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Fixation of proximal pole scaphoid nonunion with non-vascularized cancellous autograft

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Abstract

We present 20 patients with established proximal pole scaphoid nonunions treated with curettage and cancellous autograft from the distal radius and screw fixation. Fractures with significant proximal pole fragmentation were excluded. Patients were treated at a mean of 26 weeks after injury (range 12–72). Union occurred in 18 of 20 patients (90%) based on computed tomographic imaging. The two nonunions that did not heal were treated with repeat curettage and debridement and iliac crest bone grafting without revision of fixation. Union was achieved in both at a mean of 11 weeks after the revision procedures. Our findings suggest that non-vascularized cancellous autograft and antegrade fixation is a useful option for the treatment of proximal pole scaphoid nonunions.

Level of evidence: IV

Keywords

Proximal pole, scaphoid fracture, computed tomography, delayed healing, scaphoid nonunion

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Introduction

The poor healing that is associated with proximal pole scaphoid fractures is likely to be multifactorial. The proximal pole is poorly vascularized, with the majority of its perfusion supplied by the dorsal ridge vasculature by retrograde flow (Grewal et al., 2016; Steinmann and Adams, 2006). This can lead to partial ischaemia or complete avascularity of the proximal pole (Peng et al., 2016; Trumble and Nyland, 2001). The proximal fragment also tends to be very small, which makes internal fixation difficult. Roughly one-third of acute proximal pole fractures will go on to nonunion when treated non-operatively (Gholson et al., 2011; Margo and Seely, 1963; Steinmann and Adams, 2006). Because of this, cast immobilization alone has been considered inadequate for the treatment of displaced proximal pole scaphoid fractures and, in most cases, surgical intervention is the preferred treatment (Eastley et al., 2013; Eddeland et al., 1975; Krimmer, 2002; Puopolo and Rettig, 2003; Raskin et al., 2001; Russe, 1960; Steinmann and Adams, 2006). A delay in treatment is an independent risk factor for nonunion (Gholson et al., 2011; Grewal et al., 2016; Margo and Seely, 1963; Steinmann and Adams, 2006).

There are several options for treatment when a proximal pole scaphoid nonunion is established. Owing to the difficulty of achieving union, several vascularized bone grafts have been described (Burger et al., 2013; Kirkeby and Baek Hansen, 2006; Larson et al., 2006; Lim et al., 2013; Tambe et al., 2006; Zaidemberg et al., 1991). These are more technically demanding than traditional methods. Although earlier reports suggested that proximal pole nonunions were not amenable to treatment by cancellous bone grafting (Kawamura and Chung,

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2008), this may no longer be the case with modern fixation techniques.

We report a series of proximal pole scaphoid nonunions that were treated with simple curettage and local bone graft obtained from the dorsum of the adjacent distal radius. The fractures were stabilized with small antegrade screws in most cases. We hypothesized that union could be achieved without the morbidity of vascularized bone grafting.

Methods

After Institutional Review Board approval, a retrospective review of skeletally mature patients who underwent surgery for a proximal pole (proximal one-third) scaphoid nonunion was carried out. Those treated within 12 weeks of injury were excluded. This cut-off was chosen because previous reports have suggested that at 12 weeks the fracture is typically chronic and requires bone grafting (Langhoff and Andersen, 1988). Those with a fragmented proximal pole with trabecular and structural collapse were also excluded (Büchler and Nagy, 1995). Therefore, all patients had relatively normal morphology of the proximal cortical shell as determined by computed tomography (CT), which was obtained pre-operatively in every case. Between December 2008 and January 2016, 21 consecutive patients were identified. One patient was lost to follow-up shortly after surgery, leaving a final cohort of 20 patients.

Patient demographics were recorded including age, sex, use of tobacco and any co-morbidities. The time since the injury and the mechanism of injury were recorded. The mechanism was further stratified as high or low energy. Low energy injuries included any mechanism in which the patient fell from a standing height; low speed sports injuries (i.e. less than 8 km per hour), or any impact with a speed of less than 8 km per hour (Brogan et al., 2015). Treatments before surgery, including immobilization and bone stimulator use, were specified. Radiographs of the wrist included standard posteroanterior, oblique, lateral and scaphoid views. All patients had pre-operative CT scans, with reformatted fine sagittal and coronal cuts in the axis of the scaphoid. Measurements of fracture location and displacement were determined on these images. Displacement was measured at the point of greatest separation of the fragments as seen on a CT slice. Four patients had had magnetic resonance imaging (MRI) of the wrist, which was ordered by the referring physician in each instance. We did not order MRIs on any patients and did not take the imaging evidence of vascularity of the proximal pole into account when deciding on the type of surgical procedure. Based on our algorithm, the requirements for non-vascularized bone grafting and internal fixation were near normal morphology of the cortical shell of the proximal fragment, without a trophic appearance or extensive fragmentation. Once these structural changes have occurred, these nonunions have been shown to have very poor healing potential and may best be treated with salvage type reconstruction options (Büchler and Nagy, 1995).

