SCIENTIFIC ARTICLE

Hybrid Russe Procedure for Scaphoid Waist Fracture Nonunion With Deformity

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Purpose To assess the results of a hybrid Russe procedure using a corticocancellous strut, cancellous autologous nonvascularized bone graft, and cannulated headless compression screw to reduce the deformity reliably from a collapsed scaphoid nonunion, provide osteoinductive stimulus, and stabilize the fracture for predictable union.

Methods A hybrid Russe procedure was performed for scaphoid waist fracture nonunions with humpback deformity and no evidence of avascular necrosis. A volar distal radius autologous bone graft was harvested and a strut of cortical bone was fashioned and placed into the nonunion site to restore length and alignment. We packed cancellous bone graft in the remainder of the nonunion site and fixed the scaphoid was with a headless compression screw. Union was determined by radiographs or computed tomography, and intrascaphoid, scapholunate, and radiolunate angles were calculated on final radiographs. We recorded wrist range of motion, grip strength, pinch strength, pain, and complications.

Results Fourteen male and 3 female patients (average age, 32 years; range, 16–78 years), with a mean follow-up of 32 months, were examined clinically and radiographically. All 17 scaphoids united with a mean time for union of 3.6 months. The mean postoperative intrascaphoid angle was significantly reduced from 65° preoperatively to 35° postoperatively. The mean radiolunate angle was significantly improved from 20° from neutral (lunate tilted dorsally) preoperatively to 0° postoperatively. The scapholunate angle also demonstrated significant improvement from 70° preoperatively to 56° postoperatively. Grip strength improved from 70% of the contralateral hand to 89% after the procedure. All patients were satisfied with the functional outcome and no donor site morbidity or hardware issues were identified.

Conclusions This straightforward hybrid Russe technique predictably restored radiolunate, scapholunate, and intrascaphoid angles with a 100% union incidence. The technique provides excellent functional results in patients with a challenging clinical problem, and we recommend it for scaphoid fracture waist nonunions with dorsal intercalated segment instability deformity. *(J Hand Surg Am. 2015;■(■):■–■. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Fracture, humpback deformity, modified Russe, nonunion, scaphoid.

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Treatment of scaphoid nonunion with carpal collapse presents a unique challenge for hand surgeons. Although scaphoid union is the primary concern, surgeons must also be wary of scaphoid malalignment because the failure to recognize and treat all components of the deformity can result in progressive degenerative arthritis.[1–3]

Important principles that govern the treatment of scaphoid nonunion include excision of the pseudoarthrosis, correction of malalignment, provision of a bridging bone graft, mechanical compression, and stable fixation.[4] In cases where the proximal pole remains vascularized, open reduction internal fixation of the nonunion combined with nonvascularized autologous bone graft remains the standard for treatment.[5,6] Numerous techniques of bone grafting and internal fixation have variable degrees of success.[7–12]

The so-called humpback or flexed scaphoid nonunion results from chronic volar bone loss and an intrascaphoid collapse deformity with resultant dorsal tilt of the lunate (dorsal intercalated segment instability [DISI]). The humpback scaphoid is commonly repaired using an anterior iliac crest tricortical wedge graft and internal fixation. The use of an intramedullary screw has shown improvements in carpal instability and union in 71% to 100% of patients.[7,12–14] Intercalated wedge grafting can present technical challenges of sizing the graft, graft extrusion at the time of screw fixation, and donor site morbidity, primarily pain.[15] Pure cancellous grafting has the advantages of ease of access and rapid incorporation,[12] but it may lack sufficient mechanical strength to maintain anatomic scaphoid and lunate alignment.

In this study, we altered the Russe technique as modified by Green[8] using a single (rather than double) intramedullary cortical strut and obtained stable internal fixation with a cannulated compression screw. As described by Green, Russe[16] had many iterations of his technique, starting with using cancellous bone graft exclusively, then adding a cancellous plug from the iliac crest and cancellous chips, and finally using 2 back-to-back corticocancellous intramedullary iliac crest strut grafts. Green quoted Russe: “Cortical bone for stability, cancellous bone for osteogenesis!” Green reported his success using the modified Russe graft in an initial cohort of 48 patients receiving iliac crest graft and in a subsequent cohort of 6 using distal radius graft. None received internal fixation.

