



## Four-corner arthrodesis using two headless compression screws

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We present the outcome of four-corner wrist arthrodesis using two headless compression screws for fixation. The study group consisted of 27 patients who underwent arthrodesis from 1998 through 2007. Data on demographic parameters, diagnosis, range of motion, pain and complications were collected from the medical files. A total of 77 series of anteroposterior, oblique, and lateral x-rays were reviewed by three independent interpreters; consensus of at least two was required for the bones to be considered fused. Fusion was achieved in 24/27 wrists. Overall, inter-observer agreement in identifying radiographic bony fusion was fair ( $\kappa = 0.41$ ). At the critical timing, 86 (SD 68) days postoperatively, when the decision regarding fusion was made, inter-observer agreement was poor ( $\kappa = 0.07$ ). Our rates of fusion are consistent with reports in the literature. Radiographs performed at 3 months after four-corner arthrodesis are not reliable for the diagnosis of fusion.

**Keywords** : four-corner arthrodesis ; headless compression screws ; inter-observer agreement ; wrist.

### INTRODUCTION

Advanced radioscaphoid osteoarthritis is commonly treated by scaphoid excision followed by four-corner arthrodesis. Devices used for stabilization of the four corner construct include Kirschner wires (K-wires) (1,6), staples (2,32), headless compression screws (3,20,30), and circular plates (21,31) in combination with local, distal radius, or iliac

crest bone grafting (18). All have been reported to achieve good results, but no single technique has proved superior to the others (22).

Headless compression screws for four corner fusions were introduced by Krakauer *et al* (20) and Tomaino *et al* (30) two decades ago, based on the rationale that applying compression at the fusion site would shorten the time needed for cast immobilization, allow for early range of motion (ROM) exercises, and improve postoperative ROM (26,28). However, only a few studies have investigated the outcome of four-corner arthrodesis with headless compression screws (3,7,9,10,13,19,20,24,26,30,31) (Table I), and data on their effectiveness are limited.

The aim of the present study was to evaluate the results of this technique and to determine the inter-observer agreement in the postoperative radiographic assessment of bony fusion.

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Table I. — Literature review of four-corner arthrodesis with headless compression screws. Eleven studies, total 118 patients

Authors/year	Study type	Fixation Method	No. pts.	Union rate
Ball & Bergman, 2012	Surgical technique	3 Retrograde HCS	NA	NA
DeSmet <i>et al</i> , 2009	Retrospective case series	<b>HCS</b>	<b>11</b>	100%
		K-wire	5	
		Staples	1	
Draeger <i>et al</i> , 2014	Retrospective case series	<b>HCS</b>	<b>11</b>	100%
Dutly-Guinand <i>et al</i> , 2009	Surgical technique	<b>HCS volar approach</b>	<b>13</b>	92%
Gaston <i>et al</i> , 2009	Retrospective case series	<b>HCS</b>	<b>6</b>	89%
		K-wire	9	
		Staples	3	
Korus <i>et al</i> , 2013	Surgical technique	<b>HCS exclusion of hamate</b>	<b>10</b>	100%
Krakauer <i>et al</i> , 1994	Retrospective case series	<b>HCS</b>	<b>1</b>	91%
		K-wire	19	
		Staples	3	
Ozyurekoglul & Tulker, 2012	Retrospective case series	<b>Percutaneous HCS</b>	<b>33</b>	94%
Richards <i>et al</i> , 2011	Surgical technique	<b>HCS</b>	<b>19</b>	94%
Tomaino <i>et al</i> , 1994	Retrospective case series	<b>HCS or K-wire</b>	<b>9</b>	100%
Vance <i>et al</i> , 1994	Retrospective case series	<b>HCS</b>	<b>5</b>	97%
		K-wire	14	
		Staples	12	
Total			<b>118</b>	

## METHODS

The study protocol was approved by the local Institutional Review Board. The electronic records of the department of surgery of a tertiary medical center were searched for all patients with advanced osteoarthritis who were treated with scaphoid excision and four-corner arthrodesis under the supervision of the senior author, from 1998 through 2007. Demographic parameters, diagnosis, previous surgeries, co-morbidities, medications, smoking history, and preoperative ROM were collected from the individual medical charts. Operative and postoperative complications and casting time were recorded, as was the postoperative ROM and need for any additional surgical procedures. The level of pain at the last follow-up was graded as none, mild, moderate or, severe.

