SCIENTIFIC ARTICLE

The Role of Bone Allografts in the Treatment of Angular Malunions of the Distal Radius

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Purpose Two cohorts of patients who had corrective osteotomies and volar platings for malunited fractures of the distal radius were compared retrospectively to determine whether the time to union and the outcome were affected by bone allograft.

Methods Patients in the first group (n = 14) did not receive any bone graft; patients in the second group (n = 14) had allograft bone chips following volar plating. Indications for surgery, surgical technique, and postoperative rehabilitation were the same in both groups. Volar cortical contact was maintained using a volar locking plate in all patients. Radiographic parameters of deformity correction, time to union, wrist and forearm range of motion, grip strength, patient-rated wrist evaluation and Disabilities of the Arm, Shoulder, and Hand questionnaire were used to evaluate the outcome before and after the surgery. Average follow-up time was 36 weeks. Patients who had diabetes, who smoked, who had a body mass index of more than 35, and who required lengthening for deformity correction were excluded from the study.

Results Osteotomies in both groups healed without loss of surgical correction. Final outcome and time to union revealed no significant differences, clinically or statistically, between the 2 groups. The Disabilities of the Arm, Shoulder, and Hand score was improved in both groups.

Conclusions When volar cortical contact was maintained using a volar locked plate, bone allograft at the osteotomy site did not improve the final outcome. *(J Hand Surg 2011;36A:1804–1809. Copyright © 2011 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic III.

Key words Bone graft, corrective osteotomy, distal radius, locking plate, malunion.

Corrective osteotomies of the distal radius are traditionally supplemented with osteoinductive and/or osteoconductive materials to stimulate bone healing and to support the hardware, regardless of the plane of correction.[1–15] Autogenous bone graft, particularly the iliac crest, results in considerable donor site morbidity, as much as 73% in some series.[16–19] Synthetic materials, allograft, and bone morphogenic proteins come with a substantial cost without a clearly defined indication, particularly in the case of distal radius osteotomies.[13,17] With recent advances in implant design, we hypothesized that time to union and functional outcome would not be adversely affected by an opening wedge osteotomy of an extra-articular distal radius malunion, with contact on the volar cortex maintained with a locking plate, in the absence of bone allograft. To test this hypothesis, we retrospectively compared 2 groups of patients having opening wedge osteotomies of the distal radius with volar locked plating.

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MATERIALS AND METHODS

The institutional review board approved this study. All patients gave consent before surgery. Patients were 35 years old on average (range, 18–65 y). All patients had opening wedge osteotomy and volar locked plating. In the first group, 14 patients chose not to have bone graft

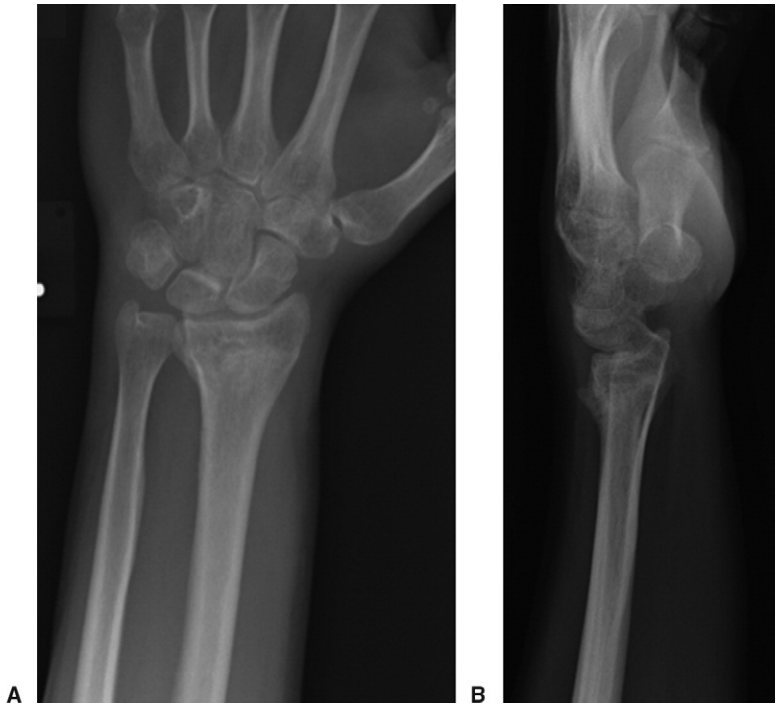

FIGURE 1: **A** Anteroposterior and **B** lateral radiographs of a 57-year-old woman who presented with pain and limited motion of her left wrist are shown 4 months after the injury. Radiographs showed 24° of dorsal tilt.

and had corrective osteotomy and volar plating only. In the second group, 14 patients had allograft bone chips packed at the fracture site through the same incision. Volar cortical contact was maintained in all patients.

