Published in final edited form as:

J Hand Surg Am. 2016 February ; 41(2): 203–207. doi:10.1016/j.jhsa.2015.11.006.

Radiographic Parameters to Predict Union after Volar Percutaneous Fixation of Herbert Type B1 and B2 Scaphoid Fractures

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Abstract

Purpose—To study the angle of screw placement in relation to the scaphoid fracture plane and its effect on union after percutaneous fixation of scaphoid waist fractures.

Methods—Twenty-four consecutive scaphoid waist fractures were retrospectively evaluated for the orientation of screws in relation to the fracture plane using a method in which the sum-of-smaller angles (SSA) in three different radiographs were used to correlate with time to fracture union.

Results—All but one patient achieved union after percutaneous fixation of the scaphoid. One other patient required revision surgery within the study period for inadequate fixation. A shortened time to union was significantly correlated to larger sums of small angles (SSA).

Conclusion—SSA may be a reasonable predictor of union after percutaneous fixation of scaphoid waist fracture. It can be reliably calculated using plain radiographs. An SSA of 190 degrees or more correlated with union by eight weeks post operatively.

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Level of evidence—Prognostic Retrospective level IV**Keywords**

scaphoid; waist; fracture; percutaneous; union

INTRODUCTION

The scaphoid is the most frequently fractured carpal bone with an estimated annual incidence of 43 fractures per 100,000 people (1, 2). One widely used fracture classification system, described by Herbert and Fisher, subdivides unstable fractures (B type) into oblique waist (B1) and transverse waist (B2) (3). The B1 oblique type occurs along the dorsal oblique sulcus of the scaphoid, and the B2 transverse type occurs directly across that sulcus as Campson described (4).

Little information exists which can predict the healing time of an unstable fracture treated operatively despite the well documented understanding that operatively treated unstable scaphoid fractures are more likely to heal than those treated without surgery (3).

There is a common understanding that the best hardware position for fixation of a fracture is perpendicular to the fracture plane. For the scaphoid the goal is to place the screw along the bone's long axis (5). This allows the screw to exert maximal compression and minimal shearing forces, thereby optimizing stability (6, 7). No data clearly favors volar or dorsal percutaneous approach for the ability to place the screw perpendicular the fracture line in one or another type of fracture (7, 8).

There are many ways to scrutinize the plane of the fracture in relation to fixation hardware including standard radiographs (9), CT (10), and theoretically magnetic resonant imaging. We hypothesized that a measurement of the relationship between the angle made by the screw and the fracture plane on multiple simple views of the scaphoid after surgery could be combined to provide a reasonable index of perpendicular orientation, which, in turn, would relate to the time to union after fixation. We retrospectively analyzed consecutive cases under our care - all treated with a single volar percutaneous approach - to test this hypothesis in the setting of a relatively uniform group of patients affected with unstable isolated scaphoid fractures.

MATERIALS AND METHODS

Institutional review board approval was obtained for this study, which included the retrospective evaluation of cases involving percutaneous fixation of closed scaphoid fractures in patients under the care of a single surgeon. Scaphoid fractures were classified using the Herbert classification (3) and excluded if treatable non-operatively (stable fractures, Type A) or associated with other fractures in the carpus or the radius (unstable Type B4 injuries) or isolated to the proximal pole of the scaphoid (Type B3). Consecutive patients were included if they had simple, non-comminuted, closed fractures of the scaphoid that could be treated with standard percutaneous technique using cannulated screws (Herbert and Fisher type B1 and B2 fractures).

Twenty-four cases with isolated unstable scaphoid waist fractures were included in this study (type B1 n=4 and type B2 n=20). All patients were non-smokers, and none had a history of poor healing in the past or a co-morbidity that would delay healing. All cases were treated with the volar percutaneous placement of a single cannulated screw in the best possible position that could be achieved by the operative surgeon. We first applied the guide wire to the volar aspect of the trapezium (best visualized by the pronation oblique view) and then advanced retrograde through the scapho-trapezial articulation. Then we advanced the wire parallel to the volar cortex of the scaphoid (best visualized by the supination oblique view). The scapho-capitate joint was avoided by assessment of the anteroposterior ulnar deviation as the wire was further advanced into the center of the proximal pole. Then wrist was then flexed slightly to avoid penetration of the radiocarpal joint.