At each follow-up visit, each patient underwent a series of three digital x-rays in the antero-posterior, oblique, and lateral views to assess the position of the arthrodesis and to search for signs of bony fusion. For the present study, the x-rays were reviewed by three independent, fellowship-trained, hand surgeons who did not participate in the patients' treatment. Looking at factors

that included presence of bony trabecula crossing the fusion line, absence of a gap between the carpal bones, and lucency around the implant or changes in its position on sequential x-rays, each interpreter independently classified the findings for each series as "fused" or "not fused". Consensus of at least two interpreters was required for the bones to be considered fused. Since late fusion was reported despite lunocapitate screw back-out (13), screw back-out was not considered a criteria of non-union by itself. Since the surgical technique preserved the lunotriquetral ligament, fusion between the lunate and triquetrum was neither expected nor necessary for a final decision of fusion.

### Surgical technique

The standard technique for four-corner arthrodesis was used with some modifications. The joint was approached through a typical third compartment exposure. The capsule was incised within the limits of the dorsal radiocarpal and dorsal intercarpal ligaments. The scaphoid was removed, taking care to preserve the volar capsule and the radioscapocapitate ligament; the bone was

saved to be used for grafting. Using a burr, the surgeon removed the cartilage of the lunocapitate, capitolunate, and hamotriquetral joints. Some of the cartilage of the lunotriquetral joint was also removed as long as the ligament was preserved. The usual DISI deformity was reduced, and the position of the arthrodesis was temporarily fixated with two 1.6-mm K-wires. The first K-wire was inserted retrograde from the capitate into the lunate, and the second was driven from the triquetrum across the hamate and into the capitate bone. Its position was checked with an image intensifier. If the alignment was acceptable, the wrist was flexed, and the headless compression screws were placed in an anterograde fashion. The final position of the implants was confirmed with an image intensifier. Additional bone graft was obtained from the distal radial metaphysis and impacted carefully in the gaps between the carpal bones. The capsule was closed with an absorbable suture, and the skin was closed in layers.

A volar plaster splint was applied and replaced 10 days later with a below-elbow cast. The cast was removed after four weeks, and x-ray films were obtained; if the position of the implants was unchanged, gentle passive and active ROM exercises were started. Either technical considerations such as the quality of the fixation of the four-corner construct at surgery, or logistic considerations such as the surgeon's or the patient's schedule, shortened or lengthened the immobilization period. At two months, additional x-rays were performed to search for signs of fusion. If there was satisfactory progress, ROM exercises without limitations were encouraged.

### Statistical analysis

Descriptive statistics and Fisher's exact test were used to analyze the postoperative results, and paired Student's t-test was used to compare the preoperative and postoperative data. Inter-observer agreement for each group of two interpreters was analyzed with Cohen's kappa statistics, and for multiple interpreters, with Fleiss's kappa statistics. The degree of agreement was categorized according to Fleiss (12).

## RESULTS

The study group consisted of 27 patients, 24 men and 3 women, of mean age 46.3 (SD 14) years (range 17-74). Table II summarizes their clinical characteristics. Herbert screws were used in 25 cases, Wipple-Herbert screws in one case, and cannu-

Table II. — Clinical characteristics of 27 patients (27 wrists) undergoing four-corner arthrodesis

Characteristics	No. pts.
Sex	
Male	24
Female	3
Hand dominance	
Right	20
Left	7
Diagnosis	
SNAC	17
SLAC	10*
Prior wrist surgery	
Yes	18
No	9
Smoking history	
Yes	6
No	21
Chronic ASA/NSAID use	
Yes	9
No	16

SNAC : scaphoid nonunion advanced collapse ; SLAC : scaphuloate advanced collapse ; ASA : acetylsalicylic acid ; NSAID : nonsteroidal anti-inflammatory drugs.

