Corrective osteotomy of the malunited distal radius fracture: use of periosteal bed may reduce the extent of postoperative graft resorption

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Received: 21 April 2009 / Accepted: 20 May 2009 / Published online: 16 June 2009
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Abstract The aim of this study was to compare osteotomy for malunited distal radius fracture with embedment of a corticospongiuous graft into a periosteal flap of the recipient bone (test) with the standard procedure (control) with respect to graft resorption. A retrospective assessor-blind analysis of consecutive patients (test: $n=19$, control: $n=30$) was performed. Ulnar tilt, palmar tilt and capitate-ulna distance were assessed from radiographs taken before, two to four days after and over three months after the surgery to determine loss of correction achieved by the surgery and estimate graft resorption during the postoperative period. In both unadjusted and adjusted comparisons, loss of correction of all parameters was lower in the test group ($P<0.05$). The odds of “none to mild” resorption were greater in the test group with an adjusted odds ratio of 5.43 (95% confidence interval: 1.32–26.5, $P=0.025$). Total graft collapse occurred in five of 30 controls and in none of 19 test patients. Graft embedment into the periosteum may improve its preservation.

Introduction

Malunion is the most common complication of the distal radial bone fracture and results in pain and reduced hand strength and function [2, 3, 21, 22]. In the case of malunited fracture, particularly in younger and more active patients with no arthritic changes, open-wedge corrective osteotomy with bone autograft is indicated [1, 10–13, 16, 17, 19, 20]. In order to achieve a precise reconstruction with optimum functional effects and to avoid bone graft collapse during the postoperative period, the surgical procedure requires careful planning and a precise technique [4–6, 8, 9, 14]. Nevertheless, a certain level of graft resorption or even complete resorption may occur despite all efforts [4–6, 8]. In an attempt to reduce the amount/occurrence of graft resorption we tried using an osteotomy procedure that included implantation of the graft into a membrane of the vital periosteum (“periosteal bed”) of the receptive bone. Here we present the results on a group of patients treated with this method and compare them with the results for a group of patients who underwent the standard procedure.

Patients and methods

Patients

Candidates for this retrospective analysis were consecutive patients who underwent corrective osteotomy with a corticospongiuous bone autograft due to malunited distal radial bone fracture over the two years before the decision to modify our practice and, hence, underwent the standard or “control” procedure, or during the subsequent two years after the decision to modify the practice and, hence, underwent the “test” procedure that included implantation

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of the graft into a periosteal bed. They were included if the following criteria were met: (a) operated up on by the same surgeon (to eliminate the surgeon's skill factor); (b) availability of anteroposterior and lateral radiographs of the radius taken preoperatively, shortly after the surgery (within a few days) and on at least one occasion after more than three months since the surgery had elapsed, i.e., the healing process had been completed (unless a complete graft collapse had occurred prior to that); (c) consented to the use of their (anonymous) medical data for research purposes.

Surgical procedure

Open-wedge corrective osteotomy with corticospongious bone autograft and dorsal approach was performed according to Fernandez [10]. The test procedure included formation of a bed, i.e. a membrane of the vital periosteum of the recipient bone (Fig. 1a). After a cross-sectional cut, a longitudinal cut of the the periosteum is performed in the middle of the dorsal part of the radial bone. Then, using a raspatory, the periosteum is carefully lifted along the whole circumference of the radial bone, as widely as needed to fit the planned graft (Fig. 1b). The osteotomy line is at the base of the periosteal membrane so that after osteotomy has been performed and the graft has been implanted into the periosteal bed, the graft is almost completely wrapped into the membrane (Fig. 1c). Fixation of the radius and the graft with a small T-plate follows (Fig. 1d).

Evaluations and end points

All radiographs were assessed by the same investigator unaware of the treatment implemented. Ulnar tilt, palmar tilt and the height of the radius measured as a distance from the height of the distal ulnar surface to the top of the capitate [7] (capitate-ulna distance) were determined from radiographs taken before the surgery (a), shortly after the surgery (b) (within two to four days) and more than three months after the surgery (c). Correction of the three measures achieved by the surgery was determined as a difference $b - a$. Differences in the three measures between over three months after the surgery and two to four days after the surgery were determined ($c - b$) as indicators of the loss of correction achieved and were considered *primary end points* illustrative of the graft resorption. Since the graft collapse, depending on the affected side, may result in either an increase or a decrease in the ulnar or the palmar tilt, the amount and not the direction of the change is of relevance. Hence, all changes in the ulnar and palmar tilts were considered as positive values. In the case of the capitate-ulna distance, on the other hand, graft collapse results in its reduction. Based on the amount of these differences, patients

Fig. 1 Schematic outline of the corrective osteotomy of the radial bone with embedment of the graft into a flap of the vital periosteum of the recipient bone. **a** The solid line shows the periosteal flap, whilst the broken line shows the osteotomy site. Incision of the periosteum, by a sharp knife, is followed by thorough and precise periosteal elevation, by a small raspatory, to the level of the osteotomy (**b**). The osteotomy of the radial bone and embedded bone graft (shaded in light grey) is partly covered by the periosteum (**c**). The plates are fixed in a way that the screws do not penetrate the periosteal flap (**d**)

were classified into three categories in respect to the estimated graft resorption as a *secondary end point*:

