Percutaneous screw fixation without bone grafting for established scaphoid nonunion with substantial bone loss

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Ununited fractures of the scaphoid with extensive bone resorption are usually treated by bone grafting and internal fixation, using either an open or a minimally invasive technique. We studied the feasibility of percutaneous fixation without bone grafting in a consecutive series of 27 patients with established nonunion of an undisplaced fracture of the scaphoid and extensive local resorption of bone. They were treated by a single surgeon with rigid fixation alone, using a headless cannulated screw inserted through a volar percutaneous technique. Clinical examination, standard radiographs and CT confirmed that the fracture had united in all patients at a mean of 11.6 weeks (8 to 16), and that their functional scores had improved.

We concluded that extensive resorption at the fracture site is not an absolute indication for bone grafting, and that percutaneous fixation alone will eventually produce healing of ununited undisplaced fractures of the scaphoid regardless of the size of the gap.

The reported failure rate for treatment of nonunion of the fractured scaphoid is between 25% and 45%.1,2 These fractures are difficult to treat because of their unique anatomy and vascular supply, along with the high stresses to which they are subjected.3-5 In a systematic review of 147 publications that included 5246 cases of nonunion of the scaphoid, Munk and Larsen6 reported a rate of nonunion of 20% in patients treated by bone grafting without internal fixation and 16% with the addition of internal fixation.

Slade and Dodds7 classified nonunion of the scaphoid into six grades and stated that fixation alone is sufficient in those fractures where there is delayed presentation, fibrous nonunion and minimal sclerosis (grades I, II and III). They also noted that if the ununited proximal fragment is well perfused but there is substantial bone loss (2 mm to 10 mm) without significant flexion deformity (grades IV and V), bone grafting is essential to achieve union. For such nonunions, percutaneous and minimally invasive bone grafting techniques have proved successful.7-10 Nonunions with more advanced resorption (grade VI) require open debridement and bicortical structural bone grafting to fill the gap and to correct the humpback deformity.7,11 Slade and Dodds7 further subdivided nonunion of the scaphoid according to associated characteristics, namely proximal pole, avascular necrosis, ligamentous injury and scaphoid deformity.

In cases with no humpback deformity the fracture fragments are connected by fibrous tissue or an intact cartilaginous cap sufficient to prevent deformity and dilution of growth factors. Our hypothesis was that mechanical stabilisation without bone grafting would be enough to reduce the strain across the nonunion and allow bony healing. Previous recommendations that bone grafting was necessary for this type of nonunion have not hitherto been challenged.6,7 The purpose of this study was to evaluate the healing of ununited undisplaced fractures of the scaphoid more than six months old, with extensive bone loss of ≥ 2 mm but no humpback deformity (grade IV and V), which were fixed percutaneously by headless cannulated screws without bone grafting.

Patients and Methods

We reviewed 27 consecutive patients treated by the senior author (MM) between 2004 and 2007. Their data were collected prospectively and the study was approved by the institutional review board. There were 26 men and one woman, with a mean age of 28.3 years (20 to 40) and a mean time between injury and operation of 18.2 months (6 to 36). The dominant hand was affected in 15 patients and the non-dominant in 12. The injuries were caused by a fall onto the outstretched hand in 16 patients, a motorcycle accident in seven and...
during sport in four. Six of the fractures were initially mis-diagnosed, and 21 patients were treated in a short arm thumb spica for a mean of 5.9 weeks (4 to 9). None was a smoker, and 25 reported occasional use of non-steroidal anti-inflammatory drugs when pain was severe.

The patients presented with a painful wrist that was worse on exertion, extension and radial deviation, and with tenderness in the anatomical snuffbox. Grip strength and range of movement were evaluated by an independent hand therapist and pain was measured by a visual analogue scale (VAS) ranging from 0 (no pain) to 10 (maximum pain). Further evaluation used the Mayo modified wrist score, which is based on four categories: pain, functional status, movement and grip strength. The score is given in a range from 0 to 100; where 0 to 60 is poor, 60 to 80 fair, 80 to 90 good and 90 to 100 is excellent. All the patients had plain radiographs and CT scans, and none had undergone previous wrist surgery.