Our purpose was to present the surgical technique and clinical results of the hybrid Russe procedure to treat humpback scaphoid nonunion with DISI.

MATERIALS AND METHODS

Patients

We reviewed all skeletally mature patients from 2 institutions who had humpback scaphoid nonunion and DISI, had been treated with our hybrid Russe technique since 2006, and had a minimum of 6 months’ follow-up. The study was performed with approval by an institutional review board from each institution. We excluded any patient with osteoarthritis (scaphoid nonunion advanced collapse) or avascular necrosis. We defined waist fractures as those occurring in the central one third of the scaphoid. Iliac crest bone grafts were used in 3 patients who had received prior distal radius grafting.

Seventeen patients (14 male and 3 female; average age, 32 years; range, 16–78 years) were identified with an average follow-up of 32 months (range, 6–103 months). Five patients had failed previous scaphoid nonunion surgery. One male patient was lost to follow-up after 6 months of follow-up and was excluded from the analysis because of insufficient clinical data. A review of his chart demonstrated that he had healed clinically and radiographically at 8 weeks after surgery. There were no differences in age, time to union, or preoperative intercarpal angles of the missing patient compared with the remaining patients.

The operating surgeon performed all diagnostic imaging reviews and physical examinations (including range of motion and strength). A hospital radiologist who was not aware of the protocol of the study confirmed radiographic and computed tomographic (CT) evaluation of union. Research staff collected Patient-Rated Wrist Evaluation (PRWE) scores, Disabilities of the Arm, Shoulder, and Hand (DASH) scores, visual analog scale, and radiographic angle measurements.

Criteria for union included the absence of snuffbox tenderness and the presence of bridging trabeculae on the posteroanterior, scaphoid, lateral, and oblique wrist radiographs. Computed tomography was obtained in 12 of the 17 patients and confirmed union in each. Postoperative flexion-extension and radioulnar deviation were measured with a goniometer and compared with preoperative range of motion. Grip strength (Jamar dynamometer level II, Sammons Preston Rolyan, Bolingbrook, IL) and pinch strength (Biometrics Ltd, Gwent, United Kingdom) were compared with the contralateral side. Pain was assessed using a visual analog scale (0 = no pain; 10 = the worst pain imaginable). Patient-Rated Wrist Evaluation and DASH scores were completed at the final follow-up.

