

The Functional Outcomes of Scaphoid Nonunion with Deformity Treated with Anterior Wedge Bone Grafting: A Case Series

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ABSTRACT

Introduction. Scaphoid nonunion is one of the most difficult fractures to treat. Restoration of carpal alignment and fracture stability can provide good outcomes in the management of scaphoid nonunion.

Objective. The purpose of this study was to determine the functional outcomes of scaphoid nonunion associated with humpback deformity treated with anterior wedge bone grafting and internal fixation.

Methods. A retrospective review of all patients with scaphoid nonunion treated with anterior wedge bone grafting from January 1, 2014 to December 31, 2019 was done. Outcome measurements were time to union, pre- and post-operative FIL-DASH scores, grip, pinch, and scapholunate angle improvement. The other outcome measures were pain and complications.

Results. A total of 12 patients were included in the study. All were males with an average age of 27.4 years (SD, 9.6). The average delay to surgery was 9.5 months (SD, 10). All fractures were at the waist, except for three proximal pole fractures, none had established avascular necrosis. Eleven out of 12 scaphoids healed at an average of 11.5 weeks (SD, 3.2). There was a significant improvement in the FIL-DASH score and scapholunate angle after surgical reconstruction. Grip strength averaged 83% of the contralateral side. All returned to previous normal activities. One patient with persistent proximal pole nonunion was managed with a 4-corner arthrodesis.

Conclusion. Anterior wedge bone grafting for scaphoid nonunion restored the scapholunate angle and was able to establish union in 11 of 12 scaphoid nonunions with good outcomes.

Keywords: anterior wedge iliac crest bone grafting, internal fixation, functional outcome, scaphoid nonunion

INTRODUCTION

Most of the scaphoid fractures heal, however 10% can go into nonunion.¹ The diagnosis of scaphoid nonunion is important since delay in the diagnosis and treatment is one of the factors for decreased union rate.² In established nonunion of the scaphoid with deformity, stress during hand loading will result to a cascade of events and over time, patients will experience decreased range of motion, weakness in grip and decreased functional capacity as the fracture nonunion goes to a humpback deformity, altering the kinematics of the carpus leading to scaphoid nonunion advanced collapse.³

The treatment options for scaphoid nonunion vary from percutaneous fixation to open reduction with vascularized or non-vascularized bone grafting.^{2,3} Unstable nonunion has abnormal carpal alignments suggested by the presence of

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scaphoid shortening, humpback deformity and DISI (dorsal intercalated segment instability) deformity, while stable nonunion does not have these characteristics.⁴

The management of scaphoid nonunion with deformity should address both the deformity and union by using a strut graft to provide immediate stability, at the same time providing cancellous bone graft to achieve union. The modified Matti-Russe method⁵, hybrid Russe method⁶ and the use of an anterior wedge bone grafting⁷⁻⁹ have been reported with variable success rates of union and restoration of function. Recently, some authors have reported the use of pure cancellous bone grafting alone with internal fixation for unstable nonunion.^{10,11} In a comparative study on the treatment of unstable scaphoid nonunion with cortico-cancellous bone grafting versus cancellous grafting only showed similar union rates, postoperative range of motion, and correction of carpal alignment, but the cancellous only bone grafting has a shorter union time (11 vs. 15 weeks).¹¹

The objective of this study was to investigate the functional outcomes of scaphoid nonunions with deformity treated with anterior wedge bone grafting and internal fixation.

METHODS

A retrospective review of all patients diagnosed with scaphoid nonunion from January 1, 2014 to December 31, 2019 was done. Inclusion criteria include all cases of established nonunion with deformity diagnosed with x-ray and/or with plain CT scan, treated with anterior wedge bone grafting, and with at least six months follow-up. Exclusion criteria included patients with bilateral injuries, other injuries in the same extremity, and those treated with

artificial bone grafting other than the anterior wedge bone grafting, and patients not capable of answering the Filipino Version of the Disability of the Arm, Shoulder and Hand (FIL-DASH) questionnaire.

