

# Effectiveness of Four-Corner Arthrodesis with Use of a Locked Dorsal Circular Plate

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## Abstract

**Background** Compared with traditional methods of fixation in four-corner arthrodesis, reviews of results using a dorsal circular plate (DCP) have identified higher complication rates. As the use of circular plate fixation for limited wrist arthrodesis was found to be a valuable concept per se and continued innovation and technical advancement are crucial to improve future treatment, changes in plate design were encouraged.

**Questions/purposes** To further evaluate the use of DCP fixation in four-corner arthrodesis, we report the first results using a radiolucent, nonmetallic (polyetheretherketone), locked DCP for four-corner arthrodesis.

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One of the authors (PH) is eligible to receive royalties from the sale of the Xpode® cup, in any 1 year, an amount in excess of \$10,000, from TriMed Inc (Valencia, CA, USA) and would benefit from the outright sale of the manufacturing rights.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at the Institut Français de Chirurgie de la Main, Paris, France.

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**Methods** We retrospectively analyzed the clinical and radiographic results of 24 patients who underwent four-corner arthrodesis with a locked DCP at a minimum followup of 63 months (mean, 76 months; range, 63–91 months). There were nine women and 15 men, with a mean age of 53 years (range, 37–78 years) at the time of surgery. We evaluated ROM with a goniometer and grip strength with a dynamometer. Function was assessed using QuickDASH. Radiographs were evaluated for union, carpal alignment, and hardware problems.

**Results** At latest followup, ROM averaged 66% and 77% of the uninjured side in flexion-extension and radioulnar deviation, respectively. Grip strength averaged 70% of the uninjured side. The average postoperative QuickDASH score was 19.11. Union was achieved by 22 of the 24 patients.

**Conclusions** Our data show four-corner arthrodesis with a radiolucent, nonmetallic, locked DCP is an effective procedure that allows stable primary fixation as a basis for good functional outcome, provided surgical technique and quality of bone graft are adequate.

**Level of Evidence** Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

## Introduction

Scapholunate advanced collapse (SLAC) is the most common pattern of degenerative arthrosis in the wrist [27]. Most cases are the late sequelae of scapholunate dissociation, either traumatic or secondary to attenuation of the scapholunate ligament. Chronic scaphoid nonunion also can lead to a SLAC pattern of arthritis and has been more correctly termed scaphoid nonunion advanced collapse (SNAC). As a

separate entity, scaphoid chondrocalcinosis advanced collapse (SCAC) is a SLAC pattern that has been shown to occur as a consequence of scapholunate ligament attenuation by calcium pyrophosphate dihydrate deposition, also known as chondrocalcinosis or pseudogout [7, 19–22, 24]. The SLAC pathway has consistently spared the radiolunate joint, even when there is severe or chronic dorsal intercalated segmental instability (DISI) of the lunate. Consequently, these conditions have been addressed jointly through numerous surgical salvage procedures described in the literature [24].

Although total wrist fusion has a predictable success rate in terms of pain relief, many patients find the loss of wrist motion objectionable. For Stages I and II SLAC, the proximal row carpectomy has gained widespread use as a motion-preserving salvage procedure. Alternatively, four-corner arthrodesis with scaphoid excision is a time-tested, motion-sparing procedure also applicable for Stage III SLAC. A meta-analysis of the literature comparing the two techniques regarding clinical outcome concluded proximal row carpectomy may provide more postoperative motion and lacks the complications related to four-corner arthrodesis (ie, nonunion, hardware problems, and dorsal impingement), but it is associated with a greater risk of subsequent osteoarthritis [18].

Traditionally, methods of fixation in four-corner arthrodesis included K-wire [9, 27], screw [2], or staple [30] fixation. The first DCP for limited wrist arthrodesis, called the Spider<sup>™</sup> Limited Wrist Fusion Plate (Kinetikos Medical Inc, San Diego, CA, USA), was introduced in 1999 and was promoted as facilitating more rigid fixation, allowing early active ROM exercises [22]. However, first reviews of results using the DCP for internal fixation in four-corner arthrodesis were discouraging. Compared with the published results using other fixation methods, DCP fixation reportedly produced a greater number of nonunions and inferior grip strength and ROM. Moreover, technical difficulties, cases of implant failure, and a high incidence of dorsal radiocarpal impingement were reported [8, 12, 23, 26]. Subsequent studies reported more encouraging results and emphasized the role of meticulous surgical technique [4, 17]. As the use of plate fixation for limited wrist arthrodesis was found to be a valuable concept, additional biomechanical studies and changes in plate design were encouraged [8, 12, 23, 26]. Kraisarin et al. [13] recently performed a biomechanical comparison of different fixation techniques used for four-corner arthrodesis and reported a radiolucent, nonmetallic (polyetheretherketone), locked DCP (Xpode<sup>®</sup> cup; TriMed Inc, Valencia, CA, USA) (Fig. 1) was the most stable construct.