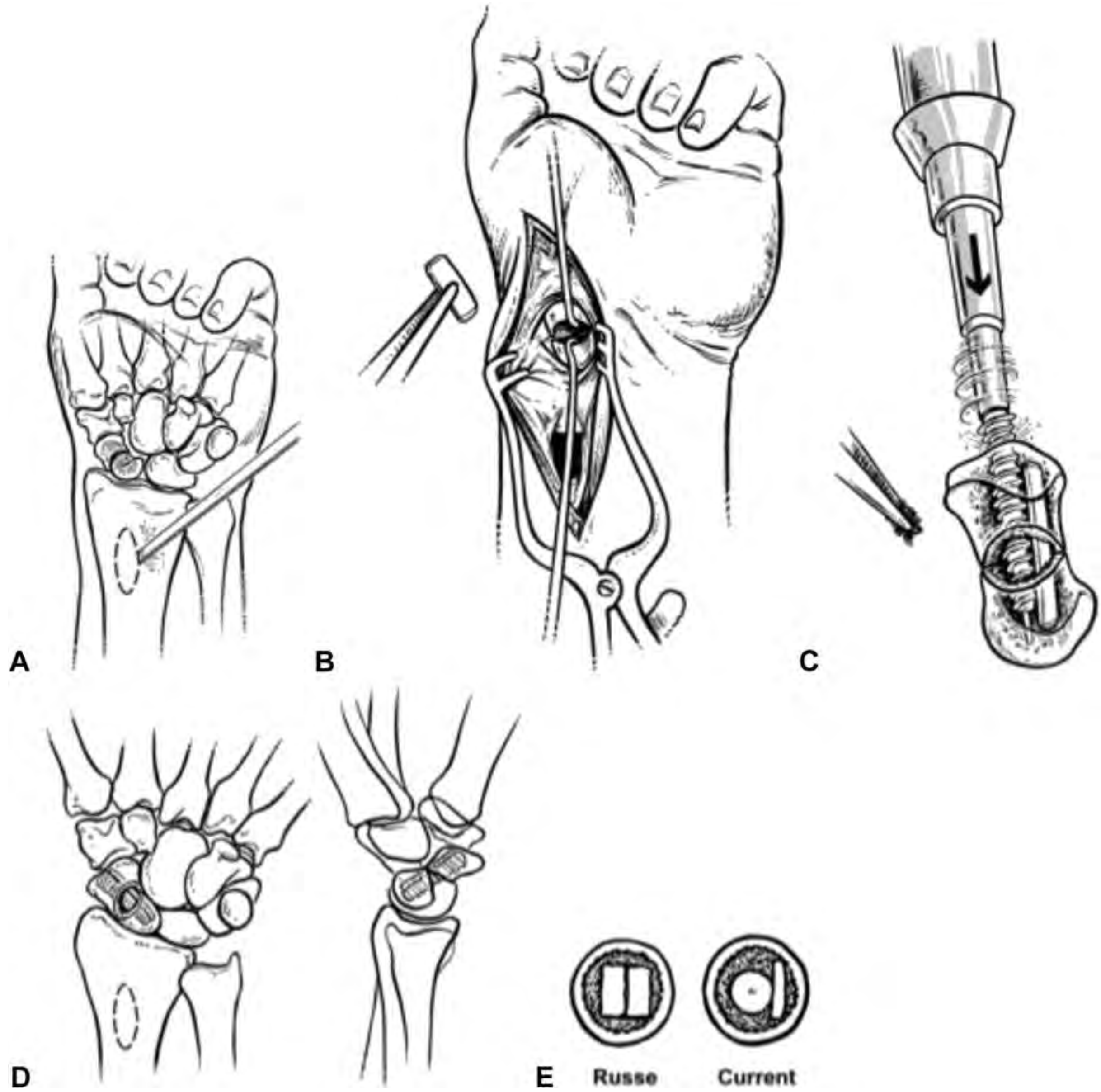

FIGURE 1: Schematic of the hybrid Russe technique. **A** Cancellous bone is harvested from the volar radius through an oval cortical window. **B** A cortical strut is shaped from the cortical bone and placed in an intramedullary fashion into the cavitated proximal and distal poles to restore scaphoid length and correct carpal alignment. **C** Cancellous bone graft is packed in the remainder of the nonunion site followed by fixation with a headless screw. **D** Radiographs demonstrate the correct position of the screw and strut. **E** Comparison of the traditional Russe procedure (left) and the hybrid procedure (right) with screw and graft. (Images courtesy of Steve K. Lee, MD.)

We measured the scapholunate, intrascaphoid, and radiolunate angles on preoperative and final postoperative lateral radiographs of the wrist to assess the correction of the scaphoid humpback deformity and carpal collapse.[17]

Surgical technique

We made an extended volar Henry approach along the course of the flexor carpi radialis tendon and extended it distally in a slightly curved configuration along the border of the glabrous skin of the thenar eminence. The distal extent of the incision was limited to the level of the scaphotrapezial joint. The superficial branch of the radial artery to the superficial arterial arch was retracted radially or divided between sutures. The floor of the flexor carpi radialis sheath was incised longitudinally to expose the extrinsic volar carpal ligaments, which were carefully identified, divided, and tagged with sutures for later repair. The distal and proximal poles of the scaphoid