No case required an open approach, and no deviation from the standard technique was used in any patient during the study period. All cases were analyzed post-operatively on the same set of standard radiographs and followed biweekly until union. Consecutive patients were included, and one patient was excluded post-operatively after we discovered that the fixation of the the proximal fracture fragment was insufficient on initial post-operative radiographs.

Postoperatively patients were restricted from any loading, but no immobilization was used, and. patients were allowed immediate range of motion.

Radiographs were evaluated biweekly, and the orientation of screws was measured in relation to the fracture. Final confirmatory CT scans were obtained in all patients to confirm healing. Standard manual radiographic views of the scaphoid were used to best show the relationship between fracture and hardware (11-13). The angle made by the screw and the fracture in each of three standard radiographs (postero-anterior, 45 degree supination oblique, and 45 pronation oblique all in ulnar deviation) was measured, and the lesser of the two angles (the smaller angle, or acute angle made by the screw and the fracture) on each radiograph was added across all three images. This sum of the smaller or acute angles was termed the sum of small angles (SSA, Figure 1). The lateral projection was not used because of the difficulty in reliably assessing the fracture line when obscured by other bones. Three blinded surgeon-assessors independently measured the SSA, and the average value was recorded (Table 1). The SSA correlated with the time to documented fracture union on bi-weekly radiographs. Once this correlation coefficient was obtained and statistically analyzed using the Pearson correlation coefficient, the SSA for which union could reliably be expected within eight weeks was calculated as the SSA that predicted union by this time point.

RESULTS

The mean time to final radiologic follow up was 26 months (range 24-28 months). Twenty-three of 24 scaphoids (96%) achieved union at a mean time of 7.7 weeks (range 6-12 weeks). One fracture had not by 24 months after the index procedure (Case 1, Figure 2).

The average sum of small angles (SSA) in all cases was 199 degrees (range 105-260, SD=29). The individual measurements on the standard postero-anterior radiograph with the

wrist in ulnar deviation revealed a mean acute angle of 79 degrees (range 30-90, SD=15, Table 1). The corresponding measurements on 45 degree pronated and supinated oblique views were 62 degrees (range 30-90, SD=18) and 58 degrees (range 40-90 degrees, SD=15) respectively. In case 1, where union was not achieved by 24 months, the SSA was 105°. The SSA negatively correlated with the length of time before union was achieved (Pearson correlation coefficient between SSA and time of persistent non-union, $r = -0.76$, $P < 0.001$). This indicated a strong and significant relationship between the measured sum of smaller angles and the speed of fracture healing. According to this analysis, an SSA value of 190 degrees or more predicted healing by eight weeks.

DISCUSSION

Scaphoid waist fractures are commonly treated operatively and may benefit from precise screw placement perpendicular to the fracture plane. The relationship between operative approach and the angle achieved by the screw has been the subject of some debate (14). Some approaches to the scaphoid prevent free placement of the screw in a position that can be perfectly perpendicular to all fracture planes. For example, it has been shown that the ability to place a screw down the center of the scaphoid from the volar approach is dependent on placing the initial guide wire into the trapezium from the volar approach as the middle of the bone is not collinear with the tuberosity (5, 15). With time-to-union and related outcomes likely improved with operative fixation in a subset of scaphoid fractures (Herbert and Fisher type B1 and B2), the optimal measure of the quality of fixation may be a predictor of the likelihood of union (7). In all cases, there is no clear single approach which offers the benefit of allowing the placement of a screw perpendicular to every fracture, and all approaches hinder the placement of screws at some angles (1, 2, 3, 16-19). There is no evidence suggesting that one of these approaches is associated with fewer complications (14). This is true even when the complication is considered delayed union or non-union.

