FOUR-CORNER ARTHRODESIS

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Although nearly every combination of intercarpal arthrodeses has been described, excision of the scaphoid and fusion of the remaining carpal bones in neutral alignment was a unique concept when it was introduced nearly 20 years ago. This time-tested and established procedure that is commonly known as the 4-corner or 4-bone arthrodesis is based on the principle that the radiolunate articulation is often spared from degenerative changes from conditions that result in rotatory subluxations of the scaphoid. The 4-corner arthrodesis is a motion-sparing, limited arthrodesis that reliably results in pain relief, improved grip strength, and overall high patient satisfaction with low associated nonunion and complication rates.

Congenital carpal fusions or coalitions are often discovered serendipitously on radiographs taken for other purposes. The wrists of these individuals are often normal, without symptoms or conditions that can be recognized by clinical examination. Because wrists with carpal coalitions often have normal appearance and function without pain, disability, weakness, or instability, it was postulated that intercarpal arthrodesis could restore acceptable function to an injured wrist and obviate the need for total wrist arthrodesis, which results in complete loss of motion.

One of the earliest descriptions of an intercarpal arthrodesis was in 1924 by Thornton, who excised the base of the capitate and fused the hamate, trapezoid, scaphoid, lunate, and triquetrum. In 1946, Sutro reported 4 cases of scaphoid nonunions treated by intercarpal arthrodesis of the scaphoid fragments to the capitate. Similarly, in 1952 Helfet reported 7 cases of scaphocapitate arthrodesis for the treatment of scaphoid nonunions. By the 1960s the concepts and indications of intercarpal arthrodesis were further refined. Graner and associates described intercarpal arthrodesis with excision of the lunate or proximal scaphoid fragment in patients with Kienböck disease, scaphoid nonunions, or old carpal fracture-dislocations. Soon after Graner’s report, Peterson and Lipscomb of the Mayo Clinic reported the successful outcome of 8 patients treated with intercarpal arthrodesis performed for degenerative arthritis secondary to scaphoid nonunion, posttraumatic scaphoid subluxations, scaphoid nonunion, and Kienböck disease. One of the intercarpal arthrodeses they performed was the scaphoid-trapezium-trapezoid arthrodesis, subsequently popularized as the triscapho arthrodesis by Watson.

Early results of treatment of scaphoid nonunion by excision of part or all of the scaphoid often resulted in
weakness, pain, and loss of function of the wrist. As such, scaphoidectomy was generally not recommended for the treatment of scaphoid nonunions. However, when the scaphoid fragments were arthrodesed to the capitate, pain diminished and strength improved. Intercarpal arthrodesis of the scaphoid and capitate provided pain relief, stability, and the preservation of some wrist motion. As intercarpal arthrodeses evolved, nearly every conceivable combination of carpal bone fusion was described.

Despite the historical recommendations against scaphoidectomy, Watson and associates described the unique concept of combining the scaphoidectomy, neutral alignment of the remaining carpal bones, and arthrodesis of the capitate, hamate, lunate, and triquetrum to maintain the neutral alignment. Arthrodesis of the capitate and lunate was difficult to achieve, with nonunion rates reported as high as 30%. Thus, to increase the union rates, the hamate and triquetrum were added to the capitolunate arthrodesis. The resultant arthrodesis of the capitate, hamate, lunate, and triquetrum was termed a 4-corner arthrodesis. In 1981, Watson and associates described the results of 2 patients (3 wrists) who underwent a 4-corner arthrodesis, excision of the scaphoid, and replacement with a silicone implant spacer for degenerative arthrosis. Three years later, Watson and Ballet described the scapholunate advanced collapse (SLAC) pattern of degenerative arthritis and reported on the results of 16 patients who underwent scaphoidectomy, neutral alignment, and 4-corner arthrodesis. A decade later, Ashmead and associates reported 100 cases in which scaphoidectomy and 4-corner arthrodesis were performed for SLAC wrist salvage.

Today, nearly 20 years after its formal introduction, scaphoidectomy and 4-corner arthrodesis with neutral alignment of the carpus has become an accepted and time-tested procedure for the treatment of a variety of carpal maladies.

