ORIGINAL ARTICLE

Evaluation of outcomes in aseptic non-unions of the forearm bones in adults treated with LCP and autograft

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ABSTRACT

BACKGROUND: The aim of the present study was to evaluate the effect of locking compression plate (LCP) and autografting application in patients with nonunion of forearm fractures on radiologic and clinical outcome.

METHODS: A total of 26 patients (16 males, 10 females; mean age: 45.7 years) with nonunion after surgical treatment of forearm fractures were included. Nonunion was located in the ulna in 14 patients, in the radius in 5 patients, and in both in 7 patients (21 ulna, 12 radius).Infection markers were checked prior to surgery. Samples for microbiologic cultures were peroperatively obtained in 7 patients with a history of open fractures. Autografting from the iliac crest and 3.5-mm LCP were applied. Type of nonunion, time to unification, range of motion in the wrist and elbow joints, and complications were analyzed. Functional evaluation was performedusing the scoring system described by Anderson et al.

RESULTS: Mean follow-up period was 49.3 months (range 24–73 months). Unification was achieved in a mean 5.7 months (range 3–14 months). Additional surgical process was not required. No bacterial proliferation was observed in cultures. Superficial infection was observed in 3 patients and deep infection in 1. Results were scored as excellent in 10 (38.4%) patients, satisfactory in 13 (50%), and unsatisfactory in 3 (11.6%).

CONCLUSION: Treatment of aseptic forearm nonunion in adults with autografting from the iliac crest and 3.5-mmLCP fixation increases unification rate and aids in function recovery.

Keywords: Aseptic; autograft; forearm; nonunion; plate.

INTRODUCTION

Surgical treatment of ulnar and radial fractures with compression plates has been widely performed for many years. Low complication rates and successful results in large series have been reported.[1–5] The most commonly reported conclusion is that fixation with plate provides anatomical, reliable reduction that makes early mobilization possible.[5,6–15] However, infection, neurovascular injury, non-union, malunion, compartment syndrome, and radioulnar synostosis are potential complications.[16]

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In spite of the number of studies in which successful results have been reported after use of dynamic compression plate (DCP), locking compression plate (LCP), anatomical plate, or locking nail applications, rates of non-union still vary between 2–10%.[1,5–7] Factors related to the fracture, patients, or customization of the initial treatment have been held responsible for the development of non-union, as is the case with fractures in all long bones. The aim of surgical treatment of forearm non-union is to restore proper bone length, anatomy, and functionality. In spite of recently developed surgical techniques and use of modern implants, the results are not fully satisfactory, and debates regarding the necessity of grafting and type of implant to be used continues.[15–21]

In the present study, efficacy of LCP application and autografting in the treatment of aseptic non-union of the adult forearm was retrospectively evaluated from a radiological and clinical perspective.

MATERIALS AND METHODS

Presently included were 26 adult patients (16 male, 10 female) who presented between 2005 and 2012 with com-

plaints of non-union in the forearm (20 dominant arm, 6 non-dominant arm). They were treated with LCP and autografts harvested from the iliac wing. Mean age at time of surgery was 45.7 (range: 19–73) years (Table 1). Reasons for surgical intervention included radiological non-union, clinical pain, and loss of range of motion (ROM) and strength. Patients who underwent follow-up of less than 2 years, and those who received conservative treatment or had active infection were excluded.

The mechanism of fracture was a fall in 16 patients, motor vehicle accident in 6, and assault or occupational accident in 4. Thirteen patients had ulnar, 7 had radial, and 6 had both ulnar and radial non-unions. Three patients had type 22-A1 fracture, 3 had type 22-A2, 3 had type 22-A3, 11 had type 22-B1, 2 had type 22-B2, 3 had type 22-B3 and 1 had type 22-C2 fracture according to Müller AO Classification. Seven (26.9%) patients had open fractures according to the Gustilo open fracture classification system;[22] 6 were type 1, and 1 was type 2. One patient had an injured radial artery, another had an injured radial nerve (Table 1).

