Anteroposterior and lateral radiographs taken six months after the primary surgery show the nonunion and loosening of the screws. **(B)** Radiological union was achieved in this patient 13 weeks after our surgical intervention with LCP fixation and autografting.

the previously operated patients was done during surgery. Shortening was performed in patients with atrophic nonunion. Autografts from the iliac wing were used to fill the defect area after bone regeneration in patients with oligotrophic nonunion and to provide biological support after shortening in atrophic cases. Stable fixation was performed using 4.5 mm LCPs which would pass through a minimum of eight cortices on both sides.

Patients were given long-arm splints for three weeks after surgery. Passive exercises were begun after the third week. Presence of union was checked during follow-up visits made in the first, third, and sixth month and every three months afterwards. Callus formation on a minimum of three planes was considered as radiological union. Clinical union was confirmed with no pain upon bearing weight and with the movement of the joint. Functional evaluation was made using the Constant-Murley functional scoring system (7).

RESULTS

The mean follow-up period of the patients was 43.6 months (range: 24-73 months). The mean time to the final surgery was 8.6 months (range: 4-18 months). A mean of 1.8 cm (range: 0.5-3.5 cm) of shortening was performed in patients with atrophic nonunion. Radiological union was achieved in all patients except one (95.8%) in a mean period of 19 weeks (range: 12 to 31 weeks). No statistical relationship was found between the time to final surgery and time to union (p=0.121). Ten previously operated patients had undergone a mean of 1.5 surgeries (range: 1 to 3).

Clinical union was confirmed when a patient had no pathological movement or pain in the fracture line during clinical assessment. Four patients had delayed unions; the latest one was seen after 24 weeks.

One patient with postoperative radial nerve palsy showed complete recovery after 6 months of follow-up. None of our patients developed superficial infection, deep infection, or osteomyelitis. No complications were observed in the iliac wing used for graft harvesting.

According to the Constant-Murley scoring system used for clinical evaluation, 10 patients (41.7%) had excellent, 12 (50%) had good and two (8.3%) had fair results. The mean Constant-Murley score in the preoperative period was 14 (range: 3 to 34) whereas the mean score at the final follow-up was 77.3 (range: 35-95). The difference between the pre- and postoperative scores was statistically significant (p<0.005).

DISCUSSION

Nonunions following humeral fractures are not uncommon.1 The prevalence of nonunions was reported to be approximately 10% among conservatively treated and between 10% and 15% among surgically treated patients (1,2). The reasons for nonunions following humeral fractures include inadequate fixation, mistakes in surgery, severity of the injury, fracture pattern, dehiscence in the fracture line, soft tissue interposition, and obesity (2). Several methods of treatment, including intramedullary nailing, cortical bone

Table 1: Patient demographics and preoperative/postoperative clinical results

Age Sex	Time to Surgery (M)	Type of Nonunion	Previous Treatment	Time to Fusion (W)	Follow-up Time (M)	Preop C-M Score	Final C-M Score	Evaluation of C-M Score	Complication
33M	4	Oligotrophic	Conservative	12	25	34	95	Excellent	None
34M	5	Oligotrophic	Conservative	14	36	27	90	Excellent	None
34M	6	Oligotrophic	Conservative	16	16	15	70	Good	None
36M	18	Oligotrophic	IM nail	19	71	20	83	Good	None
37F	11	Oligotrophic	Ex Fixator	17	64	24	71	Good	None
38M	7	Oligotrophic	Conservative	21	91	22	90	Excellent	None
38F	9	Oligotrophic	Screw	25	23	7	68	Good	None
41M	9	Atrophic	Plate	19	27	11	72	Good	Delayed fusion
42M	11	Atrophic	Plate	23	24	9	70	Good	None
45F	6	Oligotrophic	Conservative	14	25	20	85	Excellent	None
45M	5	Oligotrophic	Conservative	14	72	19	88	Excellent	None
47M	10	Oligotrophic	IM nail	15	33	14	65	Good	None
47M	10	Atrophic	Plate	31	78	5	50	Moderate	Delayed fusion
48M	18	Atrophic	Plate	20	25	9	72	Good	None
53M	5	Oligotrophic	Conservative	17	36	15	91	Excellent	None
53M	5	Oligotrophic	Conservative	22	36	11	80	Good	None
58M	7	Oligotrophic	Conservative	18	98	14	92	Excellent	None
68M	14	Atrophic	Plate	28	38	3	35	Moderate	Delayed fusion
69M	8	Oligotrophic	Conservative	13	28	12	71	Good	None
74F	7	Oligotrophic	Conservative	14	28	10	88	Excellent	Radial nerve injury
24F	12	Atrophic	Plate	18	32	10	75	Good	Delayed fusion
25F	5	Oligotrophic	Ex Fixator	24	27	12	90	Excellent	None
28M	9	Oligotrophic	Screw	21	44	9	73	Good	None
29F	5	Oligotrophic	Conservative	20	60	11	86	Excellent	None

graft application, external fixation, and the use of various plates, have been reported with varying results (1-4).