Patient selection criteria

We included symptomatic patients who had malunited extra-articular fractures of the distal radius with more than 15° of dorsal angulation in the lateral plane and/or more than 2 mm of shortening on the anteroposterior plane (Fig. 1). All patients maintained volar cortical contact following corrective osteotomy. Patients requiring more lengthening on the volar cortex, who smoked, who had diabetes, and who had a body mass index of more than 35 were excluded. All patients were informed about the risks, benefits, and potential complications of the surgery with or without bone grafting before the surgery.

Surgical technique

A 10-cm skin incision was made on the volar aspect of the flexor carpi radialis tendon at the distal/volar third of the forearm. Through the interval between the flexor carpi radialis tendon and the radial artery, the pronator quadratus was reflected from the volar aspect of the radius, and the malunion site was exposed. One of the 2 standard-sized volar locking plates (Synthes, Paoli, PA; Accumed, Hillsboro, OR) was matched to the distal end of the radius with distal locking screws that were pre-drilled and measured. During pre-drilling, the surgeon held the plate's distal rim parallel to the lunate facet and left no space between the plate and volar cortex. A transverse osteotomy was then performed at the apex of the malunion site, using an oscillating saw. The plate was placed on the distal segment, and pre-drilled holes were filled with a minimum of 4 locking screws. The plate was fixed to the shaft with the aid of a 3.5-mm cortical screw and at least 1 locking screw (2.8 or 3.5 mm). As a result, correction was achieved in the coronal and sagittal planes by having the distal radius conform to the tilts of the plate. In all cases, the contact on the volar cortex of the distal radius was maintained at the end of the fixation (Fig. 2). In group 2, allograft chips were packed in the osteotomy site through the same incision.

Following surgery, all patients were immobilized in a volar splint until their sutures were removed in 2 weeks. They began active and active-assisted range of motion exercises of their fingers immediately after the surgery. Unrestricted wrist motion was allowed at 2 weeks. All patients were instructed not to lift, pull, or push more than 2 kg before radiographic healing was seen on x-rays. Otherwise, all patients were allowed to return to activities of daily living immediately after their