Surgical Technique

General anesthesia was used in all cases and all cortico-cancellous bone grafts were harvested from the iliac crest except for one case (distal radius). The standard volar approach to the scaphoid was done. The fracture line was usually covered with cartilage and fibrous tissue and this was debrided to expose the fracture gap. Two K-wires were applied in the distal and proximal pole to serve as joysticks or a dental pick and to open up the fracture site for adequate debridement (Figure 1). Once the fracture site was debrided, the tourniquet was released to assess punctate bleeding of the proximal and distal poles of the scaphoid. In all patients, the proximal pole exhibited punctate bleeding, thus none were diagnosed with avascular necrosis. The size of the graft was determined after fracture site debridement and when the distal pole of the scaphoid was extended using a K-wire as joystick. The size of the required bone graft was measured and verified with the correction of the scapholunate angle or lunate dorsiflexion with image intensification. In this maneuver, we measure the scapholunate angle, correct the lunate to neutral, and measure the graft thickness anteriorly to finalize the size of the cortico-cancellous graft (Figures 2A and B). If after graft fixation there was still residual DISI deformity, we reduce the lunate to neutral by extending the wrist and place a dorsal radio-lunate pin to keep the lunate in place for 6 weeks.

In one proximal pole fracture, the anterior wedge bone graft was applied anteriorly with retrograde application

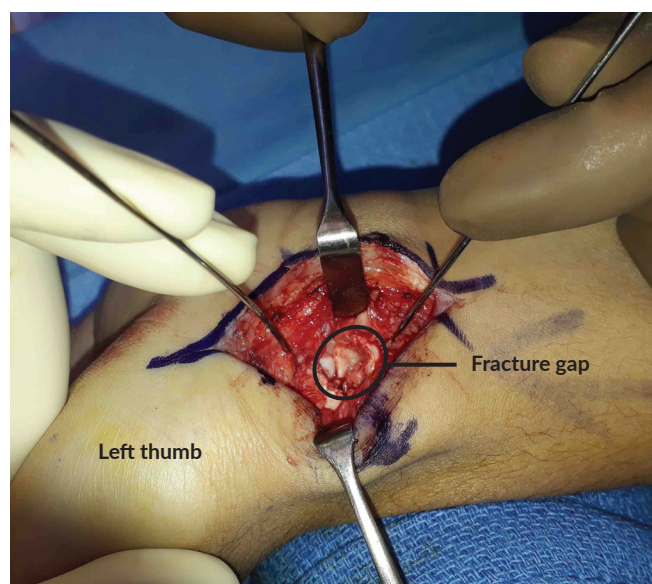


Figure 1. Use of K-wires as joysticks to expose the nonunion fracture gap.

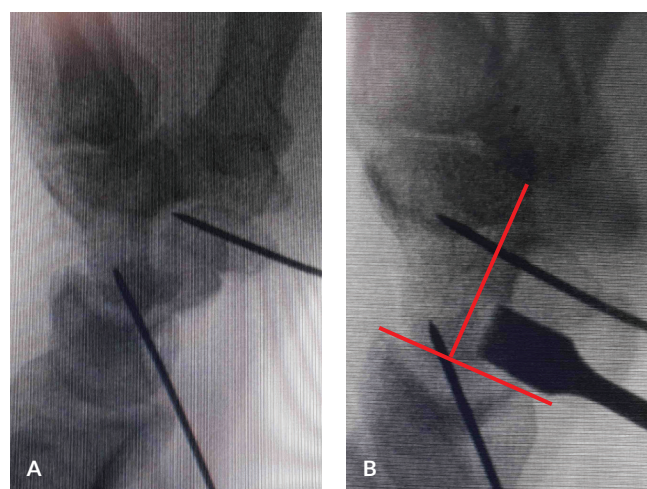


Figure 2. (A) K-wires used as joysticks to extend the scaphoid and correct the lunate to neutral. (B) An osteotome of 1 cm width was used to measure the anterior thickness of the graft which corrected the lunate to neutral and normal scapholunate angle.

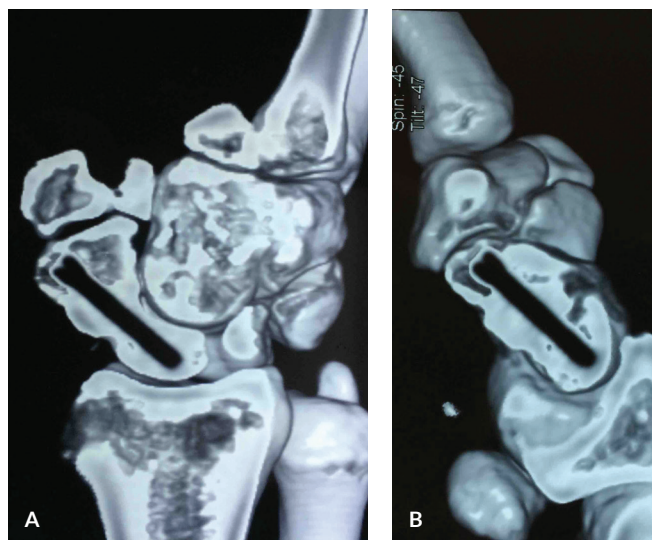


Figure 3. (A) Coronal CT scan of >50% union of scaphoid. (B) Sagittal CT scan also showing >50% union of scaphoid.

of the guide pin, but the screw was percutaneously applied dorsally. All patients had a headless screw fixation done except for two patients where multiple 0.045 k-wires were used as internal fixation for the anterior wedge bone grafting.