Eight (30.7%) patients were smokers, and 4 (15.3%) had accompanying diabetes mellitus. All patients had undergone at least 1 surgical intervention (with plate-screw in 21 patients, with intramedullary k wire in 3 patients, and with tension band [secondary to proximal metaphyseal fracture] in 2 patients). Complete blood count, sedimentation, and C-reactive protein (CRP) were analyzed for preoperative assessment of infection. When lab results were within normal range, and when clinical symptoms of infection were not observed, patients were considered to have aseptic non-union.

Type of non-union was radiologically evaluated prior to surgery. Patients with no callus formation on fracture ends, and those with atrophic presentation or bone defects were considered to have atrophic non-union. Absence of obvious cal-

Table 1. Preoperative demographic characteristics and radiological findings of the patients

n	Age	Follow-up (M)	Bone	Type of fracture (AO-22)	Type of nonunion	Smoking	Diabetus mellitus	Open fracture
1	60	73	Ulna	B1	Atrophic		+	Type I
2	50	69	Ulna+Radius	B3	Oligotrophic	+		
3	41	64	Ulna+Radius	A3	Oligotrophic			
4	33	63	Ulna	A1	Oligotrophic			Type I
5	28	60	Ulna	B1	Oligotrophic			
6	23	58	Ulna	B1	Oligotrophic	+		
7	58	58	Ulna	B1	Oligotrophic	+		
8	45	55	Ulna+Radius	A3	Oligotrophic			Type I
9	40	54	Ulna	B1	Oligotrophic			
10	37	53	Ulna	A1	Oligotrophic			
11	19	52	Ulna	B1	Oligotrophic			
12	69	50	Radius	A2	Oligotrophic	+		
13	53	50	Radius	B2	Atrophic		+	Type I
14	55	49	Ulna+Radius	A3	Oligotrophic	+		
15	31	49	Ulna+Radius	B3	Oligotrophic			
16	37	48	Ulna	B1	Atrophic			Type 2
17	52	47	Radius	A2	Oligotrophic			
18	64	45	Radius	A2	Oligotrophic			
19	58	42	Ulna	A1	Atrophic	+		Type I
20	40	41	Ulna+Radius	C2	Oligotrophic	+		
21	31	40	Ulna	B1	Oligotrophic			
22	41	37	Ulna	B1	Oligotrophic			
23	45	37	Ulna+Radius	B3	Oligotrophic			Type I
24	63	33	Radius	B2	Oligotrophic		+	
25	73	31	Ulna	B1	Oligotrophic		+	
26	42	24	Ulna	B1	Oligotrophic	+		

lus formation and atrophy on bone ends were accepted as oligotrophic non-union.[17]

All devitalized tissue and foreign matter were removed during surgery. Both sides of the medullar cavity were drilled, and cultures were taken from various spots during debridement in 7 patients with open fractures. After restoration of anatomical parameters in bone alignment, size and rotation were confirmed with radiological and clinical assessments during surgery. Fixation was performed with LCP, allowing for use with both locking and non-locking screws. In order to enhance reduction and stability on at least 1 side of the non-union site, compression was performed with a single non-locking screw, and fixation was achieved with either locking screws (engaged on a minimum of 6 cortices on both sides of the fracture), or with bicortical non-locking screws (Fig. 1). Autografts harvested from the iliac wing were used in an attempt to cover the defect and support the biological environment. Postoperatively, patients used long-arm splints until formation of a callus, indicating a union, was observed. Sutures were removed at the end of the 2nd week, and rehabilitation was begun by the end of the 3rd week. Patients were allowed to perform controlled mobilization after callus formation was observed, and were advised to avoid heavy activities for a period of 3–4 months.

