Percutaneous Treatment of Unstable Scaphoid Waist Fractures

HAND
2017, Vol. 12(4) 362–368
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DOI: 10.1177/1558944716681948
hand.sagepub.com

Andrew P. Matson¹, Ryan M. Garcia^{1,2}, Marc J. Richard¹,
Fraser J. Leversedge¹, J. Mack Aldridge³, and David S. Ruch¹

Abstract

Background: Percutaneous techniques have been described for the treatment of nondisplaced scaphoid fractures, although less information has been reported about outcomes for unstable, displaced fractures. The aim of this study was to evaluate the union and complication rates following manual closed reduction and percutaneous screw placement for a consecutive series of unstable, displaced scaphoid fractures. **Methods:** A total of 28 patients (average age, 27 years; 22 male/6 female) were treated for isolated unstable displaced scaphoid waist fractures. Closed reduction and percutaneous headless, compression screw fixation was successfully performed in 14 patients (average age, 32 years; 10 male/4 female), and the remaining 14 patients required open reduction. Patients who underwent percutaneous treatment were followed for radiographic fracture union and clinical outcomes. **Results:** Thirteen of 14 fractures (93%) had clinical and radiographic evidence of bone union at an average of 2.8 months postoperatively. Average visual analog pain score at the time of union was 0.9. The average Quick Disability of the Arm, Shoulder, and Hand score at 2.5 years follow-up (range, 1.5–8.3 years) was 9.6 (range, 0.0–27.3). Complications included 1 case of nonunion and 1 case of intraoperative Kirschner wire breakage. **Conclusions:** Manual closed reduction followed by percutaneous headless, compression screw fixation was possible in 50% of patients who presented with acute unstable, displaced scaphoid fractures. This technique appears to be a safe and effective method when a manual reduction is possible, and it may offer a less invasive option when compared with a standard open technique.

Keywords: fracture, navicular, percutaneous, scaphoid, unstable

Introduction

Scaphoid fractures occur commonly, accounting for 60% of carpal fractures and 11% of all hand fractures.²¹ Historically, they have been treated nonoperatively with prolonged periods of immobilization; nonunion rates for scaphoid fractures with greater than 1 mm displacement have been reported to be as high as 53% to 92%,^{14,16,28} with risk of nonunion being 17 times higher with nonoperative treatment compared with operative fixation.³⁶ For this reason, many authors have recommended open reduction and internal fixation (ORIF) for these for displaced, unstable scaphoid fractures.^{20,29,33,39,40}

Percutaneous placement of a headless, compression screw is an alternative approach to open treatment, usually reserved for nondisplaced scaphoid fractures and has been shown to be highly effective in these cases.^{19,22,30,32} Potential advantages of the percutaneous approach include decreased morbidity, earlier return of function, less risk of violating the already tenuous blood supply to the scaphoid, and a shorter time to union.²² Prior technique articles have included “reducible” or “minimally displaced” scaphoid fractures as

being an indication for the percutaneous approach.^{31,42} However, to our knowledge, there is minimal data describing outcomes following a closed reduction and percutaneous placement of a headless compression screw in displaced or unstable scaphoid fractures.^{13,24}

The primary aim of our study was to evaluate fracture union in a consecutive series of patients who were treated with closed reduction and percutaneous screw fixation for unstable scaphoid waist fractures. The secondary aims of this study were to evaluate pain scores, patient-rated functional outcomes, and complications in this group of patients.

¹Duke University Medical Center, Durham, NC, USA

²OrthoCarolina Hand Center, Charlotte, NC, USA

³Triangle Orthopaedic Associates, Durham, NC, USA

Corresponding Author:

David S. Ruch, Department of Orthopaedic Surgery, Duke University Medical Center, Duke University, DUMC Box 3000, Durham, NC 27710, USA.

Email: d.ruch@dm.duke.edu

Materials and Methods

Approval for this retrospective chart review was obtained through our institutional review board.