**Indication for 4-Corner Arthrodesis**

In 1984, Watson and Ballet reviewed 4,000 radiographs of the hand and wrist to determine the patterns of sequential change in degenerative arthritis of the wrist. The most common pattern of degenerative arthritis of the wrist was described as SLAC and represented a final common pathway for a variety of carpal conditions, of which the most common were rotatory subluxations of the scaphoid and scaphoid nonunion. Most cases of SLAC wrist represent the late sequelae of scapholunate dissociation, either traumatic or secondary to attenuation of the scapholunate ligament. Scapholunate ligament attenuation by calcium pyrophosphate dihydrate deposition disease or rheumatoid arthritis can also result in SLAC wrist. Chronic scaphoid nonunions can also lead to a SLAC pattern of arthritis and have been more correctly termed scaphoid nonunion advanced collapse (SNAC) (Fig 1). Despite the etiology, the pattern of SLAC wrist shows a consistent progression of degenerative changes that first occurs between the tip of the radiostyloid and the scaphoid (stage I) (Fig 2). The arthritic changes then progress along the radioscapoid articulation (stage II). The radiolunate joint is spared, and the degenerative changes progress to the capitolunate joint (stage III). Despite the etiology, the SLAC pathway has consistently spared the radiolunate articulation, even when there is severe or chronic dorsal intercalated segmental instability (DISI) stance of the lunate. This preservation of the radiolunate joint is the foundation of the 4-corner arthrodesis.

Another group of patients who may benefit from the 4-corner arthrodesis includes those with chronic dynamic carpal instability, chronic perilunar instability or nondissociative carpal instability. When soft tissue reconstruction or repair has failed or when soft tissue reconstruction would result in a greater limitation of motion than limited arthrodesis, 4-corner arthrodesis with scaphoidectomy can decrease pain, improve strength, and preserve motion.

The 4-corner arthrodesis is indicated in patients with nondissociative carpal instability that has failed soft tissue reconstructions and those with arthritic involvement of the radioscapoid joint with or without capitolunate involvement, chronic dynamic carpal instability, or chronic perilunar instability not amenable to soft tissue procedures. Absolute contraindications to the 4-corner arthrodesis include ulnar translation of the carpus and radiolunate degenerative changes, observed intraoperatively or in preoperative radiographs.
BIOMECHANICAL CONSIDERATIONS

Although a complete discussion of biomechanics of the wrist is beyond the scope of this article, basic understanding of the normal mechanics and the effects of the 4-corner arthrodesis on overall wrist motion and force transmission is essential in communicating the expected outcome to patients.

In the normal wrist, there is a balanced synchrony between the proximal and distal carpal rows. When motion occurs in the flexion-extension plane, there is coordinated motion between the distal and proximal carpal rows. As the distal carpal row flexes, the proximal carpal row also flexes. Similarly, when the distal carpal row extends, the proximal carpal row extends. The relative contributions of flexion and extension of each of the carpal rows depends on the frame of reference evaluated. If the central portion of the carpus (capitate-lunate-radius linkage) is considered, radiocarpal and midcarpal motion are equally divided in a third of wrists, with the remaining two thirds having approximately 60% of flexion at the midcarpal joint and 66% of extension at the radiocarpal joint. However, when the frame of reference is changed to the lateral portion of the carpus (radius-scaphoid-trapezium linkage), nearly two thirds of the global arc of motion occurs at the radioscaphoid joint. With radial and ulnar deviation, there is a complex reciprocating motion of the proximal and distal carpal rows. With radial deviation, the distal carpal row inclines radialward, extends, and supinates. The proximal carpal bones principally flex and translate ulnarward. With ulnar deviation the opposite occurs: The distal carpal row inclines ulnarward, flexes, and pronates, while the proximal carpal bones extend and translate radialward. Such complex

FIGURE 1. An anteroposterior (A) and lateral (B) radiograph of a wrist with a SNAC. The radiolunate articulation and the radioscaphoid articulation proximal to the nonunion site are preserved, and the distal radioscaphoid and capitolunate articulation show significant degenerative arthritis.
motions are required to maintain the carpal congruency and spatial consistency in all wrist positions.33,40,41