Preoperative radiographs of patients were retrieved from archives, and anteroposterior and lateral radiographs of the forearms, including the wrist and elbow, were obtained at final follow-up. Radiological evidence of a bridging callus in the non-union site on 3 or 4 planes was considered a union. Clinically, absence of pain with palpation over the fracture line or during daily activities was accepted as union. In addition, the scoring system based on the evaluation of joint ROMs, as used by Anderson et al.,[1] was utilized at final follow-up for functional evaluation. Results were recorded as excellent, good (satisfactory), fair (unsatisfactory), or poor.

RESULTS

Mean follow-up was 49.3 months (range: 24–73), mean time to union was 5.7 months (range: 3–14), and mean time to return to work was 7.1 months (range: 3–18). No bacterial growth was observed in cultures obtained during surgery. Radial nerve palsy developed in 1 patient in the postoperative period, and the patient recovered by the fourth month. Superficial infection was observed in 3 patients in the early postoperative period. The infection was treated with antibiotics; no surgical intervention was required. One patient had deep infection, and Staphylococcus aureus grew on the culture. Serial debridements and parenteral antibiotic treatment were successful. No patient developed chronic osteomyelitis or radioulnar synostosis.

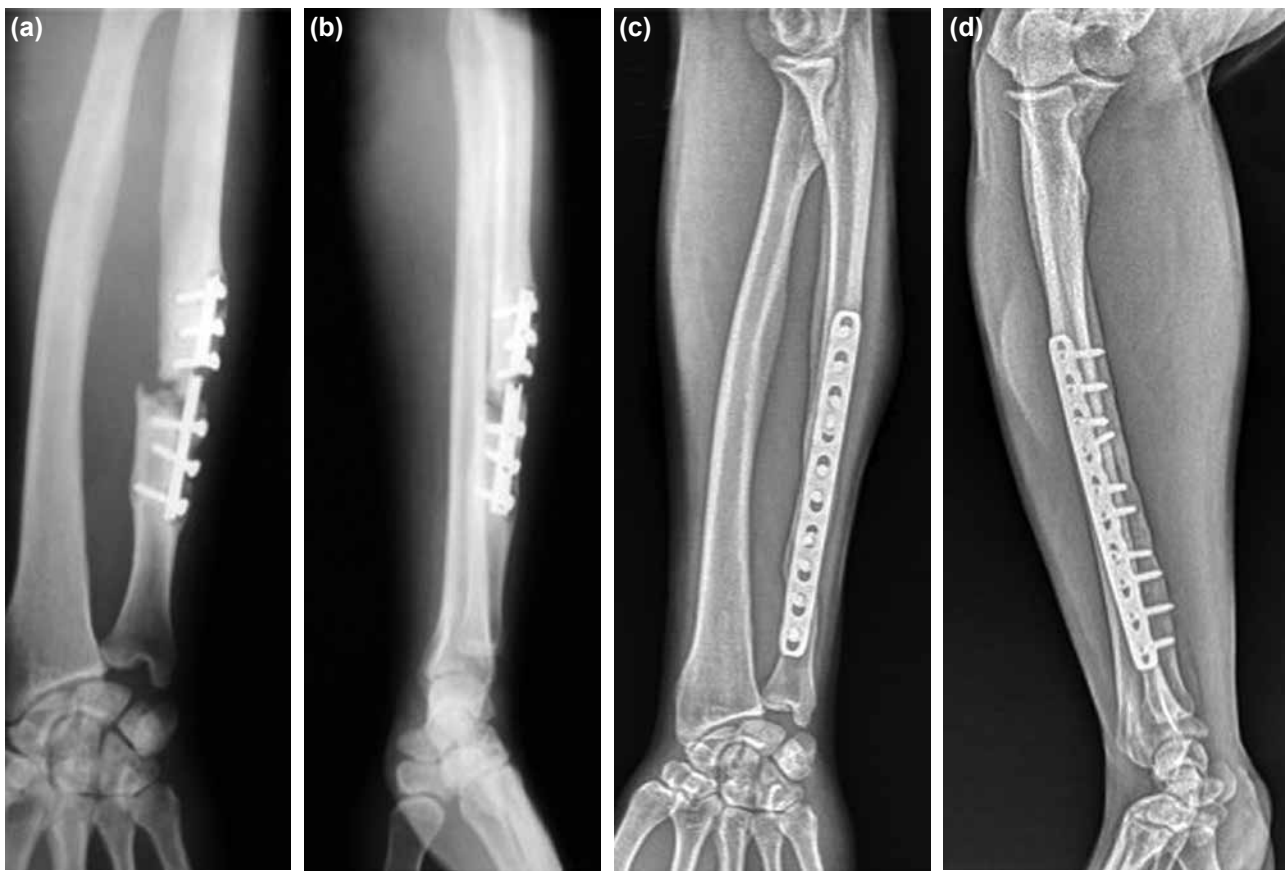

Figure 1. A 33-year-old male patient who had previously undergone both conservative and surgical treatment. **(a, b)** Oligotrophic non-union. **(b, c)** Follow-up radiographs taken at the 52nd month following rigid fixation with long plates and grafting.

Mean ROM was 55.4° (range: 30°–80°) in flexion of the wrist, 56.2° (range: 20°–80°) in extension of the wrist, 66.2° (range: 30°–80°) in pronation of the wrist, 69.2° (range: 45°–80°) in supination of the wrist, and 120.7° (range: 80°–130°) in flexion of the elbow. Mean loss of extension in the wrist was 4.2° (range: 0°–30°). Details regarding time to union, ROM, and functional evaluation are summarized in Table 2.