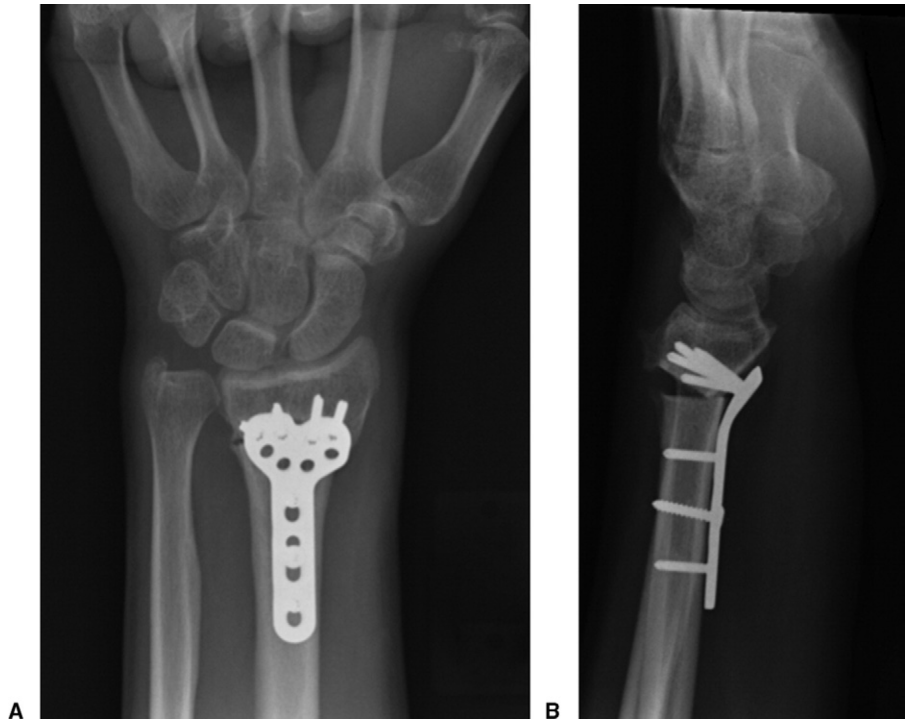

FIGURE 2: The patient had corrective osteotomy and volar plating without bone graft. **A** Anteroposterior and **B** lateral radiographs show the postoperative view after 4 weeks.

suture removal. Anteroposterior, lateral, and oblique views were obtained at 8, 12, 16, 20, and 24 weeks.

Clinically, patients' grip strength, wrist flexion and extension, radial and ulnar deviation, and forearm rotation were measured. Grip strength was measured as the average of 3 attempts using a grip meter (Asimov Engineering, Los Angeles, CA) set at the third setting, with the elbow flexed to 90° and the forearm in neutral rotation. Patient-rated wrist evaluation and Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaires were used to evaluate patient-rated outcome. Volar tilt, radial height, and radial inclination were measured on radiographs before surgery and at each follow-up visit. Hardware loosening and the first sign of union (defined as bridging callus forming at the osteotomy site, characterized by loss of fracture margins) were noted. Two independent observers performed radiographic measurements of the deformity correction, and the senior attending surgeon (K.O.) evaluated the time to union. Bone healing was considered complete when the osteotomy gap was filled with bone at the dorsal cortex.

The change in the DASH score and time to union were used as primary outcome variables. Means and standard deviations were used to describe the outcomes. Differences in outcomes between the 2 groups were determined by paired *t*-tests with a 5% significance level.

RESULTS

No statistically significant difference was noted between the 2 groups regarding average age, follow-up time, injury to surgery time, preoperative wrist motion, grip strength, and DASH scores (Table 1). Time to union was greater than 12 weeks in 3 patients in the group without allograft (average, 11 wk) compared to only 1 patient in the allograft group (average, 10 wk). This difference was not statistically significant ($P = .18$; Fig. 3). Comparison of postoperative functional outcome parameters revealed no statistically significant differences. Although patients with bone grafts tended to have a better grip strength at the final follow-up, this was likely related to the presence of a higher number of male manual laborers in the group who recovered more than the average grip strength at the their final visit.

One patient in the bone-grafting group had an extensor pollicis longus rupture due to a prominent bone chip on the dorsal aspect of the distal radius and received a tendon transfer (extensor indicis proprius to extensor pollicis longus) 5 months after the index procedure.

TABLE 1. Summary of Results

	Group 1 (n = 14) No Bone Graft		Group 2 (n = 14) Allograft		*P* Value (†)
Average age	35 (10)		37 (10)		.59
Gender	7 male, 7 female		10 male, 5 female		
Time from injury to surgery (wk)	11 (4)		10 (2)		.18
	Preop.	Postop.	Preop.	Postop.	
Radiographic measurements					
Radial incl	4 (5)	11 (2)	−2 (4)	13 (2)	.11
Volar tilt	−18 (12)	9 (4)	−20 (6)	8 (3)	.47
Radial height	−2 (1)	0 (1)	−2 (1)	1 (1)	.2
Range of motion					
Flex/Ext	62 (14)	120 (23)	70 (20)	123 (11)	.54
Radial/ulnar dev	12 (4)	21 (4)	10 (4)	19 (2)	.1
Pron/Sup	87 (20)	142 (14)	81 (16)	139 (17)	.56
Grip strength (kgf)	14 (3.4)	28 (7.6)	13 (2.9)	37 (5.4)	.09
PRWE score: Symp Sev	8.9 (2.3)	2.5 (1.3)	8.1 (1.5)	2.8 (2.2)	.5
Function	7.7 (3.1)	2.9 (1.1)	7.9 (2.1)	2.6 (1.9)	.4
DASH score	38 (12.5)	10 (4.5)	42 (10.4)	10 (6.1)	.29*
Time to union (wk)	11 (3.5)		10 (1.9)		.18

Numbers in parentheses represent standard deviations.

