Four-corner arthrodesis with a radiolucent locking dorsal circular plate: technique and outcomes

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Abstract

Background Scaphoid excision and four-corner arthrodesis (FCA) is an acceptable motion sparing procedure used to treat wrist arthritis. Recently, a locking dorsal circular plate composed of polyether-ether-ketone has been introduced (Xpode®; TriMed Inc.). The purpose of this study is to assess the efficacy of this specific plate design with regard to FCA.

Methods A retrospective chart review of all patients who underwent FCA with an Xpode® between January 1, 2008 and December 31, 2012 was conducted. Patients were contacted and asked to return to clinic for clinical and radiographic follow-up. Patient demographics, range of motion, grip strength, and complications were collected from medical records. Patients completed a patient-rated wrist evaluation (PRWE). A paired *t* test was used to compare means, and *p* values <0.05 were considered statistically significant.

Results Twenty-six procedures (24 patients) were identified. One patient required full wrist fusion following the initial procedure. Of the 25 remaining wrists, arthrodesis was successfully achieved in 20 (80 %). Eleven patients (13 wrists, 52 %) returned to clinic for an average follow-up of 28 months. Mean wrist extension improved from 30 to 47°, and flexion decreased from 33 to 23°. Average grip strength was 77 % of the uninjured side. The mean PRWE scores for pain and function were 19.7 and 17.1, respectively. Five patients underwent additional operations (two hardware removals, two contracture releases, and one distal radial ulnar joint arthroplasty).

Conclusions FCA with the Xpode® yielded reasonable results for pain and function and demonstrated a fusion rate of 80 %.

Keywords Four-corner fusion · Wrist arthrodesis · Outcomes · Wrist

Introduction

Scaphoid excision and four-corner arthrodesis (FCA) is an acceptable salvage procedure for treatment of scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse (SNAC). First described by Watson and Ballet in the 1980s, four-corner arthrodesis has been demonstrated to provide reliable pain relief while preserving a functional range of motion and grip strength [1, 12, 17, 20]. Fixation methods for this procedure have varied and include the use of Kirschner wires (K-wires), staples, and headless compression screws. Dorsal circular plates (DCPs) were developed with the idea that they could allow earlier range of motion while limiting postoperative stiffness. The first DCP designed for four-corner fusion, the Spider™ Limited Wrist Fusion Plate (Kinetikos Medical Inc., San Diego, CA, USA), was introduced in 1999. Initial results were fairly discouraging, due to a high incidence of nonunions [9, 19], dorsal impingement [18, 19], broken hardware [5, 18], limited range of motion, and grip strength [5, 9, 18, 19]. Although subsequent studies demonstrated more positive results with fewer complications [3, 14], persistent inconsistencies in reported outcomes have continued to promote further changes in plate design.

More recently, locking dorsal circular plates (LDCP) have been introduced. The Xpode® cup (TriMed Inc., Santa Clarita, CA, 2006) is the first in this class to be composed of a radiolucent polyether-ether-ketone (PEEK-Optima). This plate is designed to allow for more accurate radiographic assessment of cup placement intraoperatively, as well as union postoperatively, compared to prior stainless steel constructs. In addition, PEEK has a modulus of elasticity similar to cortical bone. In a biomechanical comparative study between

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the Xpode® cup, the Spider™ DCP, and K-wire fixation models, Kraisarin et al. concluded that the Xpode® provided the most stable construct of the three [11]. Initial clinical outcomes of four-corner fusion with a LDCP have been encouraging; however, they remain limited at this time [4, 15]. The purpose of this study was to assess clinical outcomes and union rates for four-corner arthrodesis using the Xpode® cup. We hypothesized that this implant would provide pain relief, improved function, and a higher union rate compared to existing data of other circular plates.

Materials and methods

Patient selection

Institutional review board approval was obtained prior to initiation of this study. A retrospective chart review was performed for all patients who had undergone scaphoid excision and four-corner arthrodesis between January 2008 and December 2012 at our institution by two specific surgeons. Patients were considered for inclusion in the study if they were 18 years of age or older and were treated with the Xpode® cup for degenerative arthritis at the time of surgery. Patients were excluded from the study if they underwent arthrodesis using any other device. Patients were considered to have a failed outcome if a full wrist arthrodesis was performed following the primary surgery. A total of 26 surgeries on 24 patients were identified that met the study criteria and were considered for inclusion.

