The Long-Term Outcome of Four-Corner Fusion

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Abstract

Introduction Four-corner arthrodesis with excision of the scaphoid is an accepted salvage procedure for scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse (SNAC) and has been performed in our unit for over 20 years. We have undertaken a retrospective review of 116 of these procedures performed in 110 patients between 1992 and 2009. Fifty-eight patients attended for a clinical evaluation, and 29 responded by postal questionnaire.

Methods The surgical technique undertaken was standard. That is, through a dorsal approach the scaphoid and tip of the radial styloid were excised. The capitate, lunate, triquetrum, and hamate articular surfaces were then prepared down to bleeding bone. Bone grafts from the scaphoid and radial styloid were then inserted and fixation undertaken. For the latter, various methods were used, including Kirschner (K)-wires, staples, bone screws, but predominantly the Spider plate (Integra Life Sciences, USA). Thereafter the wrist was immobilized for a minimum period of 2 weeks prior to rehabilitation.

Results Follow-up was done at a mean of 9 years and 4 months (range 3–19 years). All patients reported a significant improvement in pain relief and ~50% of flexion extension, although only 40% of radioulnar deviation. Grip strength was again ~50% of the contralateral side. Most patients reported a significant improvement in function with 87% returning to work. In addition, radiologic evaluation identified 28 patients (31%) who demonstrated ongoing signs of nonunion, particularly around the triquetrum. Fourteen of these (15%) underwent a further procedure, generally with success. Finally, none of the patients demonstrated any arthritic changes in the lunate fossa on follow-up X-ray, and all secondary procedures were undertaken within 2 years of the primary.

Discussion This research has demonstrated that four-corner fusion fixed with a circular plate can result in a satisfactory outcome with a reduction in pain, a functional range of motion, and a satisfactory functional outcome. The bulk of the complications appear to occur in the first 2 years after surgery. Thereafter, analysis shows long-term satisfaction with little deterioration. Nonunion, particularly around the triquetrum, continues to be a problem, but it may be that this bone should be excised along with the scaphoid, resulting in a three-part fusion only. Alternatively, a simple capitulunate fusion may be satisfactory.

Keywords

- four-corner fusion
- spider plate
- long term follow-up
- complications

Scaphoid excision with four-corner fusion is commonly used as a partial motion-preserving salvage procedure for treating wrists with symptomatic appropriately staged scapholunate advanced collapse (SLAC)¹ or scaphoid nonunion advanced collapse (SNAC).² The aim of surgery is to achieve a stable, pain-free wrist while preserving as much movement as possible.

Over the years various fixation techniques have been used, including Kirschner (K-)wires, headless screws, and, more recently, bespoke plates and staples.^{3–7} Despite these improvements in techniques, several potential complications have been reported. These include nonunion, impingement, subsequent development of further arthritis, and also metalwork issues.^{1,8–12}

At our institution the combination of a four-corner fusion with a scaphoidectomy has been routinely performed since 1992. The purpose of this study is to analyze the outcome, specifically with regard to improvement in pain, together with residual range of motion (ROM) and grip strength in this patient group. We will also assess function as well as focusing on the method of fixation, but also complications and how they can be avoided.

Materials/Methods

The patient group studied included patients with osteoarthritis of the radiocarpal joint secondary to longstanding scapholunate dissociation (SLAC) and scaphoid nonunion (SNAC). Patients with other diagnoses, including inflammatory arthritis, were excluded. The key to a successful procedure is that the lunate fossa is spared involvement of the arthritic process, the rationale being that once the scaphoid has been excised and the midcarpus fused, all subsequent movement will occur between the lunate and lunate fossa. As a consequence only grade 2 SLAC and grade 2 SNAC (not grade 3) were considered appropriate for this procedure.

Between 1992 and 2009, 116 of these procedures were performed in 110 patients at Wrightington Hospital. Of these patients, 58 attended a special research clinic. Of the rest, 29 replied by postal questionnaire, and for the rest, information was obtained from clinical records.

The assessment included a pain score using a visual analog scale¹³; ROM as measured by a goniometer with comparison to the contralateral side; grip strength using a Jamar dynamometer (Lafayette Instrument Company, Lafayette, IN, USA), again comparing to the contralateral side; a functional assessment using the shortened Disabilities of the Arm, Shoulder, and Hand (QuickDASH)¹⁴; and the Wrightington wrist score¹⁵ (► **Table 1**). The latter is a scoring system based on the assessment of pain, range of motion, grip strength, and function, reporting pain, impairment, and disability as three separate figures each up to 100 (the lower score being better). An assessment of complications and further surgery was also undertaken.