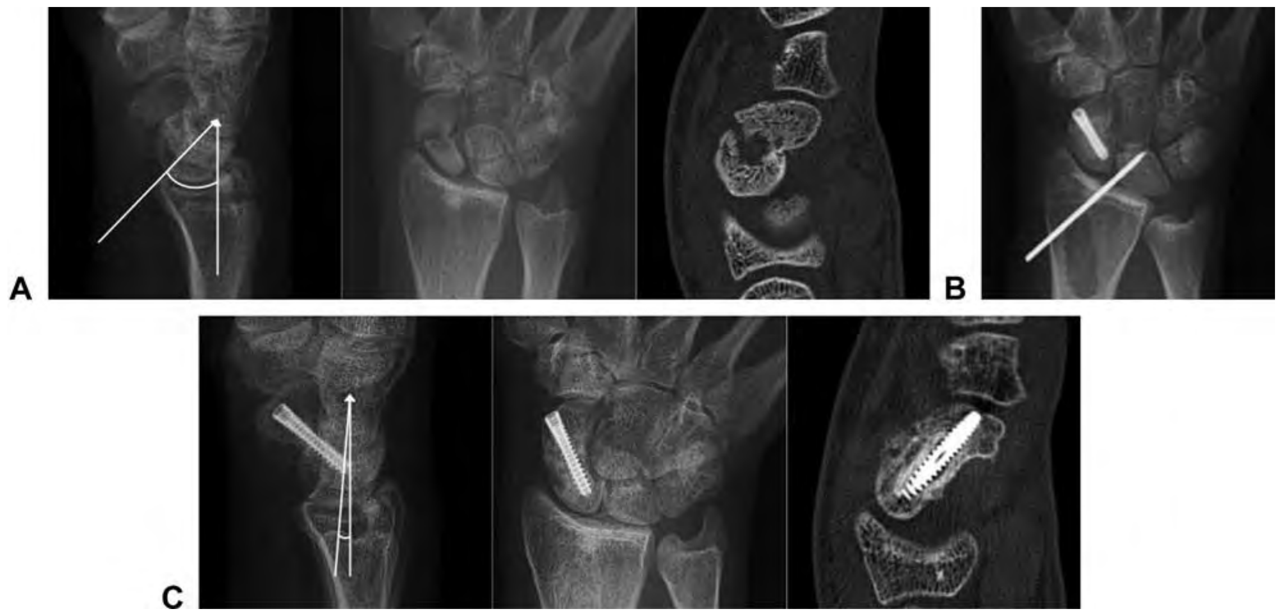

FIGURE 2: Representative case of a 21-week-old nonunion in a 17-year-old patient with collapse and DISI. **A** Preoperative radiographs and CT in the long axis of the scaphoid. **B** Postoperative radiograph with screw placement and lunate secured by a 1.6-mm transradial Kirschner wire. **C** Radiographs and computed tomography in the long axis of the scaphoid demonstrating union of scaphoid and correction of DISI. The cortical strut is just dorsal to the screw on the CT scan.

were exposed with the aid of skin hooks or 1.6-mm (0.062-in) K-wire joysticks. We removed all of the fibrous tissue at the nonunion site and used a curet to remove sclerotic bone and fibrous tissue down to a bleeding cancellous surface. The proximal and distal poles cavitated to retain only healthy bone in each pole. Generous curettage of each scaphoid pole was essential to expose healthy bleeding cancellous bone and prepare an adequate cavity to accept a cortical strut graft.

The distal radius bone graft site was exposed through a proximal extension of the Henry incision. The pronator quadratus was incised from its lateral attachment and reflected subperiosteally.[18] We marked an oval cortical window, approximately 20 mm long × 8 mm wide, with multiple drill holes using a 1.1-mm (0.045-in) K-wire and lifted it with a narrow osteotome (Fig. 1). Abundant cancellous bone graft was harvested from the distal radius and the cortical and cancellous grafts were saved in a moist sponge. A thrombin-soaked absorbable gelatin compressed sponge was placed in the defect and the pronator quadratus was repaired to the edge of the brachioradialis.

