TECHNIQUE

Three-Corner Midcarpal Arthrodesis and Scaphoidectomy: A Simplified Volar Approach

AQ1 Michèle Dutly-Guinand, MD and Herbert P. von Schroeder, MD

ABSTRACT

Midcarpal arthrodesis has been a treatment of choice in the last decade for scapholunate advanced collapse and related conditions of the wrist. In this study, we present a new uncomplicated technique in which a *3-corner* intercarpal fusion is done with screw fixation from a volar approach. The advantages of this technique include simplified excision of the scaphoid, radial styloidectomy, and straightforward placement of 2 screws from the lunate into the capitate and hamate, respectively, to maintain a readily achievable correction of the dorsal intercalated segment instability. With adequate debridement and compression of the midcarpal joint, fusion is readily achieved.

Keywords: wrist, osteoarthritis, salvage procedure, midcarpal arthrodesis, 4-corner arthrodesis, internal fixation, SLAC, SNAC, DISI

The treatment method for advanced carpal collapse after scapholunate ligament disruption (SLAC) or scaphoid nonunion (SNAC) is midcarpal arthrodesis with complete excision of the scaphoid.[1–10] This treatment is designed to preserve some wrist mobility while relieving pain.

The first report about an intercarpal fusion dates back to 1924, when Thornton described a fusion between scaphoid, lunate, capitate, and hamate. During the 1950s and 1960s, intercarpal arthrodesis was described by several authors for the treatment of different pathologies.[11–14] In 1971, Linscheid et al[15] classified the carpal instabilities based on dorsal and volar collapse. With scapholunate dissociation and scaphoid fractures, dorsal tilt of the lunate was termed dorsi-flexed intercalated segment instability (DISI); whereas volar (palmar) displacement was termed volar-flexed intercalated segment instability.

In 1979, Watson[16] described capitolunate fusion for scaphoid nonunion s and scaphoid rotatory displacements with severe arthritis between the radius and the scaphoid and secondary destruction of the capitolunate joint. He and others[4,17–20] have found that the radiolunate joint is usually well preserved under these conditions, thus maintaining the basis for the articulation.

The classic description of the midcarpal or 4-corner arthrodesis involved scaphoid excision, removing the articular surfaces between at the midcarpal joint and between the carpal bones, packing these spaces with cancellous bone graft, and pinning across the former joint spaces.[1,2,4–7,9,10] In the past, excised scaphoid has been replaced with a silicon implant[1,21–23] until the mid-1980s when silicone synovitis and other disadvantages were described.[24,25] Others have tried to reconstruct the scaphoid at the same time as the fusion[26] or replace the scaphoid with an extensor carpi radialis longus tendon "anchovy" graft.[8]

After reviewing 4000 wrist x-rays, Watson and Ballet[22] were able to establish the pattern of sequential changes in degenerative wrist arthritis. They found that the most common form was arthritis caused by articular alignment problems at the radioscaphoid articulation and between the scaphoid and lunate. They named this progressive condition SLAC. It was also shown that scaphoid fracture nonunion would follow the same pattern[17] and was termed SNAC.[2] In both SLAC and SNAC wrists, the radiolunate joint is typically preserved in that it has minimal or more commonly no arthritis; hence, the surgical treatment for SLAC and SNAC wrists is a capitolunate or 4-corner fusion, or a proximal row carpectomy.

We have used various techniques to perform intercarpal fusions but have had occasional poor results due to certain technical aspects of the procedure. These included dorsal impingement between the radius and the carpus due to excessive bone graft, bone overgrowth, prominent hardware or persistent malalignment, and nonunion with single 3-0-mm cannulated screw in attempted capitolunate fusion. In response to these outcomes, we changed our management and developed a new technique. We now perform a 3-corner fusion via a volar approach. The technique described below is a novel and simplified operation that allows straightforward excision of the scaphoid (plus radial

Address correspondence and reprint requests to Herbert P. von Schroeder, MD, University of Toronto, Toronto Western Hospital, 2nd Floor East Wing, 399 Bathurst St, Toronto, Ontario, Canada M5T 2S8. E-mail: herb.vonschroeder@uhn.on.ca.

