Is Bone Grafting Necessary in the Treatment of Malunited Distal Radius Fractures?

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Abstract

Background Open wedge osteotomy with bone grafting and plate fixation is the standard procedure for the correction of malunited distal radius fractures. Bone grafts are used to increase structural stability and to enhance new bone formation. However, bone grafts are also associated with donor site morbidity, delayed union at bone-graft interfaces, size mismatch between graft and osteotomy defect, and additional operation time.

Purpose The goal of this study was to assess bone healing and secondary fracture displacement in the treatment of malunited distal radius fractures without the use of bone grafting.

Methods Between January 1993 and December 2013, 132 corrective osteotomies and plate fixations without bone grafting were performed for malunited distal radius fractures. The minimum follow-up time was 12 months. Primary study outcomes were time to complete bone healing and secondary fracture displacement. Preoperative and postoperative radiographs during follow-up were compared with each other, as well as with radiographs of the uninjured side.

Results All 132 osteotomies healed. In two cases (1.5%), healing took more than 4 months, but reinterventions were not necessary. No cases of secondary fracture displacement or hardware failure were observed. Significant improvements in all radiographic parameters were shown after corrective osteotomy and plate fixation.

Conclusion This study shows that bone grafts are not required for bone healing and prevention of secondary fracture displacement after corrective osteotomy and plate fixation of malunited distal radius fractures.

Level of evidence Therapeutic, level IV, case series with no comparison group

Keywords

- malunited distal radius fractures
- corrective osteotomy and plate fixation
- bone grafts
- bone healing
- secondary fracture displacement

Malunion is the most common complication of distal radius fractures.^{1–4} Almost 24% of the patients who are treated conservatively for distal radius fractures develop a malunion. The rate of developing malunion in surgically treated patients is ~10%.^{3–6}

Malunions are associated with increased pain, weakness, decreased range of motion, and/or neurological symptoms.^{1–4,6} These symptoms can have a great impact on daily activities. However, malunions can also be asymptomatic, with minimal loss of function in spite of severe radiographic

abnormalities. In particular, patients over 55 years of age have shown no association between functional and radiographic outcomes.^{7–9} Therefore, clinical symptoms rather than radiographic abnormalities determine whether surgical intervention in malunited distal radius fractures is necessary.^{1–3,6,10}

The goal of surgical correction is to restore the anatomy of the wrist in a symptomatic patient with a malunited distal radius.^{1,11–14} In 1932, Ghormley and Mroz described surgical correction at the radial site of the deformity for the first

time.¹⁵ Over the years, several surgical techniques have been described for the correction of the radial deformity, including closed or open wedge osteotomy, the use of different types of bone graft and biomaterials, plate fixation, and the use of additional procedures. Nowadays, open wedge osteotomy and plate fixation with bone grafting is considered the standard procedure, because the distal radius is usually shortened and/or angulated.^{1,3,4} Open wedge osteotomy effectively restores the length of the radius, but it also creates a void. Bone grafts or bone graft substitutes are used to fill this void, based on the concept that they create better structural stability and optimal substance for bone formation.^{16–18} Autogenous bone grafts from the iliac crest are used in most cases.¹⁶ However, the use of bone grafts can lead to donor site morbidity, delayed union at bone-graft interfaces, size mismatch between the graft and the osteotomy defect, additional operation time, and higher costs.^{16,19–21}

Corrective osteotomy and plate fixation of the malunited distal radius fracture with the use of bone grafts has been extensively described in the literature.^{22–39} Only a few studies have evaluated bone healing after corrective osteotomy and plate fixation without bone grafting.^{40–43} None of these studies reported healing problems. However, these studies included only small numbers of patients.^{40–43} Therefore, the purpose of this study was to assess bone healing and secondary fracture displacement after corrective osteotomy and plate fixation without bone grafting in a large patient cohort. We hypothesized that all osteotomies healed within 4 months.

Patients and Methods

Study Design

This retrospective study was conducted at a single center. The study was approved by the local Medical Research Ethics Committee.

