Four-Corner Arthrodesis: Description of Surgical Technique Using Headless Retrograde Crossed Screws

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Abstract

Background: Four-corner fusion has been shown to be a reliable option of treatment of wrist arthritis, but there is no consensus about which implant and surgical procedure should be used in the arthrodesis. The present study aimed to describe a surgical technique using 2 crossed screws as implants, inserted in a retrograde manner, and to demonstrate preliminary results of the use of the technique. **Methods:** A retrospective study was conducted using medical records and imaging tests (radiographs and computed tomography) of all 15 patients who underwent a standardized 4-corner fusion technique, between December 2011 and July 2015, in the Department of Hand Surgery of *Instituto Nacional de Traumatologia e Ortopedia* (INTO), Rio de Janeiro, Brazil. We collected data on the following variables: fusion rate, time to fusion, and percentage of patients who had any complications or needed another surgical procedure on the same wrist. **Results:** All but one patient achieved fusion of arthrodesis. The average time to union was 5.54 months (SD = 3.84). Only the patient who developed nonunion of the 4-corner fusion required another surgery on the same wrist. **Conclusions:** The procedure described in this study demonstrated a low complication rate and high fusion rate, and can therefore be considered a reliable surgical technique for 4-corner fusion.

Keywords: four-corner fusion, surgical technique, screws, SLAC, SNAC, arthrodesis, hand surgery

Background

The scapholunate advanced collapse (SLAC) wrist (Figure 1) is considered the most common pattern of degenerative osteoarthritis of the wrist. According to Watson and Ballet³⁰ and Watson and Ryu,³¹ when the wrist joint is subject to trauma of considerable intensity, resulting in scapholunate ligament injury, it suffers a process of degeneration that shows a predictable pattern: It starts in the styloid process (stage I), affects subsequently the radiocarpal joint (stage II), and finally reaches the articular cartilage between the scaphoid and capitate (stage III). The same predictable pattern of degeneration of the wrist was later associated with nontreated scaphoid nonunions, named scaphoid nonunion advanced collapse (SNAC²³; Figure 2).

Four-corner fusion is a main treatment option that reaches the expected results in the treatment of radiocarpal arthrosis. It has been shown to reduce the patient's pain and preserves about 50% of opposite side range of motion and 75% of the opposite wrist grip strength.^{24,28,32} Watson and Ballet³⁰ were the first to popularize the 4-corner fusion technique; they described the resection of the scaphoid and arthrodesis between lunate, capitate,

hamate, and triquetrum using Kirschner wires (K-wires). Later, other researchers began to use multiple screws²² and staples³² successfully. A circular nonlocking dorsal plate has been recently used for stabilizing the fusion, resulting in a more stable fixation and allowing the patient to start early rehabilitation, in about 4 weeks.^{10,19,24} However, subsequent studies have shown a high rate of complications related to the use of dorsal plates: hardware breakage, irritation, and dorsal impingement.^{14,18,25,28}

The 4-corner fusion technique using Herbert screws is one of the most widespread among surgeons.^{4,20,22,24} It is usually done through a dorsal wrist approach with a longitudinal incision. The posterior interosseous nerve and scaphoid are excised. The adjacent surfaces of lunate, capitate, triquetrum, and hamate are decorticated. The bones are then reduced (the lunate to neutral or slightly volar

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Figure 1. Preoperative posteroanterior and lateral radiographs of a left scapholunate advanced collapse wrist.