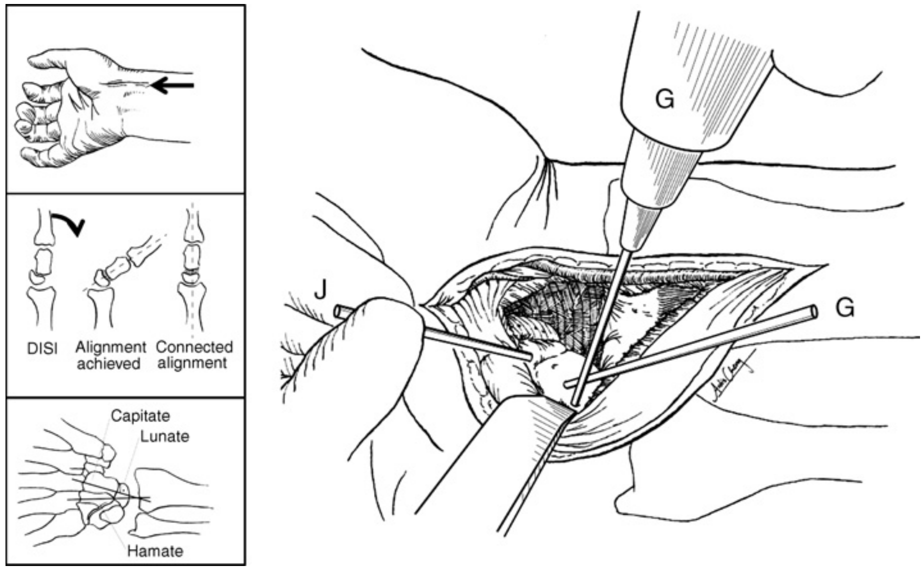


FIGURE 1. Surgical technique of volar midcarpal fusion. A longitudinal incision is made from the scaphoid tubercle proximally adjacent to the flexor carpi radialis tendon (inset: top—arrow). The radioscaphocapitate ligament is incised (and later repaired), and the scaphoid and radial styloid are dissected and excised. With further dissection along the volar rim of the radius, the lunate and lunocapitate joint are exposed. The midcarpal joint is excised and packed with bone graft. With the wrist in the extended position, the capitate is aligned with the already extended lunate (inset: middle), and in this position, the guide wires (G) are passed from the lunate to the hamate and capitate, respectively (inset: bottom). K-wires are also used as joysticks (J) to optimize the position of the carpal bones for internal fixation.

styloidectomy as is commonly necessary) and correction of the DISI deformity.

■ TECHNIQUE

The procedure is typically done under an axillary block anesthesia but can be done under any type of regional or general anesthesia. A longitudinal incision is made on the volar aspect of the wrist beginning at the scaphoid tubercle and carried proximally over the flexor carpi
F1 radialis tendon 5 to 6 cm (Fig. 1). The subcutaneous tissue is divided down to the FRC tendon, and dissection is carried out on the radial aspect of it around the scaphoid tubercule. The volar ligaments between the scaphoid and the trapezium and trapezoid are incised. The radioscaphocapitate ligament is incised (and later repaired). The scaphoid is brought into flexion as the dorsal attachments at the ridge are incised with a knife or curved osteotome. A bone reduction forceps is placed around the waist of the scaphoid to twist it 360 degrees to detach any remaining ligaments and extract it. The scaphoid can also be transected across its waist using an osteotome to facilitate separate removal of the distal and proximal halves.

The wrist is then put through a range of motion to assess impingement or impending impingement between the trapezium and radial styloid. If this is the case, as it typically is, further dissection is carried out around the styloid, and approximately 4 mm of the styloid is excised using osteotomes and a rongeur. The resected styloid and scaphoid are both minced to provide cancellous bone graft for the midcarpal fusion site.