Because the proximal and distal carpal rows function separately, procedures linking the rows will result in profound effects on wrist range of motion and force transmission across the radiocarpal joints. Simulation of intercarpal arthrodeses have shown that capitulonate arthrodesis resulted in the greatest reduction of dorsiflexion, palmar flexion, and ulnar deviation compared to scaphoid-trapezium-trapezoid, scaphocapitate, and triquetrohamate arthrodesis.42 Specifically,
there was a reduction of 9° of ulnar deviation, 34° of
dorsiflexion, and 25° of palmar flexion. Gellman and
associates showed that intercarpal arthrodesis within
a carpal row had minimal effects on wrist motion in
all planes. However, when intercarpal arthrodesis oc-
curred between rows, profound losses of motions were
observed. Capitolunate arthrodesis resulted in the
greatest loss of motion in the flexion-extension plane
(loss of 30% flexion and 41% extension) and less in
the radio-ulnar planes (loss of 11% ulnar deviation
and 21% radial deviation).

Elegant studies of load mechanics and force
transmission across the radiocarpal by Viegas and
associates have allowed the determination of
normal and abnormal radiocarpal joint loading me-
chanics. By using pressure sensitive film, normal
cadaver wrists were compared with the same wrists
with simulated intercarpal arthrodeses. In the ra-
diocarpal joint of the normal wrist, the scaphoid
was found to transmit 60% of the load, whereas the
lunate accounted for 40%. Overall, the amount of
contact in the radiocarpal joint accounted for only
20% of the surface area but increased to 40% with
increased load. In capitolunate simulated arthrode-
ysis, in which the lunate was brought back into neutral
alignment, there was improved loading across the
radiocarpal joint that more closely approximated the
normal wrist model.

**TECHNICAL ASPECTS**

**Surgical Exposure and Technique**

The exposure of the carpus should be planned to
afford maximal exposure of the carpal elements and to
allow for future salvage procedures should the 4-cor-
ner arthrodesis fail. A dorsal midline longitudinal
incision centered over the third metacarpal-capitate-
lunate-radius axis is the traditional approach that
allows for extensile exposure of the carpus. An alter-
native to this is the T incision, in which the transverse
limb is centered over the carpometacarpal joints and the
longitudinal limb is midline and extends proximally (Fig 3). Excellent carpal exposure with this
incision can be obtained with no skin complications
when used in elective wrist surgery. Additionally,
when future salvage procedures were required (ie, total
wrist arthrodesis), there have been no adverse wound
problems. When a total wrist arthrodesis is performed
after use of a T incision, a fusion plate that does not
require exposure of the third metacarpal, such as the
Cobra wrist fusion plate (Kinetikos Medical Inc, San
Diego, CA), is preferred.

The skin flaps are raised, and the superficial branch
of the radial nerve is identified and protected. The
extensor retinaculum over the extensor pollicis longus
is divided in line with the tendon, and an ulnarly
based flap of extensor retinaculum is created by divid-

**FIGURE 3.** A T-shaped incision, with the distal transverse
limb centered on the carpometacarpal joints and the longitudi-
nal incision in line with the third metacarpal, is an alternative
incision that enables wide exposure of the carpus.

**FIGURE 4.** After the T incision is made, the skin flaps are
elevated, the extensor retinaculum over the extensor pollicis
longus is divided, and a ulnar-based flap of retinaculum is
created by dividing the septations between the third and
fourth and fourth and fifth extensor compartments.
ing the septations between the third, fourth, and fifth extensor compartments (Fig 4). The extensor tendons are retracted, and the dorsal wrist capsule is exposed. A longitudinal incision in the capsule can be made on the ulnar aspect of the fourth compartment to expose the carpal bones, or alternatively, a ligament-sparing capsulotomy can be made along the dorsal intercarpal, the dorsal radiotriquetral ligaments, and radioscaphoid joint (Fig 5). The ligament-sparing capsulotomy, when repaired, may prevent dorsal capsular contracture, and thus improve ultimate range of motion. A radial based flap of capsule is then raised, exposing the carpal bones (Fig 6). The radiolunate articulation is inspected for degenerative wear and if normal, the scaphoid is excised either piecemeal with a rongeur or in its entirety sharply. Care is taken not to injure the volar radiocarpal ligaments (radioscaphocapitate and long radiolunate ligaments), because injury to these structures may result in ulnar translocation of the remaining carpals. The articular surfaces of the capitohamate, triquetromate, triquetrohamate and lunotriquetral joints are denuded of articular cartilage, and further prepared by placement of 1-mm burr holes evenly spaced throughout the surfaces to be arthrodesed (Fig 7).