Figure 2. Preoperative posteroanterior and lateral radiographs of a right scaphoid nonunion advanced collapse wrist.

position and the capitate ulnarward) and fixed. In this critical step of the procedure, many surgeons place antegrade screws through the lunate and triquetrum into the distal carpal row.^{6,16,22} Few surgeons try to preserve the cartilage of the lunate joint by inserting screws in a retrograde manner.^{4,9} The numbers of screws used and their configuration do not follow a set pattern.^{4,6,9,16,22} It is known that the crossed positioning of implants 90° from each other provides greater stability biomechanically.^{8,11,17} However, this principle shown in several studies^{8,11,17} has not been applied in 4-corner fusion techniques yet. Skie et al proved that the 4-corner fusion redistributes the cartilage contact area and the pressure in the radiocarpal joint: The load is

relieved in the scaphoid fossa while increased in the lunate fossa.^{15,26} As the pressure will increase between the radius and lunate after the procedure, it would be reasonable to attempt to preserve the integrity of the proximal surface of the lunate. Nevertheless, this does not seem to be taken into consideration by many surgical techniques of 4-corner fusion, which often injure the lunate cartilage by inserting screws in it.^{6,16,22}

The present article aims at describing the 4-corner fusion technique that has been used in the authors' institution, in which 2 screws are inserted in a retrograde manner and aligned with each other at 90°, sparing the cartilage of the lunate and resulting in a good mechanical stability. We describe the operational details of the technique and present preliminary results of outcomes obtained in patients operated with the technique, discussing them in light of the literature on the results of other surgical techniques.

Materials and Methods

Participants

The participants of the present study were patients with advanced carpal collapse who underwent scaphoid excision and 4-corner fusion using crossed retrograde screws at the *Instituto Nacional de Ortopedia e Traumatologia* (INTO), a tertiary teaching hospital in Rio de Janeiro, Brazil, between December 2011 and July 2015. All the surgeries were performed by the same team of 7 hand surgeons, following the same technique.

Patients eligible met the following criterion: to have undergone 4-corner fusion according to the described technique. We excluded from the study: (1) any patient who was submitted to a wrist arthrodesis different from 4-corner fusion (eg, total wrist arthrodesis or scaphocapitate arthrodesis), and (2) any patient who was submitted to 4-corner fusion but using different techniques or hardware (eg, 4-corner fusion performed using plates, K-wires, or even screws, but in numbers or configuration different from those described in this article).

The indications for 4-corner fusion were all traumatic: SNAC (n = 8) and SLAC (n = 7) wrists.

The INTO research ethics committee approved the study.

Data Collection and Analysis

We searched the hospital patients' dossier database for the procedure "arthrodesis" in surgeries performed between December 2011 and July 2015 to identify the patients to be included in the study. The first author (J.M.) performed the search and reviewed each patient's medical records, collecting data on the patient background, operation, and subsequent consultations, including findings from imaging

Figure 3. Dorsal access.

tests (radiography and computed tomography). Descriptive statistics were computed for the patients' background data.

The following variables were computed to evaluate the outcomes of the surgical technique: arthrodesis union rate, time to confirmation of fusion, and percentage of patients who had any complication or need of another surgical procedure in the same wrist. Arthrodesis union was defined as the bone bridging between the lunate and capitate observed in X-ray images or computed tomography (CT). The usual practice in the hospital is to request CT only when the union is uncertain and cannot be determined by X-ray images and clinical examination only. Therefore, both exams were not available in the medical records of all patients included in the study.

The data were analyzed using Microsoft® Excel 2007 for Windows.

Surgical Technique

A dorsal midline incision aligned with the third metacarpal is made and the retinaculum is exposed (Figure 3). The third compartment is released and transposed radially and the fourth compartment is elevated and retracted ulnarly, exposing a segment of the posterior interosseous nerve, which is excised. The capsulotomy is performed according to the technique by Berger et al⁵ and, after scaphoidectomy (Figure 4), the cartilage of the bone surfaces between lunate, triquetrum, capitate, and hamate is removed. This step is achieved by using a combination of curettes and rongeurs.

At this moment, we always seek to reestablish the anatomy of carpus. Under fluoroscopic guidance, an imaginary line is drawn as a parameter, passing between the fourth and fifth metacarpal bones distally and the capitate and triquetrum proximally. We had observed that this line crosses the hamate and lunate exactly in their centers, dividing them

Figure 4. Scaphoidectomy.

equally in normal wrist radiographs, provided that an appropriate posteroanterior (PA) incidence has been obtained (Figure 5).