The volar rim of osteophytes on the radius is excised if present, and the volar wrist capsule is released off of the radius to expose the lunate, which is typically tilted dorsally into the DISI position. With further dissection of the volar capsule, the lunocapitate joint is exposed. After placing a 1.1-mm Kirschner wire (K-wire) into the lunate to be used as a joystick, the articular cartilage surfaces between the lunate and the capitate are removed with a curved osteotome, rongeur, and finally a 3-mm burr. The relative curved shapes of the adjacent surfaces are maintained, and care is taken to remove all cartilage between the 2 bones as well as the sclerotic subchondral bone. Bone graft is packed into the midcarpal space. Under lateral fluoroscopic guidance, the hand is placed into extension such that the capitate is brought into alignment with the dorsally tilted lunate (Fig. 1, middle inset). With the aid of the joystick, the lunate is held as close as possible in the neutral alignment with the capitate to restore the relationship between the 2 bones. Two additional 1.1-mm guide wires are then driven from the proximal articular surface of the lunate into the capitate and hamate, respectively (Fig. 1). With the exposure to the lunate in its extended "DISI" position and with the alignment of capitate to the lunate by extending the wrist, the guide wires are advanced in a straight direction, and bending of the wires does not occur. Care

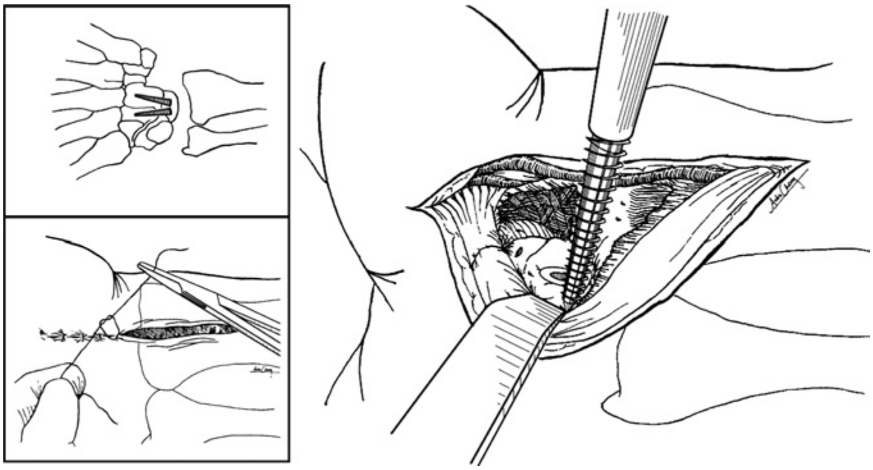


FIGURE 2. Surgical technique of volar midcarpal fusion, continued. Headless compression screws are passed over the guide wires. One screw achieves fixation and compression between the lunate and hamate, the other between the lunate and capitate (inset: top). After removal of the guide wires and joystick, K-wires, RSC ligament, and capsule are repaired, followed by skin closure (inset: bottom).

must be taken *not* to bring the wrist into neutral at this point which would bend the wires against the radius. The guide wires are then measured, advanced (to prevent inadvertent removal during subsequent steps), and overdrilled. Additional bone graft is packed into the midcarpal space. Cannulated headless screws (Acutrak) of appropriate length are then passed over the wires after packing local cancellous bone graft into the midcarpal F2 region (Figs. 2 and 3). Additional bone from the volar rim of the radius can be removed if necessary to improve exposure to the lunate for drilling or screw insertion. After ensuring that excellent fixation and compression has been achieved, the K-wires and the joystick are removed and final radiographic images are obtained. The wrist is put through a range of motion to check the stability and ease of motion. The wound is irrigated, and the volar wrist capsule is closed, followed by skin clo- F2 sure (Fig. 2).