All charts were reviewed for patient demographics, pertinent physical examination findings, surgical technique, pre- and postoperative grip strengths, pre- and postoperative range of motion, and postoperative complications.

Functional and radiographic assessment

All patients who met the inclusion criteria were contacted and asked to return to the clinic in order to obtain the most current range of motion and grip strength measurements. At that time, radiographs of the wrist were performed, and patients were asked to complete a patient-rated wrist evaluation (PRWE) to assess postoperative wrist pain and function.

Due to gaps and inconsistently recorded data recorded during routine clinical follow-up, only range of motion and grip strength data from the patients who returned to clinic for the purpose of research were analyzed. Written informed consent was obtained from all patients who returned to clinic. Wrist range of motion measurements were collected by a physician or physical therapist using a wrist goniometer. Grip strength was measured using a JAMAR hydraulic hand dynamometer (Sammons Preston, Bolingbrook, IL) in both the II and III positions. Lateral pinch, two-digit pinch, and

three-digit pinch measurements were also collected using a pinch gauge (Sammons Preston, Bolingbrook, IL).

If a patient was unable to return to clinic for postoperative evaluation, but desired to participate in the study, verbal consent was obtained and a PRWE was completed over the phone. For any patient who could not be reached by telephone, a recruitment letter was mailed. A follow-up PRWE was included with the letter, and patients were asked to complete it if they could not return to the clinic for the functional assessment.

Radiographic assessment of carpal fusion was based on posteroanterior (PA) and lateral wrist radiographs (Fig. 1). No advanced imaging modalities were utilized to determine fusion. For those patients unable to return to clinic, as well as those who had completed a PRWE over the phone or by mail, the most recent postoperative radiographs were used for assessment. Presence of fusion was determined by a fellowship-trained hand surgeon at our institution. Radiographic evidence of successful arthrodesis was demonstrated by the presence of bridging trabeculae and bony consolidation at the capitulunate and triquetral-hamate joints. Postoperative radiographs were also analyzed for any evidence of hardware breakage, screw migration, dorsal impingement, and carpal malalignment.

Pain and function, as assessed by the PRWE, were considered the primary outcomes of interest in the study. A paired *t* test was used for statistical analysis of outcome variables, and a *p* value of <0.05 was considered statistically significant.

Operative technique

All surgeries were performed by two fellowship-trained hand surgeons (S.M.J. and M.S.R.). A longitudinal wrist incision was made over the dorsal aspect of the wrist just ulnar to Lister's tubercle, centered about the radiocarpal joint. The third extensor compartment was released, allowing for retraction of the extensor pollicis longus tendon radially. The fourth extensor compartment was then elevated using a periosteal elevator, gaining exposure to the dorsal wrist capsule. The capsule was incised in a ligament-sparing fashion as described by Berger et al. [4] and the carpus was inspected. The dorsal scapholunate ligament was divided, and the scaphoid was removed using a rongeur. Complete excision of the scaphoid was confirmed visually and fluoroscopically. The dorsal two-thirds of the articular surfaces of the four carpal bones to be fused were decorticated using a rongeur and small burr. Subsequently, the carpus was reduced, with particular attention to creating a neutral capitulunate angle, and provisionally stabilized with K-wire fixation. K-wires were inserted from the triquetrum to the lunate as well as the triquetrum to the capitate. Care should be taken to ensure that K-wires are in the volar half of each carpus, in order to avoid interference with the burr. Carpal alignment was confirmed with fluoroscopy. Reaming of the carpus was performed until the reamer

Fig. 1 PA and lateral radiographs demonstrating appropriate fusion of the carpal columns

was countersunk just beyond the dorsal aspect of the carpal bones to prevent impingement on the dorsal radius, as described by Rhee et al. [15]. Trialing was performed in order to ensure that no impingement was present prior to definitive fixation. Local autograft from the distal radius or healthy scaphoid and reaming remnants was packed within the joints to be fused. The carpal bones were then definitively fixed using the Xpode® cup and screw fixation. Effort was taken to make sure that each of the four carpal bones to be fused had two screws placed within them. Appropriate plate fixation was confirmed visually and with fluoroscopy.