Subsequently, with the aid of retractors and K-wires as joysticks, we orient ourselves to keep the 4 bones in arthrodesis position (Figure 6). We correct the position of the lunate, often in dorsal intercalated segment instability, to neutral or slightly volar intercalated segment instability. This is usually done with the aid of the K-wires inserted into the dorsal lunate and capitate, acting as joysticks. In difficult cases, we consider the release of the dorsal capsule from the triquetrum and temporary fixation of the bones. In these cases, K-wires are used: They are inserted from the distal to the proximal row without crossing the radiocarpal joint. Then we insert 2 crossed Kirschner guide wires: the first one following the virtual line that enters between the fourth and fifth metacarpal bones and passes from the hamate to the lunate. The position of the

Figure 5. Imaginary line (red arrow) used for reestablishment of the anatomy and for orientation of insertion of the first guide wire and screw.

Figure 6. Insertion of the first guide wire, after decortication of the 4 bones.

first guide wire is checked by performing fluoroscopy to assure that it crosses the center of the bones in the lateral incidence. The second guide wire is passed perpendicular to the former, transecting the capitate and triquetrum. The K-wires are always aligned to the center of the bones and crossed at a 90° angle. Efforts are made to achieve the perfect PA incidence on fluoroscopy, by using the distal radioulnar joint (DRUJ) for orientation before inserting the guide wires (Figure 7).

After finding the appropriate position of the guide wires on fluoroscopic PA and lateral incidences, we changed them for 2.5-mm cannulated, self-tapping, headless compression screws (Autofix; Medartis, Basel, Switzerland), inserted from distal to proximal, thereby preserving lunate proximal cartilage.

Figure 7. Intraoperative fluoroscopy: crossed Kirschner wires (K-wires) at a 90° angle. Reduction was achieved with the aid of 2 K-wires as joysticks.

The joystick wires are removed and the passive range of motion is recorded, to see if there is any kind of hardware impingement. Only after that the remaining space between the bones is packed with morcellized bone graft (removed from scaphoid), and the wound closure is initiated (capsule, retinaculum, and skin). Whenever we believed that the bone graft from the scaphoid was of poor quality, opaque, or not bleeding, bone graft from the distal radius was used instead. When needed, the distal radius bone graft was harvested from beneath the Lister tubercle by using chisel to hinge up the dorsal cortical flap and replace the cortical back after harvesting cancellous bone.

The wrist is immobilized in a slightly extended position by using a splint, which is replaced by a below-elbow cast 1 week after surgery. The cast is retained until the consolidation is confirmed in plain radiographs, when mobilization is allowed under hand therapist supervision (Figure 8). If consolidation has not been obtained after 8 weeks, the cast is changed to a removable splint.

Results

A total of 15 four-corner fusions were performed using this technique over the period from December 2011 to July 2015.

Fourteen of the 15 patients who were operated with the technique were male. Patients' mean age at the time of the surgery was 47.56 years (range, 29-63 years; SD, 9.48). The patients had a variety of occupations, but 11 out of the 15

Figure 8. Postoperative (10 weeks) posteroanterior and lateral radiographs (right wrist), showing headless compression screws and confirming consolidation of the arthrodesis.

patients were manual workers. Five patients were tobacco smokers, and 4 were diabetics.

Table 1 presents a summary of the cases. All but one patient achieved stable fusion of the 4-corner arthrodesis. The average time to fusion was 5.54 months based on CT scans and radiographs obtained in the return visits. The earliest consolidation was observed at 7 weeks and the latest at 58 weeks.

Complications of the surgery were observed in 2 of the studied patients. One patient developed a nonunion of the 4-corner fusion and, at the time the data were collected, was waiting for revision surgery. This patient was a 45-year-old, diabetic and nonsmoker man. Another patient developed reflex sympathetic dystrophy, which was treated with oral medication and progressed well.

At the moment of the data collection, only the patient who developed the nonunion of the 4-corner fusion had been considered to require another surgical procedure in the same wrist (arthrodesis revision with iliac bone graft).