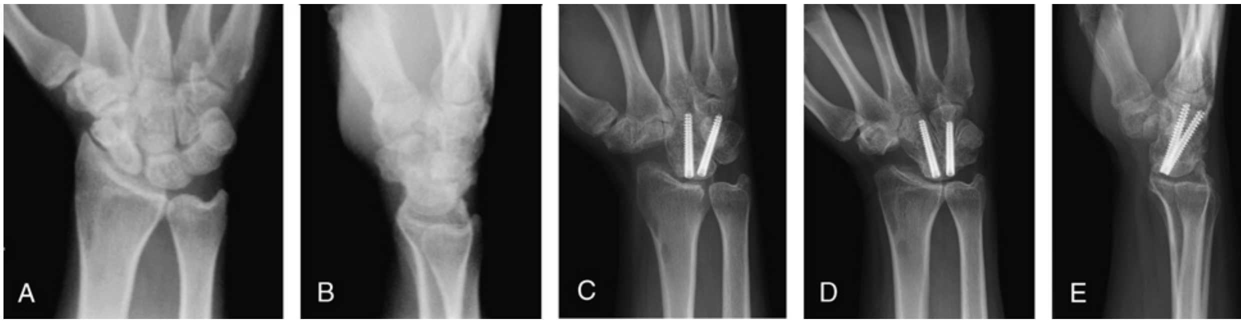
The procedure can also be performed with a single lunocapitate screw instead of 2 screws if the pathology is completely isolated to the radial side of the wrist and if single screw fixation is solid. This is tested by completing the fixation with a single lunocapitate screw, then removing the guide wire (and joysticks) and inspecting the lunocapitate joint for micromotion while putting the wrist through a maximum range of motion. If there is any micromotion, a second screw is placed from the lunate to the hamate.

Alternatively, if there is clinical tenderness, pathology, or laxity on the ulnar portion of the wrist around the triquetrum, we begin with a single lunohamate screw via a volar approach as described above, and then turn the hand over and perform a mini-open procedure that involves an incision over the triquetrum, burring and bone grafting the midcarpal joint and placement of a headless compression screw from the triquetrum (at its dorsal exostosis) to the capitate.

The patient is placed in a volar forearm plaster splint for 2 weeks, followed by a circular cast or a removable thermoplastic splint for 4 more weeks. Motion may begin based on pain and swelling. Early motion is tolerated due to excellent fixation.

PRELIMINARY EXPERIENCE AND CASE EXAMPLE

To date the procedure has been performed in 13 patients (12 males; average age, 50 years; age range, 37–61 years). Preoperative diagnosis was SLAC arthritis in 9 and SNAC arthritis in 3 and arthritis secondary to scaphoid malunion in 1 patient. Symptoms were on the right side in 9, left in 2, and bilateral in 2. Original injury was moderate trauma, such as a fall from the standing position or twisting injury in 8 patients, repetitive injury in 1, and no known injury in 4. Average duration of symptoms was 83 months (range, 9–288 months). Patients have been followed up an average of 2.6 years (range, 1.1–3.4 years) after their intercarpal fusion. After surgery, total range of motion (flexion + extension) of the wrist decreased from 58% to 47% compared with the opposite side (range, 25%–80%). Grip strength increased from 59% to 64% of the opposite side (range, 29%–100%). Two additional procedures have included 1 repeat intercarpal fusion for nonunion and 1 screw removal for prominent hardware. Additional procedures were also required in 3 patients with preexisting conditions: 1 total wrist fusion for pancarpal arthritis in a patient in which the advanced arthritis was recognized preoperatively, but he had chosen to



AQ3 **FIGURE 3.** Preoperative (A and B) and postoperative (C–E) PA, oblique and lateral wrist radiographs of a male patient with radiocarpal arthritis (A) and DISI deformity (B) that developed after scaphoid malunion. Surgical treatment consisted of an intercarpal arthrodesis using 2 screws from the lunate into the capitate and hamate, respectively, performed via a volar approach (C–E). The scaphoid and radial styloid were excised through the same volar incision and used as bone graft in the midcarpal joint.

proceed with the partial fusion as an attempt to preserve some wrist motion realizing that further surgery would probably be required; 1 carpal tunnel release in a patient with preexisting compressive symptoms that did not improve after intercarpal fusion; and 1 chronic regional pain syndrome that recurred in a patient with a history of the same after previous cast treatment.