Neutral Alignment of the Capitolunate Axis

Reduction of the capitolunate axis in neutral position is critical to the success of the 4-corner arthrodesis. Without reduction of the capitolunate axis, dorsal impingement on the radius can occur, often resulting in pain and limitation of extension. Correction of carpal alignment improves motion and prevents dorsal impingement. When significant DISI deformity is associated with the carpal pathology, neutral alignment can be difficult to obtain. Use of a K wire placed into the lunate to act as a joystick can be helpful; however, the K wire can often be in the way of future fixation methods. An alternative technique, which we prefer, was described by Linscheid. Under fluoroscopy, a lateral view of the flexed wrist is obtained. The wrist is flexed and slightly ulnarily...
deviated until neutral alignment of the radius and lunate are seen. A 0.0625-inch K wire is then drilled from the dorsal distal radius into the lunate, with the lunate held in the reduced position. With the K wire in place, the wrist is extended, while the neutral alignment of the radiolunate joint is preserved.

Choice of Bone Graft

Allograft or autologous bone graft obtained from the distal dorsal radius or the anterior iliac crest is packed into the interstices of the denuded articular surfaces. Autologous cancellous grafts are the most effective grafting material, because they are osteoconductive and osteoinductive and contain living osteogenic cells. Autogenous iliac crest bone graft, on the other hand, is more dense and has greater numbers of osteogenic cells, but it requires an additional surgery site that is often more painful than the wrist surgery. Despite the histomorphogenic differences in iliac crest and distal radius bone graft, clinical studies have not borne out these differences and have shown both to be effective in affording arthrodeses. Allografts become attractive, because their use avoids additional surgery. However, the lack of osteoinductivity and osteogenic cells, in addition to the potential for disease transmission, tempers the decision to use allograft materials. The choice of bone graft and the surgeon’s preference should be discussed with the patient before surgery.

METHOD OF FIXATION

After bone graft is packed into the interstices of the denuded articular cartilage, the capitolunate axis is reduced, and a 0.045-inch K wire placed across the capitate and triquetrum maintains the alignment. Several methods of securing the 4-corner arthrodesis have been described and include fixation with K wires, staples, screws, and specially designed plates.

K-Wire Fixation

In Watson’s original description of the 4-corner arthrodesis, K wires were the method of fixation. After the carpal bones are temporarily held in neutral alignment and bone graft is placed, 0.045-inch K wires are placed from the capitate to the lunate, hamate to lunate, triquetrum to capitate, and triquetrum to lunate (Fig 8). The placement of wires is confirmed on fluoroscopy. The wires are cut and buried under the skin or left protruding through the skin. Additional bone graft is placed to fill the gaps.

Staple Fixation

Since the advent of power staple fixation, the placement of staples has increased in accuracy and biomechanical properties. The 3M Staplizer (3M, Minneapolis, MN) is an air-powered stapler/impactor that uses staples in cartridges ranging from 7 mm to 16 mm in width and depth. Power-driven staples showed increased pullout strength compared with manually driven staples. When used in 4-corner arthrodesis, staples can be used in conjunction with K wires (Fig 9) or by themselves. When used by themselves, one of
FIGURE 8. K-wire fixation of the 4-corner arthrodesis has been a very common method of securing the carpal bones. Typically, 0.045-inch K wires are placed percutaneously, engaging the capitate-lunate, capitate-triquetrum, hamate-lunate, and hamate-triquetrum bones (A, B). Additional K wires are placed as needed. After K-wire fixation, bone graft is packed between the bones to be arthrodesed (C).
two configurations can be used. One configuration uses 4 staples in a “box” pattern (Fig 10). The staples span the capitolunate, capitohamate, triquetrohamate, and lunotriquetral articulations. The lunotriquetral staple is difficult to place and may impinge on the dorsal lip of the radius if improperly positioned. The second configuration, which avoids impingement on the radius, is placement of 3 staples that span the capitohamate, capitolunate, and triquetrohamate joints (Fig 11). Typically, a 13-mm–wide by 10-mm–deep staple is used. Once the staples are placed, temporary K wires, which maintained carpal alignment, are removed and wrist motion is evaluated; careful fluoroscopic evaluation of the depth of the staple is necessary in order to prevent irritation of the pisotriquetral joint or other volar structures.57 Additional bone graft is placed in the 4-corner area.