By the time the study was completed, patients' postoperative time was on average 24.84 months, with a range from 5.97 to 39.97 months.

Discussion

The principle of current treatments for SLAC and SNAC wrists is based on the fact that the lunate fossa cartilage generally is spared in the development of osteoarthritis process. The 2 main treatment options are proximal row carpectomy (PRC) and 4-corner fusion. The PRC is considered in the initial stages (stages I and II), when the cartilage of the capitate has not been affected yet, being a simpler procedure.² Comparative studies between both techniques show that patients undergoing PRC have a better wrist range of motion and are spared of complications related to implants

(nonunions, hardware problems), but evolve with early radiocarpal arthritis more often.^{18,32} Wyrick and colleagues³² found a statistically significant difference in favor of PRC relative to 4-corner fusion both in the total arc of motion (64% vs 47%) and grip strength (94% of opposite wrist vs 74% of opposite wrist). However, when Walls and collaborators²⁹ evaluated patients submitted to PRC at the 20-year follow-up, they found evidence of radiocapitate degeneration in about one-third of patients, although often asymptomatic. Six out of 17 of these patients had been reoperated on. Moreover, several studies indicated an increased failure risk when patients younger than 35 years of age were submitted to PRC.^{7,29}

Many patients referred to the hand surgery services have wrist articular degeneration already in stage III, with the involvement of the cartilage of the capitate, preventing the indication of PRC, leaving only 4-corner fusion as the alternative of treatment.

The 4-corner fusion has already proved to be an appropriate method for treating wrist arthritis, especially in advanced stages of SNAC and SLAC wrists.^{28,32} However, the literature has described a wide range of techniques and the use of different materials to achieving fusion. The 4-corner fusion was initially performed by using K-wire fixation, and subsequently developed to incorporate the use of staples and headless screws fixation. In recent years, some authors have also described the use of dorsal plates.^{18,24,25,28}

The purpose of this study was primarily to describe the technique of 4-corner fusion with the use of headless screws that we have employed in our service and to present preliminary outcomes for patients operated by using this technique. Our retrospective review of case series of 15 four-corner fusions using retrograde headless screws intended to assess whether a technique that uses a widely available implant option would provide reliable compression and stable fixation, thereby leading to a arthrodesis union. We used only 2 crossed screws, reducing costs and leaving the bones with less hardware, which facilitated the visualization and confirmation of fusion. We believe that an increased number of screws in the arthrodesis bone block also increases the likelihood of prominent screws irritating soft tissue, as often occurs with the use of dorsal plates.

The average time to fusion was 5.54 months, slightly high when you compare with the literature rates (ranging between 1.6 and 4.5 months).^{16,24,27} We understand that this result should be analyzed with caution, as that may have been influenced by operational problems. The average could have been lower if the patient return dates in our hospital were standardized and if there were no frequent absences to the reevaluation visits. However, this occurs frequently in our context. We temporarily lost follow-up of 4 patients, because they were unreachable, which may have delayed the confirmation of arthrodesis consolidation.

Table 1. Patient Demographics.

Patient	Gender	Age at the time of surgery, y	Indication for arthrodesis	Time to radiograph fusion	Diabetic	Tobacco smoker
1	M	45	SNAC	Nonunion	Yes	No
2	M	36	SNAC	19.43 weeks	No	No
3	M	54	SNAC	7.86 weeks	No	Yes
4	M	50	SNAC	37.57 weeks	Yes	Yes
5	M	45	SLAC	28.57 weeks	No	No
6	M	47	SLAC	13.43 weeks	No	No
7	M	52	SLAC	25 weeks	No	Yes
8	M	48	SLAC	7.43 weeks	No	Yes
9	F	56	SLAC	58 weeks	Yes	No
10	M	63	SLAC	11.14 weeks	No	No
11	M	45	SNAC	43 weeks	No	No
12	M	30	SNAC	45.57 weeks	Yes	No
13	M	29	SLAC	17.14 weeks	No	No
14	M	48	SNAC	11.43 weeks	No	Yes
15	M	56	SNAC	7 weeks	No	No

Note. M = male; SNAC = scaphoid nonunion advanced collapse; SLAC = scapholunate advanced collapse; F = female.