F3 Figure 3 shows preoperative and postoperative radiographs of a 37-year-old man who sustained a scaphoid fracture 12 years before. He had undergone a bone grafting procedure but developed radial-sided wrist pain with arthritic changes. Symptoms progressed despite ongoing medical management, and he underwent simple radial styloiodectomy. This did not result in significant improvement, and he therefore underwent volar 3-corner arthrodesis approximately 3 years ago. Postoperatively, he developed mild de Quervain tendonitis but has not required any further surgical intervention. He still uses a splint for lifting activities and is pleased with his outcome.

DISCUSSION

A great deal has been written about the treatment of SLAC wrists in the last 15 years, and the literature has included variable and very high nonunion rates, lengthy immobilization periods, and the use of specialized plates in an attempt to establish a stable midcarpal fusion.

Watson[16] has found that there was negligible difference in postoperative range of motion between lunocapitate fusions and capitate-hamate-lunate-triquetral fusions (4-corner fusion), but Watson described that addition of a triquetrohamate fusion to the lunocapitate fusion increased the union rate of the midcarpus. Very high nonunion rates of up to 50% have been reported when only the lunocapitate articulation was fused to achieve a stable midcarpal joint,[1,2,9] compared with lower nonunion rates (0%–8%) with 4-corner fusion.[2,3,5,7–9,23] A high nonunion rate has certainly also been our experience with lunocapitate fusions and prompted us to perform our 3-corner (lunotriquetrocapitate) fusions that have resulted in 1 nonunion to date.

Several techniques have been described using different bone grafts for intercarpal fusions, including cancellous graft from the iliac crest or the distal radius[3,5,7,9,10] and corticocancellous grafts.[8,27] Likewise, several techniques have been described using K-wires,[2,4,5,7,9,21,28] staples,[1,2,9,19] screws,[2,28] or specially designed dorsal circular plates, which have shown very high nonunion rates up to 63% and complications as implant failures, low pain relief, and a high incidence of hardware impingement.[29–32]

If compression is achieved with screws, only small amounts of local cancellous bone graft are sufficient to ensure fusion. An advantage to our approach is that no secondary incision is needed because the bone graft is taken from the excised scaphoid and radial styloid. In our experience, the Acutrak screw provides excellent compression compared with other cannulated screws. Another advantage of stable screw fixation is that the immobilization period is relatively short. This allows for early hand therapy.

The standard approach to intercarpal fusions has always been described from the dorsal side of the wrist (through either a transverse or longitudinal incision), and a lateral approach has also been described[9] but is not commonly performed. With our new technique, a simple volar approach is used and a small dorsal incision can be added. The scaphoid can be readily excised, and the realignment of the midcolumn between capitate and lunate is easily addressed. Although one author found that correction of the DISI deformity does not correlate to outcome,[9] it is generally accepted that the goal of midcarpal fusion is alignment of the carpus and complete excision of the scaphoid. The transmitting forces are exclusively through the lunate and no longer transmitted to the scaphoid fossa. The available arc of radiolunate motion is then maximized, and the pain seems to be addressed better and dorsal impingement is reduced.[4,5,7,8,10,28]

The progressive stages of the SLAC wrist have been described as follows: stage I arthrosis at the radial styloid, stage II periscaphoid arthrosis including the scaphoid fossa, and stage III capitolunate degeneration as well.[2,6,28] Either a midcarpal fusion or a proximal row carpectomy can be considered for a stage II SLAC wrist[2,28]; however, the pattern of arthritis precludes a proximal row carpectomy for stage III, unless an interpositional arthroplasty is also performed. Although a total wrist arthroplasty or total fusion can be considered for stage III, the procedures and outcomes have significant limitations; hence, we feel that a midcarpal arthrodesis is presently the procedure of choice for stage III SLAC wrists.