Soubeyrand et al compared the dorsal and volar surgical approach for percutaneous fixation of the scaphoid with respect to the sagittal orientation of the fracture (B1 or B2 in Herbert and Fisher's classification scheme) using computer modeling of cadaveric wrists. They found that virtual screw placement perpendicular to the fracture could be achieved for B2 fractures equally well from either approach. For B1 fractures, the virtual screw could not be placed strictly perpendicular to the fracture with either approach, but the dorsal approach with maximal wrist flexion allowed the best screw placement (14).

In a biomechanical study, Faucher et al noted that in an oblique scaphoid fracture, a screw placed perpendicular to the fracture plane could be shorter in length but preserve the strength of fixation when compared to a screw placed centrally (20).

We reasoned that a rational method for assessment of scaphoid fixation angle would allow the prediction of healing time from any surgical approach. We benefitted from a standardized surgical intervention employed in all of these patients that used only the percutaneous volar approach. Hence there was little soft tissue disruption of blood vessels critical for healing. The assessment we chose is both inexpensive and accessible to all surgeons using standard radiographs.

We were particularly attracted to our method of measuring angles because, if effective, it could then be used to assess the placement of wires for preliminary fixation in the operating room prior to screw placement. In this way, a measurement, if found to predict healing time, could be used to discard screw placements that could delay union.

The ultimate value of any measure used to assess scaphoid fixation lies in the ability to either predict union or predict complications. Any measure able to satisfy either of these two goals is only applicable insofar as it is inexpensive and easy to assess, preferably in the operating room. The strength of this study was the use of a simple measurement of angles that were taken from three relatively inexpensive radiographs.

The weaknesses of this study include the lack of randomized and prospective application of this measure in patients. Another limitation was the inability to obtain CT scans every two weeks to follow fractures to union. However, CT scans may be the optimal tool to assess union, it cannot be repeated frequently (21). This is not routinely done in the treatment of scaphoid fractures and such exposure to radiation might be detrimental. One feature of our series was the unrestricted postoperative mobilization. This may serve as a weakness when viewed from the vantage point that many surgeons place their patients in orthoses or casts for variable amounts of time after surgery. Those surgeons would naturally doubt the applicability of our findings to their practice. However our patients healed, on average, within the timeframe of those treated in other studies where post-operative immobilization is routinely used. This may mean that the immobilization acts as a confounder but may not add to the healing after adequate hardware placement.

ACKNOWLEDGES

support by NIH K08 AR060164-01A

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Figure 1.
The relation between the screw and the fracture site as detected in PA view with maximum ulnar deviation (left), pronation oblique view (middle) and supination oblique view (right).

Figure 2.
Postero-anterior radiograph in ulnar deviation showing nonunion two years after percutaneous screw fixation of B1 type fracture of the waist (Case 1)

Table 1

Calculation of the Union Predictor Index (UPI) (the sum of three angles) in the study patients.

Cases	PA with ulnar deviation	450 pronation oblique	450 supination oblique	Sum of small angles	Time to union	Type
1	30	30	45	105	Nonunion (24 mos)	B1
2	90	90	45	225	6	B1
3	50	55	60	165	8	B2
4	90	70	60	220	8	B2
5	60	30	80	170	8	B1
6	80	60	80	220	8	B2
7	80	70	40	190	12	B2
8	80	70	45	195	8	B2
9	70	60	80	210	6	B2
10	70	50	90	220	8	B2
11	70	90	40	200	10	B2
12	90	90	45	225	8	B2
13	90	90	80	260	6	B2
14	90	45	60	195	6	B2
15	90	50	60	200	8	B2
16	70	80	40	190	10	B2
17	70	60	50	180	8	B2
18	90	70	60	220	6	B2
19	80	60	60	200	8	B1
20	90	45	45	180	8	B2
21	90	50	50	190	8	B2
22	90	45	70	205	6	B2
23	90	70	60	220	6	B2
24	90	60	50	200	8	B2