Finally, a radiological evaluation was performed to ascertain whether the bones had fused and whether there was any arthritis affecting the lunate fossa.

The data were statistically analyzed using Student's *t*-test (SPSS for Windows).

Surgical Technique

All of the procedures were undertaken through a dorsal longitudinal incision, with the long extensors to the fingers and wrist being retracted and protected. The capsule of the wrist was opened, again through a dorsal longitudinal excision with radial and ulnar extensions. The radiocarpal joint was then visualized. At this stage, the status of the lunate and lunate fossa articular cartilage was assessed. If this was found to be satisfactory, then the scaphoid was removed using a combination of sharp dissection and rongeurs. In most cases a radial styloidectomy was also performed to prevent impingement on radial deviation.

At this stage the lunate was fixed to the radius in a neutral position by way of a trans-radial K-wire as confirmed under image intensifier. Thereafter, the four bones to be fused—that is, the lunate, capitate, triquetrum, and hamate—were exposed and the intercarpal articular surfaces removed using a combination of fine rongeurs and osteotomes, leaving bleeding bone exposed. The excised scaphoid and radial styloid were then prepared into strips or small fragments and used as bone graft. This was then inserted into the gaps between the four bones. In the early cases, fixation was by multiple crossed K-wires (1.6 mm), many of which ultimately being removed. Thereafter the Spider plate (Integra Life Sciences, Plainsboro, NJ, USA) was predominantly used, but more recently two or three headless screws and staples have been incorporated. The position of the implants was checked by intraoperative X-ray images or using an image intensifier. At this stage it was important to confirm that the lunate was aligned perpendicular to the radius, that any metalwork was buried to prevent impingement, and that there was no intraarticular protrusion of any screw or wire (► **Fig. 1**).

Closure involved suturing the capsule, restoring the extensor retinaculum, and allowing the extensor tendons to return to their normal position. Prior to skin closure, a small suction drain was left in situ. This was removed after 24 to 48 hours. At that time the arm was immobilized in a short-arm cast.

Rehabilitation was very much dependant on the method of fixation. In all cases, however, the wrist was immobilized for a minimum of 2 weeks. At that time sutures were removed. If the method of internal fixation was felt to be rigid (that is, using plates, staples, or headless screws), then gentle mobilization out of a protective splint was allowed for a period of 6 to 8 weeks. In a small number of patients where K-wires alone were used, the wrist was immobilized for 6 weeks prior to rehabilitation.

Initially, active mobilization was undertaken under supervision only. When movement had maximized, strengthening exercises were begun. The whole rehabilitation process typically took 3 months.

Results

Patient Demographics

Of the 110 patients (116 procedures), 83 were male and 27 female. The median age at surgery was 47 years 10 months (standard deviation 15 years 5 months). Of these, 44 had a

Table 1 Wrightington wrist score assessment form

Patient Self-Assessed Wrist Evaluation						
Name						
Hosp no				Date		
Rate your pain during the last week						
Please circle one number in each line						
	No pain					Worst pain imaginable
AT REST	0 1	2 3	4 5	6 7	8 9	10
AT NIGHT	0 1	2 3	4 5	6 7	8 9	10
Your WORST pain	0 1	2 3	4 5	6 7	8 9	10
<i>Pain score = Average pain score</i>						
Rate your ability to do the following activities with your AFFECTED hand during the last week.						
Please circle one number for each item. If you haven't done the activity please make your best guess.						
	No problem					Unable
1) Turn a screwdriver	0 1	2 3	4 5	6 7	8 9	10
2) Carry groceries (10 lbs)	0 1	2 3	4 5	6 7	8 9	10
3) Pour from a jug	0 1	2 3	4 5	6 7	8 9	10
4) Turn a key in a lock	0 1	2 3	4 5	6 7	8 9	10
5) Cut meat using a knife	0 1	2 3	4 5	6 7	8 9	10
6) Open and close a jar	0 1	2 3	4 5	6 7	8 9	10
7) Turn a doorknob	0 1	2 3	4 5	6 7	8 9	10
8) Wring a dishcloth	0 1	2 3	4 5	6 7	8 9	10
9) Use toilet paper	0 1	2 3	4 5	6 7	8 9	10
10) Turn a can opener	0 1	2 3	4 5	6 7	8 9	10
<i>Function score = Average of questions 1–10</i>						
Clinical Examination						
Affected wrist	R	L	Handedness		R	L
Flexion						
Extension						
Rad Deviation						
Ulnar Deviation						
Pronation						
Supination						
Grip strength						