Next, we reduced the extended lunate manually; and in doing so, the attached proximal scaphoid pole returned to its anatomic position. The approximate length of the strut graft was measured with the 2 poles held in their reduced position, and the cortical strut graft was sculpted to fit. In 6 patients with severe lunate dorsal tilt, the lunate was temporarily fixed in the reduced position with a single 1.6-mm transradial K-wire (Fig. 2).[19] Depending on the surgeon's preference, the K-wire was either left exposed or buried below the skin. In the remaining patients, lunate alignment was corrected by restoring scaphoid length and alignment using the cortical strut graft. Using temporary hyperextension of the distal scaphoid pole with a skin hook, the nonunion site was gapped open and the cortical strut was positioned. Radiographs confirmed satisfactory scaphoid and lunate alignment with correction of the DISI. Abundant cancellous bone graft was then packed tightly in the remainder of the nonunion site (Fig. 1). We performed stable fixation using either a retrograde (n = 14) or antegrade (n = 3) headless cannulated screw (Fig. 1). The type and size of screw varied depending on the surgeon and case. Screw options included the Acutrak II mini or Acutrak standard screw (Acumed, Hillsboro, OR), Synthes 2.4-mm headless compression screw (Synthes USA, West Chester, PA), or Medartis 2.2-mm headless compression screw (Medartis, Basel, Switzerland). Antegrade fixation was generally chosen for revision surgeries when previous surgery or cavitation created by a loose screw compromised retrograde fixation in the distal pole. In those cases, the prior track was packed with cancellous bone and a limited dorsal approach was used to place the screw precisely from the apex of the proximal pole. Intraoperative fluoroscopy confirmed satisfactory hardware placement in all

TABLE 1. Demographic Features and Selective Results of Patients Treated With the Hybrid Russe Procedure

Sex	Age, y	Prior Surgery	Follow-up, mo	Union, mo	Postoperative DASH	Postoperative PRWE	Postoperative Pain	Complications
Male	23	No	77	5	0	0	0	None
Male	26	No	53	3	3	8	0	None
Male	28	No	61	3	3	11	1	None
Male	19	Yes	38	4	0	0	0	None
Male	16	No	35	3	2	3.5	0	None
Female	17	No	13	3	0	0	0	None
Male	40	Yes	36	3	17	23	4	None
Male	65	No	29	3		5	1	None
Male	32	No	21	5	1	3	0	None
Male	22	No	26	3		5	0	None
Male	31	Yes	103	2	8	4.5	0	None
Female	62	No	14	3	2	0	0	None
Female	78	No	14	3	5	0	0	None
Male	18	No	8	6	34	31	1	None
Male	16	No	6	4		6	0	None
Male	28	Yes	7	7	18	25	2	Prior infection
Male	19	Yes	10	3		33.5	2	None

cases. The extrinsic ligaments and volar capsule were repaired with interrupted sutures and the subcutaneous layer and skin were closed in layers. Postoperatively, patients were placed in an orthosis for 10 to 14 days. A long-arm thumb spica orthosis or cast was used in patients with a radiolunate pin. The pin was removed in the office 4 weeks postoperatively and a short-arm thumb spica cast was applied for 4 additional weeks. In patients without a radiolunate pin, a short-arm thumb spica cast was applied for 6 to 8 weeks. Subsequently, the patient was placed in a custom-molded removable orthosis until radiographs or CT confirmed union. Gentle active range of motion exercises were allowed during the orthotic portion of the recovery.

Statistical methods

Descriptive statistics are presented as means $\pm$ SD except for postoperative pain, which is presented as frequency counts and percentages for each pain level. Preoperative to postoperative differences in angle and range of motion variables were assessed with Wilcoxon signed rank tests, as were postoperative differences between the affected and contralateral sides. The level of significance was $\alpha = .05$ for all tests.

RESULTS

The mean patient age was 32 years (range, 16–78 years). Follow-up time averaged 32 months (range, 6–103 months), with all procedures resulting in union at a mean time of 3.6 months (range: 2.0–6.8 months) (Table 1).