Patients

We retrospectively reviewed the medical records and radiographs of 94 consecutive patients who were treated by 4 fellowship-trained hand surgeons for a scaphoid fracture with a headless, compression screw from April 2007 to November 2013 at a single institution. Of the 94 patients, 37 were determined to have displaced, unstable fractures. As defined previously, in the present study, displacement was defined by gapping or translation >1 mm on posteroanterior (PA) or lateral radiographs, >15° of lunocapitate angulation, >60° scapholunate angulation, or >15° dorsal tilting of the lunate relative to the radius on the lateral radiograph.^{9,10,12,14,26} Displaced fractures were considered to be unstable.^{10,12,14} Of the 37 patients who had displaced, unstable scaphoid fractures, 28 patients had an isolated scaphoid fracture without concomitant bony injury to the ipsilateral hand, wrist, or forearm. There were no open scaphoid fractures in this group.

The 28 patients with isolated, unstable scaphoid fractures included 22 males and 6 females with an average age of 27 years (range, 18-51 years). All patients were taken to the operating room for a planned closed reduction and percutaneous, headless, compression screw placement. Closed reduction was successful in 14 patients, whereas in the remaining 14 patients, a closed reduction maneuver was unsuccessful and they were converted to an open reduction followed by internal fixation.

The 14 patients who underwent a closed reduction and percutaneous screw placement are represented in Table 1. There were 10 males and 4 females with an average age of 32 years (range, 19-51 years). Average time from initial injury to surgery was 1.6 months (range, 0.1-5.2 years). Injury mechanisms included falls onto outstretched hands in 10, automobile accident in 1, assault in 1, and unknown in 2. Nine injuries occurred on the right side, and 5 occurred on the left.

Operative Technique

Operative reports were available for all patients and were reviewed. Ten fractures were fixed with a single screw, and 4 fractures were fixed with 2 screws. Percutaneous screws were placed antegrade (dorsal) in 9 cases and retrograde (volar) in 5 cases. Bone grafting was not performed at the time of the index procedure.

Each surgeon chose a volar or dorsal approach based on their individual preference, and marked landmarks including the scaphoid tubercle volarly and Lister's tubercle dorsally. Fluoroscopy was then used to mark out the long axis

Table 1. Patient, Injury, and Management Specifics.

Patient	Age (y)	Sex	Side	Mechanism	Delay (m)	Screws used	Approach
1	20	M	R	FOOSH	0.1	1	Dorsal
2	33	M	R	na	0.3	1	Dorsal
3	43	F	R	FOOSH	0.9	1	Dorsal
4	23	M	R	FOOSH	1.2	1	Dorsal
5	32	M	R	FOOSH	0.7	1	Dorsal
6	44	M	L	FOOSH	0.6	1	Volar
7	32	M	L	MVC	5.2	2	Volar
8	25	M	R	FOOSH	0.5	1	Dorsal
9	26	F	R	FOOSH	4.3	2	Volar
10	51	F	R	Assault	2.7	1	Volar
11	19	M	L	na	na	1	Volar
12	43	M	L	FOOSH	0.4	2	Dorsal
13	36	F	R	FOOSH	2.0	2	Dorsal
14	21	M	L	FOOSH	1.3	1	Dorsal

Note. Patients treated with closed reduction and percutaneous screw fixation. FOOSH = fall on outstretched hand; MVC = motor vehicle collision; na = not available.