The inclusion criteria were a nonunion of a fracture of the wrist of the scaphoid of at least six months’ duration, with bone resorption of ≥ 2 mm (mean 4.48 mm (2 to 7)) and the absence of humpback deformity, excessive sclerosis or arthritis. Humpback deformity was excluded as it is a sign of erosion of the anterior cortex which requires bone grafting for correction. The extent of bone resorption was measured as an average of readings by two separate radiologists from 1 mm cuts on the CT scans. The humpback deformity was evaluated indirectly by measuring the scapho- and radiolunate angles to rule out dorsal malalignment of the lunate, and directly by the sagittal CT cuts. The viability of the proximal fragment was not assessed. However, no patient showed any hyperdensity of the proximal fragment on routine radiographs. Of the 27 nonunions, 13 were grade IV (gap < 5 mm) and 14 were grade V (gap ≥ 5 mm). There were no fractures of the proximal pole, and none with avascular necrosis or an associated ligamentous injury.

Percutaneous retrograde screw fixation was performed under C-arm control through a volar approach under general or brachial plexus anaesthesia. A self-tapping 3 mm standard cannulated screw was inserted freehand over a guide wire. The screw was inserted through the scapho-trapezial joint by pulling on the thumb dorsally and to the ulnar side, thereby exposing the most volar and radial part of the joint. There was no need to perform an osteotomy of the radial edge of the trapezium to insert the screw, but as we inserted the guide wire in close contact with the radial edge of the trapezium, part of this edge was inevitably reamed. The leading part of the screw was anchored in the centre of the proximal pole with its threads completely across the nonunion. The final axis of the screw was parallel to the volar surface of the scaphoid when viewed in a supination/oblique radiograph. The head was buried under the distal articular surface when viewed in a pronation/oblique radiograph. Good purchase was assured during the last turns of the screw threads. There was no need to insert a second guide wire to prevent torsional stresses, nor to block the midcarpal joint using a scaphocapitate wire.

A short arm cast excluding the thumb was worn for six weeks, followed by a removable splint for four weeks. Patients were allowed to exercise the wrist after removal of the cast, but instructed to avoid contact sports or full loading until union was achieved.

Radiographs were taken at four weeks post-operatively and repeated every two weeks until union was established. This was verified by the presence of bone trabeculae crossing the fracture site in five scaphoid views, and confirmed immediately thereafter by multislice CT (Fig. 1).

Statistical analysis. The data were described statistically in terms of range, mean, SD, and median whenever appropriate. The time to union between the different subsets of the study group was compared using the Mann-Whitney U test for independent samples. Correlation between variables was by using Pearson’s moment correlation equation for linear relationship. A p-value < 0.05 was considered statistically significant. All statistical calculations were done using Microsoft Excel 2003 (Microsoft Corporation, New York, New York) and Statistical Package for the Social Sciences version 15 for Windows (SPSS Inc., Chicago, Illinois).

Results
No patients were lost to follow-up, which was for a mean of 24.6 months (12 to 39). At the final follow-up, clinical examination, radiological grading and assessment of union was conducted by an independent hand therapist. There was less pain, either in the snuffbox or with wrist movement, and the VAS improved from a mean of 4.1 (3 to 6) to a mean of 1.07 (0 to 2). The mean pre-operative range of movement was 40.9° (30° to 60°), 50.6° (35° to 70°), 5.6° (0° to 15°) and 15.3° (10° to 25°) for extension, flexion, radial deviation and ulnar deviation, respectively. The post-operative range of movement improved to means of 60.7° (45° to 80°), 65.7° (55° to 80°), 10.7° (5° to 20°) and 26° (20° to 35°) for extension, flexion, radial deviation and ulnar deviation, respectively.

Pre-operatively, the Mayo modified wrist score was poor in 15 patients (55.6%), fair in 11 (40.7%) and good in one (3.7%). This improved to 25 excellent (92.6%) and two good (7.4%) results at one year. Radiologically, all fractures healed with a mean time to union of 11.6 weeks (8 to 16; Figs 1 and 2). Functional scores were not statistically analysed.

The correlation between the mean time to union and between injury and operation showed a shorter mean time to union in six cases presenting less than one year after injury (nine weeks (8 to 10)), compared with 21 cases presenting after one year (12.38 weeks (10 to 16)). This difference was statistically significant (p = 0.001; Fig. 3).

The correlation between the mean time to union and gap size was also tested and showed that there was no statistically significant difference between the 13 cases with a gap < 5 mm (12.5 weeks (8 to 16)) and 14 with a gap ≥ 5 mm (10.86 weeks (8 to 14)) (p = 0.097). This could be
explained by the longer time after fracture in the first group (19.38 months (6 to 36)) compared with the second (16.43 months (6 to 30)), but this did not reach statistical significance (p = 0.235).

