Outcomes of open reduction and internal fixation of acute proximal pole scaphoid fractures

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Abstract

Background Proximal pole scaphoid fractures are less common than waist fractures, and successful management can be difficult. We hypothesize that time to union is increased by delays in surgical fixation, greater initial displacement, and higher energy mechanisms of injury.

Methods A retrospective review was conducted of all patients undergoing open reduction internal fixation (ORIF) of acute proximal pole scaphoid fractures at our institution over a 19-year period. A review of clinical as well as radiographic data was undertaken. The mechanism of injury, patient demographics, timing of surgery, initial displacement, fixation method, smoking status, and lunate morphology were recorded. Functional outcome measures were recorded when available. Univariate analysis using Kaplan-Meier survival curves was performed.

Results A total of 10 out of 23 patients (43 %) showed evidence of union at 14 weeks post-injury. Rates of early union were higher in non-displaced fractures (70 %) when compared to displaced fractures (23 %). Similarly, fractures sustained via low energy mechanisms had a higher rate of early union compared to high energy mechanisms (69 versus 10 %). A delay in ORIF did not appear to influence rate of union.

Conclusions Initial displacement and mechanism of injury have the most significant effects on early rates of union. Delay in ORIF of up to 28 days did not affect the rate of initial union, but the authors recommend early fixation of these fractures to prevent further displacement. Patients with widely

displaced fractures or those with high energy mechanisms should be counseled regarding prolonged healing time.

Level of Evidence: IV—therapeutic

Keywords ORIF · Proximal pole · Scaphoid fracture

Introduction

The scaphoid is the most commonly fractured carpal bone, accounting for 80–90 % [8] of all carpal injuries and occurring most commonly in young, adult males. Traditionally, these fractures have been classified based on the anatomic location within the scaphoid into four categories: tuberosity (17 %), waist (66 %), and proximal (6 %) and distal poles (11 %) [8]. This distinction is important because of the unique blood supply to the scaphoid which is retrograde via the palmar and dorsal branches of the radial artery [4, 14]. The proximal pole is supplied entirely by branches entering the foramina along the dorsal ridge. The absence of significant vascular foramina proximal to the waist has been hypothesized to result in the high incidence of osteonecrosis and nonunion after scaphoid waist and proximal pole fractures [5]. Rates of nonunion in acute proximal pole scaphoid fractures treated with conservative management are quite high [7, 13]; therefore, open reduction internal fixation (ORIF) has been recommended [11, 12].

Much has been written regarding treatment of proximal pole scaphoid nonunions [3, 6, 16]; however, comparatively, little is known about the outcomes of ORIF of acute proximal pole fractures. A meta-analysis of 692 scaphoid fractures included only 16 proximal pole fractures distilled from seven different randomized controlled trials [17]. To date, the largest and most highly referenced study examining the outcomes from ORIF of acute proximal pole fractures is a series of 17 patients by Rettig and Raskin [10]. In this study, no

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comparison was made regarding the effect of timing of acute ORIF or severity of injury (energy imparted on the scaphoid) on ultimate fracture healing. The purpose of our study was to identify the effects of initial fracture displacement, mechanism of injury, and delay in fixation on healing rates in ORIF of acute proximal pole scaphoid fractures.

Methods

After IRB approval, a retrospective review of skeletally mature patients who underwent open or closed reduction and internal fixation of the scaphoid was performed. Between January 1990 and December 2008, 209 patients treated at our institution met the above criteria. This cohort was further refined to include only patients who had a fracture of the proximal third of the scaphoid (i.e., proximal pole) treated surgically. Patient selection was further restricted to those who underwent surgery within 4 weeks (28 days) of the initial injury and who were at least 16 years of age at the time of treatment. Patients were excluded if they had any previous injury to the scaphoid as an evidence of a nonunion or fractures beyond the proximal pole of the scaphoid. A total of 30 patients were identified who met the above criteria. Four of these had insufficient clinical documentation of follow-up and were excluded; an additional three underwent pinning of the scaphoid without screw fixation and thus were excluded. This yielded a final cohort of 23 patients.

