Percutaneous Screw Fixation without Bone Grafting of Scaphoid Non-Union

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ABSTRACT: **Background:** Delays in diagnosis and inadequate treatment of acute scaphoid fractures can lead to non-unions, presenting surgeons with unique challenges regarding optimal management.

Objectives: To evaluate the clinical and radiographic outcome of scaphoid non-unions treated with percutaneous screw fixation.

Methods: The study group comprised 12 patients with scaphoid non-unions of an average duration of 8.7 months. There were 11 males and 1 female with an average age of 24 years (range 14–47 years). All patients were initially treated with percutaneous screw fixation without bone grafting. A volar percutaneous approach was used in eight patients and a dorsal percutaneous approach in four. Wrist range of motion (ROM) and disabilities of the arm, shoulder, and hand (DASH) questionnaires were used to assess clinical outcomes. Postoperative radiographs were reviewed to assess the fracture union, carpal alignment and screw position.

Results: Eleven of the 12 (92%) fractures united successfully with no additional procedures. These fractures achieved radiographic union at an average of 4 months. One patient with sickle cell anemia required revision fixation, which consisted of repeat percutaneous fixation and bone grafting. In this patient his non-union healed 3 months after the revision procedure. The average DASH score at final follow-up was 6 (range 0–16). Average wrist ROM was extension of 66 degrees (range 50–80) and flexion 71 degrees (range 55–90). None of the patients showed radiographic signs of osteoarthritis, osteonecrosis of the scaphoid, or hardware-related complications.

Conclusions: For scaphoid waist non-unions without collapse, percutaneous fixation without supplementary bone grafting provides satisfactory results with a high union rate, early return of function and minimal complications.

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KEY WORDS: scaphoid, non-union, percutaneous fixation, dorsal, volar, range of motion (ROM), disabilities of the arm, shoulder, and hand (DASH)

Scaphoid fractures are the most common fractures of the carpal bones, accounting for 70% to 80% of all carpal fractures [1,2] and 11% of all hand fractures [3]. In adults, 70% of all scaphoid fractures involve the waist of the scaphoid, 20% involve the proximal pole, with the remaining 10% involving the distal pole [4]. Young males between 10 and 19 years of age are at highest risk for fracture of the scaphoid [5]. The scaphoid has several unique characteristics that affect its healing potential. Approximately 80% of the bone is covered with articular cartilage and the scaphoid has a tenuous blood supply. The dorsal carpal branch of the radial artery enters the dorsal ridge at the level of the waist and supplies the proximal 70%–80% of the scaphoid. Distal-to-proximal orientation of blood supply of the scaphoid and the lack of anastomoses between the dorsal and palmar vessels makes the proximal pole of scaphoid more susceptible to non-union and avascular necrosis after fracture. Non-displaced fractures of the distal third of the scaphoid have excellent healing potential, while fractures of the waist and proximal third of the scaphoid have higher rates of non-union [6]. Appropriate and early diagnosis of scaphoid fractures is imperative since delay in diagnosis can lead to complications such as non-union, avascular necrosis, carpal collapse and, subsequently, a predictable pattern of arthrosis [7].

The incidence of scaphoid non-union is reported to be between 5% and 25%, with various fracture, patient and treatment characteristics affecting the union rate [8,9,10]. Proximal pole fractures have a reported union rate of 67%, versus 87% for scaphoid waist fractures [11]. Scaphoid fractures with a delay in diagnosis, presenting more than 8 weeks after injury, have an 88% non-union rate [12]. Factors associated with increased risk of non-union are proximal pole fractures, associated ligamentous injury, delay in diagnosis (> 6 weeks), inadequate immobilization [7], and smoking [13].

The standard method for treatment of scaphoid non-union is an open approach for deformity correction, bone grafting and rigid internal fixation. The grafts utilized can be non-vascularized or pedicled rotational vascularized bone grafting. Recently, free vascularized bone grafting has been described for treatment of difficult non-unions [14]. Percutaneous screw fixation has been advocated for minimally displaced acute scaphoid fractures and was recently reported for dis-

placed scaphoid fractures. A few reports have described the percutaneous approach for treating scaphoid delayed unions and non-unions [15,16]. This technique has the advantages of not devascularizing the scaphoid, avoiding division of the carpal ligaments, and providing a much more aesthetic scar. The present study investigates the use of percutaneous fixation techniques, without supplementary bone grafting, in the treatment of established non-unions of the scaphoid.