In this retrospective study, we aimed to assess the clinical results of four-corner arthrodesis achieved using this plate by measuring ROM, grip strength, pain,



**Fig. 1** The Xpode<sup>®</sup> cup is shown.

satisfaction, and the QuickDASH questionnaire. We also assessed the ability to return to work and radiographic results noting union rate, carpal alignment, hardware problems, and joint line narrowing.

### Patients and Methods

With institutional review board approval, we identified 25 patients who had scaphoid excision and four-corner arthrodesis with the Xpode<sup>®</sup> cup between 2003 and 2005 for degenerative arthritis attributable to SLAC, SNAC, or SCAC. Demographic material and preoperative status were gleaned from office chart review. All but one patient were available for followup and thus were included in the study. There were nine women and 15 men, with a mean age of 53 years (range, 37–78 years) at the time of the surgery. Surgery was performed on the dominant wrist in 15 patients and on the nondominant wrist in nine. Fourteen of the patients were manual workers. The minimum followup was 63 months (mean, 76 months; range, 63–91 months). Indications for arthrodesis were Stage II SLAC (n = 2), Stage III SLAC (n = 10), Stage III SNAC (n = 7), and Stage III SCAC (n = 5). Seventeen of these lesions were posttraumatic, five were secondary to scapholunate ligament attenuation by calcium pyrophosphate deposition (chondrocalcinosis or pseudogout), and two were of unknown origin. Bone graft was morselized scaphoid combined with reaming debris in 14 patients, distal radius and morselized scaphoid in three, distal radius and reaming debris in one, distal radius alone in two, reaming debris alone in two, and not documented in two.

For surgery, a dorsal “lazy S”-shaped or longitudinal wrist incision was used. The third extensor compartment was opened, and the extensor pollicis longus tendon and

muscle were transposed radially. The second and fourth compartments then were elevated, unopened, from the radius, and a segment of the posterior interosseous nerve was excised proximal to the fourth compartment. The joint was exposed using the dorsal ligament-sparing approach advocated by Berger et al. [5]. If present, dorsal radial osteophytes were excised marginally with a small rongeur. The scaphoid was excised completely while preserving all the volar radiocarpal ligaments. A 1.5-mm K-wire was brought into the lunate as a joystick for reduction of the DISI deformity. Alternatively, the method described by Linscheid and Rettig [15] was used. The reduction was held by temporary fixation with two K-wires placed as volar as possible to avoid any interference with subsequent reaming. Contrary to common recommendations in the literature [22], fusion of the lunate was performed in the neutral position or slight undercorrection (dorsiflexion intercalated instability) relative to the capitate to obtain more rigid primary fixation. Concurrently, we favor good primary stability over a 100% alignment of the radial borders of the lunate and capitate. The correct positions of the lunate and capitate were confirmed by perioperative fluoroscopy, and the wrist was put through a complete ROM to exclude impingement attributable to insufficient reduction. Subsequent positioning of the reamer over the four-corner junction was facilitated by a specific centralizer, which also served to determine the correct cup diameter (medium or large) dependent on wrist size. Care was taken to ensure sufficiently deep reaming to avoid any dorsal radiocarpal conflict of the cup. As a rule, the proximal pole of the cup was positioned 5 mm distal to the proximal border of the reduced lunate. Cartilage-to-cartilage contact was maintained at the volar periphery of the joints to undergo arthrodesis to maintain appropriate carpal dimensions when the remaining cartilage of the adjacent joint surfaces of the capitate, lunate, hamate, and triquetrum subsequently were denuded with a small rongeur. Meticulous denudation of cartilage from at least the dorsal  $\frac{2}{3}$  of the joints between all four bones before application of autogenous cancellous bone graft was essential.