**Discussion**

Fibrous union of scaphoid fractures occurs because the healing process is arrested in its early stages due to micro-movement and lack of mechanical stabilisation. Barton studied a group of such fibrous unions that had initially appeared to be solidly healed. However, there had been insufficient remodelling to resist bending and torque, and half of these fractures subsequently developed nonunion.

Nonunions with minimal sclerosis are similar to fibrous unions and require only compression and rigid fixation for healing. Healing can still proceed in a stable fracture with a gap < 1 mm, and Cosio and Camp stabilised such nonunions with multiple Kirschner wires, achieving solid union in 77% of their cases without open repair or bone grafting.

During open grafting in 50 cases of symptomatic non-union, Shah and Jones encountered eight cases of fibrous union and elected to stabilise them with a compression screw. These eventually healed without bone grafting. Other authors have suggested that selected nonunions may heal with rigid fixation alone, and Kim, Kim and Lee recorded union with slight resorption at the fracture site in 12 patients with delayed union of the waist of the scaphoid treated by percutaneous screw fixation.

Slade et al advocated the dorsal approach for treating scaphoid fractures. They also used an arthroscopically assisted dorsal approach to stabilise nonunions without extensive sclerosis or bone resorption. Union was achieved in all cases, but they excluded those with cysts and sclerosis > 1 mm, where there might not have been sufficient purchase for the screw thread in the proximal fragment. However, the dorsal approach has the disadvantages of damage to the articular cartilage of the proximal pole of the scaphoid and potential injury to the extensor tendons. Moreover, in order to insert the screw proximally, the wrist has to be fully flexed,
causing the distal fragment to adopt a flexed position, thereby producing the humpback deformity leading to malunion.\textsuperscript{22}

Despite its technical difficulty, many authors found the volar limited access or percutaneous approach more practical and with several advantages\textsuperscript{23-25} It was easier to identify the bony landmarks and interpret the fluoroscopic images, and the position of the wrist helped to maintain the reduction during the operation. This approach can be used for proximal pole nonunions provided there is adequate bone stock in the proximal fragment for sufficient purchase by the leading threads of the screw.\textsuperscript{17,23,26} Recent cadaveric studies using computer-assisted navigation for accurate placement of guide-wires succeeded in reducing radiation exposure and the number of trials for accurate placement, and concluded that its clinical application could offer significant benefits.\textsuperscript{24,25,27}

We believe that valuable and reliable information regarding the size of the gap can be gained from plain radiographs. However, CT is needed pre-operatively for its accurate assessment, exclusion of pseudarthroses with sclerosed edges, and to assess carpal alignment. We routinely performed CT post-operatively to confirm union, as recommended by many authors.\textsuperscript{28,29}

Anteroposterior radiographs of a 28-year-old male patient with a 16-month history weakness and pain after a fall, a) pre-operatively, b) at six weeks post-operatively and c) at 12 weeks post-operatively with complete union.
There are no clearly reported data on the extent of bone resorption at the nonunion site and its effect on the need for bone grafting. This study showed that, regardless of the size of the gap, undisplaced fractures can heal without bone grafting provided that mechanical stabilisation is obtained and carpal alignment maintained. The delay between injury and fixation was the determining factor in time to union, rather than the size of the gap. The gap in patients with a duration since fracture of one year or more was smaller than in those with a duration of less than one year. This may be because patients with extensive resorption presented to earlier than those with less resorption, possibly due to symptomatic variance. However, the small number of patients who presented less than one year after the injury prevented us from pursuing this correlation further.

The high rate of union in this study is believed to be the result of careful selection of patients. The limitations of the study are the relatively small number of patients, and the fact that this technique cannot be applied to many other patients with scaphoid nonunion. Also, we did not perform MRI to identify cases with avascular necrosis, which might have had an effect on the pathogenesis of nonunion and how to treat it. However, proximal pole fractures, which have a higher incidence of AVN, were excluded.

We recommend this method of treatment for patients who are middle-aged, non-smokers without previous wrist surgery, who have a nonunion of a fracture of the waist of the scaphoid with no deformity and without avascular necrosis or ligamentous injury, and who have had a CT scan to exclude excessive sclerosis and confirm adequate bone for proximal and distal purchase of the threads of the screw. We also recommend post-operative immobilisation for six weeks and restriction of activities until union.

Selected ununited undisplaced fractures of the scaphoid, even those with a gap ≥ 2 mm, have the biological ability but not the mechanical stability for bone healing. If this is provided by percutaneous rigid fixation, these fractures will unite without requiring a bone graft.

References


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