Midcarpal arthrodesis is also suitable for cases in which arthritic changes are caused by chronic scaphoid fracture pseudoarthrosis or SNAC wrist. In these cases, the degenerative arthrosis also begins on the radial aspect of the wrist but begins to a greater extent at the radial styloid. Because the base of the scaphoid facet of the distal radius is often preserved, consideration can be given to incorporating the proximal portion of the scaphoid into the midcarpal arthrodesis. In such cases, the distal part of the scaphoid and radial styloid are excised. This arthrodesis can be performed via the described approach. Our early results with this technique are promising. As with all intercarpal fusions, nonunion of the fusion is a known risk and can be reduced by adhering to basic standards of the procedure that include appropriate excision of joints, adequate bone grafting, and solid fixation. Preexisting conditions such as compressive neuropathies, pain syndromes, and advanced arthritis beyond the radioscaphoid articulation and midcarpal joint are not addressed by arthrodesis.

Our technique highlights the critical principles for surgical treatment of the SLAC (and SNAC) wrist toward achieving a stable midcarpal fusion. Our early results with this technique do show a reduction in motion as anticipated, and a slight reduction in grip strength as maximal recovery has not yet been attained. Patient satisfaction remains high. By using 2 screws via a volar approach, this technique can be achieved in an easy, fast, and reliable way.

REFERENCES

1. Kirschenbaum D, Schneider LH, Kirkpatrick WH, et al. Scaphoid excision and capitolunate arthrodesis for radioscaphoid arthritis. *J Hand Surg Am*. 1993;18:780–785.
2. Krakauer JD, Bishop AT, Cooney WP. Surgical treatment of scapholunate advanced collapse. *J Hand Surg Am*. 1994;19:751–759.
3. Siegel JM, Ruby LK. Midcarpal arthrodesis. *J Hand Surg Am*. 1996;21:179–182.
4. Giunta RE, Krimmer H, Kraphol B, et al. Patterns of subchondral bone mineralization in the wrist after midcarpal fusion. *J Hand Surg Am*. 1999;24:138–147.
5. Watson HK, Weinzweig J, Giudera PM, et al. One thousand intercarpal arthrodeses. *J Hand Surg Br*. 1999; 24:307–315.
6. Sauerbier M, Tränkle M, Linsner G, et al. Midcarpal arthrodesis with complete scaphoid excision and interposition bone graft in the treatment of advanced carpal collapse (SNAC/SLAC wrist): operative technique and outcome assessment. *J Hand Surg Br*. 2000;25:341–345.
7. Cohen M, Kozin S. Degenerative arthritis of the wrist: proximal row carpectomy versus scaphoid excision and four-corner arthrodesis. *J Hand Surg Am*. 2001;26:94–104.
8. Garzia-Lopez A, Perez-Ubeda MJ, Marco F, et al. A modified technique of four-bone fusion for advanced carpal collapse (SLAC/SNAC wrist). *J Hand Surg Br*. 2001;264: 352–354.
9. Kadji O, Duteille F, Dautel G, et al. Four bone versus capito-lunate limited carpal fusion. Report of 40 cases [French]. *Chir Main*. 2002;21:5–12.
10. Kitzinger HB, Löw S, Karle B, et al. The posttraumatic carpal collapse long-term results after midcarpal fusion [German]. *Handchir Mikrochir Plast Chir*. 2003;35:282–287.
11. Helfet AJ. A new operation for ununited fracture of the scaphoid. *J Bone Joint Surg Am*. 1952;34:329.
12. Mazet R, Hohl M. Fractures of the carpal navicular. *J Bone Joint Surg Am*. 1963;45:82–111.
13. Graner O, Lopes EI, Carvalho BC, et al. Arthrodesis of the carpal bones in the treatment of Kienböck's disease, painful ununited fractures of the navicular and lunate bones with avascular necrosis, and old fracture-dislocations of carpal bones. *J Bone Joint Surg Am*. 1966;48:767–774.
14. Schwartz S. Localized fusion at the wrist. *J Bone Joint Surg Am*. 1967;49:1591–1596.
15. Linscheid RL, Dobyns JH, Beabout JW, et al. Traumatic instability of the wrist. Diagnosis, classification, and pathomechanics. *J Bone Joint Surg Am*. 1972;54:1612–1632.
16. Watson HK. Limited wrist arthrodesis. *Clin Orthop Relat Res*. 1980;149:126–136.
17. Vender MI, Watson HK, Wiener BD, et al. Degenerative change in symptomatic scaphoid nonunion. *J Hand Surg Am*. 1987;12:514–519.
18. Viegas SF, Patterson RM, Peterson PD, et al. Evaluation of the biomechanical efficacy of limited intercarpal fusions for the treatment of scapho-lunate dissociation. *J Hand Surg Am*. 1990;15:120–128.
19. Simmen BR, Bloch HR. Partial arthrodesis of the carpal bones in advanced carpal collapse in chronic scapholunar instability and following scaphoid pseudoarthrosis [German]. *Orthopade*. 1993;22:79–85.