Ideally, distal radius cancellous bone taken at Lister's tubercle was inserted into the denuded joint lines between the four bones. Alternatively, if the scaphoid had healthy cancellous bone, morselized scaphoid bone was used in this series together with bone debris from reaming. Next, an 18- or 22-mm-diameter Xpode® cup was aligned, and one to two holes per bone were drilled before secure placement of the screws. We found it helpful to position the first screw into the lunate, followed by a screw into the opposing capitate and a second screw into the lunate and capitate before placement of screws in the hamate and triquetrum. After positioning of all screws, they were tightened progressively in a clockwise fashion, allowing for controlled

successive placement of the cup without tilting. No bone graft was placed under the cup, as this would only raise its final position, associated with the risk of dorsal radiocarpal impingement.

The wrist was again taken through a complete ROM to ensure stability of the fusion and to confirm there was no dorsal impingement of the plate. If necessary, limited resection of the dorsal distal radius or partial radial styloidectomy was done at this stage. Final fluoroscopy was required to check appropriate alignment of bones and correct length of screws (Fig. 2). After proper irrigation of the wound, the joint capsule was closed and the extensor retinaculum was sutured, leaving the extensor pollicis longus tendon subcutaneously. The wrist was immobilized in a forearm plaster cast (without inclusion of the proximal phalanx of the thumb) until removal of stitches, followed by a custom-made removable forearm orthosis for another 4 weeks. Gentle and intermittent ROM exercises of the radiocarpal joint were started after removal of stitches ( $\pm$  Day 15) and were intensified progressively according to clinical evolution and radiographic findings.

Followup was done by a fellowship-trained hand surgeon who did not participate in the clinical care of included patients (ML). ROM was measured by goniometer and grip strength by a JAMAR dynamometer (JAMAR Technologies, Inc, Hatfield, PA, USA) preoperatively and postoperatively for the surgically treated wrist and compared with the opposite side by calculating the percentage of the normal, unaffected side. Subjective pain was evaluated on a scale from 0 to 10, with 0 indicating no pain and 10 indicating persistent or severe pain. We also asked the patients to indicate their overall satisfaction as very satisfied, satisfied, fairly satisfied, or dissatisfied. Postoperative functionality was measured with the QuickDASH



**Fig. 2** Perioperative fluoroscopy shows correct placement of the plate and screws.

standardized survey. Scoring of the QuickDASH questionnaire is as follows: 0 = no limitations, 10 = mean of normal population, and 100 = full disability [1].

An additional questionnaire concerning preoperative and postoperative work status distinguished manual from nonmanual labor, delay of return to work, and ability to return to the same occupation.

We evaluated AP, lateral, and oblique radiographs for evidence of union and proper carpal alignment (< 15° lunate extension). Successful arthrodesis was determined by solid trabeculation across the intercarpal articulations and no persistent joint interstices visible on the radiographs. Lucency around the screws on radiographs and tenderness directly over the fusion site during clinical examination were used as indirect signs of nonunion. If nonunion was suspected, a CT scan was used for confirmation. The radiolunate angle was measured on lateral radiographs according to a standard technique by goniometer after indicating the longitudinal axis of the radius and lunate. The films were further inspected for hardware failure or malposition and joint line narrowing.

## Results

At latest followup, all patients in this series showed clinical improvement as the result of the four-corner arthrodesis. ROM averaged 66% and 77% of the uninjured side in flexion-extension and radioulnar deviation, respectively (Table 1). Grip strength averaged 70% of the uninjured side. Before surgery, no patient was pain free, 13 patients (54%) rated sustained pain as moderate and 11 (46%) as severe. At latest followup, 22 patients (92%) were pain free and two patients (8%) reported residual moderate pain. Seven patients were very satisfied with the overall result, 14 were satisfied, three were fairly satisfied, and none was dissatisfied. The average postoperative QuickDASH score was 19.11 (range, 2.27–61.36), which reflects a good functional outcome with only moderate disability [1].

Of the 14 patients in the study who were employed as manual laborers, two had to modify their work duties postoperatively owing to problems with the wrist and

began new positions 13 and 17 months after four-corner arthrodesis, respectively. One patient modified his work duties owing to unrelated causes and returned to work 18 months later. Two patients who once worked as manual laborers (one as a cleaning lady and the other as a nurse) have not returned to work. None of the three patients who were nonmanual laborers in the study had to modify or restrict their employment. For the 12 patients who returned to their original jobs, the average delay was 7 months (range, 4–12 months). Six patients were retired before the surgery, and one woman was not employed.

Radiographs showed union of the whole fusion mass in 22 of 24 patients. The radiolunate angle averaged 23° (range, 15°–40°) lunate extension preoperatively and 6° (range, 0°–15°) postoperatively. Intraoperative or postoperative assessment revealed no dorsal radiocarpal impingement or hardware failure. At the most recent followup, no decrease in the radiolunate joint space was observed.