All patients were immobilized with a splint for 7-10 days to allow swelling to subside and suture removal. A short arm thumb spica cast was applied after serial x-rays were taken at 2, 4 and 6 weeks, and at 8-10 weeks, a CT scan was requested to confirm union. Fracture union was assessed if $\geq 50\%$ trabecular crossing was observed on CT scan (Figures 3A and B). The cast was then removed and physical therapy was started to regain motion and strength.

Outcomes Assessment

The outcomes of interest were time to union, post-operative grip strength, range of motion, pain, scapholunate angle for the wrist, FIL-DASH scores and complications. Assessments were done every month and the results reported on the most recent follow-up was included. Grip strength was measured using a standard dynamometer. The mean grip was taken three times for both hands and the mean taken. Range of motion was taken using a standard goniometer for both wrists. These measurements were expressed as a percentage of the normal side. Pain was measured using the visual analogue scale (VAS) of 0-10. The scapholunate angles were measured using radiographs of the wrist using a standard goniometer.

The FIL-DASH Questionnaire

Functional outcome was measured using the FIL-DASH score. The scoring system is a self-administered, region-specific outcome measure developed to assess self-rated upper extremity disability and symptoms.

This is a 30-item disability/symptom scale and is scored from 0 (no disability) to 100.

Descriptive analysis of the patient demographic, time of union, pre-operative and post-operative radiographs, and post-operative scapholunate angles were determined. Continuous data were expressed as means, standard deviation and ranges. Categorical variables were described using frequency and percentages. Mann-Whitney U-test was used to compare continuous variables. A p-value of less than 0.05 was considered to be statistically significant.

RESULTS

All patients were male with a mean age of 27.4 years (range, 16-44). The dominant hand was involved in four patients. One patient was involved in heavy manual labor, one was a professional rugby player, one an amateur boxer, and one was an amateur football player, while the rest were students and office-type workers. The mean delay to surgery was 9.6 months (range, 2-36).

Fracture description

All scaphoid nonunions were at the waist except for three which were proximal pole nonunions. Three nonunions presented with cysts formation while two presented with sclerosis of the fracture ends. All had pre-operative CT scans which showed a "humpback" deformity and scaphoid shortening. The DISI has a mean pre-operative scapholunate angle of 75.6° (range, 65° - 90°). Preoperative planning consisted of an x-ray measuring the contralateral scaphoid to assess scaphoid length and shortening.

The mean follow-up for all patients after cast removal was 23.8 months (range, 6-72). There was a significant improvement in the FIL-DASH score from a mean of 30.1 (SD, 17) to 6.4 (SD, 4.7), ($p = 0.001$). There was also a significant improvement in the mean pre-operative scapholunate angle from 75.6° (SD: 9°) to 51° (SD, 5°), $p = 0.001$. A summary of the clinical outcome is summarized on Table 1.

Complications

On latest follow-up (22 months post cast removal), Patient 2 has some CT scan signs of radio-scaphoid arthritis (Figure 4), but this was mild with a pain score of 2. His FIL-DASH score is 15. Patient 9 had a retained pin. He has a proximal pole fracture which united after 20 weeks (Figures 5A and B). On latest follow-up at 19 months post-cast removal, his pain score was 2, and FIL-DASH score was 5.9. He was able to return to playing football. Patient 10 had a proximal pole fracture with only 2 months surgical delay but already presented with cysts formation, DISI and humpback deformity (Figure 6). The proximal pole fracture had persistent non-union after anterior wedge bone grafting with radio-scaphoid arthritis on CT scan. A scaphoid excision with four-corner fusion was done 10 months after index surgery, using K-wires with bone grafting with good

Table 1. Demographics and Clinical Outcome of Anterior Wedge Bone Grafting for Scaphoid Non-union