PATIENTS AND METHODS

Twelve patients with scaphoid non-unions treated with percutaneous screw fixation were evaluated retrospectively. Excluded from the study were patients with significant scaphoid collapse, humpback deformity, dorsal intercalated segment instability deformity, osteonecrosis of the proximal scaphoid fragment, or arthrosis of the wrist. There were 11 male and 1 female patients with an average age of 24 years (range 14–47 years). There were six right-sided fractures and six left-sided fractures. Mechanism of injury included fall (n=10) and motor vehicle accident (n=2). The location of the non-union in all patients was the scaphoid waist. Average duration of non-union was 8.7 months (range 2–14 months). The approach was volar in eight cases and dorsal in four. Before and after surgery all patients had radiographic examinations that included anterior-posterior and lateral plain X-rays [Figures 1 and 2]. The study was approved by our institutional review boards.

SURGICAL PROCEDURE

All procedures were done with a percutaneous technique using a cannulated headless screw. If the volar approach was used, the wrist was gently extended over a folded towel and the guidewire was inserted through the base of the thenar eminence. The goal was to have the wire within the scaphoid in all views and centered in the proximal pole. When the optimal guidewire position was achieved, a cannulated drill was used to drill the scaphoid, and an appropriately sized screw was placed. If the wire traversed the edge of the trapezium, it was removed with a larger drill bit. With the dorsal approach, the wrist was hyperflexed for guidewire placement. A small incision was made to ensure avoidance of the extensor tendons. Typically two to three sutures were utilized and the hand was placed in a thumb spica splint. At 2 weeks the sutures were removed, and either a removable splint or short-arm cast was applied subject to patient compliance. The immobilization was continued until bony healing was achieved.

Figure 1. Preoperative anterio-posterior **[A]** and lateral **[B]** views of a scaphoid non-union (red arrow) with mild cystic changes. The patient is a 14 year old male who sustained a fracture to his scaphoid 14 months prior to presentation

Figure 2. Anteroposterior **[A]** and lateral **[B]** views demonstrating the final radiographic examination 8 years postoperatively. The scaphoid non-union is completely healed and there are no signs of arthrosis or avascular necrosis.

RESULTS

Eleven of the 12 (92%) fractures united successfully with no additional procedures. These fractures achieved radiographic union at an average of 4 months (range 3–6 months) post-screw fixation. One patient with sickle cell anemia required revision fixation, which consisted of repeat percutaneous fixation and percutaneous bone grafting. In this patient the non-union healed 3 months after the revision procedure. Clinical follow-up was at 35 months (range 12–96) postoperatively. The average DASH score (disabilities of the arm, shoulder, and hand) at final follow-up was 6 (range 0–16). Average wrist ROM (range of motion) was extension of 66 degrees (range 50–-80) and flexion 71 degrees (range 55–90). None of the patients showed radiographic signs of osteoarthritis, osteonecrosis of the scaphoid or intra-articular screw penetration. Scapholunate angle, scapholunate gap, scaphoid length, and radioscaphoid angle were all measured preoperatively and postoperatively [Table 1].

Table 1. Pre- and postoperative radiographic measurements

	Preoperative				Postoperative				
	SL angle	Scaphoid length (mm)	RS angle	SL gap (mm)	CL angle	SL angle	Scaphoid length (mm)	RS angle	SL gap (mm)	CL angle
	50	30	60	1	2	49	29	60	1	0
	45	32	55	2	3	45	32	55	1	0
	52	28	63	1	0	50	28	61	1	1
	55	26	65	2	4	52	26	60	2	2
	47	30	58	1	0	48	29	59	1	0
	46	31	55	1	4	47	30	55	1	2
	56	22	67	1.5	7	57	20	55	1	4
	67	29	77	1	8	65	25	57	1	6
	65	32	79	1	5	50	28	67	1	6
	52	30	65	1	6	55	29	62	1	5
	47	27	40	1	4	50	25	45	1	2
	40	28	45	1	5	45	25	50	1	3
	Averages									
	53	29	61	1.2	4	51	27	57	1.1	2.6

SL = scapholunate, RS = radioscaphoid, SL = scapholunate, CL = capitate-lunate

The final radiographic follow-up was recorded at an average of 20 months (range 6–84) post-procedure. There were no intra-operative or postoperative complications. All study participants returned to their pre-injury level of work activity.

DISCUSSION

Non-union of the scaphoid is generally defined as failure of radiographic evidence of union at 6 months after the injury. Anatomically, the complex three-dimensional shape, tenuous blood supply, and 80% cartilage covering of the scaphoid make effective management of non-unions challenging. Slade and Dodds [17] proposed a progressive classification for scaphoid non-unions [Table 2]. This classification is a useful guide to determine the applicability of minimally invasive procedures for scaphoid non-unions [18]. Minimally invasive surgery is indicated in early scaphoid non-unions without substantial cystic bone resorption, without appreciable collapse of the scaphoid architecture, and without clear avascular necrosis of the proximal pole (grades 1–4). Additional inclusion criteria for percutaneous treatment of these non-unions should be an intact external cartilaginous shell and intact and normal scapholunate angle without a humpback deformity [18]. The integrity of the cartilage shell can be evaluated by arthroscopy, as done by Slade and Geissler [15] or by a magnetic resonance imaging study. In our series, if the external architecture appeared normal on plain X-ray, with no collapse or shortening, we felt that the peripheral bony anatomy of the scaphoid was intact. In grade 5 non-unions, open bone grafting is often indicated to fill the gap after debridement of a large devitalized zone. Grade 6 non-unions require an open approach with structural or vascularized grafts [18]. Cases with complete avascular necrosis of the proximal pole would often be better treated with some type of open vascularized grafting.