of the scaphoid in the coronal and sagittal planes. Reduction was performed manually under fluoroscopic guidance consisting of traction followed by pronation, ulnar deviation, and direct manual pressure on the distal pole of the scaphoid. An acceptable reduction was defined by no evidence of step or gap on PA or lateral fluoroscopic imaging and restoration of < 45° of lateral intrascaphoid angulation. Intrascaphoid angulation was measured on PA and lateral fluoroscopic imaging in a similar fashion to that previously described for its measurement in computed tomography (CT).^{2,40} A pointed tenaculum reduction clamp was then applied percutaneously at the proximal and distal aspects of the scaphoid to maintain reduction prior to percutaneous screw fixation. A small, 5 mm incision was then made allowing blunt dissection to the scaphoid to avoid injury to tendons or neurovascular structures. Then a standard cannulated guidewire was introduced under direct fluoroscopy, and aimed perpendicular to the fracture. Adjustment of the tenaculum reduction clamp was occasionally needed to allow for optimal placement of guidewires and screws. When a single screw was used, the guidewire was aimed to be in a center-center position along the long axis of the scaphoid, whereas when 2 screws were used, the screws were separated by the diameter of the screw to allow passage of both. An additional Kirschner wire was occasionally used to prevent loss of reduction during drilling and screw insertion. The scaphoid is then drilled and the cannulated, headless, compression screw is then inserted under direct fluoroscopy visualization (Figure 1). In this series of patients, screws used were either the Acutrak Mini, the Acutrak 2-Micro (Acumed, Beaverton, Oregon), or the NexFix (Orthohelix Surgical Designs, Inc., Medina, Ohio)

Figure 1. (a) Intraoperative fluoroscopy posteroanterior images showing use of a pointed tenaculum reduction clamp and guidewires to temporarily hold scaphoid reduction via the percutaneous approach, and (b) subsequent application of two cannulated, headless compression screws in the volar to dorsal direction.

headless compression screw at variable lengths (18-28 mm). Choice of screw type, as well as number of screws used (1 vs 2) was based on individual surgeon preference. Screw position and avoidance of articular penetration is confirmed fluoroscopically.

Postoperative Data Collection

All patients were immobilized in a plaster thumb spica cast in the immediate postoperative period. After 2 weeks, this was changed to a removable thumb spica orthosis. At 4 to 6 weeks, the thumb spica orthosis was discontinued entirely, and hand therapy at 2 to 3 times per week began with gentle range of motion activities followed by progressive strengthening thereafter. Progression to full-weight-bearing was permitted once patient's x-rays demonstrated radiographic evidence of osseous union as well as symptomatic improvement.

Serial PA and lateral radiographs were obtained in all cases, and these studies were obtained at all postoperative follow-up visits after 2 weeks. Images were interpreted by a radiologist, the orthopedic surgeon providing care, and a physician reviewer who was not involved with the care of these patients. Patients were followed until fracture union was confirmed by PA and lateral radiographs or computerized tomography. Osseous union was defined as radiographic evidence of bridging trabeculation obscuring the fracture line on both PA and lateral radiographs. The Visual Analog Scale (VAS) was obtained on all patients based on a 10-point scale. Range of motion in the flexion-extension range was recorded also. Patients were assessed for any complications including wound-healing issues, infection, chronic pain, stiffness, and need for a revision procedure. At the time of the study, Quick Disability of the Arm, Shoulder, and Hand

(DASH) questionnaire scores⁴ were attainable from 7 of 14 patients in the percutaneous group, and were obtained via phone interview by a physician who did not perform the surgery.

Results

Thirteen of 14 patients who underwent closed reduction and percutaneous screw fixation for unstable, displaced scaphoid fractures demonstrated radiographic evidence of osseous union at an average of 2.8 months (range, 1.9-3.4 months). To confirm fracture union, most patients (12 of 14) had serial radiographs (Figure 2) only, whereas 2 patients underwent computerized tomography to confirm fracture union (Figure 3). The average visual analog pain score at the time of fracture union and last follow-up was 0.9 (range, 0-3). Range of motion at the time of union was 52° of flexion (range, 30°-75°) and 59° of extension (range, 35°-80°) with an overall average arc of motion of 113° (range, 65°-155°).

At the time of telephone follow-up for the 7 patients who could be contacted (average 2.5 years postoperatively; range, 1.5-8.3 years), the average QuickDASH score for all was 9.6 (range, 0.0-27.7) and the average VAS pain score was 1.1 (range, 0-4).

