Micro Screw Fixation for Small Proximal Pole Scaphoid Fractures with Distal Radius Bone Graft

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Abstract

Background Achieving adequate fixation and healing of small proximal pole acute scaphoid fractures can be surgically challenging due to both fragment size and tenuous vascularity.

Purpose The purpose of this study was to demonstrate that this injury can be managed successfully with osteosynthesis using a "micro" small diameter compression screw with distal radius bone graft with leading and trailing screw threads less than 2.8 mm.

Patients and Methods Patients with proximal pole scaphoid fragments comprising less than 20% of the entire scaphoid were included. Fixation was accomplished from a dorsal approach with a micro headless compression screw and distal radius bone graft. Six patients were included. Average follow-up was 44 months (range, 11–92).

Results Mean proximal pole fragment size was 14% (range, 9–18%) of the entire scaphoid. The mean immobilization time was 6 weeks, time-to-union of 6 weeks, and final flexion/extension arc of 88°/87°. All patients had a successful union, and no patient had deterioration in range of motion, avascular necrosis, or fragmentation of the proximal pole.

Conclusion Small diameter screws with a maximal thread diameter of $\leq$ 2.8 mm can be used to fix the union of proximal pole acute scaphoid fractures comprising less than 20% of the total area with good success.

Level of Evidence Therapeutic case series, Level IV.

Keywords
- scaphoid
- fracture
- proximal pole
- screw
- bone graft

Surgical management of small proximal pole scaphoid fractures involves a balance of attaining secure fixation while minimizing the risk for iatrogenic comminution. The difficulty in obtaining union following fixation is compounded by the unreliable local vascular supply that renders proximal fractures more prone than middle and distal third scaphoid fractures to avascular necrosis (AVN).[1] Consequently, surgeons may choose to expose the fracture site and the scapholunate joint because directly visualizing an anatomic reduction and fixation of the native proximal pole fragments with preservation of the fracture fragment integrity ensures minimal disruption of the scapholunate ligament and preservation of the native subchondral bone–cartilage interface.

The size of small proximal pole fragments may preclude traditional screw fixation. One example of this is the Mini-Acutrak 2 with a leading diameter of 3.5 mm. In addition, the use of larger screws while still possible can lead to hoop stress failure and fracture of the proximal pole. This has led authors to suggest several alternative techniques to these delicate fractures, including Kirschner wire (K-wire) or suture anchor fixation, and supplemental distal radius and medial femoral autograft.[2–5] As headless compression screws have been

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extensively utilized for scaphoid fixation, newer generation screws offer improved compression forces and load to failure profiles, thereby, potentially permitting comparably effective fixation with smaller implants.[6] These include headless "micro" compression screws that have a small diameter with 2.5 mm leading and 2.8 mm trailing threads.

The purpose of this study was to demonstrate the efficacy of small diameter headless compression screws (with a maximal trailing diameter of less than 2.8 mm) supplemented with distal radius bone graft in a cohort of patients with small proximal pole acute scaphoid fractures. We hypothesized that proximal pole fractures comprising less than 20% of the scaphoid area could be managed successfully with this fixation technique.

Patients and Methods

Institutional review board approval was obtained and patients who had surgery between 2007 and 2014 were retrospectively reviewed. Consecutively, presenting patients were identified via current procedural terminology code 25628, who had open treatment of scaphoid fracture with internal fixation. Images were retrospectively reviewed to measure proximal pole fragment size. The inclusion criteria were use of a micro screw with a 2.4-mm leading thread and a 2.8-mm trailing thread diameter in a proximal pole scaphoid fragment that comprised less than 20% of the entire scaphoid.

Radiographic Evaluation

All six patients had preoperative computed tomography (CT) scans in addition to plain radiographs, and three patients had an additional preoperative magnetic resonance imaging (MRI). Calculations of the size of the proximal pole fragment relative to the total scaphoid were performed according to a previously published technique for estimating cross-sectional area.[3] A posterior–anterior scaphoid view radiograph was obtained with the wrist in ulnar deviation and flat on the cassette. We used our institution's picture archiving and communication system to create a freehand polygonal region of interest area calculation of both the proximal fragment and total scaphoid (Sectra Workstation IDS7, Sectra AB, Linköping, Sweden) (►**Fig. 1**). Analyses were repeated three times per subject by a hand surgery fellow, and the average ratio of proximal pole fragment relative to the entire scaphoid was calculated.

With corresponding plain radiographs that demonstrated interval healing, CTs were obtained at 6 weeks postoperatively and evaluated by both a senior musculoskeletal radiologist and the operating surgeon to confirm progressive healing as was evident on the serial plain X-rays.[7] Bridging trabeculation across the fracture site in a minimum of two consecutive slices in the coronal and sagittal plane was diagnostic of healing.[7,8] This parameter was modeled after the study by Trumble et al[7] that considered union to be present if trabecular bridging was seen on at least two coronal or sagittal CT images.

