Management of Non-United Four-Corner Fusions

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Abstract

Purpose Wrist degeneration, resulting from scaphoid nonunion or scapholunate ligamentous disruption, is widely managed with scaphoid excision with four-corner fusion. There are no specific details in the literature regarding “salvage” of nonunion after attempted “four-corner fusions” or the patient outcomes. The purpose of this paper is to present the results of patients who underwent treatment for nonunion after four-corner fusion, the subsequent surgeries done for wrist salvage and the functional results.

Methods We reviewed, retrospectively, 37 patients who underwent limited wrist fusion using circular plate fixation, of which eight cases (22%) went on to nonunion and necessitated revision surgeries with plate exchange and bone graft. (Table 1) Five of eight patients were available to return to the clinic, and the wrist range of motion and the disabilities of the arm, shoulder, and hand (DASH) score were recorded.

Results The average DASH score was 46 (range, 15 to 60.8). Grip on the affected limb was, on the average, 62% of the contralateral limb. Average arc of wrist motion was 70° (35.7° of flexion and 34.3° of extension). Three of the five patients were laborers, and two returned to the previous employment. The remaining two patients returned to their previous sedentary jobs. All patients reported difficulty with recreational activities involving heavy activity.

Conclusions Complications of four-corner arthrodesis using circular plate fixation were recorded, revealing a high number of nonunions and hardware failures. All nonunions were salvaged with allograft or autogenous grafting

with plate revision; however, the patients did have considerable limitations.

Keywords Non-united · Four-corner fusions · Management · Circular plate

Introduction

Scapholunate advanced collapse (SLAC) of the wrist is the most common pattern of degenerative arthritis in the wrist [18]. The most common cause of SLAC wrist is scapholunate dissociation with rotatory subluxation of the scaphoid. Initial treatment of the cause of the SLAC wrist (e.g., scaphoid nonunion, scapholunate dissociation) may prevent subsequent degeneration. Limited wrist arthrodesis (four-corner fusion), proximal row carpectomy, or wrist arthrodesis are surgical options for the arthritic wrist and are indicated based on the condition of the carpus and the demands and functional status of the patient, once arthritis has developed.

A “four-corner fusion” SLAC reconstruction involves scaphoid excision and arthrodesis of the capitate, lunate, hamate, and triquetrum. During the early 1990s, surgeons began performing scaphoid excision with four-corner fusion, which fused the lunate, capitate, hamate, and triquetrum [11, 15, 21]. This procedure is theoretically advantageous, as it maintained height and tendon tension, as opposed to the proximal row carpectomy. However, these theoretical advantages have not been proven clinically, and one potential complication of the four-corner fusion procedure is nonunion.

The need to improve union rates and minimized hardware-related complications led to the development of circular plate fixation systems that may be applied dorsally at the junction of the lunate, capitate, hamate, and

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triquetrum, facilitating fixation of the fusion. The theoretical benefits of the circular plate are increased stability when compared with Kirschner wires (K-wires), staples, and screws. There has been recent concern with an increasing number of nonunions with this technique [7, 17].

We reviewed our cases of non-united four-corner fusions. Thirty-seven four-corner fusions were performed over a period of 5 years (from 1999 to 2004) and eight (22%) failed to fuse, requiring revision surgeries. These were done by a single attending surgeon. There are no specific details in the literature regarding “salvage” of failed “four-corner fusions” and the patients’ outcome. The purpose of this paper is to present the outcomes of patients who underwent revision surgeries for nonunion of four-corner fusions utilizing circular plate fixation.

Methods

Thirty-seven patients were treated with four-corner fusion using circular plate fixation between October 1999 and August 2004. The cohort consisted of 37 consecutive patients that had four-corner fusion: 21 patients were secondary to SLAC, 12 patients were secondary to scaphoid nonunion advanced collapse (SNAC), 2 midcarpal arthritis, 1 failed scaphotrapeziotrapezoidal (STT) fusion and 1 volar intercalated segment instability (VISI) deformity.

