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CASE REPORTS

A Qualitative Evaluation of Scaphoid Remodeling in Bone-Grafted Scaphoid Nonunions

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Abstract The purpose of this case series is to identify and illustrate the phenomenon of scaphoid remodeling in skeletally mature subjects following bone grafting for scaphoid nonunion. Nine patients with scaphoid nonunions were treated with interpositional bone grafting (with iliac crest bone graft) and K-wire fixation. The mean length of follow-up was 28.6±9 months. Radiographs and CT scans were reviewed and assessed for degree of union and a qualitative assessment of scaphoid architecture. Following surgery, there was marked distortion of the scaphoid. Once healed, the contour of the scaphoid was still significantly distorted in all nine patients. Remodeling then became evident along the articular surfaces between 8 and 12 months. By 3 years, the scaphoid was completely recontoured and the normal architecture was completely restored in all nine patients. We conclude that the articular surface of the scaphoid remodels over time in skeletally mature subjects.

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Introduction

The phenomenon of bone remodeling in the immature skeleton and in long bone fracture healing is well documented [4], however, remodeling of the scaphoid has not previously been described. We present an illustrative case series focusing on a qualitative assessment of the phenomenon of scaphoid remodeling in skeletally mature subjects following bone grafting for scaphoid nonunion.

Materials and Methods

Nine patients (eight males, one female) with scaphoid nonunions were treated with the Fisk-Fernandez [1] method of interpositional bone grafting (with iliac crest bone graft) and K-wire fixation (two parallel wires). The mean age of patients in this series was 22.7±10 years (range 15–46) and all patients were skeletally mature.

All patients were followed with sequential radiographs to determine union. Once union was determined to be at least 50%, the K-wires were removed and patients were followed for an additional 1–3 years to confirm full union. The mean length of follow-up was 28.6±9 months, one patient was followed for 12 months, one for 18 months, two for 2 years, and five patients were followed for 3 years. Each radiograph and CT scan was reviewed by the senior author and assessed for degree of union and a qualitative assessment of scaphoid architecture following interposition bone grafting was made.

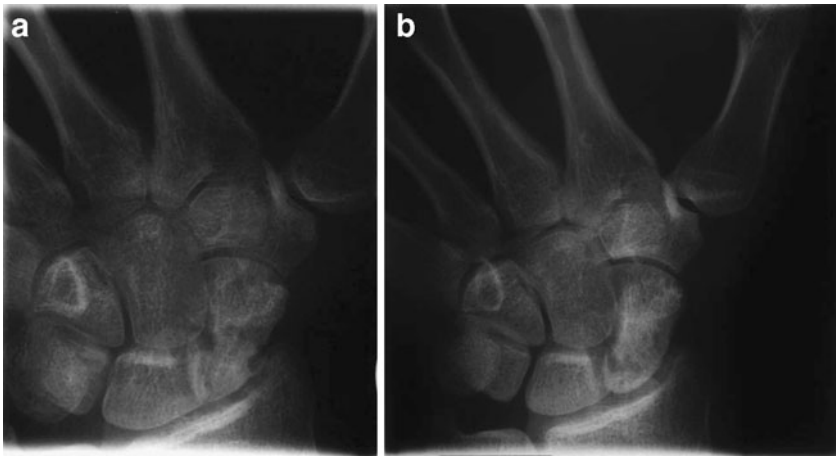

Figure 1 **a** Radiograph demonstrating healing of iliac crest bone graft for the treatment of scaphoid nonunion in an 18-year-old male. Although there is evidence of union, there is *marked distortion* of the scaphoid architecture. **b** Radiograph taken at 2 years and 9 months following surgery demonstrating remodeling of the scaphoid, with restoration of normal architecture, along the articular surface.

Results

Following surgery, there was nontrivial distortion of the scaphoid. The cortico-cancellous graft harvested from the iliac crest was interposed between the proximal and distal poles with an obvious step deformity along the articular surface. Following healing of the bone graft (as confirmed by CT scan) the contour of the scaphoid was still quite distorted in all nine patients (Fig. 1a).

Postoperative imaging was performed to comply with clinical requirements and scheduling; thus the frequency and time points were not consistent between patients. This prevented a precise estimation of when remodeling first occurred. However, since all cases were followed with serial X-rays, we were able to identify evidence of scaphoid remodeling and report that in this series, it first became evident along the articular surfaces, between 8 and 12 months. The process of remodeling was very gradual and by 3 years, the scaphoid was completely recontoured and the normal architecture was completely restored in all nine patients (Fig. 1b). No age related differences in remodeling were observed. Figure 2a, 2ab, and 2ac demonstrates CT evidence of remodeling in a 23-year-old male, and Fig. 3a, b, c, d, and e demonstrates both X-ray and CT evidence of remodeling in a 46-year-old male. It was also consistently noted that the nonarticular portion of the scaphoid did not remodel to the extent of the articular surface.