Radial incl, radial inclination, measured on anteroposterior plane; PRWE, patient-rated wrist evaluation; Symp Sev, symptom severity.

**P* value was determined based on the change in DASH score (preoperative minus postoperative). Comparison of the preoperative and postoperative averages between the 2 groups showed *P* values of .41 and .85, respectively.

†*P* value comparisons between the 2 groups are based on the postoperative values.

DISCUSSION

In this study, time to union was not statistically or clinically different between the 2 groups. We conclude that allograft did not improve functional outcome after corrective osteotomy of the distal radius. The following are noteworthy details that are distinct to this study. First, all cases were chosen from a pool of patients in whom volar cortical contact was maintained after the correction; patients needing more lengthening due to severe collapse were not included. Second, we excluded patients with comorbidities that are known to delay fracture healing.[21–23] Third, we used a volar locking plate in all cases, with 4 distal locking screws and at least 2 screws proximal to the osteotomy site. Unlike acute fractures, in which distal locking screws might not have a stable bicortical purchase due to fracture communition, all distal locking screws in our report were placed into a healed bone with bicortical purchase. No hardware loosening or loss of reduction was observed. The rigid fracture stabilization achieved using the volar locking plate likely improved the functional status even before fracture healing occurred. Although the average time to a bridging callus formation was longer in the no-bone-graft group, this did not translate into a clinical or statistically significant difference between the 2 groups. It is also possible that time to union might be artificially increased, as we obtained the first postoperative radiographs in 8 weeks. Finally, using a precontoured volar locking plate, we were able to correct the rotational malalignment, radial inclination, and volar tilt. Many authors have suggested the need for 3-dimensional correction, and some have recommended computed tomography evaluation of the wrist before the surgery.[2,4,6,12,24] However, for extra-articular corrective osteotomies, precontoured volar locking plates seem to provide satisfactory correction in multiple planes.

Ghormley and Mroz[1] described interpositional bone grafts for corrective osteotomies of the distal radius in 1932. Since then, iliac crest bone graft has become the standard, and its use has been reported with success.[2–6] However, iliac crest bone grafting has a high complication rate, with associated morbidity of up to 73%, and an additional operative time averaging 20 minutes.[17–20,25–27] With advances in implant design and the need for an alternative graft