At the most recent follow-up, radiographs were assessed by an independent radiologist for new evidence of AVN or fragmentation of the proximal pole.

Fig. 1 A 26-year-old professional basketball player with a proximal pole scaphoid fracture. (**A**) Technique for estimating area of proximal pole. Regional area of proximal pole fragment is divided by the total scaphoid area to give approximate size (17%). (**B**) Fracture line on preoperative computed tomography scan. (**C**) One week postoperative radiograph showing Acutrak Micro 2.5 mm screw and (**D**) computed tomography scan showing evidence of healing at 6 weeks, at which point counter-rotation scaphocapitate pin was removed.

Surgical Technique

All operations were performed by a single attending hand surgeon. After exsanguination and tourniquet inflation, a dorsal approach to the proximal pole of the scaphoid with a one inch skin incision was used. The third dorsal compartment was opened and the extensor pollicis longus was retracted radially. To ensure anatomic reduction and preservation of the scapholunate articulation, capsulotomy was performed, and the fracture fragment was identified and reduced as needed. Local bone graft was obtained through Lister's tubercle from the distal radius using the same one inch dorsal exposure. The guidewire for the micro screw was placed through the proximal pole and passed across the scaphoid fracture under fluoroscopic guidance. Efforts were made to place the screw as perpendicular to the fracture as possible while remaining within the cancellous portion of the scaphoid. This was accomplished through choice of starting point and trajectory, based on the knowledge of the three-dimensional anatomy of the fracture from preoperative CT scans. The proximal pole was drilled just past the level of the fracture under fluoroscopic control and broached. Distal radius bone graft was morselized and placed down the same drill hole next to the guidewire to the level of the fracture site under fluoroscopic guidance. A second-generation Acutrak micro headless compression screw (Acumed, Hillsboro, OR) with a 2.5-mm leading and a 2.8-mm trailing diameter was inserted over the guidewire and across the fracture. A countersink/short reamer for the trailing threads was used in these patients to prevent proximal pole fracture and minimize the hoop stress as the trailing threads are inserted. One patient had a counter-rotation scaphocapitate pin placed for 6 weeks (►Fig. 1). This patient had an extremely small proximal pole fracture with a correspondingly large distal fragment, thereby effectively generating a long lever arm that moved with the midcarpal row. We felt a scaphocapitate pin to control rotation of the scaphoid would decrease the load on the screw.

Postoperative Management

The wrist was immobilized in a postoperative splint/dressing for 1 week, and then in a waterproof thumb spica short arm orthosis or cast for 5 weeks or until progressive healing was evident with CT scan. This thumb spica cast included a cutout over the proximal scaphoid for application of an ultrasound bone stimulator. Active range of motion exercises were initiated after confirmation of union with progression to passive motion and strengthening. All final motion assessments were performed by the operating surgeon with a goniometer after a minimum follow-up of 6 months.

Results

The demographics and operative details of all six patients are summarized in ►Table 1. There were four men and two women with a mean age of 41 years (range, 20–61). All six patients were documented nonsmokers. The dominant wrist was involved in four patients. The mean proximal pole fragment was 14% (range, 11–18%) of the entire scaphoid. There was a mean injury to surgery interval of 3 weeks, immobilization time of 6 weeks, time-to-union of 6 weeks, and final flexion/extension arc of 88°/87°. Average final radiographic follow-up was 25 weeks (range, 6–49) postoperatively. No patients had AVN documented on preoperative MRI, CT, or X-ray.

There were no wound and healing complications in this cohort. All patients had a successful union, no patient in this small series had fragmentation of the proximal pole of the scaphoid, and no patient had deterioration in range of motion at latest follow-up (►Fig. 2).

Fig. 2 A 29-year-old male with a proximal pole scaphoid fracture. (**A**) Preoperative computed tomography scan. (**B**) Preoperative X-ray. (**C**) Computed tomography scan showing evidence of healing at 6 weeks, at which point his cast was removed. (**D**) Final radiographic follow-up at 11 months, showing a completely healed scaphoid with screw in good position.