A dorsal approach to the scaphoid was used. The extensor pollicis longus tendon was freed and retracted radially, and a dorsal capsulotomy was made. The fracture site was inspected and the proximal pole assessed for stability. If the proximal pole was 'loose', the nonunion site was gently keyed open and any fibrous tissue or sclerotic bone was removed proximally and distally, using a combination of Beaver blades, small curettes and a 2.3 mm burr. In cases where the proximal pole was not loose, the burr was used to open up a cavity at and distal to the fracture site along the dorsal radial aspect of the scaphoid (Figure 1), with retrograde debridement across the fracture gap. Intraoperative water soluble, radio-opaque dye (Isovue 300, Bracco Diagnostics,

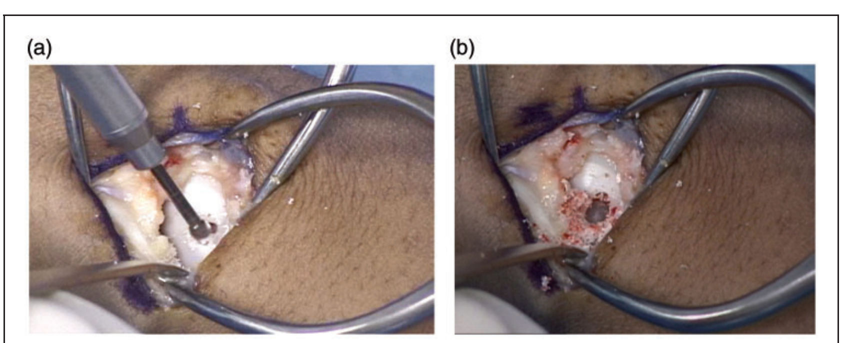

Figure 1. In cases where the proximal pole is not loose, an acorn burr is used to open up a hole at and distal to the fracture site along the dorsal and radial aspect of the scaphoid.

Monroe Township, NJ, USA) was used under fluoroscopy to define the cavity created within the bone and to document adequate debridement across the entire fracture gap (Figure 2). This was placed into the nonunion cavity using a small syringe and a 26-gauge catheter. Pure cancellous autograft bone was then harvested from the distal radius through a dorsal window just proximal to Lister's tubercle. Iliac crest bone graft was used in one revision procedure because a bone graft had been harvested from the distal radius by the previous surgeon. The autograft was compressed in a syringe and then packed into the cavity within the bone with a small tamp (Figure 3). Antegrade fixation was carried out once the grafting was completed. In 15 out of 20 cases, a small cannulated, headless screw was used (Acumed, Hillsboro, OR, USA), attempting to place the screw perpendicular to the fracture line. In two cases with smaller proximal poles, 1.5 mm locking screws were (DePuy-Synthes, West Chester, PA, USA), taking care to countersink the proximal threads on the screws (Figure 4). In three of the cases, the scaphoid

Figure 2. (a) and (b) Posteroanterior and lateral radiographs of the hand show a proximal pole scaphoid fracture with some gapping of the fracture site. (c) Pre-operative CT scan confirms nonunion of the fracture with some evidence of bone resorption and gapping of the nonunion site. (d) After operative fixation, a scaphoid view radiograph shows no bony union. (e) CT scan at 12 weeks after operation shows no evidence of bony bridging across the previous nonunion site and a revision procedure was required. This patient was a professional boxer whose initial mechanism of injury was deemed high-energy in nature. (f) and (g) Intraoperative water soluble, radio-opaque dye is used with fluoroscopy to document adequate debridement across the entire nonunion site. Note the retained fixation in this revision case. (h) and (i) Post-operative scaphoid and lateral radiographs of the wrist show evidence of union and retained fixation. (j) Repeat CT scan at 12 weeks after the revision procedure shows complete union and bony bridging across the previous nonunion site.