Study Population

A total of 132 patients were included in this study, in which two patients underwent corrective osteotomy of both wrists. All patients had clinically symptomatic malunited distal radius fractures that required corrective osteotomy and internal fixation with volar and/or dorsal plates, performed between December 1992 and December 2013. None of the patients received bone grafts during the corrective osteotomy. All patients had at least 12 months postoperative follow-up.

The mean age was 54.4 years (range 18–87 years). Ninety-seven women and thirty-five men were included in this study. The median time between trauma and surgery was 23 weeks (range 3–695 weeks) and the median follow-up time was 92 months (range 13–252 months). Eighty-four patients (63.6%) were treated with dorsal plate fixation and forty-five (34.1%) patients with volar plate fixation. Three patients had both dorsal and volar plate fixation. The majority of the initial fractures were extra-articular (AO type A; 52.3%), followed by completely intra-articular (AO type C; 31.8%) and partially articular (AO type B; 6.1%).

Surgical technique

One surgeon performed almost all surgical procedures ($N = 128$). Limited wrist function and/or pain were the most important indications for surgery, rather than radiographic abnormalities. Radiographic degrees of deformity were not used as sole criteria for surgery. All patients with a dorsal angulated malunion underwent a dorsal opening wedge osteotomy. In cases of volar angulation, volar opening wedge osteotomy was performed.

Each operation was performed under general or brachial block anesthesia. An open wedge osteotomy was made at the appropriate site of the deformity with an osteotome, in which cortical contact on the opposite site was maintained in all cases. None of the patients received bone grafts. Dorsal and volar approaches were performed using the standard surgical techniques. The following plates were used in the dorsal approach: fragment-specific plates ($N = 35$), pi-plates ($N = 6$) or T-plates ($N = 43$). In the volar approach, T-plates ($N = 39$), double-column plates ($N = 5$), or fragment-specific plates ($N = 1$) were used for internal fixation. Three patients underwent sandwich plating with dorsal fragment-specific plates and a volar T-plate ($N = 2$) or double-column plate ($N = 1$). ►Fig. 1 shows a perioperative example of corrective osteotomy and plate fixation without bone grafting. After 10 days of wrist immobilization in a below-elbow-cast, all patients started with active and passive exercises.

Measurement Outcomes

All data were derived from medical records. The primary study outcomes were complete bone healing and secondary fracture displacement. Standard posteroanterior (PA) and lateral radiographs were taken postoperatively from the injured side. These radiographs were compared with the preoperative radiographs and radiographs of the uninjured side that were used as a template. Radiographs were independently assessed by two of the authors. The radiographic parameters of radiographs between 1992 and 2003 were measured with a goniometer. After 2002 the radiographic parameters were determined with picture archiving and communications system (PACS) tools. Radial inclination,

Fig. 1 Perioperative example of open wedge osteotomy and plate fixation without bone grafting in a 60-year-old woman.

ulnar variance, and radial length were evaluated using the PA view and palmar tilt using the lateral view. Bone union was considered complete when the osteotomy gap was filled with bone formation in 4 months and/or the patients had no clinical signs of bone healing problems such as persistent pain, swelling, or motion at the fracture site. All fractures were classified on the initial fracture radiographs. The primary fractures were classified into the three main types of fractures based on the AO classification system.⁴⁴

Statistical Analysis

All baseline demographic variables and relevant clinical variables are summarized descriptively to characterize the study population. Data are presented as mean scores with 95% confidence intervals. Paired *t*-tests were performed to compare the results. Potential confounders were corrected with multivariate regression analysis. A probability *P*-value of less than 0.05 was considered significant. All computations were performed by using SPSS Statistics Software Version 22 (SPSS Inc., Chicago, IL, USA).

Results

All patients had complete bone healing without additional surgical interventions. Two patients developed a delayed union. In one patient, fracture healing was complete at 8 months. The other patient had complete bone union after 15 months. No additional interventions were performed in these patients. ►**Table 1** gives an overview of several categorized factors that can be of influence on the bone healing process (location of the osteotomy site, gap size, age, and gender). No relationship was observed between the categorized factors and the time of complete bone union. Radiographic measurements are summarized in ►**Table 2**. All patients showed significant improvement in their radiographic parameters after corrective osteotomy and plate fixation. Furthermore, none of the patients showed both statistically and clinically secondary displacement or hardware failure ($P > 0.05$). The average height of the osteotomy gap was 8.2 mm with a minimum of 3.5 mm and maximum of 15 mm based on the radiographs that were taken within 2 weeks after the operation. Estimated volume of the osteotomy gap was ~5.6 mL (based on computed tomography [CT] of an average individual). The patients with the delayed unions had osteotomy gaps of 5.3 mm and 9.2 mm. ►**Fig. 2** shows an example of open wedge osteotomy and dorsal plate fixation without bone grafting during the follow-up period.