\*One patient with SLAC underwent previous open reduction and internal fixation surgery for a perilunate dislocation.

lated Synthes screws in one case. Mean duration of follow-up was 379 (SD 529) days (range 77-2265). The cast was removed at a mean of 29 (SD 9) days after surgery. By the end of follow-up, fusion was achieved in 24/27 wrists. The average time to radiographic fusion was 82 (SD 68) days. There were no differences in rate of fusion by previous operative procedure, smoking history, or postoperative intake of acetylsalicylic acid or nonsteroidal anti-inflammatory drugs ( $p = 1$ ). At the last follow-up, 12 patients reported no pain, 12 mild pain, and 3 moderate pain.

Table III presents the preoperative and the postoperative ROMs. There was a significant and expected decrease in extension after surgery ( $p = 0.02$ ), with no significant change in flexion, pronation, or supination. The most common postoperative complication was back-out of the lunocapitate screw, in

Table III. — Preoperative and postoperative range of motion in 27 patients treated with four-corner arthrodesis

	Preoperative (degrees of motor), mean $\pm$ SD	Postoperative (degrees of motion), mean $\pm$ SD
Extension	34 $\pm$ 17	25 $\pm$ 15*
Flexion	34 $\pm$ 18	35 $\pm$ 13
Pronation	83 $\pm$ 5	85 $\pm$ 18
Supination	83 $\pm$ 5	84 $\pm$ 18

\*The decrease in postoperative extension was statistically significant ( $p = 0.02$ ).

four patients. In three of them, fusion was not achieved. Management in these cases consisted of removal of the screws in two patients, one of whom did well, with mild residual pain, and the other was lost to follow-up. The third patient underwent screw removal with wrist arthrodesis. The fourth patient with lunocapitate back-out, who was asymptomatic, eventually showed fusion with the four-corner construct and refused additional surgery. Ulnar translation of the carpus occurred in one patient who had had a previous open reduction internal fixation procedure for a perilunate dislocation; he reported mild pain at the last follow-up. Other complications were carpal tunnel syndrome, dysesthesia of the dorsal branch of the ulnar nerve, and dysesthesia of the superficial radial nerve, in one patient each.

Ninety-six postoperative series of three x-rays obtained throughout the follow-up were available for review. Nineteen series were excluded from analysis because they were obtained with the patient in a cast and therefore considered unreliable for determining bony fusion. For three patients, only x-rays taken at the last follow-up (34 weeks, 1.5 years, and 4 years) were available; all demonstrated bony fusion. Figure 1 shows the findings in a representative patient. Overall, inter-observer agreement for the entire series was fair ( $\kappa = 0.41$ ) (Table IV). Agreement among the reviewers was poor at the critical point when the decision regarding fusion was made (mean 86 (SD 68) days postoperatively;  $\kappa = 0.07$ ), and it increased to fair at the last follow-up ( $\kappa = 0.43$ ).