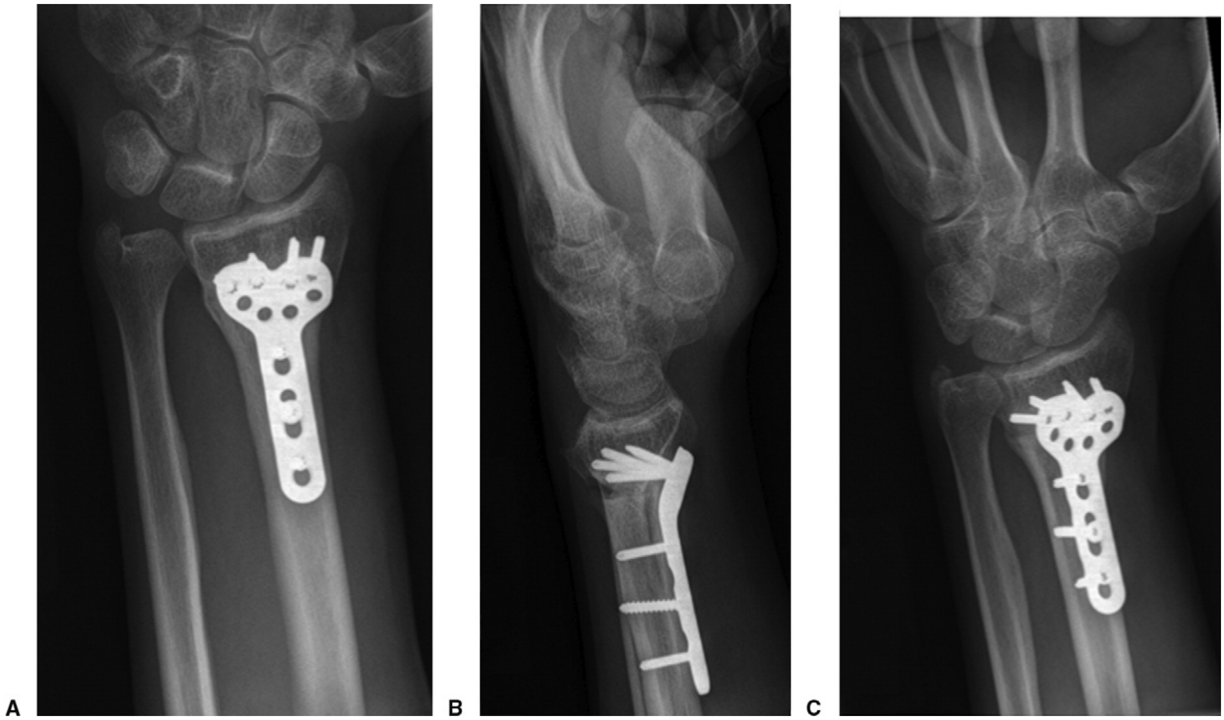

FIGURE 3: Four months after surgery, **A** anteroposterior, **B** lateral, and **C** oblique radiographs show bridging callus on the fracture site, best seen on the oblique view **C**.

material, Ring et al compared structural tricortical iliac crest graft with nonstructural (cancellous) autogenous bone graft and found no difference in the outcome.[10] Later, hydroxyapatite and allograft chips were compared to autogenous sources with no difference seen in the outcome.[14,28] Although these products come with an inherent advantage of no donor site morbidity, they also come with a cost[13,16] and sometimes a potentially low but real risk of disease transmission.[29–32] In light of these comparable results between various bone graft materials, the logical next step is to ask, "Does the use of bone graft material have an effect on bone healing and subsequently functional outcome after corrective osteotomies of the distal radius?"

This question was asked with respect to acute fractures of the distal radius in 1 study[33] in which the authors did not use bone graft to fill the void resulting from fracture communition and stabilized the fracture with an external fixator. They found no advantage of using bone graft as observed in clinical and radiographic outcomes compared to a primarily bone-grafted group. On the other hand, not using any bone graft after an opening wedge osteotomy, although intriguing, would require a deviation from conventional treatment and might not be acceptable to some hand surgeons. The reason we were able to offer the option was based on our observation of the first 5 patients who refused to have bone graft and had a complete radiographic union within 8 weeks of the surgery. These 5 patients did not want to have autogenous iliac crest bone graft due to a high incidence of reported pain and complications, and they refused to have synthetic materials or allograft due to their spiritual beliefs. They understood and accepted the risk of nonunion in the absence of bone graft. As a result, we had a selection bias between the groups. Although the demographic variables between the 2 groups were statistically similar, the bone-grafted group had a higher number of male manual laborers whose grip strength reached a higher value at the final follow-up.

Functional outcome in the current study was comparable or better than those reported by others[1–14] who used tricortical and cancellous iliac crest bone graft, allograft bone chips, calcium phosphate, hydroxyapatite, and RhBMP-7. Jupiter and Ring reported an average 97° arc of motion in flexion and extension and an average 42 kgf in grip strength without loss of reduction in a group of patients reconstructed within 6 to 14 weeks using a dorsal plate and iliac crest bone graft.[3] Later, Luchetti, using carbonated hydroxyapatite and K-wires, achieved 110° arc of motion in flexion and extension and 24 kgf grip strength with no loss of reduction.[14] Malone, using the volar locking plates and iliac crest bone graft, achieved 21° of improvement in flexion and extension and 23 points of improvement in DASH score.[15] From the functional standpoint, we achieved comparable arc of motion (average 120° in both groups), a bridging callus an average 11 weeks after the surgery, and a mean 28 points of reduction in DASH score at the final follow-up.

Limitations of this study include its retrospective design and limited sample size. Power analysis was based on DASH score and time to union. As a result, we were able to draw our conclusions within an acceptable confidence interval with 14 cases in each group. On the other hand, nonunions of the distal radius are rare (less than 1%). Consequently, one can argue that the risk of nonunion might have never increased in treating 14 patients in the no-allograft group, especially when the volar cortical contact was maintained. To reliably test the risk of nonunion in the no-allograft group, one would need a much greater number of patients on each side. Given the limited sample size, we claim only that not using allograft did not delay bone healing and consequently functional outcome. Further prospective studies with a greater study size would strengthen our conclusions. The hypothesis proven in this study might not be applicable to cases in which lengthening is needed on the volar cortex and to those patients with known comorbidities, as indicated earlier.

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