Table 2. Classification system for scaphoid non-union

Grade	Category	Characteristics of scaphoid non-union
1	Delayed presentation	Scaphoid fractures with delayed presentation (4–8 wk)
2	Fibrous non-union	Intact cartilaginous envelope, minimal fracture line at non-union interface, and no cyst or sclerosis
3	Minimal sclerosis	Bone resorption at non-union interface < 1 mm with minimal sclerosis
4	Cyst formation and sclerosis	Bone resorption at non-union interface < 5 mm, cyst formation, and maintained scaphoid alignment
5	Cyst formation and sclerosis	Bone resorption at non-union interface > 5 mm and < 10 mm, cyst formation, and maintained scaphoid alignment
6	Pseudoarthrosis	Separate bone fracture fragments with profound bone resorption at non-union interface. Gross fragment motion and deformity is often present

Percutaneous fixation of scaphoid fractures with cannulated screws was first performed in 1962 in Germany by Von R. Streli via a small volar incision [19]. Slade [15] pioneered dorsal percutaneous fixation with a headless cannulated screw using mini-fluoroscopy. Percutaneous techniques have resulted in faster recovery time and decreased duration of cast immobilization in acute scaphoid fractures, compared with non-surgical management. Bond et al. [9] in a prospective randomized study compared percutaneous fixation of acute fractures (11 patients) with cast immobilization (14 patients). They demonstrated an earlier time to union (7 weeks vs. 12 weeks)

and earlier return to work (8 weeks vs. 15 weeks with casting) with percutaneous fixation. Another prospective randomized trial of 60 patients with acute fractures of the scaphoid showed faster radiologic union (9.2 weeks vs. 13.9 weeks, $P < 0.001$) and a more rapid return of function with percutaneous screw fixation as compared to cast immobilization [20].

Percutaneous screws can be placed either by a volar or dorsal approach. The decision when choosing the approach is generally dependent on the fracture location and surgeon preference. For more proximal fractures a dorsal approach is recommended, with the screw being placed in an antegrade direction. This approach facilitates optimal screw placement in the central part of the proximal pole, ensuring good compression and better stability. Disadvantages are that the wrist must be hyperflexed and thus the guidewire may be inadvertently bent, and extensor tendon injuries can occur [21]. Conversely, for waist and more distal fractures, a volar approach is often preferred with the screw being placed from distal to proximal within the scaphoid [22]. The wrist can be placed in a comfortable supinated position and does not need to be placed in extreme flexion or extension for guidewire placement. Among the disadvantages are the potential need to remove some of the trapezium and greater difficulty placing the wire centrally in the proximal pole of the scaphoid.

Recent publications report the use of percutaneous techniques in the treatment of delayed and non-unions of the scaphoid. Wozasek and Moser [23] described 25 cases with delayed union and 8 with established non-unions treated with a percutaneous dorsal approach. Bony healing was achieved in 27 cases (81.8%) after a mean postoperative time of 82 months. In another study Ledoux and co-authors [24] reported a 100% union rate and a rapid return to work in 19 patients with acute fractures and 4 with non-unions managed with percutaneous screw fixation. Slade et al. [15] evaluated 15 patients with a fibrous or non-union of the scaphoid treated with arthroscopic examination and dorsal percutaneous fixation with a headless screw without bone graft. Computed tomography scans were performed at approximately 4–6 weeks postoperatively and then repeated every 6 weeks until union was achieved. All 15 fractures healed with the average time to union of 14 weeks with no complications. They noted that the time to union was substantially less in fractures treated within 6 months of injury (10.8 weeks) compared to those treated later (16 weeks, $P < 0.02$). Recently Kim et al. [16] treated 12 patients with scaphoid waist delayed union using the volar percutaneous approach. All fractures united uneventfully with a mean DASH score of 9.

Scaphoid fractures that progress to non-union can present as difficult clinical scenarios that may require complex management techniques. In our series, 12 established scaphoid non-unions were treated initially with percutaneous means without supplementary bone grafting. Eleven of the 12 had healed after the initial operative intervention, and the remaining patient healed after revision fixation with a larger screw and percutaneous bone grafting. These techniques can avoid the morbidity of an open approach and division of the carpal ligaments. In addition, advanced bone grafting materials and techniques may allow us to expand the indications for this percutaneous technique for treatment of difficult scaphoid non-unions.

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