Eklem Hastalıkları ve Cerrahisi
Joint Diseases and Related Surgery

Original Article / *Çalışma - Araştırma*

Joint Dis Rel Surg
2005;16(1):36-41

The use of iliac crest strut graft for forearm nonunion gaps in 10 patients: Nicoll's technique revisited

Önkolda kaynamayan kemik kaybı olan 10 hastada iliyak krest destek grefti (Nicoll tekniği) kullanımı

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Objectives: We evaluated the results of surgical treatment of established forearm nonunion gaps with the use of a corticocancellous graft block from the iliac crest (Nicoll's technique) secured with a plate and screws.

Patients and methods: The study included 10 patients (5 men, 5 women; mean age 39 years; range 25 to 60 years). Six patients had ulnar, three patients had radial nonunion gaps; both bones were affected in one patient. Five patients had open fractures and six patients had active infections. The patients were treated after a mean elapse of 19.6 months (range 10 to 36 months) from injury. The length of the bone gaps ranged from 2.5 cm to 5.0 cm (mean 4.1 cm). Stabilization was performed with a 3.5 mm AO dynamic compression plate and one or two screws. In one patient who had involvement of both bones, intramedullary nailing was used. Functional results were evaluated according to the scoring system of Anderson et al. The mean follow-up period was 28 months (range 20 to 43 months).

Results: Union occurred in all the patients in a mean of 4.65 months (range 4 to 6 months). Healing was uneventful in nine patients. One patient developed a superficial infection. All the patients regained full extension and flexion of the elbow. In one patient, distal radioulnar subluxation persisted in the postoperative period. Time to union was significantly prolonged in patients with a greater bone gap (p=0.004) and with a longer delay from the occurrence of injury (p=0.02); however, none of these had a significant effect on final functional outcomes (p>0.05).

Conclusion: The use of a corticocancellous bone block from the iliac crest is a simple and reliable procedure in the management of nonunion gaps of the forearm.

Key words: Bone plates; bone transplantation; bone screws; fracture fixation, internal/instrumentation; radius fractures/surgery/radiography; ulna fractures/surgery/radiography.

Amaç: Bu çalışmada, önkolda kaynamayan kalıcı kemik kayıplarının, plak ve vida ile sıkıştırılarak kullanılan iliyak krest kortikokansellöz destek grefti ile (Nicoll tekniği) cerrahi tedavisinin sonuçları değerlendirildi.

Hastalar ve yöntemler: Çalışmaya önkolda kemik kaybı saptanan 10 hasta (5 erkek, 5 kadın; ort. yaş 39; dağılım 25-60) alındı. Kaynamayan kemik kaybı altı hastada ulnada, üç hastada radiusta idi; bir hastada iki kemikte de tutulum görüldü. Beş hastada açık kırık vardı. Altı hastada aktif enfeksiyona rastlandı. Hastalar, yaralanmadan ortalama 19.6 ay (dağılım 10-36 ay) sanra tedavi edildi. Kemik kayıplarının uzunluğu 2.5-5 cm arasında (ort. 4.1 cm) değişiyordu. Stabilizasyon 3.5 mm'lik AO dinamik kompresyon plağı ve bir veya iki çiviyle sağlandı. İki kemikte de tutulum olan hastada intramedüller çivilemeye başvuruldu. Fonksiyonel sonuçlar Anderson ve ark.nın skorlama sistemiyle değerlendirildi. Ortalama izlem süresi 28 ay (dağılım 20-43 ay) idi.

Bulgular: Tüm hastalarda ortalama 4.65 ay (dağılım 4-6 ay) içinde kaynama elde edildi. Dokuz hastada iyileşme sorunsuz sağlandı. Bir hastada yüzeyel enfeksiyon gelişti. Tüm hastalar dirsekte tam ekstansiyon ve fleksiyona kavuştu. Bir hastada distal radioulnar subluksasyon ameliyattan sonra da devam etti. Kemik kaybı uzunluğunun daha fazla olduğu (p=0.004) ve yaralanmadan sonra daha fazla gecikme olan (p=0.02) hastalarda kaynama anlamlı derecede uzun sürdü; ancak, bu etkenlerin fonksiyonel sonuçlar üzerinde anlamlı etkisi yoktu (p>0.05).

Sonuç: Önkolda kaynamayan kemik kayıplarının tedavisinde iliyak krest kortikokansellöz kemik bloğu kullanımı basit ve güvenilir bir yöntemdir.