In 21 (15.9%) patients, wound/soft tissue complications occurred (see ►**Table 3**). Three tendon ruptures occurred: two of the extensor pollicis longus tendon and one of the extensor carpi ulnaris. All three patients were treated with dorsal plates. They underwent implant removal and tendon transfer. Five patients had tendinitis due to the use of implant and screws; three of these patients were treated with dorsal plate fixation. Hardware removal was required in four patients. Three patients underwent a release of the median nerve in combination with volar plate removal because of

neuropathy. Two patients had a stenosing tenosynovitis of the flexor digitorum tendon, which required corticosteroid injection in one patient and tenolysis in the other patient. Another patient had an asymptomatic snapping tendon of the extensor digitorum tendon. After implant removal, the snapping tendon remained without complaints. A total of four patients fulfilled the criteria of type I complex regional pain syndrome (CRPS). One patient had tendon adhesions of the flexors as a soft tissue problem, which resolved spontaneously. Two patients had problems due to the implant. One of these patients also had a screw loosening of the radial column plate. In this patient, the radial column plate was removed. Another patient had complaints of pain due to a prominent screw, which required implant removal. Seventy-three (55.3%) patients underwent hardware removal because of the complications just described, functional impairment, and/or increased pain.

Discussion

In this study we demonstrate that in patients undergoing corrective osteotomy of malunited distal radius fracture, the use of structural bone grafts is not necessary to achieve bone healing without increasing the risk of secondary displacement. The use of iliac bone graft is based on the conception that it provides better structural stability.¹⁶ In addition, it is supposed to have the most optimal biologic stimulus for new bone formation.¹⁷ Structural stability is considered as a crucial factor for bone healing.^{45,46} Biomechanical studies have already suggested that plate fixation provides significant structural stability in itself,⁴⁷ and through this stability, the normal process of fracture healing continues without restrictions. Therefore, it is questionable whether bone grafts are needed for structural stability. Disadvantages of bone grafting, such as donor site morbidity, delayed union at bone-graft interfaces, size mismatch between the graft and the osteotomy defect, additional operation time, and higher costs might be prevented by the abolition of bone grafts.^{16,19–21}

As far as we know, this study includes the largest patient cohort in which bone healing and secondary fracture displacement were evaluated after corrective osteotomy and plate fixation without bone grafting. Our study shows that corrective osteotomy without bone grafting is not associated with significant loss of postoperative reduction and showed comparable bone healing rates to previously reported studies that used bone grafts after corrective osteotomy and plate fixation (see ►**Table 4**).

The autogenous bone grafting technique using bone from the iliac crest in open wedge osteotomy and plate fixation for the treatment of malunited distal radius fractures is extensively described in the literature.^{22–24,26–28,31,34,35,37–39} ►**Table 4** summarizes a systematic review of all studies that used bone grafts from iliac crest after open wedge osteotomy and plate fixation. These studies reported an incidence of delayed union between 0–5.6% and nonunion between 0–10.5%. One study reported a loss of reduction after hardware removal with development of a nonunion.³¹ Our study showed comparable

Table 1 Factors that can have an influence on the bone healing process

Factors	Bone healing within 2 months	Bone healing within 4 months	Bone healing within 6 months	Bone healing within 12 months
Dorsal opening wedge	21.2	95.3	95.3	97.7
Volar opening wedge	13.4	100	100	100
P-value	0.62	0.47	0.47	0.69
Gap size < 7.5 mm	18.8	93.8	93.8	93.8
Gap size > 7.5 mm	15.4	94.1	94.1	100
P-value	0.11	0.97	0.97	0.30
Age < 55 years	17.0	95.1	95.1	97.6
Age > 55 years	18.2	100	100	100
P-value	0.98	0.49	0.49	0.63
Men	15.0	96.7	96.7	96.7
Women	18.4	97.8	97.8	100
P-value	0.19	0.77	0.77	0.22

All data are expressed in percentages. Bone union was considered complete when the osteotomy gap was filled with bone formation, judged on radiographs in two directions. No relationship was observed between the above mentioned factors and the time of complete bone union ($P > 0.05$).

incidences of healing problems in comparison to the previously reported studies.