Postoperative protocol

All patients had their wrists immobilized for approximately 2 months following the procedure, while radiographic imaging was obtained on a monthly basis. Physical therapy was initiated at 2 months postoperatively, beginning with gentle range of motion exercises, and progressing to strengthening exercises once there were both radiographic evidence of bony healing and patients demonstrated clinical improvement, particularly decreased pain.

Results

Of the 26 surgeries considered for inclusion in the study, one patient underwent a total wrist fusion procedure 4 months after the initial surgery secondary to persistent pain and radiolunate arthritis and was considered a failure. That patient's data were excluded from final analysis. A total of 25 wrists from 23 patients were thus included in the study. Of the 23 patients, 20 were male and 3 were female, with an average age of 50 at the time of surgery (range 29 to 73 years). Surgical indications for their procedures included SLAC (14 wrists), SNAC (9 wrists), midcarpal instability (1 wrist), and

posttraumatic midcarpal arthritis (1 wrist). Of those, 11 patients (13 wrists, 52 %) returned to clinic, 5 patients (5 wrists, 20 %) were unable to return but completed a PRWE over the phone, and 7 patients (7 wrists, 28 %) could not be reached by any method of contact.

PRWE scores were calculated at an average follow-up of 31.3 months ($n=18$, 72 %, range 11.6 to 55.4 months). The mean score of the pain component of the PRWE was 19.7/50. Pain at its worst was reported to be 5.6/10 on average (range 0 to 9), and frequency of pain averaged 4.1/10 (range 0 to 10). The mean functional component score of the PRWE was 17.1/50.

Postoperative radiographs were available for all wrists ($n=25$) at an average of 18.9 months (range 2 to 56 months). Wrist PA and lateral radiographs demonstrated union of the carpal fusion mass in 20 of the 25 cases (80 %). Partial fusion was present in the remaining five cases. Of the five partial fusions, three were of the capitulunate fusion mass and two were of the triquetral-hamate fusion mass. One patient (4 %) had evidence of persistent lunate extension in all follow-up radiographs. Screw breakage was noted in two patients (8 %), and each patient denied any specific traumatic event. Neither patient with a broken screw had evidence of nonunion within the fusion mass at most recent radiographic follow-up (Fig. 2) nor required surgery to remove the broken component. The five patients with evidence of partial fusion had an average PRWE pain score of 26.6 and a function score of 20.3.

The average clinical follow-up after surgery was 28 months (range 12–56 months, $n=13$ wrists). One patient did not have preoperative range of motion data available for review, and as such, their postoperative data were included in generating averages, but not included in statistical analysis. Statistical analysis between mean pre- and postoperative range of motion, as well as mean range of motion for all unaffected wrists can be found in Table 1. Grip strength was reported as the percentage of the operative side compared to the contralateral unaffected side. Consequently, the two patients who had

Fig. 2 PA radiograph with evidence of broken screw (*arrow*), despite appropriate fusion mass overall. The patient reported no pain and was satisfied with the procedure results

bilateral procedures performed were not included as a comparative analysis, leaving a total of nine outcomes available for comparison. Due to gaps in preoperatively recorded data, no comparisons could be made between pre- and postoperative grip strength values. Mean grip and pinch strength results can be found in Table 2.

Intraoperative graft selection consisted of distal radius in 3 patients, scaphoid plus reaming remnants in 21 patients, and scaphoid plus reaming remnants plus distal radius in 1 patient. Of the five partial fusions, two occurred in wrists when distal radius grafts were used and three with reaming remnants.