Patient	Age (years)	Delay (months)	Location	Grip* (%)	Pinch* (%)	WF* (%)	WE* (%)	SLA (degrees)		Time to Union (weeks)	VAS	FIL-DASH		Other findings	Follow-up (months)
								Pre-op	Post-op			Pre-op	Post-op		
1	16	3	waist	92	100	100	78	90	55	10	0	50.8	9.2	-	12
2	27	15	waist	100	100	57	67	70	60	10	2	30	15	Mild RSA	22
3	44	6	waist	80	85	85	87	65	45	10	4	72.5	6.3	-	12
4	36	3	waist	83	93	100	92	70	45	10	0	15	2	-	12
5	24	5	waist	85	90	86	87	87	50	10	4	21	15	-	33
6	42	4	waist	79	63	83	92	70	60	10	0	36.7	4.2	-	12
7	31	14	waist	89	100	48	59	65	45	12	0	25	2.5	-	36
8	22	7	waist	90	100	90	85	75	50	10	0	75	1	-	53
9	18	2	PP	99	100	79	86	80	50	20	2	31	5.9	Retained pin	18
10	19	2	PP	42	85	54	78	70	55	-	3	27.5	8	Nonunion	24 ^s
11	32	36	waist	81	96	83	73	90	49	9	0	16.3	5	-	6
12	18	18	PP	65	90	80	83.3	75	55	15	0	20.8	1.7	-	9
Mean	27.4	9.6	-	82	92	82	81	76	51	11.5	1.3	30.1	6.4	-	23.8
SD	9.6	10.1	-	15.6	11	14	10	9	5	3.3	1.6	17	4.7	-	20.9

*Percentage of contralateral side; SLA - Scapho-lunate angle; FIL-DASH - Filipino DASH; RSA - Radial-Scaphoid Arthritis; PP - Proximal Part of scaphoid fracture; ^snot included in the mean; SD - Standard deviation



Figure 4. Mild radio-scaphoid arthritis (radial side of scaphoid and radial styloid). There is sharpening of the radial styloid (red circle).

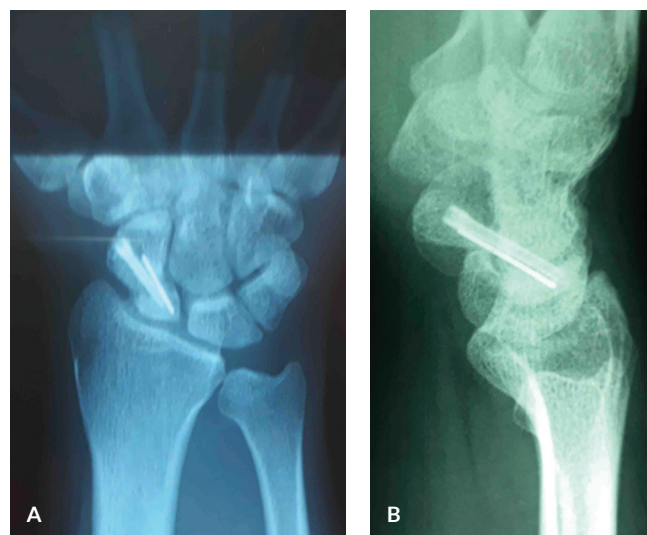


Figure 5. (A and B) A retained pin in a proximal pole nonunion with good union at 19 months follow-up.

union at 24 months follow-up. The FIL-DASH score was 8 (Figures 7A, B and C).

A representative case of a 36-year-old male with a 3-month history of a fall with collapse and humpback deformity was shown in Figure 8. Preoperative CT scan of the scaphoid showed a flexed, humpback scaphoid. Radiograph and CT of postop scaphoid showed union of >50%. Anterior wedge bone grafting was done.

DISCUSSION

In this small series of scaphoid nonunion with deformity, bony union was achieved using anterior wedge

bone grafting and internal fixation in 11 of 12 patients with significant improvement in the FIL-DASH score and scapholunate angle. All patients in this case series had no prior treatment for scaphoid nonunion. In all patients, there was shortening of the scaphoid with angular or humpback deformity and increased scapholunate angle on preoperative CT scan. Three of the 12 cases were located on the proximal pole and one went into persistent nonunion.