There were two nonunions, both confirmed by CT scan and revision surgery. The bone graft used in the initial operation in both patients consisted exclusively of bone material harvested from reaming. The first occurred in a 53-year-old woman initially presenting with Stage III SLAC who also reported severe pain located at the ulnar side of the wrist at followup. Radiographs and CT scan showed not only lack of consolidation but also a screw penetrating the distal surface of the hamate, reaching into the fifth carpometacarpal joint (Fig. 3). The second nonunion occurred in a 47-year-old man who had scaphoidectomy and four-corner arthrodesis for Stage III SNAC. Revision surgery performed 1 year after the initial procedure in both patients consisted of hardware removal, iterative denudation of the joint interstices, abundant



**Fig. 3** A radiograph of the wrist of a 53-year-old woman shows pseudarthrosis at followup. Only one screw was placed into the lunate, capitate, and triquetrum, respectively.

**Table 1.** Preoperative and postoperative ROM and grip strength

Variable	Preoperative	Postoperative
Flexion (°)	33 ± 9.6 (15–60)	34 ± 10.8 (5–55)
Extension (°)	24 ± 11.7 (0–45)	30 ± 13.2 (0–50)
Ulnar deviation (°)	15 ± 8 (0–30)	18 ± 5.3 (5–25)
Radial deviation (°)	9 ± 6.8 (0–30)	12 ± 6.2 (5–25)
Grip (% of other side)	38 ± 21 (2–100)	70 ± 19 (38–100)

Values are expressed as mean ± SD, with range in parentheses.



cancellous bone graft taken from the iliac crest in the first patient and the distal radius in the second patient, and rosteosynthesis with the locked DCP. Both patients achieved uneventful healing after the second procedure, and consolidation was confirmed by clinical examinations and conventional radiographs within 4 months. No radiocarpal or total wrist arthrodesis was needed. Other than the instance mentioned above, no screw malposition was seen in this series of patients. There were also no infections or problems with wound healing.

## Discussion

Compared with traditional methods of fixation in four-corner arthrodesis, reviews of results using a DCP have identified higher complication rates, prompting changes in plate design. To further evaluate the use of DCP fixation in four-corner arthrodesis, we report the first results using a locked DCP (Xpode® cup) for four-corner arthrodesis.

Our study has several limitations, including that it is retrospective and the consequent lack of a comparative preoperative QuickDASH score. Moreover, the relatively low number of patients did not allow for statistical analysis.

For Stages I and II SLAC, proximal row carpectomy has been recommended because of technical ease, early mobilization, and the lack of nonunion risk [25]. Technique-inherent shortening of the carpus with associated weakness attributable to slackness of the extrinsic tendons is a concern not all authors have been able to corroborate [9, 18, 25]. As the radius of curvature of the capitate head is approximately 60% of the lunate fossa in the AP and lateral planes, biomechanical studies have shown motion at the radiocarpal joint after proximal row carpectomy includes a combination of rotation and translation attributable to the described incongruity between the capitate and the lunate fossa, leading to greater excursion of the contact point and increased average pressure in the lunate fossa compared with four-corner arthrodesis [6, 11]. Moreover, some authors have reported a high incidence of visible radiocapitate degenerative changes after relatively short- to medium-term followup, with or without clinical correlation [9, 10, 14, 18].

Since its introduction by Watson et al. [28] in 1981, four-corner arthrodesis has been shown to be a time-tested and biomechanically sound intercarpal fusion that results in near-normal load transmission through maintenance of carpal height and preservation of the intact radiolunate articulation [22]. The two absolute contraindications to four-corner arthrodesis are ulnar translocation of the carpus, which disrupts the concentric congruity of the radiolunate articulation, and preexisting radiolunate

degenerative changes [2, 22]. Patients with such conditions are better treated with primary wrist arthrodesis [29]. As originally described, four-corner arthrodesis included replacement of the excised scaphoid with a silicone implant [28]. The incidence of particulate synovitis and reports of implant fragmentation triggered reassessment of the need for these implants, and side-by-side comparison of functional outcome in patients with and without silicone implants supported the conclusion that silicone scaphoid replacement was not an essential feature of four-corner arthrodesis [2, 29].