1. None to mild resorption: change in both the ulnar and palmar tilt is $\leq 5^\circ$ and at the same time reduction of the capitatum-ulna distance is ≤ 2 mm.
2. Moderate resorption: neither “none to mild” nor “severe”.
3. Severe resorption: change in either the ulnar or the palmar tilt is $> 15^\circ$ and at the same time reduction in the capitatum-ulna distance is > 5 mm, or change in any of the tilts is $\geq 30^\circ$ or reduction of the capitatum-ulna distance is ≥ 7 mm.

Statistics

Blinded data analysis was performed by a person not involved in surgical procedures or radiological evaluations.

The amount of correction of each of the three parameters achieved by the surgery was compared between the test and the control groups using analysis of covariance. Changes (loss) in correction ($c - b$ differences) of each of the three parameters were compared between the two groups using quantile regression (due to data skewness and outliers) to obtain adjusted median differences. Cumulative logistic regression was used to analyse prevalence of patients across categories of estimated graft resorption to obtain adjusted odds ratios (OR) of having “none to mild” resorption. We used SAS 9.1 for Windows (SAS Inc., Cary, NC, USA) software.

Results

Patient characteristics

During the specified time period, 55 patients were treated by corrective osteotomy for malunited distal radial fracture, 21 by the test procedure including implantation of the graft into a periosteal bed and 34 by the standard, control procedure. A total of six patients never returned for a follow-up visit. According to the medical history database, none of them was diagnosed with a complete graft resorption, i.e. scheduled for a re-operation at our institu-

tion. This left 49 patients for the planned evaluation, 19 treated by the test and 30 by the control procedure. As compared to healthy wrists, there was a considerable (and comparable) deficit of the ulnar tilt, palmar tilt and capitate-ulna distance in the affected wrists in both groups (Table 1). They were almost completely corrected (less so the palmar tilt) by surgery in both groups (Table 1). With adjustment for preoperative values and position of the osteotomy (relative to the ulnar joint surface), there was no statistically significant difference between the two groups regarding the amount of correction achieved (not shown).

Loss of correction in the ulnar and palmar tilts and capitate-ulna distance at over three months after the surgery

Differences in the ulnar and palmar tilts and capitate-ulna distance at more than three months after the surgery versus two to four days after the surgery illustrating that loss of correction was significantly ($P < 0.05$) less prominent in the test than in the control group in both unadjusted and adjusted comparisons (Table 2).

Estimated graft resorption

Patients in the test group were more frequently classified as having “none to mild” graft resorption than those in the

Table 1 Patient characteristics by treatment group. Data are summarised as count, median (range) or mean $\pm$ SD

	Periosteal bed (test)	Standard surgery (control)
<i>N</i> (M/F)	19 (10/9)	30 (18/12)
Age at surgery (years)	39 (21–55)	37.5 (17–64)
Affected wrist, left/right	4/15	17/13
Distance (mm): osteotomy vs joint ulnar surface	17.3 $\pm$ 4.1	19.5 $\pm$ 5.6
Ulnar tilt (°)		
Healthy wrist	22.12 $\pm$ 4.11	23.72 $\pm$ 5.98
Diseased wrist		
• Before surgery	8.52 $\pm$ 6.80	6.79 $\pm$ 10.03
• 2–4 days after surgery	24.65 $\pm$ 7.94	24.46 $\pm$ 5.94
• Correction achieved by surgery	16.13 $\pm$ 9.19	14.82 $\pm$ 10.04
Palmar tilt (°)		
Healthy wrist	10.50 $\pm$ 3.50	10.54 $\pm$ 3.95
Diseased wrist		
• Before surgery	–22.51 $\pm$ 6.19	–14.4 $\pm$ 17.19
• 2–4 days after surgery	2.88 $\pm$ 9.56	9.20 $\pm$ 12.65
• Correction achieved by surgery	25.39 $\pm$ 9.60	23.44 $\pm$ 18.38
Capitate-ulna distance (mm)		
Healthy wrist	12.07 $\pm$ 2.02	12.43 $\pm$ 2.01
Diseased wrist		
• Before surgery	7.26 $\pm$ 2.10	6.93 $\pm$ 3.53
• 2–4 days after surgery	11.21 $\pm$ 2.18	11.83 $\pm$ 2.59
• Correction achieved by surgery	3.95 $\pm$ 2.70	4.90 $\pm$ 3.27

Table 2 Differences in the ulnar and palmar tilts (°) and capitate-ulna distance (mm) between >3 months after the surgery and 2–4 days after the surgery in the test and the control group illustrating loss of

correction (greater values for the ulnar and palmar tilt and more negative values for capitate-ulna distance represent more prominent loss of correction)