All scores/10. Lower score = better outcome

SLAC and 72 a SNAC wrist (with no involvement of the lunate or lunate fossa).

Fifty-four had surgery to the left wrist and 62 to the right. At surgery, 85 wrists were fixed with a Spider plate, 11 with headless cannulated bone screws (Acutrak, Accumed, Portland, OR, USA), 17 with crossed K-wires, and three with staples.

Follow-up was a mean of 9 years 4 months (range 3 to 19 years). Six patients who continued to complain of significant pain after the index procedure and had been revised to total wrist fusion (TWF) were not included in the final clinical assessment.

Clinical Outcome

At latest follow up, pain ($n = 87$) was assessed by the visual analog scale (0 for no pain, 10 for the worst possible pain) and had a mean of 1.9 SD (± 3.1).

ROM in degrees ($n = 58$) is set out in ►Table 2.

Grip strength ($n = 58$) as assessed by the Jamar dynamometer was a mean of 21 kg ($\pm$ SD 11.5) on the affected side as against a mean of 39 kg ($\pm$ SD 12.7) on the unaffected.

Finally, with regard to function ($n = 87$), using Quick-DASH, the median was 37.4 (SD ± 26.3). Using the Wrightington wrist score, the three mean scores were:- pain 19, impairment 51, and disability 17. Eighty-seven percent of

Fig. 1 Final X-ray appearance with circular plate buried in bone and no prominent screws.

patients had returned to work, of whom 72% returned to the same work as prior to surgery. The rest had returned to lighter duties.

The preoperative diagnosis of SNAC or SLAC wrist did not correlate with a better or worse outcome ($p > 0.05$).

Radiological Assessment (Follow-up 7.6 Years, Range 3–17.2)

At latest follow-up, 64 of the 92 wrists whose X-ray images were available were seen to be soundly fused on plain radiograph. Of the remaining 28, there was found to be no union at all in 7 and partial union, predominantly including the triquetrum, in 21 cases (►Fig. 2). In none of the cases was the lunate fossa found to be involved in the arthritic process.

Complications/Additional Procedures

Most of the patients ($n = 13$) who had a fusion undertaken using K-wires had all or most of the wires removed. In addition, three patients who had fusion with a Spider plate had that removed because of metalwork impingement.

Fig. 2 Continuing nonunion around the triquetrum.

Table 2 Range of motion results

	Operated side	Normal side
Palmar flexion	32 ± 15.4	70 ± 9.0
Dorsal flexion	28 ± 14.9	50 ± 11.6
Radial deviation	10 ± 6.0	30 ± 10.0
Ulnar deviation	16 ± 3.2	35 ± 12.7
Pronosupination	150 ± 26.3	155 ± 15.5

With regard to additional surgery, of the whole group (110 patients), six underwent TWF as a consequence of ongoing pain, felt to be due to continuing nonunion. For ongoing discomfort on the ulnar side of the wrist, two underwent pisiformectomy having developed secondary osteoarthritis of the pisotriquetral joint; three underwent revision bone grafting and fixation, one with an additional ulnar wafer procedure to the distal radial ulnar joint. Twelve patients who had continuing discomfort declined further intervention.

Three patients underwent subsequent additional procedures. Two had carpal tunnel release, and one had a trapeziectomy. Overall, we have had no cases of deep infection, and all of the revision surgeries just described were undertaken within 2 years of the initial operation.

Discussion

Four-corner fusion as described by Watson in 1986¹ has been used widely to treat arthritis secondary to scapholunate instability or longstanding scaphoid nonunion. Various techniques of fixation have been described by Vance et al (2005),¹⁰ Espinoza et al (2009),⁶ and Ozyurekoglu et al (2012).⁷ In this study we evaluated one unit's experience over a 20-year period.