As reported by Shin [22], the concept of DCP fixation for four-corner arthrodesis was introduced in 1999. It was hypothesized rigid internal fixation afforded by DCP would allow for early active ROM exercises and help omit complications associated with the use of staples or K-wires, such as discomfort owing to protruding pins, pin tract infection, and nonunion [26]. A lower risk of tendon irritation or rupture and omission of a secondary procedure for hardware removal were further postulated advantages of a countersunk dorsal plate placed below the cortical surface. There have been various studies investigating the results of four-corner arthrodesis using DCP, with disparate results [4, 8, 12, 17, 23, 26].

Nonunion rates reported in the literature on four-corner arthrodesis with the use of K-wires, screws, or staples for fixation were between 0% and 18% [2, 9, 14, 25, 29, 30]. In contrast to reported nonunion rates with DCP of as much as 63% [12, 23, 26], Bedford and Yang [4] and Merrell et al. [17] reported zero nonunion of the primary fusion mass. The latter authors stated the explanation for the varied results seems to revolve around differences in quantity and quality of bone graft and exacting technique. In our series, we report two nonunions (8%). In both instances, bone graft for the initial procedure consisted exclusively of debris from reaming. As these were the only patients in the cohort in whom the bone graft consisted of debris from reaming alone, we conclude both nonunions were attributable to incorrect choice of bone graft. Consequently, we no longer use of debris from reaming but systematically take cancellous bone graft from Lister's tubercle in the distal radius.

In clinical trials, the reported rate of hardware failure, such as plate or screw breakage or back-out with use of the DCP, varies from 0% to 27% [8, 12, 17, 23, 26]. Other criticisms addressed difficulty following the manufacturer's guidelines in placing the screws, limited compression across the fusion site, and obscuration of the fusion site owing to the presence of the plate [12, 23]. The locked DCP used in our patient cohort facilitates placement of the cannulated titanium screws, which are locked at the desired angle when the heads are seated in the cup, thus preventing back-out migration of the screws. Furthermore,

the plate is manufactured from radiolucent, nonmetallic polyetheretherketone and thereby enables simple perioperative and postoperative radiographic assessment (Fig. 4). In a recent biomechanical comparison of fixation techniques for four-corner arthrodesis, the locked DCP was found to be superior to traditional K-wire technique and DCP for primary stability and hardware failure [13]. We concur with these authors that locked DCP allows for particularly rigid monoblock internal fixation and report no instances of hardware failure.

The importance of adequate lunate reduction to provide greater wrist extension has been reported [22], and a neutral or slightly flexed position of the lunate is considered to be ideal to facilitate wrist extension [9, 12]. By contrast, we

believe insisting on overcorrection may be a source of pseudarthrosis secondary to undue tension and we aimed for neutral position or slight undercorrection of DISI without negative effects on ROM. The postoperative radiolunate angle averaged 6° (range, 0°–15°) lunate extension in our cohort. Hardware impingement on the dorsal lip of the radius after DCP fixation, reported to occur in as much as 25% [23, 26], was not observed in our series. In his comprehensive review, Shin [22] stated the ROM after four-corner arthrodesis ranged from 41% to 53% of the normal opposite wrist and as much as 76% of normal grip strength could be expected. At 66% of ROM and 70% of grip strength compared with the normal opposite wrist, our results are slightly superior regarding ROM and fall near this range

**Fig. 4A–D** (A) AP and (B) lateral radiographs taken immediate postoperatively and (C) AP and (D) lateral radiographs obtained at a later followup after scaphoid excision and four-corner arthrodesis using the locked DCP show how the radiolucent plate enabled simple perioperative and postoperative radiographic assessments.



concerning grip strength. For subjective evaluation of functional outcome, we chose the 11-item short version of the original

30-item DASH scale (QuickDASH) because it was determined to have similar discriminant ability and precision while offering easier use and was chosen by the American Medical Association's *Guides to the Evaluation of Permanent Impairment* for the functional assessment measure of the upper extremity [16]. The average postoperative QuickDASH score in this consecutive case series was 19.11 (range, 2.27–61.36), representing a good functional outcome with only moderate disability.

Bain and Watts [3] recently reported good early clinical results with four-corner arthrodesis persist at least for up to 10 years, while they concede radiographic review was not part of the study. At a minimum followup of 5 years including radiography, we did not observe any decrease in the radiolunate joint line with time in our patient cohort.

We are confident the encountered complications can be avoided through correct choice of bone graft and accurate surgical technique. Consequently, we believe the results of this consecutive case series of patients treated for the SLAC or SNAC pattern of wrist arthritis by four-corner arthrodesis using a newly designed DCP support continued use of the locked DCP for limited wrist arthrodesis.

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