According to the functional scoring system used by Anderson et al., 10 (38.4%) patients had excellent, 13 (50%) had good (satisfactory), and 3 (11.6%) had fair (unsatisfactory) results. No patient received a poor score. All patients with fair (unsatisfactory) results had limited ROM and a stiff elbow, and 1 had a substantive loss of motion in the wrist. When previous clinical findings were analyzed, it was determined that ROM slightly increased and pain at movement significantly decreased over time.

Material removal was performed in 6 (23.1%) patients due to skin irritation after union was observed. Removal was performed from the ulna in 5 patients and from both bones in 1. Fracture during removal did not occur.

DISCUSSION

Prevalence of non-union in the forearm bones is reportedly 2–10%.[1,5–7,17–20] Factors related to fracture (comminution, open fracture, location of the fracture, state of soft tissue), patient (age, smoking, additional diseases), and initial treatment (implant used, surgical technique) have been held responsible for forearm non-union. Debridement of devitalized tissue, removal of failed implant, proper alignment during surgery, and achievement of rotation are the stages to be followed during non-union surgery. Use of grafts should be avoided to ensure a biological environment for the union. Stable fixation and early rehabilitation are essential in obtaining successful results.[23] All patients presently reported had an unstable fixation; 7 had an open fracture, 8 had a

Table 2. Functional outcomes of the patients during the final follow-up

No	Union time (M)	Extension of elbow	Flexion of elbow	Supination of forearm	Pronation of forearm	Flexion of wrist	Ekstension of wrist	Anderson Scoring
1	6	-10	120	70	60	50	50	Good
2	7	0	130	60	50	50	50	Good
3	6	0	140	80	70	60	60	Excellent
4	3	0	130	80	70	30	20	Good
5	6	-10	110	60	30	50	60	Good
6	4	-20	90	50	80	30	30	Fair
7	3	0	120	80	0	50	50	Good
8	8	-20	110	45	30	50	60	Good
9	7	0	110	45	30	50	50	Good
10	5	0	130	80	80	50	60	Excellent
11	6	-20	90	50	50	60	60	Fair
12	5	0	130	80	80	60	60	Excellent
13	4	0	120	80	80	80	70	Good
14	7	0	130	50	70	80	70	Good
15	11	0	130	80	80	50	60	Excellent
16	5	-10	130	70	60	50	50	Good
17	4	0	130	80	80	60	60	Excellent
18	3	0	120	80	70	20	40	Good
19	3	-30	80	50	60	50	40	Fair
20	14	0	130	80	80	60	60	Excellent
21	5	0	120	80	80	80	70	Excellent
22	6	0	130	70	70	60	60	Good
23	5	0	130	80	80	70	60	Excellent
24	7	0	130	70	60	60	50	Good
25	3	0	130	80	80	80	80	Excellent
26	5	0	130	70	60	70	70	Excellent