**Screw Fixation**

Screw fixation of the 4-corner arthrodesis with headless compression screws is a method of fixation that results in immediate stable fixation that would allow for early range of motion. Use of the cannulated Acutrak variable-pitched headless screw (Acumed, Beaverton, OR) or cannulated Herbert-Whipple screw (Zimmer, Warsaw, IN) is ideal. The cannulated
screw allows for accurate placement of the screw and allows the placement of multiple screws in a relatively confined space. Screws should be placed at a minimum across the capitolunate, triquetrohamate, and capito-hamate joints when using screw fixation. A variety of combinations of screw placement can result in successful outcomes.

Plate Fixation

A specially designed plate for limited wrist arthrodesis called the Spider Limited Wrist Fusion Plate (Kinetikos Medical Inc, San Diego, CA) was introduced in 1999. The Spider plate is a low-profile, conically shaped plate with 8 recessed screw holes that accept 2.4-mm screws (Fig 12). After correction of the DISI deformity with the radiolunate K wire, bone graft is packed into the interstices of the denuded carpal bones. A K wire is placed from capitate to the triquetrum, provisionally fixing the carpal bones (Fig 13). A special conical rasp is used to create a recessed, accepting bed for the Spider plate, which is centered at the junction of the 4 corners (Fig 14). In the case of a type II lunate, the rasp is centered at the articulation of the lunate and hamate. The Spider plate is placed in the accepting bed and rotated to allow the placement of 2 screws into each of the carpal bones. A 1.5-mm drill is used to place the index screw hole, typically in the capitate. The screw length is measured, and a self-tapping 2.4-mm screw is placed into the capitate. Subsequently, a screw is placed in each of the remaining carpal bones, followed by placement of the second screw into each of the carpal bones (Fig 15). The provisional K wire fixation is removed; motion is evaluated, ensuring that no plate impingement occurs; and screw

FIGURE 10. (A, B) 3M Staples used in a box configuration secure the capitolunate, lunotriquetral, capitohamate, and triquetrohamate articulations. Care must be used in placing the lunotriquetral staple, because it can impinge on the dorsal distal radius.
An alternative to the box configuration for placement of staples is the use of 3 staples placed across the capitohamate, capitolunate, and triquetrohamate joints. Bone graft is placed between the bones before staple application and is further impacted between the bones after the staples are placed.
lengths are confirmed with radiographs (Fig 16). Additional bone graft is packed into the center of the 4-corner region through the plate. The rigid fixation provided by the Spider plate allows for early active range-of-motion exercises.

**Closure**

After the 4-corner arthrodesis is secured and the temporary K wires removed, the radially based flap of the ligament-sparing capsulotomy is replaced and repaired with nonabsorbable sutures (Fig 17). The extensor tendons are replaced, and the extensor retinaculum is repaired with the extensor pollicis longus dorsally transposed (Fig 18). Tourniquet is deflated, hemostasis is obtained, and the skin edges are reapproximated (Fig 19). A bulky hand dressing with a volar plaster splint immobilizes the wrist in a neutral position and the elbow at 90°.