Only four clinical studies described in literature have evaluated bone healing after corrective osteotomy and plate fixation without the use of bone grafts (see ►Table 4). All studies reported no problems with bone healing.^{40–43} The study of Wieland et al was the first published study that retrospectively evaluated 47 extra-articular malunions treated without the use of bone grafts. The study showed improvement in functional and radiographic outcomes regardless of type of plate fixation and fracture type.⁴⁰ These results are also consistent with those of a prospective study in which 22 malunions with dorsal angulation were treated with open wedge osteotomy and volar locked plates without bone grafts.⁴¹ Another study retrospectively evaluated 28 patients with an extra-articular malunion of the distal radius.⁴² All patients were treated with volar locked plates and they were divided in two groups; one group received allograft

bone chips and the other group did not receive any bone grafts or bone graft substitutes. No significant differences in radiologic and functional outcomes were observed between the two groups.⁴² The most recent study treated 11 patients with open wedge osteotomy and dorsal bicolunar locked plates without bone grafting. All patients had complete bone healing after a mean period of 3 months. In addition, all patients had satisfactory results in terms of function and pain.⁴³

Most complications in this study occurred most likely as a result of the plate fixation technique. At present, discussion exists whether volar or dorsal plating is the appropriate technique for internal fixation of distal radius fractures.⁴⁸ Recently, a meta-analysis was published that evaluates complications in distal radius fractures treated with dorsal or volar plate fixation.⁴⁹ No significant differences were observed in the overall complication risk.⁴⁹ Patients with volar plate fixation showed a higher rate of neuropathy and carpal

Table 2 Radiographic outcomes after corrective osteotomy and plate fixation without bone grafting

Radiographic parameters	Preoperative	Direct postoperative	Late postoperative	P-value	Uninjured side
Radial inclination (°)	17.7 ± 6.9	21.6 ± 5.2	22.3 ± 5.7	0.39	22.8 ± 3.6
Radial height (mm)	9.6 ± 3.7	12.0 ± 2.7	12.7 ± 3.3	0.99	12.7 ± 1.7
Ulnar variance (mm)	3.2 ± 2.9	0.9 ± 1.9	1.2 ± 1.7	0.07	-0.2 ± 1.2
Palmar tilt (°)	-3.4 ± 17.9	7.1 ± 5.1	7.0 ± 6.4	0.32	10.9 ± 4.9

All data are expressed as mean values and standard deviations. The direct postoperative values were determined based on the radiographs that were taken within 2 weeks after the operation. The late postoperative values are derived from the last radiographs during the follow up period. There were no significant differences between the direct postoperative values and late postoperative values.

Fig. 2 A 57-year-old man sustained an extra-articular distal radius fracture after fall from ground level. He was treated with dorsal plate fixation after initial treatment with a plaster cast. Indication for corrective osteotomy was pain and reduced range of motion. He also had radiographic abnormalities. Radial inclination was 16° and palmar tilt was -25° . (a, b) Postoperative anteroposterior and lateral radiographs on the same day of the operation. A metaphyseal defect of 9.2 mm is shown. (c, d) Postoperative radiographs from the anteroposterior and lateral view after 2 months of follow up. The bone defect is filled with callus. Radial inclination was improved to 28° and palmar tilt -7° . The patient was not impaired in his daily activities anymore.

tunnel syndrome. However, patients who were treated with dorsal plate fixation had higher risk of tendon problems.⁴⁹ In our study, no significant differences were reported in complication rates between dorsal and volar plate fixation. In our opinion, the decision for the type of fixation should be based on the type of malunion and the surgeon's experience with the specific approach and technique.