The goal of scaphoid nonunion treatment with deformity was to achieve union, and to correct the deformity with stable fixation to avoid fracture movement. In established nonunion, bone grafts have been frequently used to enhance union.^{2,12} In two systematic reviews, the use of



Figure 6. Scaphoid nonunion with cysts formation, DISI deformity and a scapolunate angle of 78°.

vascularized and nonvascularized bone grafts for scaphoid nonunion had similar union rates. However, the systematic reviews did not mention the presence of deformity in the scaphoid nonunions. In those nonunions with deformity, the correction of the deformity has been known to stabilize the fracture nonunion to promote stability.¹³⁻¹⁷ Several methods to correct the deformity has been reported in literature. These include structural bone graft such as the anterior wedge bone grafting¹³⁻¹⁸ or non-structural bone grafting.^{10,18} Other non-structural bone grafting made use of a volar plate to provide immediate stability.¹⁹

In this small case series, we used a nonvascularized anterior wedge bone graft to provide immediate stability to correct the humpback deformity and fixed with a compression headless screw in all except one (fixed with k-wires). One of the advantages of using a cortico-cancellous bone graft was it provided immediate stability by correcting the humpback deformity and restoring length.^{7,15} Union rates have been high with this technique, which ranges from 86-93%.^{8,9,17} In 2014, a systematic review²⁰ investigated the use of cortico-cancellous bone graft versus cancellous only bone graft in scaphoid nonunions for correction of DISI deformity, union rate and functional scores. Their results showed that in both types of grafts, the union rates were similar, but the cortico-cancellous grafts had significantly longer union time (16 weeks vs 11 weeks) but with statistically improved scapholunate, interscapoid and radiolunate angle correction compared to cancellous grafts only. They concluded that in larger defects with significant carpal collapse, a cortico-cancellous graft may be more appropriate.

The high union rate of the cortico-cancellous bone grafting in this series may be due to the vascularity of the proximal fragment on intraoperative assessment, surgical delay of less than 5 years, and no previous surgeries. In this case series, the union rate was 11/12 or 92%. This was similar to the union rates reported by other authors who used a tricortical or cortico-cancellous bone graft.^{7-9,14,21,22} Daly, et al.⁷ found that in their series, the presence of previous surgery and correction of deformity were related to outcome. Schuind, et al.²³ reported in a multicenter study that a surgical delay of >5 years significantly decreases the chances of union. In this case series, none of the patients had >5 years surgical delay, the longest being only 3 years (36 months). In two cases, we



Figure 7. (A) A Persistent nonunion of the proximal pole with implant failure and displacement of graft at 2 months post-op. (B) Persistent nonunion of the proximal pole after removal of screw due to screw penetration and erosion of the radial scaphoid fossa (red arrowheads). (C) Scaphoid excision with 4-corner fusion (at 6 months). Notice scaphoid fossa erosion (red arrowheads).