Anahtar sözcükler: Kemik plağı; kemik transplantasyonu; kemik vidası; kırık fiksasyonu, internal/enstrümantasyon; radius kırığı/cerrahi/radyografi; ulna kırığı/cerrahi/radyografi.

- *Received: September 20, 2004 Accepted: January 8, 2005*

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Nonunion of forearm bones is relatively uncommon, with a reported incidence ranging between 2.7%[1] and 9.3%.[2] Nonunion of the radius or ulnar diaphysis with the resultant disparity in their lengths severely impairs the rotational movement of the forearm. In order to restore this, surgical procedures aim to regain the length and alignment through bridging the bone gap with various osteosynthesis modalities.[3-5]

Microvascularized free fibular grafts have been employed, but their use is technically demanding.[5] Ilizarov's bone transport technique,[4] though has good results in bridging lower extremity nonunion gaps, is cumbersome and associated with certain unique complications in the upper extremities, as both the radius and ulna are poor producers of new bone for callotasis and the transfixation of the distal and proximal radioulnar joints with tensioned wires may even restrict rotational movements.

A simple technique to manage this gap is to use a block of corticocancellous graft from the iliac crest (Nicoll's technique),[6] secured either with a plate and screws[3,7,8] or with intramedullary nailing.[9] In spite of the wide utilization of an iliac crest cancellous graft in the augmentation of unions, few studies have reported the use of strut grafting for forearm nonunion bone gaps.[3,7-9] The present paper presents our experience with this technique, with emphasis on certain clinical parameters that have not been studied so far in detail in relevant literature.

PATIENTS AND METHODS

Between 1997 and 2001, we treated 10 patients (5 men, 5 women; mean age 39 years; range 25 to 60 years) with an established forearm nonunion gap. Of these, six patients had an ulnar, three patients had a radial nonunion bone gap; in one patient both bones were involved. Five patients had open fractures at the time of initial injury (4 high velocity road-side accidents, 1 firearm injury). All the patients presented to us after an average elapse of 19.6 months (range 10 to 36 months) from the time of initial injury. All had previous operations ranging from one (n=1) to three (n=2), seven patients underwent two surgeries. Initially, six patients presented with an active infection associated with the hardware *in situ*. A standard protocol for implant removal with debridement was implemented, followed by a course of intravenous antibiotics (in reference to the culture sensitivity of the wound swab) for two weeks, and then, by administration of oral antibiotics for a period of 3 to 4 weeks. Clinical assessment of the wounds was made and hematologic parameters including total leukocyte count, differential leukocyte count, and erythrocyte sedimentation rate were measured serially during the waiting period for grafting surgery.

Operative technique

Following exposure of the nonunion site, fibrotic tissues and sclerotic bone ends were excised and the medullary canal was opened with the use of a manual forearm reamer to assess its continuity and to measure the size of the bone gap. On the other hand, the iliac crest was exposed anteriorly and a strut graft was harvested, slightly exceeding the length of a straight corticocancellous bone block which was fashioned to match the missing bone in the gap area. Finally, the corticocancellous bone block was placed to fill the gap, with its cortical face lying opposite to the plate surface to allow firm compression. The bone block and the fracture were stabilized with a 3.5 mm AO dynamic compression plate. The graft was secured to the plate with one or two screws to make a stable bone-graft construct (Fig. 1).

Postoperative immobilization was obtained with an above-elbow plaster of paris cast given for a period of 6 to 12 weeks depending on the bone quality and the fixation achieved. A first-generation cephalosporin, cefazolin, was given intravenously in a dose of 1 gm after induction of anesthesia and was continued for 72 hours. Oral antibiotic administration (first-generation cephalosporins) was started on the fourth postoperative day till suture removal. Evaluation of the wounds was made on the third postoperative day. Patients without wound problems were discharged the next day to be followed-up on an outpatient basis. During the follow-up period, routine anteroposterior and lateral radiographs were obtained with six to eight-week intervals.

All the patients were advised not to lift any weight until complete clinical and radiographical improvement occurred. Full range of elbow and forearm movements through graduated gentle physiotherapy were initiated following removal of the plaster. Union of the fracture and graft incorporation were assessed radiographically by two independent blinded observers. A fracture was considered united when there was obliteration of the fracture line and evidence of bridging trabeculae. Clinically, tenderness at the fracture site and any abnormal mobility on both anteroposterior and lateral planes were noted. The range of motion of the elbow (flexion and extension) and forearm (pronation and supination) was measured with a goniometer before surgery and on final follow-up examinations.