Our cohort of patients described in this study was similar to other reported groups. Essentially this is predominantly a problem of middle-aged males. Clinically, pain relief is good after the operation, although some patients are left with some intermittent discomfort, particularly when it is cold or following heavy activities. Movement is ~50% of flexion/extension, which is again comparable to other reported series (►Table 2). Radioulnar deviation, however, is less, at 40%. Grip strength, again compared with the contralateral side, is not as good in our series at barely 50%, compared with 70% to 80% or more in other studies (►Table 3).^{6,7,10,16} The reason for this is unclear, although we have included all our patients, even the ones with ongoing discomfort and those who have had complications apart from those who had undergone TWF. It is not clear as to whether other authors have done the same.

With regard to function in our series, most patients have been able to return to undertaking most if not all activities of daily living and to their former employment (87%). This has been demonstrated by a satisfactory DASH and particularly by the low score for disability in the Wrightington wrist score.

Table 3 Results of other studies

Author	No. in study	Follow-up	Method of fixation	Clinical results	Complications
Ashmead et al (1994) ¹⁷	100	44/12	K-wires	72% F/E 80% Grip strength	3 nonunion
Kendall et al (2005) ¹⁸	18	20/12	Spider plate	46% F/E 56% Grip	3/18 union (2 misplaced screws, 1 revised)
Vance et al (2005) ¹⁰	58		Spider plate (27) Other staples & screws (31)	50% F/E 70% Grip	26% nonunion 22% Spider plate impingement 8 revisions
Merrell et al (2008) ¹⁹	28	46/12	Spider plate	61% F/E 82% Grip	27/28 went on to union 1 screw broken, 1 broken plate 2 reops for radial impingement and lack of movement
Espinoza and Schertenleib (2009) ⁶	35	4.6 years	Rectangular plate	64% F/E 79% Grip	34/35 united 4 removal of metalwork
Ozyurekoglu and Turker (2012) ⁷	33	8/12	Acutrak screw	71% F/E 80% Grip	31/33 (94%) unions reops 1 to TWF, 1 screw removal
Neubrech et al (2012) ¹⁶	56	14.7 years	K-wires	62.5% F/E 68.4% R/U 84.9% Grip	11% nonunion, hematoma, infection, persistent pain

With regard to complications, 13 patients underwent a second operation for removal of K-wires, which are no longer routinely used for this procedure. Several patients ($n = 21$) had continuing pain, particularly on the ulnar side of the wrist. The majority of these were due to nonunion, particularly around the triquetrum or from prominence of metalwork. Overall we identified on plain X-ray 28 patients (31%) who had some signs of nonunion between carpal bones, particularly around the triquetrum. Fifteen of these underwent a second operation, either a TWF, a pisiformectomy, or a revision bone graft and fixation. Again this is in agreement with several other studies,^{10,16} of which Vance et al reported a nonunion rate of 26% and the latter 22%. Skie et al,²⁰ however, like ourselves, reported a good outcome following regrafting and fusion. Unglaub et al 2011²¹ also reported on a small number of cases of nonunion following successful rearthrodesis, although the ultimate outcome was described only as moderate. In two patients who had undergone pisiformectomy, findings at surgery were that one of the screws used along with the Spider plate for fixation had perforated the pisotriquetral joint. This confirms the work undertaken by Gaston et al,²² who also reported this complication.

To conclude, we have reported on the outcome of 116 four-corner fusions (110 patients) performed at our institution between 1992 and 2009. The mean follow-up was 9 years and 4 months, ranging from 3 to 19 years. Generally, patients were afforded good pain relief and retained some movement, particularly 50% of flexion/extension and 40% of radioulnar deviation. They also retained 50% of grip strength compared with the contralateral side. The complication rate, however, initially was high, with 31% having some evidence of nonunion on plain radiograph. Fifteen of these patients (14%) underwent further surgery, predominantly regrafting and

fixation with success. The use of the Spider plate does appear to have reduced the need for a second operation to remove the metalwork. Attention to detail, however, is paramount, particularly by way of bone preparation, the use of cancellous graft, and burial of the plate to prevent impingement. Finally, given the high nonunion rate surrounding the triquetrum, this bone could be excised along with the scaphoid, resulting in a three-part fusion only, or the surgeon could alternatively simply undertake a capitulunate fusion.

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Conflict of Interest

None

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