Five patients required further surgical intervention following the initial procedure. Two patients experienced significant wrist stiffness postoperatively that necessitated surgical release of dorsal capsular adhesions. At the time of adhesion release, one patient opted to have his hardware removed due to persistent pain. Another patient reported painful hardware secondary to possible dorsal impingement and underwent hardware removal 23 months after the primary procedure. At

most recent follow-up post hardware removal, both patients reported moderate improvement in pain and stiffness, and persistent bony fusion was confirmed. One patient underwent distal radial ulnar joint (DRUJ) arthroplasty secondary to long-standing DRUJ instability that was present prior to the four-corner arthrodesis procedure. Only 1 patient out of the 26 reviewed required a total wrist fusion, which was performed 4 months after surgery due to persistent wrist pain and evidence of radiolunate arthritis following partial arthrodesis. Bony union from the primary procedure was confirmed intraoperatively in this patient at the time of total arthrodesis. At most recent follow-up after total arthrodesis, the patient continued to report pain and soreness, especially with lifting heavy objects.

Discussion

Traditional methods of four-corner arthrodesis (K-wires, headless compression screws, staples, nonlocking dorsal cup plates) have been demonstrated to provide good results, but reported outcomes have varied [1–3, 6, 7, 14]. Nonunion rates using nonlocking dorsal cup plates have been reported to be as high as 63 % [9]. The data from the present study demonstrate that four-corner arthrodesis with the Xpode® cup is a viable treatment option, offering acceptable clinical outcomes and a fusion rate of 80 % at early follow-up.

This is not the first study to report on outcomes of the Xpode® cup. Luegmair et al. analyzed both clinical and radiographic outcomes in 24 wrists following four-corner arthrodesis with this system. In that study, at a mean of 76 months postoperatively, wrist extension and flexion averaged 30 and 34°, respectively, and grip strength was determined to be 70 % of the uninjured side. The average QuickDASH score was 19, and no patients were dissatisfied with the procedure. Radiographic bony union was evident in 22 of the 24 patients. The two cases of nonunion required a secondary procedure with a revision bone graft before adequate fusion was demonstrated [13]. Similarly, Rhee et al. analyzed fusion rates using the Xpode® system in 23 wrists. Their study

Table 1 Mean unaffected wrist motion and statistical analysis of mean pre- and postoperative affected wrist motions

	Unaffected wrist ^a	Preoperative affected wrist	Postoperative affected wrist	<i>p</i> value
Flexion (°)	50.2 (<i>n</i> =9)	33.3 (<i>n</i> =12)	23.3 (<i>n</i> =12)	0.012
Extension (°)	60.9 (<i>n</i> =9)	29.6 (<i>n</i> =12)	46.5 (<i>n</i> =12)	0.008
Flexion/extension arc (°)	76.9 (<i>n</i> =9)	62.9 (<i>n</i> =12)	69.8 (<i>n</i> =12)	0.346
Radial deviation (°)	17.9 (<i>n</i> =9)	13.1 (<i>n</i> =8)	13.1 (<i>n</i> =13)	^b
Ulnar deviation (°)	26.4 (<i>n</i> =9)	21.9 (<i>n</i> =8)	15.9 (<i>n</i> =13)	^b

^a Measured at most recent clinical follow-up. Only unaffected wrist range of motion included

^b Not calculated due to insufficient matched data points

Table 2 Mean postoperative grip strength percentages (operative/nonoperative) for patients who returned to clinic for follow-up ($n=9$)

JAMAR (setting II)	JAMAR (setting III)	Lateral pinch	2-Point pinch	3-Point pinch
76.7 %	77.9 %	81.9 %	82.7 %	81.0 %

reported union in 22 of the wrists reviewed, with 1 nonunion requiring a revision arthrodesis before union was confirmed [16]. No functional or pain outcomes were reported.

As four-corner arthrodesis is primarily used as a salvage procedure, it was felt that the most important outcomes to be assessed in the present study were postoperative pain, function, and whether the Xpode® cup provided a satisfactory fusion. To that end, the PRWE was chosen as the primary outcome measure for this study. Of the validated outcome measures available, it offered easy patient use while still providing appropriate information regarding both functional capabilities and the presence of pain following surgery. At a mean of 31.3 months, average scores for pain and function were found to be 19.7 and 17.1, respectively, representing good outcomes in both measures. These results are also

comparable to those reported by Merrell et al. using the Spider plate (pain 11.5; function 12) [14] and De Smet et al. using the Spider plate (pain 20; function 20) [8].