Discussion

Treatment of proximal pole acute scaphoid fractures is a challenge that is associated with a high risk of nonunion.[9] The vascular supply to the proximal pole is exclusively through dorsal radial artery branches which limit spontaneous healing potential.[1] Fixation with traditional size implants is limited by screw size, and nonunions are not uncommon. In the presence of a nonunion, progressive posttraumatic degenerative changes can be expected with detrimental effects on patient function and satisfaction.[10,11]

Several techniques have been described that address the challenges associated with proximal pole scaphoid

Table 1 Cohort details

Patient	Age/ Sex	Displaced	Pre-op motion (flexion°/ extension°)	Injury to surgery interval (d)	Immobilization (wk)	Time to union (wk)	Follow-up duration (mo)	Final motion (flexion°/ extension)
1	20/M	Yes	45/45	7	6	6	80	90/90
2	26/M	No	70/70	13	6	6	52	90/90
3	61/F	No	30/10	46	7	7	92	90/90
4	57/F	No	30/30	5	6	6	13	90/80
5	42/M	No	60/60	14	6	6	19	90/90
6	38/M	No	80/60	44	6	6	11	80/80
Mean	41		53/46	22	6	6	45	88/87

fractures.[2–4] Concerns with any technique involving fixation of the proximal scaphoid pole are the concomitant iatrogenic disruption of the scapholunate ligament and resultant dorsal intercalated segmental instability deformity.[12] Suture anchor fixation of proximal pole fragments measuring less than 20% of scaphoid area resulted in successful union in 10 of 11 patients in a report by Kamrani et al[5]; however, the authors point out the potential for irritation and impaired motion caused by the suture knot in the radioscaphoid joint.

Complications with standard sized screws have been documented to be as prevalent as 29%, including postinstrumentation fracture of the proximal pole.[13] Small diameter headless compression screws offer an alternative technique for fixation of small proximal pole acute scaphoid fractures. The anatomy of the proximal pole along with the scapholunate ligament is preserved, as is the native subchondral bone–cartilage interface, which is known to be biologically important for cartilage survival.[14,15]

We have observed that micro screw fixation is a useful technique for the treatment of small proximal pole scaphoid fragments. The second-generation Acutrak micro screw used in this series has a diameter that is 29% smaller than the mini screw and 38% smaller than the standard screw, making it amenable to fixation of these smaller fragments. While also having a small diameter, the choice of screw lengths was limited to those that were available at the time of surgery, therefore providing less fracture stability than longer screws that previous biomechanical studies suggest.[6,15] Over time, the manufacturer has increased the available lengths of these screws, and they are now available in 30 mm length. Despite the smaller diameter and limited lengths of the micro screw, all patients in this small series had a successful union, and no patient had deterioration in range of motion, AVN, or fragmentation of the proximal pole of the scaphoid at latest follow-up. Because of the concern for potential nonunion due to the ultrasmall size of these proximal pole acute fractures, we chose to perform distal radius bone grafting in addition to micro screw fixation using the same one inch dorsal incision that allowed exposure and visualization of the fracture and its anatomic reduction. The distal radius graft was obtained through Lister's tubercle through the same one inch exposure, and doing so posed minimal additional morbidity and risk for tendon adhesions. We believe that we had successful results without the risk of proximal pole fracture fragmentation because grafting was placed only in the drill hole in the scaphoid, and not by taking down the fracture site. We believe that taking bone graft from the distal radius may in fact increase healing by serving as a core decompression that potentially stimulates increased vascularity to the wrist. This may have improved healing in a way that was not measurable in this study.

This study has several limitations. First is related to this study's small size and retrospective design that are inherent to case series studies involving patients treated only by a single surgeon. Second is the absence of methods that measure subjective outcomes. Third is the nonuniform and limited duration of follow-up. While no avascular changes were noted in the short term, we recognize that extended follow-up and functional outcome scores are still needed. Fourth is that one of the patients received supplemental K-wire fixation of the scaphoid to the capitate which adds heterogeneity to this case series. While an added K-wire may theoretically enhance biomechanical stability in scaphoid waist fractures,[16] a comparable effect on the stability of proximal pole fractures remains unknown and can be explored with a separate biomechanical study.

Lastly, while the method and timing, as early as 6 weeks, used to assess fracture healing in our study were modeled after previous peer-reviewed reports,[7,8] application of these parameters to assess scaphoid fracture healing have not been validated. The factors that serve as reliable prognosticators for successful fracture healing remain unknown, and a consensually agreed upon and validated method of assessing fracture healing does not currently exist. In the experience of the senior surgeon, and as is supported in this retrospective analysis, we found that bridging trabecular bone, evidenced by CT imaging on at least two coronal or sagittal images, corresponds to final fracture healing.

Our study found that small diameter screws ($\leq$ 2.8 mm diameter) with distal radius bone graft can be used to fixate proximal pole acute scaphoid fractures comprising less than 20% of the total area with good success. While fixation and healing was achieved in proximal pole fragments comprising less than 20% of the scaphoid area (and in fragments as small as 11%), the limit in terms of fragment size that can be successfully managed with this technique is unknown and worthy of ongoing investigation.

Note

This work was performed at the Hospital for Special Surgery.

Ethical Approval

Institutional ethical board review approval was obtained from Hospital for Special Surgery's Institutional Review Board.

Conflict of Interest

None.

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