**POSTOPERATIVE CARE/REHABILITATION**

Postoperative care and rehabilitation are contingent on the method of fixation used; however, all patients are encouraged to commence digital range of motion, tendon-gliding exercises, and edema-control measures starting on the first postoperative day. Approximately 1 week after surgery, the bulky hand dressing and sutures are removed. If K wires or staples are used, a long arm cast with the elbow at 90° is applied for 3 weeks, at which time a short arm cast is applied until arthrodesis has occurred. When screw or Spider plate fixation is used, a short arm cast can be placed for 3 to 4 weeks, or alternatively, a removable custom-made orthoplast short arm splint can be applied to allow early active range-of-motion exercises. Serial interval radiographs should be taken to ensure the arthrodesis has united before return to full normal activities. Based on our experience, the average time to arthrodesis for K wires is approximately 8 to 10 weeks, for
staple fixation is approximately 6 to 8 weeks, and for Spider plate fixation is approximately 4 to 5 weeks.

A formalized hand therapy program emphasizing range of motion, strengthening and endurance is often beneficial following prolonged immobilization.

CLINICAL OUTCOMES

The earliest reported outcomes for 4-corner arthrodesis was by Watson and associates. They reported on 2 patients with 3 wrists that underwent the 4-corner arthrodesis, of which only the results of 1 patient (1 wrist) were reported. This patient had a follow-up of 2 years and 6 months and had 10° of extension (40° opposite wrist), 50° flexion (55° opposite), 20° radial deviation (35° opposite), and 20° ulnar deviation (20° opposite) and reported that he was without pain. Three years later, Watson and Ballet reported on the treatment of 19 patients treated for SLAC wrist. Of these, only 9 were treated with silicone scaphoid replacement combined with the 4-corner arthrodesis and 1 with 4-corner arthrodesis. The average age of this subset of patients was 55 years, and the average follow-up was 17.5 months. Overall this cohort reported less pain, with the exception of 1 patient who reported more pain. The average grip strength of the operative wrist of this cohort was 73% of the unaffected wrist. The average flexion of the operative wrist was 30° (45% of the opposite), average extension was 33° (54% of opposite), average radial deviation was 11° (40% of opposite), and average ulnar deviation was 26° (66% of opposite).

In 1993, Voche and Merle reported on 12 patients who underwent 4-corner arthrodesis that were followed up for an average of 18.8 months. They reported that 75% had pain relief and an average grip strength of 57% of the opposite, unaffected wrist. The average flexion of the operated wrist was 27°, extension was 18°, radial deviation was 4°, and ulnar deviation was 13°.
The first large series to evaluate the outcome of scaphoidectomy and 4-corner was done by Ashmead and associates in 1994. These authors reported on 100 cases followed up for an average of 44 months. 85% of patients reported excellent or good pain relief. The average grip strength was 81% of the opposite unaffected wrist. The average flexion of the operated wrist was 32°, extension was 42°, radial deviation was 15°, and ulnar deviation was 22°. The average total flexion-extension arc of motion was 53% of that of the opposite wrist.

Watson and associates reported their results of 252 patients who underwent the 4-corner arthrodesis for SLAC wrist. This report appears to include the patients in Ashmead’s series. Despite this, the average flexion-extension arc was 88° (53% of opposite wrist), with 91% of patients reporting pain relief. The average grip was 80% of the opposite grip.

**Complications**

Of the 431 cases reported in 8 series of 4-corner arthrodesis, the overall complication rate was 13.5%. Dorsal impingement of the capitate and radius occurred in 4.4% (Fig 20), reflex sympathetic dystrophy occurred in 3%, superficial infections occurred in 3%, nonunions occurred in 2%, deep infections occurred in 0.5%, and deQuervain’s tenosynovitis occurred in 0.5%. Only 7 failures of 4-corner arthrodesis that required conversion to total wrist arthrodesis were reported, representing a 2% incidence.
ALTERNATIVE PROCEDURES

Capitolunate Arthrodesis

The 4-corner arthrodesis was innovated secondary to the difficulties in obtaining union in capitulunate arthrodesis. Several authors have described scaphoidectomy and capitulunate arthrodesis for the treatment of radioscaphoid arthritis. The average range of motion obtained with capitulunate arthrodesis was 48% of normal extension, 59% of normal flexion, 59% of normal radial deviation, and 59% of normal ulnar deviation. Grip strength averaged 67% of the normal grip strength. A comparison of clinical results shows that the addition of the hamate and triquetrum to the capitulunate arthrodesis does not diminish motion. Despite the advantages of requiring a less extensive exposure, less bone graft and less surgical time compared with 4-corner arthrodesis, this procedure is not without complications. Kirshenbaum and associates reported a 33% nonunion rate and 33% pin tract infection rate.