Patient demographics were recorded, including age, sex, use of tobacco, and patient comorbidities. Mechanism of injury was recorded and further stratified into high or low energy. Low energy mechanisms included any fall from standing height, low velocity sports injury (likely less than 5 mph), or collision with a velocity of less than 5 mph.

Preoperative imaging was evaluated to assess fracture displacement, carpal displacement, and lunate morphology. All patients were evaluated with preoperative plain films of the wrist to assess fracture and carpal displacement, as well as lunate morphology (Fig. 1). Fracture displacement was defined as ≥ 1 mm of displacement. Twelve of the 23 had preoperative cross-sectional imaging which could be utilized to calculate fracture displacement; eight of the patients underwent preoperative CT scans, two patients had an MRI to assist in the diagnosis of a scaphoid fracture, and two had both a CT and MRI preoperatively. Any associated ligamentous injuries were noted along with dates of injury, presentation, and surgery. No open fractures were included in the study.

All patients underwent surgical fixation of the scaphoid fracture by a fellowship trained hand surgeon. A dorsal approach was utilized for 19 patients (Fig. 2), a percutaneous approach in three patients and a volar approach in one. Headless compression screws were used for fixation in all patients, with or without additional K-wires as needed for

Fig. 1 Initial injury films—AP and lateral of right wrist showing a transscaphoid perilunate fracture dislocation with >1 mm displacement of the proximal scaphoid fracture

intercarpal ligament stabilization. No additional bone graft was used during the index procedure in any of the patients.

A total of 20 out of the 23 patients were placed into a postoperative dressing, then thumb spica splint, or cast postoperatively with subsequent transition into a splint for an average duration of immobilization of 11.2 weeks. In one of the remaining three, a Royce splint was utilized after the initial post-op dressing, and in the last two patients, the exact nature of the cast was not specified in the medical record. Follow-up was determined by each individual surgeon, with average follow-up totaling 69.1 weeks and median of 27.7 weeks (range 7.3 weeks to 13.9 years).

Healing was verified by serial examination of plain films for the duration of the follow-up period by the lead author. In 14 patients, a CT scan was obtained to confirm union at the

Fig. 2 Intraoperative photo prior to ORIF with headless screw

Fig. 3 **a** Less than 50 % union at 12 weeks status post ORIF. **b** Near complete healing at 19 weeks status post ORIF

discretion of the treating surgeon. Union was defined as evidence of greater than or equal to 50 % union on both AP and lateral radiographs or both sagittal and coronal CT scans when available (Fig. 3).

Previous work has shown that non-displaced proximal pole fractures heal within 13 weeks (91 days) [10]; thus, an endpoint of 14 weeks was established to enable analysis using survivorship statistics.

Bilateral grip strength was recorded from the last follow-up visit at which it was available with a JAMAR dynamometer (Patterson Medical, Bolingbrook, IL). Wrist range of motion (radial and ulnar deviation, flexion, and extension) was measured with a handheld goniometer. Complications and any additional procedures required after the index operation were recorded.

Univariate analysis utilizing Kaplan-Meier survival curves was employed to analyze the effects of varying parameters on rate of healing within the first 14 weeks. Specifically, survival curves were utilized to identify the relationship of healing with initial displacement, mechanism of injury, delay in ORIF, lunate morphology, tobacco use, overall immobilization time, and presence of perilunate dislocation. Significance level was set at an alpha less than or equal to 0.05 and a log-rank test was employed to identify statistically significant differences between groups.

Results

Patient demographics and injury characteristics are noted in Tables 1 and 2, respectively. Ten patients had non-displaced fractures, 13 were displaced ≥ 1 mm, of which eight of these had associated perilunate fracture dislocations.

A total of 10 out of the 23 patients reviewed showed evidence of bony union at 14 weeks, a rate of 43 %. In the non-displaced fracture subset, 7 of 10 (70 %) healed within 14 weeks, while only 3 of 13 (23 %) with displaced fractures healed in the first 14 weeks, and this was statistically significant ($p=0.026$). Included in the displaced fracture subset were eight transscaphoid perilunate dislocations. If these dislocations were excluded from the analysis, the rate of union by 14 weeks was 8/15 (53 %).