The success rate in the treatment of nonunions in the long bones increases when certain rules are followed (1). The most important ones are the extensive debridement of the devitalized tissue, removal of the implant, opening of the medullary canal, shortening when necessary, obtaining the proper alignment and rotation, and stable fixation following the filling of the defect area with grafts. Considering our success rate of 95.8% in radiological union, we can conclude that radical debridement, proper alignment, the use of autografts and stable fixation with plates are the major factors that increase the rate of success of single-stage surgery in these patients.

Although the use of grafts in patients with nonunion of the long bones is still a matter of debate, autografts are favored as they do not carry the risks of immunological response or transfer of infectious diseases. Nicol et al. used corticocancellous grafts in nonunions of the forearm bones for the first time and, upon their success, the use of these grafts has become widely accepted (9,10). Ring et al. reported successful results with the application of non-vascularized, autogenous bone grafts in patients with atrophic defects not exceeding 6 cm (5). Padhye et al. demonstrated that 3-4 cm of shortening when necessary and corticocancellous graft and plate application in cases with atrophic and oligotrophic nonunions achieved excellent radiological and clinical results (11). When the coverage of the surrounding soft tissue is considered, the donor site morbidity is less observed in the iliac wing where the autograft is harvested (12), which is why we preferred utilizing this region. In addition, autograft application was performed to fill the defect area after bone regeneration in patients with oligotrophic nonunion and to provide biological support after a mean shortening of 1.8 cm in atrophic cases, in accordance with the literature.

Locking intramedullary nails are widely preferred in the treatment of humeral shaft fractures. However, persistent shoulder pain, findings of subacromial impingement, rotator

cuff tears, iatrogenic fractures, high incidence of delayed union, and radial nerve injury are among the reported complications (11,13). Although exchange nailing is a treatment modality in humeral nonunions, its success rate is lower when compared to the tibial and femoral applications. The lack of cyclic loading due to the non-load-bearing nature of this bone and its exposition to distractive and rotational forces have been held responsible for this inefficiency. For this reason, plate osteosynthesis is recommended by several authors rather than nail application in the treatment of both primary fractures and nonunions (13-16). Two patients with intramedullary implants (one had locking nails and the other one a titanium elastic nail - TEN) following fracture showed signs of nonunion. The same technique was successfully employed in these two patients who also had dehiscence and a defect on the fracture line. Thus we can assert that successful results can be achieved through revision surgery using plates and autografts in patients who had experienced nonunion following nail application.

Several advantages of external fixation in the treatment of humeral nonunions have been reported (4,17,18). The technique may be used in patients with infection and is known to eliminate the need for grafting (17,18). Lammens et al. (8) treated 28 of 30 patients with humeral nonunions with the Ilizarov technique and had to administer oral antibiotics due to pin site discharge and infection in all patients. Furthermore, the possible inability to adapt to the fixator, pin tract infection, pressure exerted by the external fixator on the chest wall, and risk of nerve injury during the passage of the wires have reduced the popularity of the technique. We did not favor the use of external fixators as we did not have any patients with infection and also sought to avoid possible complications and inability to adapt to the fixator. We also observed that one of our patients, whose oligotrophic nonunion had been managed with the combination of minimal internal fixation (two screws) and external fixation, had been treated according to the stated procedure.

Locking compression plates provide high rates of union and successful results in the nonunions of several long bones (5,6,8,20). In their biomechanical study, Gardner et al. investigated locking and non-locking plates on the humerus and showed that locking plates endure cyclic torsional forces in osteoporotic bones significantly better (19). Ring et al. achieved stabilization in 24 patients with osteoporotic fractures in the humerus through the use of LCPs and reported full union in all patients without the need for additional surgery (5). Kumar et al. treated 24 patients with humeral nonunions using LCPs and asserted the stability of the technique even in patients that were highly active (20). Due to the probability of osteopenia – as our patients have not used their involved extremities actively in the past – we preferred to use LCPs which we believed would provide a more stable fixation. We believe our preference of LCPs resulted in our rates of 95.8% of radiological and 100% clinical union.

Its retrospective design and the lack of a control group are the limitations of our study. However, the evaluation of the results of a contemporary treatment modality, its long follow-up period and homogeneity of our patient group renders our study a valuable one.

CONCLUSION

Locking and non-locking compression plates are widely used in various long bone fractures. Biomechanical and controlled studies have reported a higher stability and rate of union with the use of locking plates. Locking plates are safely used also in the treatment of humeral nonunions with varying rates of success. The role of autograft application in these patients' rate of success is still controversial. When we evaluated our results based on the above information, we observed that the combined technique of 4.5 mm LCPs and autografting is an efficient and successful treatment modality for single-stage surgery in patients with humeral nonunions. However, support by future prospective, controlled studies will increase the reliability and accuracy of our findings.

Ethics Committee Approval: Ethics committee approval was received for this study from the local ethics committee.

Informed Consent: Informed consent was obtained.

Author Contributions: Conception/Design of study -Y.A., B.O., Y.M.D., U.Y.; Data acquisition - Y.A., O.L., Y.E.A.; Data analysis/Interpretation - Y.A., U.Y., B.O.; Drafting manuscript - Y.A., U.Y., B.O., Y.M.D.; Critical revision of manuscript - Y.A., O.L., Y.E.A.; Final approval and accountability - Y.A., Y.E.A., B.O., B.O., O.L., Y.M.D.; Supervision - Y.A., U.Y., O.L., Y.M.D., Y.E.A., B.O.

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