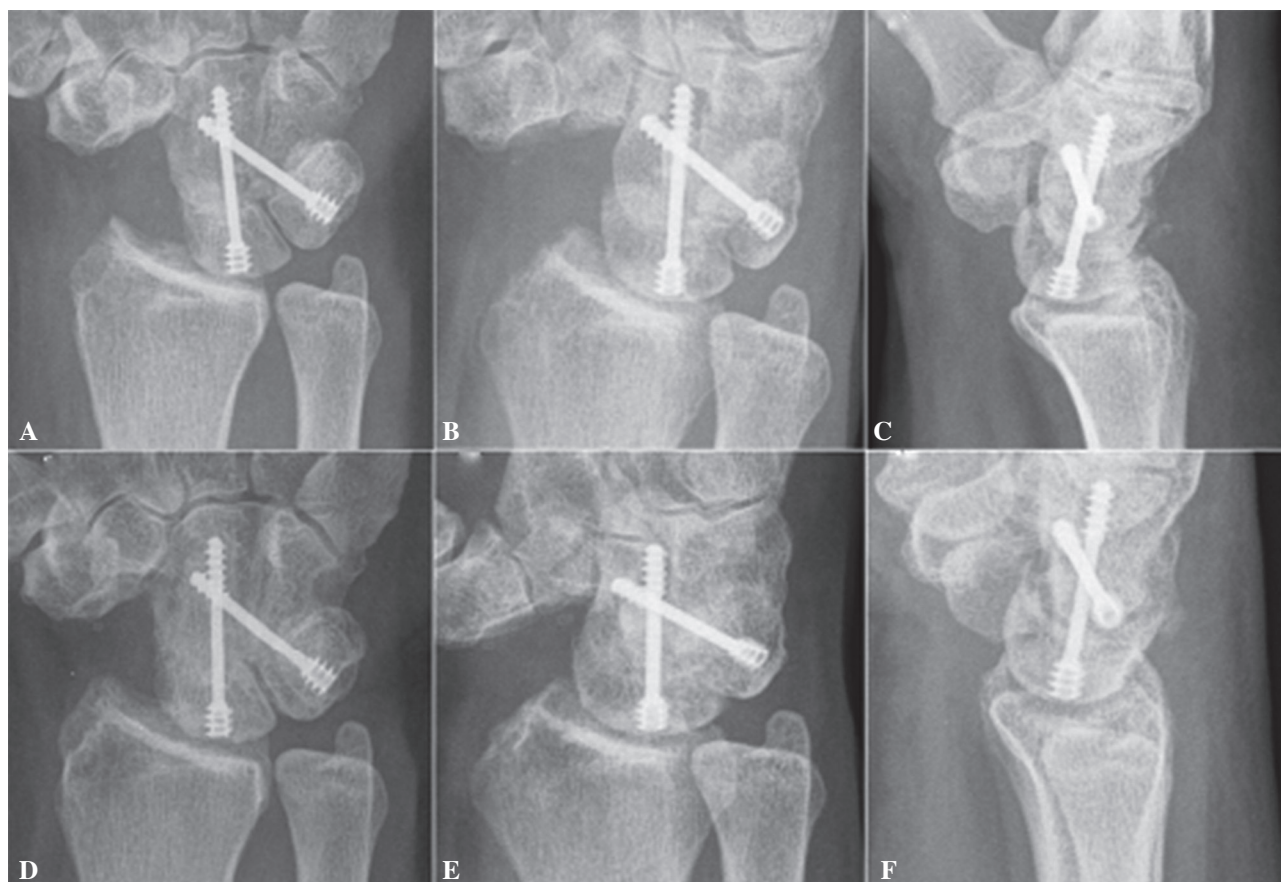
## DISCUSSION

Various methods of fixation are used during four-corner arthrodesis. Although K-wire fixation is associated with high fusion rates of 96%-97% (1,23), it requires prolonged cast immobilization (6,11), and complications related to the wires protruding through the skin are relatively common (32). For circular plates, reported fusion rates range widely, from 38% to 100% (17,21), though the results seem to be improving since the introduction of locked plate constructs (25). Bain and Watts (2) used staples to stabilize arthrodeses, with a 92% fusion rate and a consistent clinical outcome over a ten-year follow-up period.

Currently, there are few reports on the results of four-corner arthrodesis when headless compression screws are used for fixation (Table I). Most studies combined them with mixed K-wires and staples (7, 13,20,30,31) and others were limited to a description of the surgical technique only (3,10,19,26). One recent retrospective study of four-corner arthrodesis with percutaneously inserted headless compression screws reported fusion in 31 of 34 wrists (94%) and good functional results (24). In the specific setting of four-corner fusion and in the English language literature, we could identify outcome reports of only 118 patients in over two decades of use of the technique.

In the present study, we applied a simple method of fixation consisting of anterograde insertion of two headless compression screws. Solid fusion was obtained in 24 of 27 wrists. This rate is consistent with reports of four-corner arthrodesis in the literature (22). Although Herbert screws were used in most of the patients reported here, we switched to second-generation cannulated headless compression screws because they were found to consistently provide better compression at the fracture site (4, 15,16). We expect our rates of fusion to improve accordingly.