Range of motion and grip strength was tested at final follow-up and was expressed as a percentage of the normal contralateral wrist. Mean wrist flexion was 95.0% of the contralateral wrist, extension 88.1%, supination 98.6%, and pronation 97.9%. Mean final grip strength was 94.8% of the contralateral hand. The patient rated wrist evaluation (PRWE) was used to quantify pain and disability [2]. The median PRWE score was 16.5 indicating that overall, patients experienced little pain and functional disability.

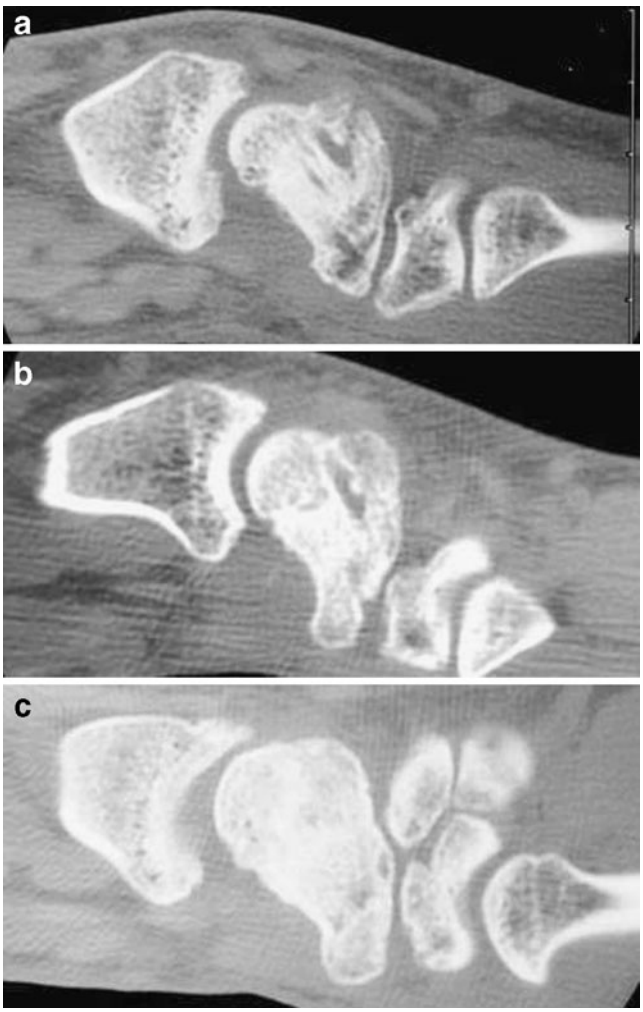

Figure 2 Twenty-three-year-old male. Serial CT scans demonstrating progressive remodeling of scaphoid at sequential time points following surgery. **a** 6 months. **b** 8 months. **c** 33 months.