The theoretical benefit of this plate, which consist in increasing wrist stability, is that the screws are pulling the bones toward the center of the plate creating a stable construct. Circular plate fixation for limited wrist fusion is indicated for the treatment of posttraumatic or degenerative wrist arthritis. Neurological, vascular, or severe tendon deficiencies that may compromise the affected extremity contraindicate this technique.

A retrospective review was conducted on eight patients who had nonunions following limited wrist fusion. Diagnosis of a nonunion was based on the presence of persisting pain with wrist motion, along with change in position of the hardware on sequential radiographs. Patients were routinely followed-up until there was both radiographic evidence of union and return to required activities. The clinical data of all patients failing limited wrist fusion were retrospectively reviewed, and the data is summarized in Table 1.

To date, there are no specific details in the literature regarding “salvage” of failed “four-corner fusions” and the patient outcomes. All these eight patients underwent subsequent surgeries as salvage technique of the four-corner fusion. Four-corner fusions, using circular plate fixation, were performed in seven wrists as the first choice for partial wrist fusion, while one patient had secondary four-corner fusion using a circular plate after a failed four-corner fusion using K-wires.

Limited wrist fusion using the circular plate involved scaphoid excision and arthrodesis of the capitate, lunate, hamate, and triquetrum. The carpus was exposed through a longitudinal midline approach between the third and fourth extensor compartments. We totally decorticated the mid-carpal joint. The lunate–triquetrum and capitate–hamate were partially decorticated. Bone graft was obtained from the excised scaphoid or if that was inadequate from the distal radius. Provisional K-wires were used providing resistance to the rasp and preventing toggling of the bones. Cancellous bone graft was packed between the interstices of the four bones. Immobilization after primary surgery used a rigid splint for 2 weeks, followed by a removable splint, until there was evidence of fusion. For the revision surgery, the type of immobilization was dependent on the bone quality and rigidity of fixation at the time of surgery.

The “salvage” subsequent surgery was done after a variable period ranging between 2 and 16 months (average 8.75 months). Five of the seven patients who had salvage of four-corner fusions were able to be contacted, beyond routine clinical follow-up, for assessment of wrist range of motion and the DASH scores. The average duration of follow-up was 34 months (range, 5 to 60 months). Five patients were available for follow-up exams, DASH score testing, and radiographs. Two patients were unable to be located for follow-up; their range of motion was gathered from the clinic record.

Results

Nonunion was found in eight patients (22%) who underwent four-corner fusion with circular plate fixation during that time period. The average time, until subsequent surgery was done as a salvage procedure after failed four-corner fusion, was 8.75 months with a range between 2 and 16 months. The salvage procedure was usually a revision four-corner fusion, except in one patient with total fusion.

The average duration of follow-up was 34 months (range, 5 months to 60 months). Five patients were available for follow-up exams, DASH score testing, and radiographs. Two patients were unable to be located for follow-up; their range of motion was gathered from the clinic record. One patient developed radiocarpal arthritis, 1 year after four-corner fusion, and this was converted to a total wrist arthrodesis. This patient was not included in range of motion or DASH scores, but was included in the review, as the patient did have a non-united four-corner fusion, which was initially salvaged. All radiographs were analyzed.

The average DASH score was 46 (range, 15 to 60.8). Grip on the affected limb was, on the average, 62% of the contralateral limb. Average arc of wrist motion was 70° (35.7° of flexion and 34.3° of extension). Three of the five

Table 1 Individual patient data.