Complications occurred in 2 of 14 patients, including 1 major and 1 minor complication. The major complication was nonunion and avascular necrosis of the proximal scaphoid. This occurred in a 51-year-old female who presented in a delayed fashion, undergoing closed reduction and percutaneous screw placement 2.7 months after her initial injury. She experienced ongoing pain following surgery that prompted the surgeon to obtain magnetic resonance imaging

Figure 2. (a-b) Posteroanterior and lateral radiographs of a 20-year-old man who sustained a displaced fracture of the scaphoid waist and (c-d) radiographs obtained 2 months postoperatively following closed reduction and percutaneous fixation of the scaphoid with a single screw in the dorsal to volar direction, confirming radiographic union.

Figure 3. Coronal computed tomography image obtained to confirm reduction in a 26-year-old female 2.5 months postoperatively following closed reduction and percutaneous screw fixation in the volar to dorsal direction for a scaphoid waist fracture.

Note. Bridging trabeculation is present throughout most of the fracture site.

that demonstrated proximal pole avascular necrosis. She subsequently underwent a revision procedure with a dorsal capsular-based vascularized bone graft to the scaphoid. This failed to restore vascularity, and she went on to develop radioscaphoid arthritis treated definitively by a proximal row carpectomy. The only minor complication was intraoperative breakage of the cannulated guidewire that required extension of the incision by 1 cm for removal. This patient had no further consequences and went on to heal the fracture at 2.7 months. There were no cases of infection or wound-healing problems.

Discussion

The aim of our study was to evaluate the union and complication rates of manual closed reduction and percutaneous

screw placement for a series of unstable scaphoid fractures. In our series, 14 (50%) of 28 patients presenting with unstable scaphoid fractures could be successfully reduced and treated with percutaneous screw fixation. These patients achieved radiographic union in 13 of 14 cases (93%), and had good outcomes with regard to pain, range of motion, and function. To our knowledge, there is limited data describing outcomes of this percutaneous technique when used for unstable scaphoid fractures.^{13,24}

This study has several potential limitations. First, we recognize that our small retrospective case series reports outcomes of the percutaneous technique only, and lacks the value of direct comparison with the open technique. We chose to report outcomes of only the percutaneous technique to focus on demonstrating efficacy of this emerging technique, and to avoid confounders that would potentially obscure direct comparison between the percutaneous and open techniques. Second, the final follow-up rate for the QuickDASH phone survey was only 50% (7 of 14). Although phone survey for the QuickDASH questionnaire has been demonstrated to be reliable,³⁹ we recognize that this is a low rate of responders. However, we maintain that obtaining functional outcomes was a secondary aim of the study which served to supplement the primary goal of reporting efficacy at achieving union. Third, our analysis included patients who presented both acutely and subacutely, which we define as initial presentation > 4 weeks after injury.²⁷ Often, acute and subacute scaphoid fractures are managed differently; however, we sought to investigate the efficacy of percutaneous treatment regardless of injury timing, as long as adequate closed reduction could be achieved intraoperatively. Finally, our definition of an unstable fracture was based only on static radiographic criteria, and thus we may have omitted some injuries which appeared nondisplaced but may have been unstable upon dynamic testing.

Previously reported outcomes following ORIF for unstable scaphoid fractures include union rates from 83% to 100%,^{20,33} time to union from 2.9 to 4.2 months,^{33,40} and average arc of motion from 109° to 120°.^{33,40} Our data are consistent with these findings, with slightly faster time to union of 2.8 months and average arc of motion of 113°. However, a standardized time interval for obtaining radiographs postoperatively was not established for our study, and this could influence identification of time to union. Furthermore, it is conceivable that arc of motion may have continued to improve beyond 2.5 months, which is when it was measured in the present study.

Percutaneous fixation has been demonstrated to be safe and effective for the treatment of nondisplaced and minimally displaced scaphoid fractures, achieving union rates from 89% to 98%,^{5,22,32} and DASH scores from 3.0 to 7.4.^{5,22,32} In addition, screw fixation for nondisplaced fractures results in earlier return to work^{3,8} faster time to union,⁸ and better patient-rated outcomes³ compared with nonoperative management.