In the 13 patients that did not exhibit evidence of union by 14 weeks, seven went on to complete union at an average of 20 weeks. One patient had evidence of partial union at 7 weeks, but was subsequently lost to follow-up. Two demonstrated partial union at the time of their final CT scan at 18 and 25 weeks, respectively, but were asymptomatic. Bone stimulators were used by two patients in the late union group who eventually went on to heal and by one of the patients who was asymptomatic with partial union at 18 weeks. The overall eventual union rate (including asymptomatic partial union not requiring revision) was 20 patients out of 23 (87 %).

Three patients demonstrated evidence of a symptomatic nonunion, and two of these were subsequently treated with a 1,2 ICSR bone graft—one at 8 months post-injury and the other at 6 months. The latter patient went on to nonunion and eventually required a total wrist fusion. The third patient was treated with a radiocarpal fusion and subsequent total wrist fusion.

Functional Outcomes

Grip strength measurements were available in 12 patients; the average grip strength of the injured side was 35 kg compared to 45 kg on the contralateral, uninjured side. Wrist flexion and extension data were available on 16 patients and averaged 47° and 51°, respectively, while wrist radial and ulnar deviation (measured in nine patients) averaged 17° and 32°, respectively. One patient had painful hardware requiring removal. The

Table 1 Patient demographics

Patient demographics	
Average age (years)	25.6
Age range (years)	16–53
M/F ratio	19:4
Non-tobacco/tobacco users/ unknown	18:2:3
type 1/type 2 lunates	10:13

Table 2 Injury characteristics

Mechanism	No. of injured	No. of displaced
High energy		
Motorcycle collision	1	1
ATV	2	2
Snowboarding	1	0
Fall from roof	1	1
MVA	3	3
Meat grinder injury	1	1
Mountain biking	1	1
Low energy		
Hockey	2	0
Football	4	0
Soccer	1	1
Fall from standing height	4	3
Struck in hand	2	0

average time from surgery to measurement of functional outcomes was 35 weeks.

Variables Influencing Healing

Kaplan-Meier survival curve analysis showed a higher rate of early union in patients with fractures sustained via low energy mechanisms ($p=0.0036$) (Figs. 4 and 5). Fractures with no displacement also showed a higher rate of early union ($p=0.026$).

Despite having similar numbers of patients with type 1 [6] and type 2 [10] lunates, lunate morphology showed no statistically significant influence on healing. Surprisingly, length of immobilization had an inverse correlation with rate of early union ($p=0.033$), whereby those who were immobilized for less than 12 weeks tended to have a higher rate of early union. The effect of tobacco use on fusion rate was not analyzed as

Fig. 4 Survival curve demonstrating rate of union in the first 14 weeks stratified by displacement; red = non-displaced, blue = >1 mm displacement

Fig. 5 Survival curve demonstrating rate of union in the first 14 weeks stratified by high versus low energy mechanism; red = low energy, blue = high energy

only two tobacco users were included in the study and both suffered perilunate dislocations. The use of tobacco in three patients was not known.

The average delay from injury to surgery for all patients was 1 week, with a median of 4 days and a range from 0 to 3.7 weeks. For the purpose of analysis, patients were stratified into three different groups based on their time to ORIF: (1) 0–2 days; (2) 3–7 days; (3) 8–28 days. Univariate analysis with these three groups did not show any statistically significant difference in union within the first 14 weeks ($p=0.73$) (Fig. 6).

Discussion

Fractures of the proximal third of the scaphoid are considered inherently unstable, in large part due to the lack of ligamentous structures attaching to the proximal fragment [7]. Surgical treatment of proximal pole fractures is recommended; yet,

Fig. 6 Survival curve demonstrating rate of union in the first 14 weeks stratified by delay in ORIF; red = ORIF in 0–2 days, green = ORIF in 3–7 days and blue = ORIF >7 days

despite operative intervention, nonunion continues to remain a common problem. Little is known of the patient, fracture, or injury characteristics which may predispose to nonunion despite acute surgical treatment.

The largest previous series by Rettig and Raskin [10] demonstrated 100 % union of 17 proximal pole scaphoid fractures. Union occurred at an average of 10 weeks post-surgery, and all fractures were fixed with a headless compression screw and casted for variable time periods ranging from 10 days to 4 weeks with healing confirmed by a CT scan. The average time from injury to surgery in this series was 15 days. Four of the 17 fractures were displaced >1 mm, none had additional carpal or ligamentous injuries. The authors concluded that early surgical intervention with headless screw fixation of proximal pole scaphoid fractures presented a reasonable alternative to prolonged cast immobilization.