The most common complication in this series was lunocapitate screw back-out, in four patients. It was associated with nonfusion in three patients; in the fourth, fusion was eventually achieved without additional intervention. In a study of 16 cases of lunocapitate fusion, Gaston *et al* (13) reported screw



**Fig. 1.** — Antero-posterior (A), oblique (B), and lateral (C) x-rays obtained at 7 weeks postoperatively. One reviewer interpreted the series as fused, and two interpreted it as not fused. At the last follow-up, at 636 days postoperatively (D, E, F), all three reviewers interpreted the series as fused.

back-out in 5 ; in all of them, fusion was eventually achieved without additional bone grafting. Retrograde screw insertion from the capitate into the lunate does not seem to prevent this complication. Using a retrograde insertion method, Ozyurekoglul and Turker (24) reported lunate cortex penetration in 2 of 33 cases.

In the present study, the inter-observer agreement regarding achievement of bony fusion was fair ( $\kappa = 0.41$ ), but at the critical point, when fusion was determined, it was poor ( $\kappa = 0.07$ ). We expected the inter-observer agreement to decrease from the early postoperative period ( $\kappa = 0.37$  at cast off), when there was no fusion, to the subsequent period when gradual fusion occurred and a positive consensus of two of the three reviewers was required for the final

decision. Interestingly, at the last follow-up at approximately one year, kappa values were still fair ( $\kappa = 0.43$ ). These findings cast doubt on the ability of hand and orthopedic surgeons to declare fusion based solely on plain x-ray films.

Inter-observer agreement among multiple reviewers has not been previously reported in the setting of four-corner arthrodesis. However, in a similar study on the radiographic assessment of scaphoid fracture healing, Dias *et al* (8) reported poor inter-observer agreement. They concluded that plain radiographs taken 12 weeks after scaphoid fracture do not provide reliable and reproducible evidence of fusion.

While CT scans have been used in selected cases to decide on four corner fusions (24,25,27), the

Table IV. — Inter-observer agreement for each group of two interpreters (Cohen's kappa statistics) and for multiple interpreters (Fleiss's kappa statistics)

Time point*	No. pts.	Kappa 1-3	Kappa 1,2	Kappa 1,3	Kappa 2,3
All series	78	0.41	0.48	0.24	0.5
Cast off	24	0.38	0.51	0.29	0.36
Bony fusion	24	0.07	0.3	-0.1	0.14
Last follow-up	27	0.43	0.41	0.35	0.52

\*Cast off – first postoperative x-ray series obtained without a cast, at a mean of 45 (SD 28) days.

Bony fusion – by agreement of at least two of the three reviewers, achieved at a mean of 86 (SD 68) days postoperatively.

Last follow-up – at a mean of 379 (SD 529) days postoperatively.

primary basis to evaluate union in all previously reported series is still plain x-ray. The implication of our findings, supported by Dias, is that we should relate to the four corner fusion rates described in the literature with reservations.

In the setting of scaphoid fracture union, better inter-observer agreement was reported using CT scans when compared to plain x-rays (5). While we do not recommend that CT scans be obtained routinely in the clinical setting for four corner fusions, especially when the patient is asymptomatic and the plain x-rays suggest bony healing, we believe they should always be obtained in the research setting. Methods such as those described by Singh *et al* (29) and Grewal *et al* (14) for scaphoid fractures can be adapted in order to better estimate healing time and fusion rates.

This study is limited by its retrospective chart-review design and relatively small number of patients. Furthermore, we could not obtain functional scores, and we based our conclusion on subjective evaluations at the last follow-up. Nevertheless, our study adds to the still-sparse body of available information on the outcome of four-corner arthrodesis using headless compression screws. The slight to moderate inter-observer agreement found on interpretation of plain x-rays suggests that CT scans should be used to evaluate bony fusion in the research setting.

Level of Evidence : Level IV.

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