20. Krimmer H, Wiemer P, Kalb K. Comparative outcome assessment of the wrist joint-mediocarpal partial arthrodesis and total arthrodesis [German]. *Handchir Mikrochir Plast Chir*. 2000;32:369–374.

21. Watson HK, Goodman ML, Johnson TR. Limited wrist arthrodesis. Part II: intercarpal and radiocarpal combinations. *J Hand Surg Am*. 1981;6:223–233.

22. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J Hand Surg Am*. 1984;9:358–365.

23. Watson HK, Ryu J. Evolution of arthritis of the wrist. *Clin Orthop Relat Res*. 1986;202:57–67.

24. Smith RJ, Atkinson RE, Jupiter JB. Silicone synovitis of the wrist. *J Hand Surg Am*. 1985;10:47–60.

25. Kleinert JM, Stern PJ, Lister GD, et al. Complications of scaphoid silicone arthroplasty. *J Bone Joint Surg Am*. 1985;67:422–427.

26. Martini AK. Indications and technique of partial arthrodesis of the carpus [German]. *Z Orthop Ihre Grenzgeb*. 1992;130:175–180. Review.

27. Sandow MJ, Wai YL, Hayes MG. Intercarpal arthrodesis by dowel bone grafting. *J Hand Surg Br*. 1992;17:463–466.

28. Tomaino MM, Miller RJ, Cole I, et al. Scapholunate advanced collapse wrist: proximal row carpectomy or limited wrist arthrodesis with scaphoid excision? *J Hand Surg Am*. 1994;19:134–142.

29. Middleton A, Macgregor D, Compson JP. An anatomical database of carpal bone measurements for intercarpal arthrodesis. *J Hand Surg Br*. 2003;28:315–318.

30. Kendall CB, Brown TR, Millon J, et al. Results of four-corner arthrodesis using dorsal circular plate fixation. *J Hand Surg Am*. 2005;30:903–907.

31. Vance MC, Hernandez JD, DiDonna ML, et al. Complications and outcome of four corner arthrodesis: circular plate fixation versus traditional techniques. *J Hand Surg Am*. 2005;30:1122–1127.

32. Chung KC, Watt AJ, Kotsis S. A prospective outcomes study of four-corner wrist arthrodesis using a circular limited wrist fusion plate for stage II scapholunate advanced collapse wrist deformity. *Plast Reconstr Surg*. 2006;118:433–442.