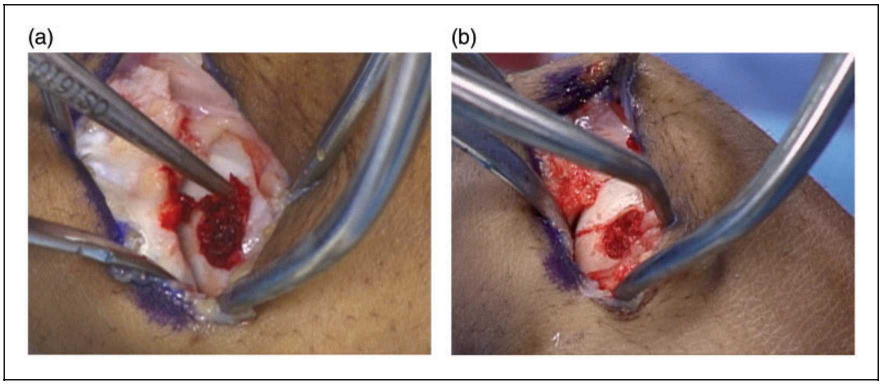

Figure 3. The autograft is compressed in a syringe and then is packed within the scaphoid through the newly created trough. These images are from two separate cases.

Figure 4. (a) Pre-operative CT scan shows an extreme proximal pole scaphoid fracture that was deemed to be not amenable to standard cannulated screw fixation. (b) and (c) Post-operative posteroanterior and lateral radiographs of the wrist show the use of two parallel 1.5 mm locking screws to achieve stable fixation. There is evidence of union on these follow-up images. The proximal threads are countersunk into the cortex to prevent screw prominence. (d) Post-operative CT scan 12 weeks after surgery shows the fixation construct and confirms union.

fracture fragment was deemed too small for the introduction of a screw and Kirschner wires were used.

Wrists were splinted post-operatively and placed in a short arm cast at the first post-operative visit. Immobilization was continued until complete healing was confirmed. Healing was monitored by serial radiographs at 4-week intervals. Patients underwent a CT scan to assess union when healing was suggested on plain radiographs, most commonly between 10 to 12 weeks after surgery. These studies were interpreted by an independent musculoskeletal radiologist. Union was defined as greater than 50% bridging bone across the fracture site (Singh et al., 2004).

Results

The mean age was 21 years (range 14–34). All were male. One patient had a history of asthma and one patient used chewing tobacco several times a week. He was asked to cease this before the index procedure. Otherwise, all were young and healthy with no co-morbidities. All complained of pain with activities and loading of the affected wrist. Patients were treated at a mean of 26 weeks after injury (range 12–72). The mechanism injury was low energy in 19 of 20 cases, with one in a professional boxer considered to be a high-energy injury. There were no associated ligamentous injuries identified. Pre-operative immobilization was used in 15 of 20 patients. The mean size of the proximal pole fragment was 23% (range 14%–31%) of the length of the scaphoid as determined by CT. Seventeen of 20 fractures were considered to be displaced, with a mean fracture gap of 1.5 mm (range 1.1–2.1). The remaining three fractures were non-displaced cracks with less than 1 mm of displacement. All showed an established nonunion with a complete lack of bony trabeculae across the fracture site.

Two patients had been previously treated surgically and were referred because of persistent nonunion. Both had undergone antegrade screw fixation elsewhere. In these cases, the previous fixation was removed at the time of revisional surgery, the screw track was debrided and new fixation was placed after curettage and autograft placement. In the first case, failure was deemed to have been cause by poor technique at the index procedure, with no autograft having been used. For the revision procedure, a larger screw size was used in the same trajectory with a bone graft from the distal radius. In the second case, there was insufficient purchase for a larger screw diameter and Kirschner wires were used instead, with an iliac crest bone graft.

The wrists were immobilized until healing was confirmed on advanced imaging. All patients were prescribed bone stimulators post-operatively. At a median of 11 weeks post-operatively (range 8–321), all patients underwent a follow-up CT scan to assess healing. Union was achieved in 18 or 20 patients (90%). The mean healing time was 11.5 weeks (range 8–16) after operation.

Of the two failures, one was the patient who used tobacco. The second case occurred in a professional boxer whose injury was initially categorized as high-energy (Figure 2). Neither had been treated surgically before the index procedure and both had been treated with antegrade headless screw fixation. Both were treated with repeat curettage and debridement at 17 and 21 weeks, respectively, after the index procedure. The screws were found not to be loose at the time of revision surgery. Both underwent debridement of the nonunion around the existing screw (Figure 2), followed by placement of compressed cancellous bone obtained from the anterior iliac crest. Careful debridement of the nonunion site back to healthy appearing trabecular bone was done with a combination of rongeurs, curettes, a Beaver blade and a 2.4 mm burr. The overlying articular cartilage was preserved as much as possible. The tourniquet was not deflated to assess bone bleeding. The screw was visible within the nonunion site and if the burr was used, care was taken to direct the tip away from the screw threads. Both of these nonunions went on to heal, with union documented at 10 and 11 weeks, respectively, after the revision procedures (Figure 2).