Functional results were rated based on the scoring system of Anderson et al.[1] Any pain, breakage or loosening of a plate or screw, refracture of the bone, recurrence of infection, or need for additional surgical procedures, donor site morbidity like pain, wound hematoma, or infections were also considered at the end-result evaluations.

Functional outcome scores and union time were analyzed in relation to clinical parameters such as age, affected bone, open or closed initial injury, previous infections, the time delay from initial injury, number of previous surgeries, and the bone gap. Statistical significance of these variables in relation to union time and functional scoring was evaluated with the use of unpaired t-test and Fisher's exact test, respectively. A *p* value of less than 0.05 was considered to be statistically significant.

RESULTS

The follow-up period ranged from 20 to 43 months (mean 28±6.94 months). In one patient who had nonunion involving both bones, the graft and the fracture were stabilized with intramedullary nailing because the bones were very osteoporotic. Similarly, during the evolving phase of the study, the graft was not secured with a plate in one patient.

The length of the final bone gap ranged from 2.5 to 5.0 cm (mean 4.05±0.75 cm), being 3.38±0.62 cm

Fig. 1. A 45-year old male patient. **(a)** Nonunion with infection and osteolysis underneath the plate. **(b)** Bone gap with nonunion after debridement and removal of the plate. **(c)** Early postoperative period, with iliac crest strut graft. **(d)** Final follow-up with complete incorporation of the graft.

for the radius and 4.43±0.53 cm for the ulna. The length of time from injury to final definitive surgery ranged from 10 to 36 months (mean 19.6±8.26 months).

Radiographically, union occurred in all the patients between four to six months (mean 4.65±0.74 months), being 4.38±0.62 months in the radius and 4.86±0.74 months in the ulna.

During the follow-up period, all the patients regained full extension of the elbow. Elbow flexion, which had been in full range in six patients preoperatively, showed complete improvement in all the patients. The forearm rotational movements also improved in all the patients, with two patients having full restoration of rotational movements. Six patients had full supination, while the rest had mild restrictions (10°-15°) with no residual weakness. Similarly, two patients had full pronation, whereas eight patients had mild to moderate restrictions (5°-25°). Patients with a greater bone gap took significantly more time to unite than those did with a smaller bone gap ($p=0.004$). So did the patients with a longer delay from the occurrence of primary injury ($p=0.02$). (Table I). However, neither the size of the bone gap nor the length of time from injury to final treatment significantly affected the final functional outcomes ($p>0.05$). Functional results and the time to union were not significantly influenced by other clinical parameters, either ($p>0.05$; Table II).

TABLE I

Correlation between time to union and selected clinical parameters

Parameters	Mean±SD	*r*	*p*
Age (years)	39±11.53	-0.116	0.749
No. of previous surgeries	2.1±0.56	-0.170	0.638
Time delay (months)	19.6±8.2	0.712	**0.020**
Bone gap (cm)	4.05±0.75	0.810	**0.004**
Open fracture (months)	4.60±0.41	0.20	0.84
Closed fracture (months)	4.70±1.03		
Infection (months)	4.83±0.68	0.94	0.37
No infection (months)	4.38±0.85		
Union of radius (months)	4.38±0.62	1.08	0.30
Union of ulna (months)	4.86±0.74		

Healing was uneventful in nine patients. One patient developed superficial infection which was adequately controlled by oral antibiotics within two weeks. Chronic infections did not occur. No complications were observed in the donor area, except for pain during the first few postoperative days, which subsided with oral analgesics and did not interfere with activities.

In one patient, distal radioulnar subluxation persisted in the postoperative period with limitation in the terminal rotational movements. However, the patient was satisfied with the clinical outcome and did not accept a subsequent operation. One patient had occasional ulnar neuralgia that responded to hot water application and analgesics.

TABLE II

Comparison between functional results and clinical parameters

Parameters	Excellent outcome (Mean±SD)		Satisfactory outcome (Mean±SD)		*t*	*p*
Age (years)	36.88±11.98		47.50±3.53		1.19	0.26
No. of surgeries	2±0.5		2.5±0.7		1.13	0.29
Time delay (months)	21±8.48		14±5.65		1.08	0.31
Bone gap (cm)	4.19±0.65		3.67±1.04		1.01	0.33
	No. of patients	%	No. of patients	%		
Open injury	3	60.0	2	40.0	p=0.625	
Closed injury	5	100.0	–	–		
Infection	4	66.7	2	33.3	p=0.234	
No infection	4	100.0	–	–		
Involvement of the radius	2	50.0	2	50.0	p=0.331	
Involvement of the ulna	6	85.7	1	14.3		