Patient Number	Age	Sex	Diagnosis	Surgery	Subsequent Surgery	Complication	Interval to Second Surgery	Length of Follow-up (months)	ROM	DASH	Grip	Work Status
1	66	M	SLAC wrist arthritis	Four-corner fusion using Spider plate	Revision with distal radius bone graft plate exchange and additional K-wires	Nonunion	5 months	16	Flex-55 Ex-45 Total 100	15	R-42 L-28	Returned sedentary
2	45	M	SNAC wrist arthritis	Four-corner fusion using Spider plate	Revision with plate exchange, allomatrix graft and additional K-wires-developed degenerative changes in radiocarpal joint. Wrist fusion at one year postsurgery	Nonunion	6 months	21	NA	NA	Not done	returned
3	47	M	SLAC wrist arthritis	Four-corner fusion using Spider plate	Revision with distal radius autograft, plate exchange. Plate removed at 2.5 years due to synovitis.	Nonunion	6 months	36	Flex-50 Ex-35 Total 85	49.2	R-20 L-48	returned labor
4	47	M	SLAC wrist arthritis	Four-corner fusion using Spider plate	Revision with plate exchange and Bacitracin impregnated Allomatrix. Infection resolved.	Nonunion Infection	10 months	36	Flex-10 Ex-20 Total 30	60.8	R-32 L-48	returned labor
5	73	M	SLAC wrist arthritis	Four-corner fusion using Spider plate	Revision with plate exchange and Allomatrix with additional K-wires.	Nonunion cellulitis	2.5 months	5	Flex-20 Ex-30 Total 50	Not done	Not done	retired
6	39	M	SLAC wrist arthritis	Four-corner fusion using Spider plate	Index procedure outside facility. Revision with plate exchange and Allomatrix with additional K-wires.	Nonunion	1 year	48	Flex-50 Ex-40 Total 90	50	R-62 L-46	returned sedentary
7	46	M	SLAC wrist	Four-corner fusion using K- wires	Index procedure outside facility-four-corner fusion no scaphoid excision. Revision was scaphoid excision and plate revision with Allomatrix	Nonunion	3 years	60	Flex 30 Ex 30 Total 60	Not done	Not done	Not known
8	50	F	SLAC wrist	Four-corner fusion using Spider plate	Revision with plate exchange and Allomatrix with additional K-wires.	Nonunion	16 months	50	Flex-35 Ex-40 Total 75	55	R-25 L-15	Light labor-currently sedentary

Table 2 A review of the literature comparing DASH scores from four-bone fusion without complications.

Author	Year	Diagnosis	Surgery	Cohort	Follow-up	DASH Score
Gohritz A et al. [6]	2005	SNAC/ SLAC wrist	Bilateral midcarpal arthrodesis	20	48 months	45
		SNAC/ SLAC wrist	Total wrist fusion	22	42 months	39
Sauerbier M [12]	2000	SNAC/ SLAC wrist	Midcarpal arthrodesis with complete scaphoid excision and interposition of bone graft	36	25 months	28
Dacho A et al. [3]	2006	SNAC/ SLAC wrist	Midcarpal arthrodesis	49	47 months	29
Lukas B et al. [10]	2003	SNAC/ SLAC wrist and radiocarpal arthrosis	PRC (14 cases) LWF (Limited midcarpal arthrodesis) (12 cases)	26	16.8 months (PRC) 13.7 months (LWF)	36 30
Tunnerboff HG et al. [16]	2001	SNAC/ SLAC wrist, perilunate dissociation, calcium pyrophosphate disease	Medio-carpal arthrodesis with excision of scaphoid	27	27 months	22
Krimmer H et al. [9]	2000	SNAC/ SLAC wrist	Midcarpal arthrodesis (97 patients) Total wrist fusion (41 patients)	138		33 45
Saubier M et al. [13]	2000	SNAC/ SLAC wrist	Midcarpal arthrodesis	31	15 months	39
Dacho A et al. [4]	2005	SNAC/ SLAC wrist	Midcarpal arthrodesis	49	47 months	29

patients were laborers, and two returned to the previous employment. Two patients returned to their previous sedentary jobs, and one was retired. All patients reported difficulty with recreational activities involving heavy activity.

Discussion

The majority of initial literature on SLAC wrist reconstruction is based on K-wire fixation, and not circular plate fixation [8, 18, 19, 21]. There are also studies comparing four-corner fusion to proximal row carpectomy, which used several different types of fixation [2, 8, 15, 21]. There is little literature (until recently) outlining the outcomes of patients suffering from complications of four-corner fusions using circular plate fixation [5, 17].