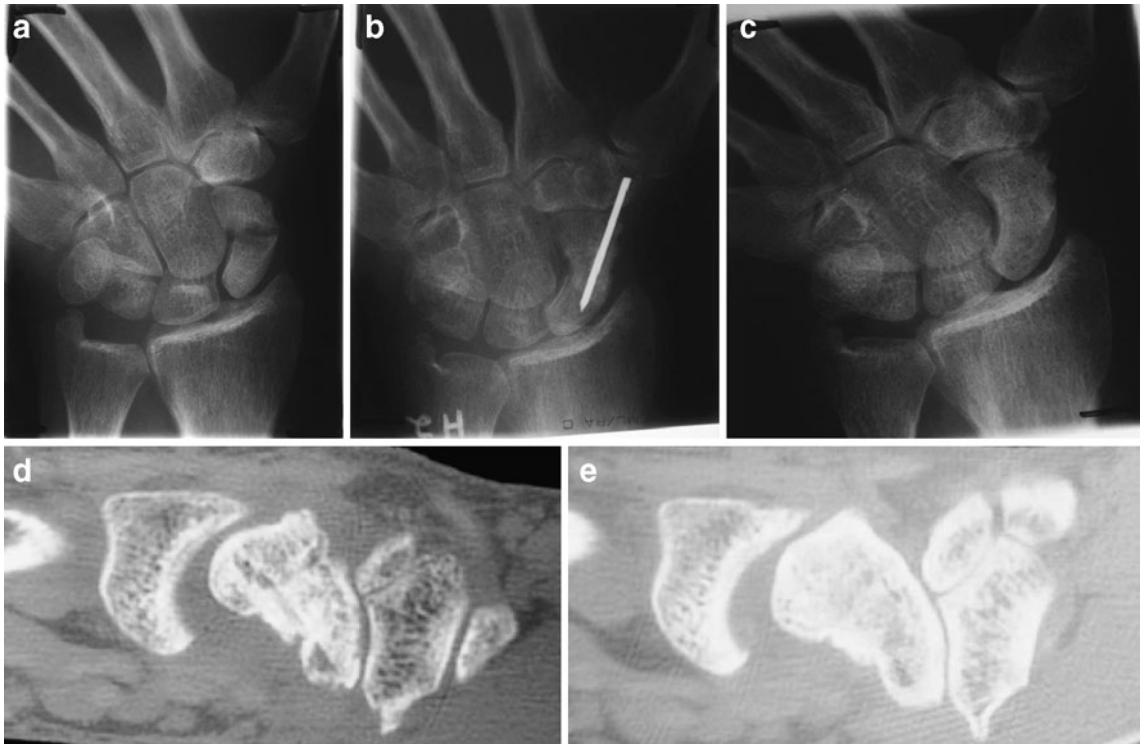

Figure 3 Forty-six year old male. **a** Preoperative radiographs demonstrating nonunion of scaphoid waist. **b** Evidence of union of iliac crest bone graft at 3 months post-operative. Contour of scaphoid showing obvious distortion with *marked narrowing* of scaphoid waist at level of graft. **c** Radiographs taken 58 months (4 years 10 months) post surgery demonstrating restoration of normal scaphoid architecture. **d** CT evidence of maturation of bone graft between 5 months and 57 months. **e** Note that the nonarticular portion has not remodeled.

Discussion

Remodeling is the last phase of bone healing and is an essential step in the restoration of normal bony architecture. This phenomenon is well established in pediatric and long bone fractures; however it has not been previously reported in the healing of scaphoid nonunions [4].

The scaphoid is anatomically unique. It is a bone with a predominantly articular surface with only few potential sites for the entrance of its vascular supply [3]. Due to its retrograde blood supply, bone healing can be challenging particularly when dealing with established scaphoid nonunions.

The contouring of an iliac crest bone graft to fit anatomically with the scaphoid defect and articular surface can be difficult. The graft must be contoured to correct the underlying humpback deformity, restore length, and ensure articular congruity at the radioscaphoid and scaphocapitate joints. Our cases illustrated this difficulty in that substantial incongruency and step were observed in the initial postoperative radiographs (Fig. 1).

Serial radiographs or CT scans used to follow these cases first showed signs of progressive union with union typically progressing from partial to full over the course of several weeks. Following full union or incorporation of the bone graft, the structural integrity of the scaphoid as a carpal strut was restored, however, was still far from its normal appearance.

Observations of articular incongruity can raise concerns about the development of degenerative changes at the radioscaphoid joint, a primary reason for the initial surgery. This concern is amplified by the fact that scaphoid fractures commonly occur in young patients and thus early dramatic arthritis would have profound functional implications. These nine cases demonstrate that with time, the scaphoid can remodel along these articular surfaces and the normal architecture can be restored. It was also consistently noted that the nonarticular portion of the scaphoid did not remodel to the extent of the articular surface. Evidence of remodeling in these nine cases suggests that patients should be informed of the possibility of remodeling and that future studies should focus on whether the presence of remodeling relates to clinical outcomes and a reduced incidence of subsequent post traumatic arthritis. The process can take a long time, up to 3 years as illustrated in this case series.

We recommend following patients yearly with X-ray until there is evidence of restoration of the normal architecture of the healed scaphoid. Articular irregularities may improve, as seen with these cases, especially if no degenerative changes are present preoperatively.

There are some limitations of this report. Three of our patients were 15 years old, although they were skeletally mature and their growth plates were closed, their young age may have contributed to the remodeling potential of the scaphoid. Although we did not see any age-related differences in this series, our sample size may not be large enough to identify such possible trends and this phenomenon may not be equally evident in all age groups. In addition, all nonunions were treated with K-wire fixation. These wires may allow some settling between the scaphoid and bone graft, potentially contributing to the ability of the construct to remodel.

Long-term remodeling of the scaphoid has not been examined in detail previously in the literature. Our observations in this study clearly demonstrate remodeling for over 3 years following surgery for ununited mid-waist scaphoid fractures. The initial nontrivial distortion in scaphoid architecture was consistently improved with the passage of time, to the point where intra-articular portions of the scaphoid achieved near-normal architecture and smooth contours. The difference between intra-articular and extra-articular regions was consistent and impressive.

We conclude that the scaphoid remodels with time and those patients must be followed to complete union, often several years, in order to determine their final outcomes following bone grafting for the treatment of scaphoid nonunion. Our findings also suggest that the presence of a gap (versus a step) on an articular surface of a carpal bone does not necessarily mean the joint is destined to undergo degenerative change. Whether there is a clinical correlation between patient symptoms, strength, or satisfaction and the phenomenon of remodeling is yet to be determined, as are the risk of refracture and the later development of arthritis.

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