Chen and colleagues report outcomes following acute treatment of displaced scaphoid fractures with closed reduction and percutaneous fixation.¹³ These authors reported union in 11 of 11 patients who presented acutely, and good or excellent functional outcomes in all patients.¹³ We report union in most patients (13 of 14); however, our study differs from prior studies^{13,24} in that we performed our technique on patients who presented both acutely and subacutely. Average surgical delay was 1.6 months (range, 0.1–5.2 months) in the present study, with 5 patients (36%) having surgery performed in the subacute time period after injury. Another critical difference between the above study and our study is in the definition of unstable fracture used to determine eligible patients. Whereas our study included angular deformity within the adjacent carpals to define instability in addition to displacement >1 mm, the prior study used displacement >1 mm, radial cortex comminution, or oblique fracture line to define instability.¹³

Reported complication rates following percutaneous fixation of scaphoid fractures range from 0% to 30% include painful hardware,^{11,22,32,41} nonunion,^{1,11,32,41} postoperative fracture,¹¹ superficial infection,^{13,41} nerve irritation,^{15,41} intraoperative hardware breakage,¹¹ reflex sympathetic dystrophy,^{1,24} and scar problems.¹⁵ We report 1 minor complication and 1 major complication. The minor complication was intraoperative breakage of guidewire, which had no long-term consequences for the patient. The major complication was nonunion.

Our major complication raises the question of whether nonacute unstable scaphoid fractures should be treated with closed reduction and percutaneous fixation. Previous studies evaluating percutaneous fixation of unstable scaphoid fractures have included only acute injuries,^{13,24} and it is

known that scaphoid fracture union rates are higher when treated acutely as opposed to in a delayed fashion.^{20,29} Despite this, there are also studies that report successful outcomes with percutaneous treatment of delayed union or nonunion of nondisplaced fractures.^{25,34} Further investigation of the optimal patient selection for percutaneous fixation may be warranted.

Variations and modifications to the percutaneous fixation technique described in this article have been used. In our series, we used both dorsal and volar approaches (9 dorsal, 5 volar). Although there may be no difference in clinical outcomes between these two approaches,²³ cadaveric and clinical data have demonstrated more optimal screw position with the dorsal compared with volar approach.^{23,38} There are reports of good results with arthroscopically assisted closed reduction and percutaneous fixation,^{35,37} which has the advantage of enabling the surgeon to directly visualize the reduction and address soft tissue lesions at the same time.³⁵ However, in the present study, surgeons did not opt for this technique. Use of ultrasound for these injuries has not been studied extensively; however, it may allow for similar accuracy and consistency with screw placement compared with conventional fluoroscopy.^{6,7}

It has been suggested that young athletes in particular benefit from percutaneous scaphoid fracture fixation, as it is minimally invasive and offers early return to sport.^{17,18} In our series, the 1 major complication occurred in the only patient who was above age 50 years at the time of treatment. In patients younger than 50 years, the average DASH score at final follow-up is 7.2 with 100% union rate and no major complications.

In conclusion, our data demonstrate that acceptable closed reduction followed by percutaneous headless, compression screw fixation was possible in 50% of patients who presented with unstable, displaced scaphoid fractures. This technique appears to be a safe and effective method when acceptable reduction is possible. This technique may offer a less invasive option when compared with a standard open technique. Further studies that directly compare closed and open fixation techniques, and define optimal patient selection are appropriate.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This retrospective study involved human subjects and was approved by the Duke University Health System Institutional Review System (919-668-5111).

Statement of Informed Consent

Informed consent was obtained for all patients who were contacted by phone.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: M.J.R. is a consultant for Acumed. F.J.L. receives royalties from Orthohelix Surgical Designs/Tornier. J.M.A. has received speaker honorarium from Acumed.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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