Watson [20] reported a series of 250 SLAC reconstruction procedures before the advent of circular plate fixation. This study found only a 3% nonunion rate. Krakauer [8] reported the outcomes of six different procedures for stages II and III SLAC wrist in 55 cases. The nonunion rate was 9% (2 cases out of 23 cases) of scaphoid excision and four-corner arthrodesis. Wyrick et al. [21] presented similar results and recommendations. Average total wrist motion was 67° and 75% on grip strength. In this study, the nonunion rate was 18% (3 cases out of 17 patients). Tomaino et al. [15] treated 24 wrists for SLAC arthritis with either proximal row carpectomy (PRC) or limited intercarpal arthrodesis with scaphoid excision (LWF). He reported a failure rate of 6.6% (1 of 15 cases of PRC) and a 0% nonunion rate. Cohen and

Kozin [2] reported a nonunion rate of 5% (1 out of 19 cases). The patients were treated for SLAC arthritis with either scaphoid excision with four-corner arthrodesis or with proximal row carpectomy. One patient in the four-corner group had nonunion. Ashmead et al. [1] reported the results of 100 cases of SLAC wrists repaired with scaphoid excision and limited wrist arthrodesis. Nonunion rate was 3% (three cases). A literature review done by Siegel and Ruby [14] reported a 4.3% nonunion rate in 138 cases. Kendall [7] reviewed 418 cases of four-corner arthrodesis in the literature and reported nonunion rates between 0 and 18% [1, 2, 8, 15, 20, 21].

Kendall's results [7] of four-corner arthrodesis using dorsal circular plate fixation (spider plate) revealed nonunion rate of 62.5%. The average arc of motion was 46% in the opposite wrist, and the grip was 56%. It was postulated that this rate of nonunion may have been due to the plate obscuring the partial or fibrous nonunion. We agree that the plate obscuring the fusion site may hide a nonunion until the screws back out or the lunate falls back into a dorsiflexed intercalated segment instability (DISI) pattern. The paper did not discuss the means of salvage for those nonunions.

In a recent article, Vance et al. [17] compared four-corner arthrodesis to "traditional techniques" such as K-wires and Herbert screws. Interestingly, they reported a nearly identical rate of nonunion (26%) as our group (22%). Three of their cases were revised with K-wires, three with wrist fusions, and three with plate removal. They found an average DASH score of 27 for plate fixation. Their conclusion was that the plate fixation groups had higher complications, and the traditional fixation groups had better function. They con-

cluded that there is concern with the increased complication rate compared to the “traditional” methods of fixation in the four-corner fusion. They also concluded that “technical errors” in plate fixation may lead to nonunion and plate impingement and stated that the plate offers little benefit over “traditional” fixation.

A review of the literature comparing DASH scores from four-bone fusion without complications reveals mean DASH score ranging from 22 to 45 (Table 2) [3, 4, 6, 9, 10, 12, 13, 16].

Our recent experience using circular plate fixation for limited wrist fusion shows a nonunion rate to be 22%. The high rate of nonunion may be, in part, due to reliance on improved fixation and less stringent attention to proper preparation of joint surfaces and bone graft technique. Of our patients who were treated for nonunion, the “salvage” group averaged 62% of contralateral grip strength and 70° total arc of motion, with an average DASH of 46.

Conclusion

Four-corner fusion is an accepted management of the SLAC wrist with a preserved radiocarpal joint. There is a recent concern with an apparent increase of technical failures and nonunions with the use of circular plate fixation. We reviewed our cases of salvage of these nonunions with plate revision and addition of allograft or autograft. Although this is a small series, the patients obtained similar range of motion and grip strength as those in the literature, but did score worse on DASH testing, indicating more disability. The small numbers of patients precludes formal comparison of their DASH testing, and it is a possible cause of error.

This may have been, in part, due to the prolonged course of treatments in these patients, as many nonunions were identified once the screws began backing out as the plate obscured the nonunion site. This should prompt surgeons to carefully examine the technical aspects of performing the four-corner fusion operation with a circular plate and be vigilant in locating those non-united fusions. Although salvage is possible, the patient may face a prolonged course of treatment and extended period of disability.

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