Discussion

This series demonstrates a 90% union rate for the treatment of proximal pole scaphoid nonunion with the use of non-vascularized bone graft. Initial failures occurred in patients with known risk factors. Our findings suggest that non-vascularized cancellous autograft and antegrade fixation should be considered for the treatment of proximal pole scaphoid nonunion.

Proximal pole scaphoid fractures are uncommon injuries and historically union can be difficult to achieve (Inoue et al., 1997; Krimmer, 2002). Smaller fractures have a worse prognosis and the initial magnitude of displacement may be proportional to the risk of nonunion, although this is debated (Brogan et al., 2015; Grewal et al., 2016; Trumble et al., 2000). Other risk factors associated with nonunion include smoking, a high energy mechanism of injury and a patient of older age (Steinmann and Adams, 2006; Trumble et al., 2000). In a meta-analysis, Eastley et al. (2013) reported a cumulative nonunion rate of 34% for proximal pole fractures treated conservatively. They also found the relative risk of nonunion for proximal poles to be 7.5 greater compared with more distal fractures managed non-operatively. This explains the current trend towards surgical fixation of proximal pole scaphoid fractures (Eastley et al., 2013; Krimmer, 2002).

Treatment options vary for an established proximal pole nonunion. Over the past 25 years, a variety of vascularized techniques have emerged, including interposition of blood vessels alone, vascularized pedicle bone grafts and free vascularized grafts (Burger et al., 2013; Kirkeby and Baek Hansen, 2006; Larson et al., 2006; Lim et al., 2013; Tambe et al., 2006; Zaidemberg et al., 1991). Each of these procedures is technically difficult and has the potential for added morbidity. Although vascular insufficiency may be a factor, it does not appear to be the only reason why these fractures are at risk of nonunion. Several studies have failed to show any correlation between vascularity, as defined on gadolinium enhanced MRI, and union (Dawson et al., 2001; Günal et al., 1999).

Alternatively, Slade et al. (2002) have described a technique involving internal fixation without the use of bone graft with good results in a small case series. Their study contained a mixed cohort with a small number of proximal pole nonunions. They noted, in particular, that treatment of scaphoid nonunion without bone grafting should be used only in carefully selected cases. To our knowledge, their results have not been replicated in a larger case series of proximal pole nonunions.

At our institution, we have treated proximal pole scaphoid nonunions without fragmentation using techniques similar to those used for more distal patterns for many years. The theory is that with thorough curettage across the fracture site, pure cancellous grafting and stable fixation, these fractures do have the propensity to heal. In our series, we had a 90% union rate with pure cancellous bone grafting and internal fixation, and in no case did we specifically assess the vascularity of the proximal pole by the use of enhanced MRI or by looking for punctuate bleeding during operation. Even the two persistent nonunions healed with additional non-vascularized bone grafting and no change of fixation; thus, there was eventually 100% union without the need for vascularized bone grafting.

Several technical aspects may have contributed to the success noted in this series. First, proper imaging is important with reformatted frontal and lateral CT cuts obtained in the axis of the scaphoid. This better defines the plane of non-union and the degree of displacement and bone resorption. We also find that the three-dimensional surface renderings of the bone are helpful in pre-operative planning. During surgery, identification and complete debridement of the fibrous tissue across the nonunion site is sometimes difficult to assess. This is especially true when the nonunion site is not 'loose'. In these cases, we have made a cavity in the scaphoid at and distal to the nonunion line to access the nonunion site. This minimizes the chance of breaking up what may be a more stable nonunion. In addition, as noted, we find radio-opaque dye very helpful when used with fluoroscopy to guide bone debridement during surgery. The dye can be cleared with simple irrigation (it is water soluble) and used again, for example after further debridement. Lastly, we believe that it is important to place the fixation (i.e. screws or pins) perpendicular to the orientation of the fracture line when at all possible, rather than in the traditional path in the long axis of the scaphoid. This optimizes purchase in the small proximal fragment and minimizes screw cut-out secondary to shear forces. As the fracture orientation is often oblique from dorsal proximal to distal volar, this requires a slightly more volar starting point for the screw. The pre-operative three-dimensional images of the scaphoid are often crucial in understanding the optimal screw orientation.

Weaknesses of this study include its retrospective design and small sample size. The sample size is a result of the relative infrequency of proximal pole scaphoid fractures. Future studies will hopefully be designed in a prospective, randomized fashion to remove these limitations and may require a multi-centre design because of the infrequency of this fracture pattern.

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