Another variant of a capitulunate arthrodesis was described by Calandruccio and associates, who described a capitulunate arthrodesis combined with excision of the scaphoid and triquetrum. In 14 wrists treated with this technique, they showed range of motions and grip strengths similar to those of other motion-sparing procedures (53° flexion-extension arc; 71% normal grip strength). The lower nonunion rate of 14% most likely represents the results of screw fixation compared with the K-wire fixation used by Kirshenbaum et al.

Proximal Row Carpectomy

An alternative to 4-corner arthrodesis in the treatment of stage I or II SLAC is the proximal row carpectomy (PRC), which involves the removal of the proximal carpal row and allows the capitate to articulate in the lunate fossa. Although concerns regarding the differential radius of curvature between the lunate fossa and capitate and the subsequent development of progressive degenerative arthritis have been discussed, long-term studies have not borne this out.

Several studies have compared 4-corner arthrodesis to PRC in the treatment of SLAC wrist (Ta-
Tomaino and associates reported a retrospective comparison of 15 patients with SLAC wrist treated by PRC and 7 treated with 4-corner arthrodesis with an average follow-up of 5.5 years. All patients but 3 with PRC had satisfactory pain relief, grip strength, and functional performance. There were no statistical differences in subjective or objective results with the exception of motion, where PRC had improved motion over 4-corner arthrodesis. Tomaino and associates concluded that for stage III SLAC, 4-corner arthrodesis is the motion-preserving treatment of choice but that for stage I and II SLAC, PRC is more appealing, because it avoids complications of nonunion, pin tract infections, and lengthy immobilization.

**FIGURE 20.** (A) Dorsal impingement of the capitate and radius can occur if the capitolunate axis is not arthrodesed in neutral alignment. (B) Radiograph of a patient with dorsal impingement secondary to failure to completely reduce the DISI deformity of the lunate in addition to excessive bone graft being placed.
Wyrick and associates\textsuperscript{57} showed statistically significant differences with respect to total arc of wrist motion and grip strength. Specifically, in their retrospective comparison, they noted a total arc of motion of 64\% in PRC compared with 47\% in 4-corner arthrodesis and improved grip in PRC (94\% of opposite wrist) compared with 4-corner arthrodesis (74\% of opposite). These researchers recommended PRC for SLAC stage I or II.

In a retrospective evaluation of treatments for SLAC wrists, Krakauer and associates\textsuperscript{27} compared 23 patients treated with 4-corner arthrodesis to 12 patients with PRC. Similar to the findings of the previous studies, they concluded that PRC best preserved wrist mobility and that 4-corner arthrodesis was reliable in diminishing pain in SLAC stage III wrist while maintaining a functional arc of motion.

**Conclusions**

Four-corner arthrodesis with scaphoidectomy is a time-tested, motion-sparing wrist procedure that has evolved over the past 20 years. The indications for 4-corner arthrodesis include radioscaphoid arthritis with or without midcarpal arthritis, failed intercarpal ligament reconstruction, or perilunar instabilities not amenable to soft tissue reconstruction. The absolute contraindication for 4-corner arthrodesis is radiolunate arthritis or ulnar translocation of the carpus. Four-corner arthrodesis is a biomechanically sound intercarpal fusion that results in near-normal load transmission through the radiolunate articulation. Patient satisfaction is high, and the procedure offers good to excellent pain relief. The range of motion after 4-corner arthrodesis ranges from 41\% to 53\% of the normal opposite wrist, and up to 76\% of normal grip strength can be expected. Advances in surgical exposures, fixation techniques, and implants have allowed for rigid fixation that enables for rapid union and the commencement of early range of motion. Failure rates and complication rates are relatively low, and long-term outcomes have been promising.

**References**