Radiographic evaluation of a four-corner fusion mass can be challenging. Proper wrist positioning during radiographic acquisition is critical, as assessment of the fused joints may be obscured by the presence of a plate or screw, as well as by pisiform alignment. The radiolucent nature of the Xpode® cup provided both improved visualization of carpal alignment prior to intraoperative fixation, as well as postoperative evaluation of bony fusion or potential screw complications such as breakage or migration. In both instances of screw breakage, the authors commented on the ease with which the diagnosis could be made secondary to improved visualization of the carpus. The radiolucent qualities of the PEEK material also allowed for easier monitoring of the progressing fusion mass during standard follow-up visits (Fig. 3).

Bony union was achieved in 20/25 (80 %) patients reviewed, and fusion occurred as early as 51 days postoperatively in one patient. Bone graft from the distal radius, as well as scaphoid or reaming remnants, was each utilized. Recent studies have stressed the

Fig. 3 Radiographic progression of fusion. Immediately postoperatively (**a**) note absence of any fused carpal columns or rows while already at 1.7 months (**b**) the developing presence of capitulate fusion (denoted by *asterisk*). At 2.6 months (**c**), the presence of fusion in both capitulate and triquetral-hamate columns is present, as well as in the lunotriquetral row. At final 15-month follow-up (**d**), a fully fused mass is evident, with bridging trabeculae present at all carpal articulations

importance of proper bone graft selection [10]. Non-unions have been attributed to the use of unhealthy scaphoid bone [14, 21] or debris from reaming [13]. These studies conclude that in order to provide an optimal environment for fusion, rather than using the excised scaphoid or reaming remnants, only healthy bone from a separate site (distal radius, iliac crest) should be utilized. The present study identified five cases of partial fusion postoperatively, and of those five cases, two utilized distal radius autograft and three utilized scaphoid and reaming remnants. Of the 20 established fusions, 18 utilized scaphoid and reaming remnants, one distal radius only, and one a combination of distal radius, scaphoid, and reaming remnants. Complete fusion and partial fusion were thus demonstrated from both donor graft site choices. The fusion rate of 80 % is slightly below that reported from the other two studies analyzing Xpode® cup outcomes, which ranged between 92 [13] and 96 % [16]. The PRWE scores for the five partial fusions were also marginally higher (pain 26.6; function 20.3) than the mean for all patients; however, they still demonstrate a satisfactory level of pain and functionality.

As a salvage procedure, loss of motion following four-corner arthrodesis is common. The present patient cohort, however, demonstrated an overall increase in their flexion/extension arc postoperatively (63 to 70°), although it was not found to be statistically significant. This calculation was limited to the small number of patients who could be recruited to return to clinic though, and it is uncertain if this trend would continue with a larger population.

Two patients were found to have broken screws during follow-up. Neither patient reported any specific trauma, however. Due to the lack of a definable event, it was postulated that a possible combination of increased activity too early in rehabilitation paired with overtightening of the screw intraoperatively may have resulted in the break. Of note, both patients reported satisfaction with the surgical result.

There are some limitations to the present study. Due to its retrospective nature, the initial data available for analysis were limited to only those collected during routine clinical follow-up. The data gaps present thus resulted in only the range of motion and grip strength values obtained from those patients who returned to clinic to be utilized for statistical evaluation. The relatively small sample size and inability to have all patients return to clinic for follow-up limited statistical analysis capabilities as well. Another shortcoming is the lack of a preoperative PRWE score to serve as a comparison, so only the postoperative averages could be reported.

The present study demonstrates an 80 % fusion rate following scaphoid excision and four-corner arthrodesis using the Xpode® cup, as well as acceptable pain and function

outcomes at early follow-up. As a salvage procedure, the Xpode® cup is a viable implant option for degenerative and posttraumatic wrist disorders.

Conflict of Interest Benjamin Rudnick declares that he has no conflict of interest.

Peter Goljan declares that he has no conflict of interest.

Jason S. Pruzansky declares that he has no conflict of interest.

Abdo Bachoura declares that he has no conflict of interest.

Sidney M. Jacoby declares that he has no conflict of interest.

Mark S. Rekant declares that he has no conflict of interest.

Statements of Human and Animal Rights All study procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

Statement of Informed Consent Informed consent was obtained from all patients included within the study.

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Disclaimers None

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