history of smoking, and 4 had diabetes mellitus. It is believed that presence of any of these factors may have led to non-union.

In accordance with those of previous studies,[6,8,16,24,25] oligotrophic non-union was the prevailing finding. The majority of the present patients underwent surgery at another clinic and were referred upon development of non-union. The most common cause of non-union, again in accordance with other studies, was inadequate surgical fixation. In addition, the implants most frequently encountered were plates with insufficient number of screws and intramedullary k wires. Today, the fixation material most commonly preferred for recent fractures in the region is the 3.5-mm compression plate. Although bilateral passing through 4 cortices has been shown to be biomechanically sufficient,[11] most authors advocate passing through 6 cortices on each side of the fracture.[15–21,26]

In each patient, 3.5-mm LCP was used, and fixation was performed by passing through at least 6 cortices on both sides of the fracture. The high rate of union observed following this application suggests that preoperative planning and more stable fixation with the use of locking plates contribute to successful outcome.

Fixation of acute fracture of adult forearm with plate is a widely accepted treatment, and success rates of over 90% have been reported.[1,2,4,5,8,21] Until recently, DCP has been used with success rates of 92% and over.[1,4,27] However, the possibility that DCP use may lead to osteoporosis of the bone or refracture are disadvantages.[28] Today, LCP is more frequently used in treatment of long bone fracture. LCPs allow for stronger stabilization than conventional plates and more reliable stability on the osteoporotic bone.[29–31] Gardner et al. biomechanically proved that hybrid and locking systems can bear axial and torsional forces better than non-locking systems.[31] The decision was presently made to use LCPs that could be used with non-locking and locking screws. The present patients had been treated with conventional plates and various implants, with unsatisfactory results. Either a non-locking screw at a proximity of at least 1 fracture line, a locking screw in the distal, or bicortical non-locking screws were presently used. It was concluded that application of a plate enabling hybrid screwing and the presently employed reduction technique were essential in the achievement of high rates of union.

Use of autografts in the treatment of non-union of the long bones is still a matter of debate. Absence of immunological response and risk of disease transfer are the main advantages. Nicoll et al. used corticocancellous grafts for the first time in non-union of the forearm bones, and several other authors have reported results of graft application.[19,24] Ring et al. reported successful results with the use of non-vascularized autogenous corticocancellous grafts on defects up to 6 cm in size with atrophic non-union.[32] dos Reis et al. reported excellent radiological and clinical results with application of corticocancellous grafts and plates in cases with atrophic and hypertrophic non-union.[33] In a study by Kumar et al., a union rate of 96% following LCP and autograft treatment was reported in patients with atrophic and hypertrophic non-union of the humerus.[23] Saka et al. also reported high rates of union and functional recovery using nails and autografts in cases of forearm non-union.[21] When coverage of the surrounding soft tissue was taken into account, it was presently preferred to harvest autografts from the iliac wing, as donor site morbidity was lower in this region.[34] Based on the present outcomes, it is believed that when soft tissues have adequate blood supply, use of corticocancellous grafts increase the rate of union, and have a positive impact on functional recovery.