Radiographic measurements demonstrated the restoration of normal carpal alignment and statistically significant improvements in scapholunate, radiolunate, and intrascaphoid angles. Mean scapholunate angle was improved from 70° $\pm$ 12° preoperatively to 56° $\pm$ 9° postoperatively ($P = .006$). Intrascaphoid angle was improved from 65° $\pm$ 12° preoperatively to 35° $\pm$ 6° postoperatively ($P < .001$). Mean radiolunate angle was restored from 20° from full extension $\pm$ 15° (lunate tilted dorsally) preoperatively to 0.2° from full extension $\pm$ 7° postoperatively ($P = .006$) (Fig. 3). A representative radiographic case presented shows correction of DISI and restitution of scaphoid alignment (Fig. 2).

Postoperative grip strength averaged 89% (range, 43% to 113%) of the uninjured hand compared with preoperative grip strength of 70% (range, 50% to 85%). Postoperative pinch strength averaged 97% (range, 75% to 109%) of the uninjured hand compared with preoperative strength of 74% (range, 61% to 100%). Compared with the preoperative measurement of 59° $\pm$ 18°, the operated wrist improved to 64° $\pm$ 19° in postoperative flexion ($P = .030$), increased from 39° $\pm$ 21° to 62° $\pm$ 16° in extension ($P = .005$), and improved from 93° $\pm$ 38° to 123° $\pm$ 29° in overall flexion-extension arc ($P = .004$) (Fig. 4). Median visual analog scale pain score postoperatively

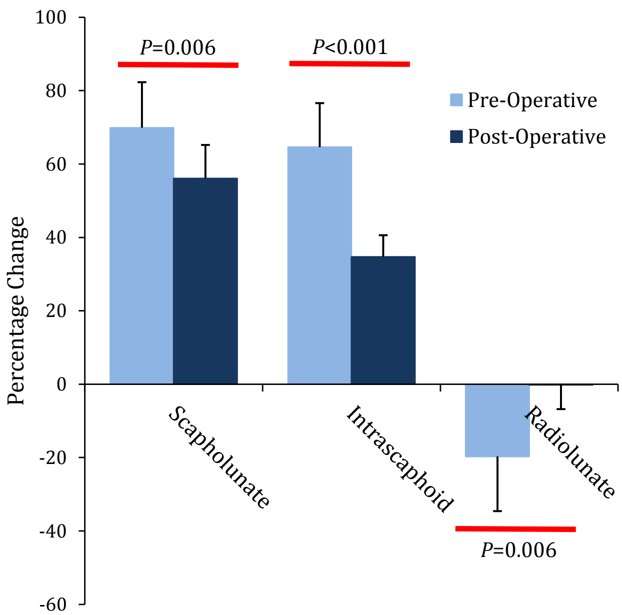

FIGURE 3: Comparing preoperative and postoperative changes in carpal alignment. Level of significance at $P < .05$.

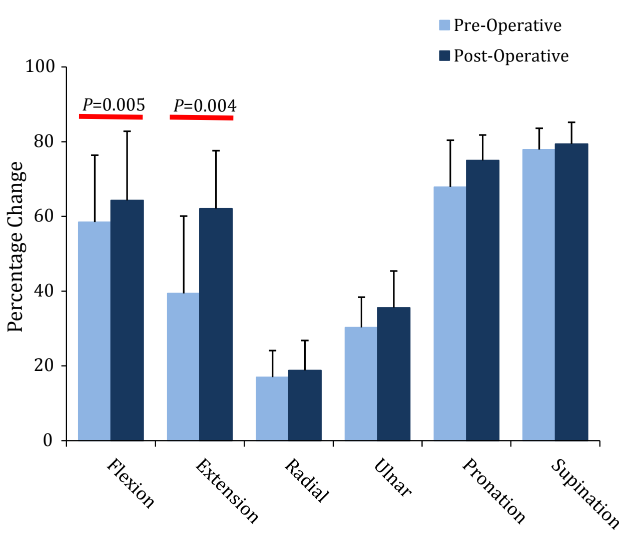

FIGURE 4: Comparing preoperative and postoperative changes in range of motion. Level of significance at $P < .05$.

was 0 (range, 0−4). All patients returned to employment and were satisfied with the procedure. Mean postoperative PRWE score was 9 ± 11 and mean postoperative DASH score was 7 ± 10 (PRWE and DASH were scored on a scale of 0−100 scale, where 0 = no disability and 100 = most severe disability). There were no complications of incisional pain, wound dehiscence, donor site fracture or pain, anesthesia, nonunion, hardware issues, or cutaneous nerve injury. One patient developed a *Staphylococcus epidermidis* infection within the nonunion site from a prior surgery but recovered completely after 12 weeks of oral levofloxacin therapy.