	Test (N=19)	Control (N=30)	Unadjusted Δ^a test-control (95% CI)	P value	Adjusted Δ^b test-control (95% CI)	P value
Ulnar tilt	3.10 (1.44–4.57)	5.70 (0.95–11.5)	–2.84 (–5.68 to –0.23)	0.041	–3.40 (–5.81 to –0.99)	0.004
Palmar tilt	2.86 (1.79–5.28)	6.75 (3.24–14.7)	–3.68 (–7.23 to –0.79)	0.004	–4.30 (–7.90 to –0.69)	0.016
Capitate-ulna distance	0 (–3.0 to 0)	–2.5 (–5.0 to 0)	1.0 (0–3.0)	0.047	1.59 (0.01–3.16)	0.043

Data are median (quartiles). Differences (Δ) are given with 95% confidence intervals (CI)^a Mann-Whitney test^b Quantile regression. Adjustments: age, sex, values (of the outcome) before surgery, values 2–4 days after the surgery

control group: adjusted odds ratio=5.43, $P=0.025$ (Table 3). Seven patients in the control group were classified as having “severe” graft resorption (vs one in the test group), and five of 30 actually underwent a re-operation due to “complete graft resorption” vs none of 19 in the test group.

Discussion

A certain level of graft resorption or even complete resorption is not uncommon after corrective osteotomy of the malunited distal radius fracture with an autologous bone graft despite careful planning and a precise surgical technique [4–6, 8]. In an attempt to improve the graft preservation we have embedded it into a flap of a vital periosteum of the recipient bone. To the best of our knowledge, such an approach has not been described before. Although graft volume is the most direct measure of graft size in a three dimensional space, we found estimation of the graft volume to be inappropriate for a comparison of this surgical method (test) and the standard procedure (control) since graft volume cannot be accurately determined for well-integrated grafts. Therefore, we relied upon straightforward measurements (ulnar and palmar tilts, capitulum-ulna distance) indicative of the graft dimensions as primary end points and approximated the extent of graft

resorption as a secondary end point. Our analysis suggests that the test procedure confers a benefit or a lesser graft resorption. Loss of correction of the ulnar and palmar tilts and capitate-ulna distance was less pronounced as evidenced by unadjusted comparisons as well as by comparisons accounting for the correction achieved by the surgery and factors potentially influencing the process (age, sex). In keeping with that, patients in the test group were more likely to be classified as having “none to mild” graft resorption, whereas one of 19 in the test and seven of 30 in the control group were classified as having “severe” resorption. The accuracy of this estimation is supported by the fact that five of 30 patients in the control and none of 19 in the test group had actually been diagnosed with “complete graft collapse” and underwent a re-operation for this reason. Prevalence of complete graft resorption after corrective osteotomy for malunited distal radial fracture has not been clearly established. For example, Flinkkilä and co-workers [13] reported three cases of complete resorption in a series of 45 corrective osteotomies. Shea and co-workers [20] described a single case of a re-operation due to a graft collapse in 25 corrective osteotomies. Fernandez [10] did not describe a single complete resorption out of 20 cases, but reported a loss of correction in two patients due to a partial graft collapse. af Ekenstam and co-workers [1] described only one complete resorption in a group of 39

Table 3 Distribution of patients in the test and control groups across the levels of estimated graft resorption (see “Patients and methods” section for classification criteria)

Estimated graft resorption	Test (N=19)	Control (N=30)	OR (95% CI) test/control for “none to mild” outcome ^a
None to mild	11	8	5.43 (1.32–26.5), $P=0.025$
Moderate	7	15	
Severe to complete	1	7	

^a Cumulative logit model was fitted with adjustment for age, sex, ulnar and palmar tilt and capitate-ulna distance values before surgery and 2–4 days after the surgery. Difference between groups regarding the frequency of “none to mild” outcome is expressed as adjusted odds ratio (OR) with 95% confidence intervals (CI).

patients and suggested that it might have been due to the use of a cancellous graft. However, Ring and co-workers [18] compared patients with unstructured cancellous grafts and those with corticospongyous grafts and found no difference in radiological signs of the graft resorption. Hence, in this respect, our observations do not seem relevantly different from reports in the literature.

Our analysis is limited by a relatively small sample and limitations inherent to its retrospective nature, in particular susceptibility to selection bias (no randomisation) and assessment bias. We attempted to reduce selection bias by including consecutive patients meeting predefined criteria, which in our view were not bias generating per se. The six patients not included (two treated by the test and four by the control procedure with no follow-up data) have not been diagnosed with a graft collapse requiring re-operation at our institution (the largest referral institution for hand surgery in the country) up to the time of preparation of this manuscript. Therefore, it seems unlikely that the current observations were relevantly biased by their non-inclusion. We attempted to reduce assessment bias by having blinded radiological assessment and statistical analysis. In this respect, we believe that our estimates may be considered fairly valid. Clearly, however, the value of the test procedure in respect to graft preservation should be conclusively assessed in a prospective randomised trial.

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