Although debridement is a routine procedure during non-union surgery, it is unusual to obtain cultures from patients who do not present with findings of infection. In spite of a lack of accepted procedure to detect subclinical infection, clinical evaluation and CRP measurement are other commonly used markers.[35,36] With a series of 87 patients, Amorosa et al. performed single-stage treatment and follow-up of aseptic non-union of the long bones, and 28% of cultures obtained during surgery yielded positive results.[37] The authors reported the need for repeat surgery in 28% of the culture-positive group, and in 6% of the culture-negative group. It was also reported that 60% of culture-positive patients had an open fracture. Cultures were also obtained from the present patients with open fractures, though no bacterial growth was observed. Nevertheless, debridement was performed in 1 patient with deep infection. Thus, even if lab results do not indicate findings of infection, it is believed that repeating the surgery can be prevented by obtaining cultures from patients with non-union who have undergone at least 1 surgery.

Limitations of the present study were retrospective design and lack of a control group. However, the adequate follow-up period included, the type of implants used, and the homogenous use of autografts are strengths.

Sufficient debridement of dead tissues and stable fixation of the bone with LCP in aseptic treatment of adult forearm fracture have a positive impact on recovery. In addition, use of autografts to cover the defect area and/or to support the biological environment will increase the rate of union and eliminate the risk of infection that may be caused by allograft. Although use of implants such as DCP or intramedullary nail may yield successful results, use of LCP and autografts is also an efficient method of single-stage treatment of non-unions. In spite of the retrospective design, the present study may be a valuable reference for future comparative, prospective studies.

Conflict of interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Erişkin ön kol kemiklerinin aseptik kaynamama tedavisinde LCP ve otogreft

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AMAÇ: Bu çalışmanın amacı erişkin ön kol kemiklerinde aseptik kaynamama gelişen hastalarda kilitli kompresyon plağı (LCP) ve otogreft kullanımının radyolojik ve klinik iyileşme üzerine etkinliğini değerlendirmektir.

GEREÇ VE YÖNTEM: Ön kol cisim kırıkları sonrası kaynamama gelişen ve cerrahi yöntemle tedavi edilen 26 hasta (16 erkek, 10 kadın; ortalama yaş 45.7 yıl) çalışmaya alındı. On dört hastada ulna, beş hastada radius ve yedi hastada her iki kemikte (21 ulna, 12 radius) kaynamama mevcuttu. Cerrahi öncesinde enfeksiyonu değerlendirmek için enfeksiyon belirteçleri bakıldı. Açık kırık öyküsü olan yedi hastadan cerrahi sırasında kültür alındı. Hastalar 3.5 mm kilitli kompresyon plağı ve iliak kanattan alınan otogreft ile tedavi edildi. Hastaların kaynamama tipi, kaynama süreleri, cerrahi sırasında greft kullanımı, el bileği ve dirsek hareketleri, gelişen komplikasyonlar sorgulandı. Fonksiyonel değerlendirme Anderson ve ark.nın tanımladığı sisteme göre yapıldı.

BULGULAR: Takip süresi ortalama 49.3 aydı (dağılım 24–73 ay). Tüm hastalarda ortalama 5.7 ayda (dağılım 3–14 ay) kaynama sağlandı. İlave cerrahi gereken hasta olmadı. Cerrahi sırasında alınan kültürlerde bakteri üremesi gözlenmedi. Üç hastada yüzeysel, bir hastada derin enfeksiyon gelişti. Anderson ve ark.nın değerlendirme sistemine göre 10 hastada (%38.4) mükemmel sonuç, 13 hastada (%50) yeterli sonuç ve üç hastada (%11.6) yetersiz sonuç elde edildi.

TARTIŞMA: Aseptik önkol kaynamamalarının tedavisinde 3.5 mm LCP ile tespit ve beraberinde iliak kanattan alınan otogreft kullanımı kaynama oranını artırmakla beraber fonksiyonel iyileşmeye yardımcı olmaktadır.

Anahtar sözcükler: Aseptik; kaynamama; otogreft; ön kol; plak.

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