This study is limited by its retrospective nature, the absence of some data, the wide range of follow-up period, and the heterogeneity of the study population. Another important limitation was that bone healing was assessed by conventional radiographs instead of CT images. Although CT is more precise in the detection of early fracture healing in the radius, independent radiographic assessment combined with clinical assessment also shows a high accuracy to evaluate bone healing.⁵⁰ Furthermore, different types of plates were used throughout the 20-year period. We did not observe a correlation between types of plates and complications or plate removals, but a possible correlation could not be excluded, because of the small patient numbers.

Table 3 Reported complications

Complications	Dorsal	Volar	P-value
Soft tissue/wound (%)	14.3	20.0	0.28
CRPS/dystrophy	2.4	4.4	
Tendinitis	3.6	4.4	
Tendon (re)rupture	3.6	0	
Neurologic problems	1.2	7.1	
Other soft tissue problems	3.6	4.4	
Implant/surgery (%)	2.4	0	0.30
Plate/screw pull out	1.2	0	
Plate/screw loosening	1.2	0	

An overview of complications (in percentages) in which a distinction is made between dorsal and volar plate fixation. Of these patients, 84 patients were treated with dorsal plate fixation and 45 patients were treated with volar plate fixation. In both groups, two patients had two complications. The patients who underwent both dorsal and volar plate fixation, had no complications. Abbreviation: CRPS, complex regional pain syndrome.

Table 4 Comparison between studies using bone grafts after corrective osteotomy and plate fixation and studies without using bone grafts

Author	Year of publication	Number of patients	Study design	Type of bone grafting	% Delayed union	% Nonunion	Occurrence of dislocation
Gradl ²²	2013	18	RCS	ICBG and RD	5.6	0	None
Henry ²³	2007	19	RCS	ICBG	0	10.5	None
Horas ²⁴	2001	31	RCS	ICBG	0	0	None
Jupiter ²⁶	1996	20	RCS	ICBG	5.0	0	None
Kiliç ²⁷	2011	17	PCS	ICBG	0	0	None
Lozano-Calderón ²⁸	2010	22	RCS	ICBG	0	0	None
Prommersberger ³¹	2001	20	RCS	ICBG	0	5.0	1
Ring ³⁴	2002	20	RCS	ICBG ^a	0	0	None
Sato ³⁵	2009	28	RCS	ICBG	0	0	None
Shea ³⁷	1997	25	RCS	ICBG	0	4.0	None
von Campe ³⁸	2006	15	RCS	ICBG	0	0	None
Wada ³⁹	2011	21	RCS	ICBG and TPBS	9.5	0	None
Wieland ⁴⁰	2005	47	RCS	—	0	0	None
Ozer ⁴²	2011	14	RCS	— ^b	0	0	None
Mahmoud ⁴¹	2012	22	PCS	—	0	0	None
Tiren ⁴³	2014	11	RCS	—	0	0	None

Overview of studies that used bone grafts after open wedge osteotomy and plate fixation. All studies included 15 or more patients. In addition, these table also summarizes the four studies in which bone grafting was not performed after corrective osteotomy and plate fixation.

Abbreviations: ICBG, autogenous cancellous iliac crest bone graft; PCS, prospective cohort study; RCS, retrospective cohort study; RD, autogenous cancellous bone graft from the radius; TPBS, tricalcium phosphate bone substitute.

^aRing et al used structural trapezoidal bone graft from the iliac crest and nonstructural cancellous bone from the iliac crest.

^bIn the study of Ozer et al, 14 patients received allograft bone chips and in the other 14 patients no bone grafts were used after corrective osteotomy and plate fixation.

In conclusion, this study demonstrates that in the treatment of malunited distal radius fractures, corrective osteotomy and plate fixation without bone grafting is a reliable technique to achieve bone union. These results are favorable in comparison to the studies with the standard technique, while not having the disadvantages and the additional costs of using bone grafts.^{16,19–21} Therefore, the use of bone grafts after corrective osteotomy of distal radius malunion should be reconsidered.

Conflict of Interest

None

Ethical Statement

The study was approved by the local Medical Research Ethics Committee.

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