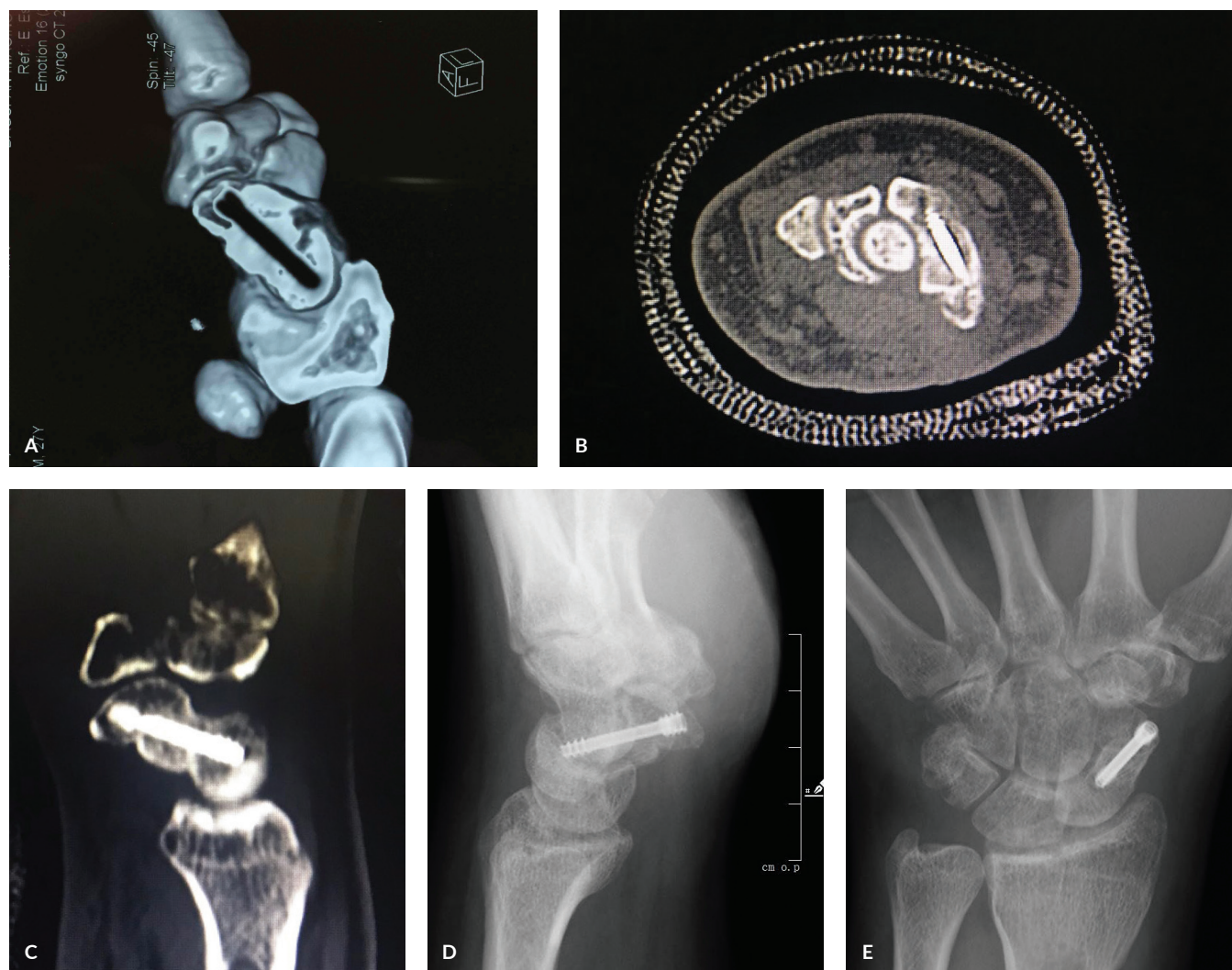


Figure 8. (A) A representative case with humpback deformity on CT scan. (B and C) Post-op CT scan at 10 weeks showed >50% scaphoid union. (D and E) Antero-posterior and lateral views post-op at 10 weeks follow-up.

had 2 months surgical delay and another two cases, 3 months. The two months delay were proximal pole fractures. Since all had DISI with humpback deformity, an anterior wedge bone grafting seemed to be the best choice to achieve correction of the deformity, to restore normal carpal mechanics and at the same time induce union through cancellous bone grafting. The use of a rigid screw or multiple K-wires added stability to the scaphoid reconstruction and promoted healing. In a systematic review by Pinder, et al.,² the nonunions fixed with a screw or k-wires were similar in terms of union rates (88%, screws vs. 92%, k-wires) but both were significantly superior to no fixation (79% union rate). We also think that the use of a rigid fixation provided stability for the union to take place. One other study that uses a cortico-cancellous graft for nonunion was that of Lee, et al.,⁶ which used a modified Matti-Russe technique where a cortical strut graft from the distal radius was taken and inserted into the cavity of the scaphoid and then stabilized with a headless screw.

In their series of 17 patients, all nonunions united with restoration of abnormal carpal angles to normal. This single sided cortical graft can provide some stability, the screw placement will provide rigid stability. This method is a good alternative to the anterior wedge bone graft. However, in larger defects anteriorly, this method may not be enough to bridge the anterior cortical defect.

The limitations of the present study include the small population size, the retrospective nature, and the missing preoperative data such as range of motion, grip, and pain in some patients. Also, a longer-term follow-up may be needed to assess the longevity of the carpal alignment and wrist motion. One of the strengths of the study was that healing of the fractures were documented using a CT scan where at least 50% of scaphoid union was appreciated in multiple planes as opposed to x-ray only. Also, we were able to document pre and postoperative FIL-DASH scores in all patients, as well as the scapholunate angle and DISI correction.

CONCLUSION

Based on this study, we recommend the use of the anterior wedge bone grafting in cases of complex scaphoid nonunion with humpback deformity and associated DISI deformity. Union rate is high and correction of the deformity improves functional FIL-DASH scores.

Statement of Authorship

EPE contributed in the conceptualization of work, acquisition and analysis of data, and drafting and revising; ERDM contributed in the conceptualization of work and initial draft.

Author Disclosure

Both authors declared no conflicts of interest.

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None.

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