DISCUSSION

A bone gap may occur primarily as a result of bone loss associated with injury, or secondarily, following an infection causing osteolysis, or due to inadequate fixation allowing movements at the fracture site, or intraoperatively, due to removal of dead, sclerotic bone particles to have a healthy vascular bed. Nonunion with bone loss is a challenging situation for orthopaedic surgeons who not only have to deal with nonunion, but also to carry out reconstructive procedures to overcome associated bone loss. An ideal reconstructive surgery is one that is easy to perform with minimal complications, with intended results being obtained in a reasonable time frame following surgery. The success of any reconstructive surgery in a forearm nonunion bone gap relies on many clinical parameters such as the length of delay from initial injury, the number of previous surgical attempts, the presence of an infection on initial presentation, the length of bone gap, and, finally, the type of fixation methods performed to yield the intended results.

As seen in similar studies,[3,7,8] all the patients in our study presented with a considerable time lapse between initial injury and final treatment, during which they had been subjected to unsuccessful surgical operations. Although delay in ultimate treatment significantly affected the time to union ($p=0.02$), it did not exert any adverse effects on functional results ($p>0.05$). Similar studies indicated postoperative infections[3,7] and excessive length of bone gap[8] as the main reasons for failure rather than the number of previous surgeries or time delay.

Irrespective of the bone for which this procedure was performed (i.e. radius or ulna), the functional outcome and time to union did not significantly differ ($p>0.05$). Theoretically, infection plays an important role in influencing the outcome, as it jeopardizes not only the union but also the final functional recovery.[10] Though five of the six patients with functional limitation had had active infections on presentation, this did not play a significant role in the final analysis ($p>0.05$). Similarly, time to union did not differ significantly between infected and noninfected patients ($p>0.05$). Nevertheless, we do agree with the reports in literature,[2,7,10] that persistent infections may adversely affect final outcomes and stress the need for an aggressive management of infections both before and after surgery. Erythrocyte sedimentation rate is a good clinical parameter at this critical juncture in timing surgery.[10] In our study, the protocol for debridement including appropriate use of antibiotics and simultaneous monitoring with serial total leukocyte count, differential leukocyte count, and erythrocyte sedimentation rate helped in better timing of definitive surgery in the presence of primary infections, thus reducing the overall incidence of graft-related problems.

The length of the bone gap was also analyzed with regard to healing time and functional limitation. With longer bone gaps, time to union was significantly prolonged ($p=0.004$), whereas functional outcome was not affected ($p>0.05$). Davey and Simonis[8] concluded in their study that, in bone gaps exceeding 60 millimeters, surgical procedures should not be attempted owing to increased chance of failure. In contrast to this, Dabezies et al.[7] reported a successful outcome following surgery in a patient with a bone gap of 75 millimeters. The upper limit of bone gap up to which surgery can be opted is still speculative at present and the final decision can be left at discretion of the surgeon dealing with such cases.

We utilized an AO dynamic compression plate and screws to secure the graft and fracture fragments. There are a few studies that used a similar fixation method.[3,7] Davey and Simonis[8] also performed dynamic compression plating, but without fixing the graft to the plate assembly. Spira[9] used an intramedullary nail to secure the graft. It has been shown that creeping substitution of the graft by resorption and replacement is important for the incorporation of the graft to the host bone.[11] This process requires a stable bone-graft-bone assembly for a complete integration of the graft; otherwise, the graft might undergo excessive osteolysis and resorption, resulting in delayed union or even nonunion. There is no clear data in the available literature for the adequate length of immobilization. We employed an above-elbow plaster of paris cast in all the cases for a variable period of 6 to 12 weeks. Considering the severity of the situation in these patients with nonunion for unusually long periods and with underlying infections further compromising the bone quality, we are of the view that immobilization of a reasonable duration promotes fixation, hence a better outcome.

As mentioned earlier, there are also other methods such as vascularized fibular grafting and Ilizarov's ring fixator with distraction osteogenesis, but they are technically more demanding, cumbersome, and associated with more complications. They may certainly produce good results, but only in the hand of experienced surgeons trained in microvascular surgeries; however, even a general orthopaedic surgeon equipped with conventional training can successively apply an iliac crest bone block graft. We conclude that the use of a corticocancellous bone block from the iliac crest is a simple and reliable procedure in the management of nonunions of the forearm with proven success.

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