In our series, the rate of union by 14 weeks was 43 %—significantly less than the previous series. However, our series of 23 patients included those with polytrauma and eight patients with perilunate dislocations. Univariate analysis of this population demonstrated that non-displaced fractures and those sustained via low energy mechanisms had a higher rate of union at 14 weeks. The detrimental effect of fracture displacement on healing of scaphoid fractures has been well known since Cooney defined scaphoid fractures as stable or unstable based on the presence of more than 1 mm of displacement [2]. In Cooney's series the nonunion rate for displaced fractures treated without surgery was 46 %.

Timing of surgery, within the 28 day window examined within this study, did not appear to significantly affect union rates; however, there were confounding variables in this data. Patients who were fixed within a day or two of injury were often victims of polytrauma or suffered significant damage to the carpus as a whole. These injuries tended to be operated on sooner, while the minimally displaced fractures presented with a longer interval time from the date of initial injury. Another counterintuitive finding was that shorter immobilization times corresponded to higher rates of union at 14 weeks. This is likely due to the fact that the treating surgeon had complete discretion with regard to the duration of immobilization. If radiographs on subsequent visits were concerning for nonunion, the surgeon tended to maintain immobilization in a cast. Thus, shorter immobilization time was likely a marker of increased healing and not necessarily the cause of such healing.

Our study is not able to contribute any information as to the effect of tobacco on early union of proximal pole fractures due to insufficient numbers of tobacco users. Previous series have shown tobacco use to be detrimental to healing in scaphoid revision surgeries for established nonunion [1, 9], as well as primary healing of acute scaphoid waist fractures [15] although

there appears to be a paucity of literature specifically examining tobacco use and proximal pole scaphoid healing after primary ORIF.

In our series, three patients required additional procedures for symptomatic nonunion. The overall union rate was 87 % with an average union time of 14.4 weeks for the fractures that did eventually unite. Therefore, the eventual rate of union was higher than the 43 % reported above; however, the time to healing was slightly longer than the 12 to 13 weeks cited by Rettig and Raskin. Trumble examined a series of patients undergoing ORIF for acute, displaced waist fractures and found an average time to union of 4 months [15], a period longer than that described in the series of proximal pole fractures by Rettig. Within our study, we found that 90 % of fractures (18 of 20) that eventually united did so by 24 weeks; thus, we suggest that if proximal pole fractures treated with internal fixation within the first 28 days of injury have not healed by 6 months, a secondary procedure should be performed to obtain union.

We recognize the limitations of a retrospective review from a single center involving multiple surgeons over a period of two decades. The patient population is as heterogeneous as the injuries sustained. A significant proportion of patients in our study suffered concomitant ligamentous injuries and/or fracture dislocations of the carpus. This is in contrast to the population in previous reports and may account for some of the differences in outcomes. Similarly, the period of follow-up varied dramatically between surgeons. A universal protocol was not followed as regards to timing of postoperative visits or data collected at each of these visits, another limitation inherent to retrospective studies. Additionally, there is not a comparative group of fractures treated conservatively to elucidate differences; however, this study demonstrates that early rates of union in proximal pole scaphoid fractures are dependent on displacement and mechanism of injury. Fractures with low energy mechanisms of injury tended to heal more quickly and reliably, as did non-displaced fractures. Time to ORIF, within the 28-day window, did not appear to affect rate of union. Based on this study, we can inform patients that union of surgically fixed acute proximal pole fractures is not universal but has a high eventual union rate (87 %) with acceptable postoperative motion and strength.

Conflict of Interest David M. Brogan declares that he has no conflict of interest.

Steven L. Moran declares that he has no conflict of interest.

Alexander Y. Shin declares that he has no conflict of interest.

Statement of Human and Animal Rights This article does not contain any studies with human or animal subjects.

Statement of Informed Consent Informed consent was not prospectively obtained as this was a retrospective chart review and presented

only minimal risk to patients, in accordance with our institution's IRB guidelines.

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