DISCUSSION

The goals for treatment of a scaphoid nonunion are to reduce the deformity, heal the nonunion, and prevent arthritis.[1−3,20−26] We present a hybrid Russe procedure using a volar cortical strut, cancellous bone graft, and headless screw fixation. The use of a piece of distal radius volar cortex as a strut restores the scapholunate, radiolunate, and intrascaphoid angles, whereas abundant distal radius cancellous bone graft and stable internal fixation promote timely and reliable union.

An advantage of this technique is the surgical efficiency and ease of bone harvesting from the same limb. Radius bone graft avoids the donor site morbidity associated with iliac crest bone graft harvesting.[15] Use of a volar cortical strut restores scaphoid length and successfully reduces the humpback deformity. Its insertion into concavities of both scaphoid poles prevents graft extrusion. Use of an intramedullary screw provides secure fixation, longitudinal compression forces, and centripetal compression of the cancellous bone within the cavitated proximal and distal scaphoid poles. Compression and stable fixation increase the probability of achieving bony union.[27,28]

Other techniques have provided high incidences of union rates and low incidences of complication. Stark et al[29] showed a 97% union incidence with K-wires and iliac crest bone graft. However, 25 patients (17%) had humpback deformities and DISI after treatment. The authors did not describe their criteria for determining avascular necrosis in 25 patients. Union was judged radiographically and CT scans were not routinely performed to assess union. These union rates were challenged by Barton[30] and Merrell et al.[14] Recent reports of similar Russe modification involving wire fixation without screw placement have indicated 87% to 91% incidences of union, but the authors did not consider carpal realignment in their analysis.[31,32] Garcia et al[33] proposed a Russe modification using 2 headless screws along with an autograft struts, similarly emphasizing the importance of maintaining carpal stability and preventing scaphoid torsion. Although they reported unions in all 19 patients, the study lacked a quantitative analysis of intracarpal alignment. Similarly, Cohen et al[12] demonstrated successful unions in all 12 patients using a headless screw and cancellous bone alone with correction of the intrascaphoid angle. However, the authors did not comment on the degree of radiolunate angle correction or residual DISI deformity.

Roh et al[34] showed that radiolunate angle is the most reliable and valid carpal alignment index for evaluating deformities of scaphoid fractures. For severe collapse deformities such as those demonstrated in this cohort, placement of a cortical strut simplifies the procedure and ensures correction of the humpback deformity and DISI. This observation is further supported by Sayegh and Strauch's[35] recent systematic review, which demonstrated that corticocancellous autografts resulted in superior carpal realignment compared with pure cancellous techniques. However, this may have been confounded by the lower use of screws in the cancellous-only group.

Our technique provided excellent radiographic and clinical results in terms of union, pain, strength, range of motion, and restoration of normal scapholunate, intrascaphoid, and radiolunate angles. Jiranek et al[36] demonstrated a long-term reduction in posttraumatic arthritis when the intrascaphoid intercarpal angles were normalized in patients with scaphoid nonunion.

The limitations of our study are its retrospective nature, the relatively small patient cohort, and the lack of preoperative range of motion, PRWE, and DASH data on some subjects. However, final postoperative differences in motion from the contralateral side were minimal (40° in total wrist motion). All patients were highly satisfied with the functional outcome and were able to return to their occupations. With full correction of scaphoid and carpal alignment and 100% union rates in this small series, we recommend the hybrid Russe technique to treat complex scaphoid nonunions with humpback deformity and associated DISI.

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