Regarding the patient outcomes obtained with the use of the technique, we evaluated the nonunion rates, percentage of conversion to total arthrodesis, and any complications related to surgery.

The nonunion rates reported in the literature vary between 0% and 63%, depending on which material or technique is used.^{14,15,24,28} Our results showed only 1 case of nonunion in 15 patients, leading to a 93.5% union rate, which can be considered a good outcome. The nonunion case was a 45-year-old, diabetic and nonsmoker man. At the moment of the study, the patient was scheduled for arthrodesis revision, with the purpose of bone grafting the arthrodesis by harvesting it from the iliac crest.

Conversion of 4-corner fusion to total wrist arthrodesis was not observed in any of the patients included in the study. This finding is in contrast to the reported rates of conversion to total arthrodesis in the literature, which varies from 2.4% to 29%.^{14,20,28} It has to be highlighted that the low rate observed in our study may in fact reflect the short time of follow-up for some of the patients (average of 24.84 months, ranging from 5.97 to 39.97 months). However, Bain and Watts article indicates that wrist function, pain scores, and range of motion are similar when evaluated at 1 year or at 10 years after 4-corner fusion.³

The literature indicates that the 4-corner fusion redistributes the cartilage contact area and the pressure in the radiocarpal joint: the load is relieved in scaphoid fossa and increased in the lunate fossa.^{15,26} Nevertheless, most of the described techniques of 4-corner fusion with screws injure the proximal cartilage of the lunate that is in contact with the radius, by inserting screws through it. We agree with Gill and Ireland⁹ that the retrograde insertion of screws preserves the proximal lunate cartilage and, as this surface will

undergo an increased pressure after surgery, it seems reasonable to preserve its integrity.

Articular cartilage has a great ability to withstand axial loads, but several studies have shown its great susceptibility to injury by surgery, either by scalpel, suture, or insertion of screws.^{1,12,13,21} There is chondrocyte death and changes in the properties of the matrix on the banks of these lesions.¹² We had no need to convert any 4-corner fusion to total wrist arthrodesis, but further studies with larger numbers of patients are needed to relate this low conversion rate to preservation of the cartilage during the insertion of the screws.

The reported rate of hardware failure in the literature can be as high as 27%, especially with the use of dorsal plate.¹⁸ During the case series reviewed in our study, there were not any problems of hardware failure such as screw breakage or dorsal impingement. We believe that the configuration of only 2 crossed screws at a 90° angle may prove to be ideal for achieving arthrodesis. By using a decreased number of screws, one is able to better visualize the bone block on X-ray images and to have less interference from cross screws during surgery. The cross-configuration already proved to be biomechanically superior in many studies.^{8,11,17}

This study has limitations. The retrospective nature of the study based on a review of medical records restricted the data collection to the information available in the patients' files. Data that would be relevant, such as grip strength, range of motion, and pain after healing, were not always available and therefore could not be collected. Nevertheless, the purpose of the study was primarily the description of the technique. The patient outcomes obtained with its use seem promising if compared with the outcomes of different techniques reported in the literature. However, any comparison between techniques is out of the scope of this study and would require

further research. The fact that the surgeries were performed by 7 different surgeons may also be seen as a limitation of our study. Questions may be raised about the uniformity in the use of the technique, but all the surgeons have been oriented to perform the technique exactly as described in the Materials and Methods section. The follow-up time of the study may also be seen as relatively short for a salvage procedure. However, it has been shown that indicators of wrist function after 4-corner fusion are similar at 1 and 10 years.³

This retrospective review of 15 cases of 4-corner fusion by using retrograde headless screws suggests that this technique provides a reliable method of fixation for 4-corner fusion, with a high union rate and low complication rate.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

The research procedures in this study were 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 2008.

Statement of Informed Consent

Institutional review board approval was acquired for this study; however, patient consent was waived due to the retrospective nature of the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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