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BASIC RESEARCH

High Fusion Rates with Circular Plate Fixation for Four-corner Arthrodesis of the Wrist

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Abstract

Background Scaphoid excision and four-corner fusion is commonly performed to reconstruct advanced scapholunate collapse and scaphoid nonunion with collapse. Metallic plates were introduced for achieving fixation of the four carpal bones. Although the developer reported high rates of fusion, several other early reports of circular plate fixation suggest higher complication rates and inferior outcomes compared with traditional fixation techniques.

Questions/Purposes To clarify the controversy in the literature we determined the fusion rates, complications, and functional outcomes of patients having circular plate fixation for four-corner fusion.

Methods We retrospectively reviewed 15 patients treated for radioscaphoid arthritis with four-corner fusion using circular plate fixation. The minimum followup was 11 months (mean, 22 months; range, 11–39 months).

Results Radiographic union was achieved by all 15 patients. There was only one postoperative complication. ROM was 71% and grip strength was 78% of the opposite normal side.

Conclusions Our results compare favorably with those using traditional fixation techniques. ROM measurements seem superior to those reported in the literature.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Since it was first popularized by Watson and Ballet in the 1980s [12], scaphoid excision combined with four-corner arthrodesis of the wrist is an accepted salvage surgical procedure for arthrosis resulting from advanced scapholunate collapse and scaphoid nonunion with collapse [1, 5, 13]. This arthrodesis traditionally uses Kirschner wires, staples, or compression screws to achieve fixation of the lunate, capitate, hamate, and triquetrum. In 1999, a metallic circular plate was introduced, which was designed specifically for limited intercarpal fusion. It offered a simple and sturdy method of internal fixation that possibly could tolerate earlier mobilization of the wrist while also resulting in higher rates of fusion. Better functional outcomes were anticipated. However, reports of early results using the circular plate suggest higher complication rates when compared with traditional fixation techniques, including nonunion (25%–39%), implant breakage or back-out (7%–27%), and hardware impingement (22%–25%) [2, 4, 9, 11]. Although higher fusion rates and fewer complications have been reported more recently by the developer of the device [6], some uncertainty exists regarding the effectiveness of circular plates because of the number of published reports to the contrary [2, 4, 9, 11].

To clarify the controversy in the literature we therefore reviewed our experience of scaphoid excision four-corner

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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fusions using a nonlocking circular plate to: (1) determine fusion rate of the four bones; (2) identify the surgical complications; and (3) determine functional outcomes, including ROM, grip strength, and pain.

Patients and Methods

We retrospectively reviewed the medical records and radiographs of 15 selected patients treated surgically for radioscaphoid arthritis with four-corner fusion using a nonlocking circular plate (Spider Limited Wrist Fusion System; Integra Life Sciences Corporation, Plainsboro, NJ) between 2003 and 2006. Surgical indications were advanced scapholunate collapse in six patients and advanced scaphoid nonunion with collapse in nine (Fig. 1). There were seven female and eight male patients, with an average age of 54.9 years. Three of the 15 patients smoked (one patient smoked two packs/day; two patients smoked one pack/day). Comorbidities included one patient with noninsulin-dependent diabetes, two with hypertension, one with iron deficiency anemia, and two with gastroesophageal reflux disease. The minimum followup was 11 months (mean, 22 months; range, 11–39 months). No patients were recalled specifically for this study. We obtained Institutional Review Board approval for this study.

We performed surgery through a dorsal midline incision. The extensor pollicis longus tendon was released and transposed radially. The dorsal capsule was incised longitudinally and partially elevated off the dorsal cortex of the distal radius. We segmentally excised the posterior interosseous nerve. The scaphoid was excised in a piecemeal fashion using osteotomes and a bone rongeur. We used a small curette to remove all remaining articular cartilage and eburnated subchondral bone along the fusion surfaces. The dorsiflexed lunate was realigned by hyperflexing the wrist. A 0.045-mm smooth Kirschner wire was driven along the dorsal edge of the distal radial articular surface into the lunate to maintain its position. We placed at least two additional Kirschner wires from the ulnar side to maintain the reduced position of the four-corner carpal bones. Fluoroscopy was used to confirm the position of bones. In 13 of the cases, we harvested cancellous bone graft from the distal radius through the same incision using a curved curette. No radial styloidectomies were performed. The appropriate-sized conical reamer then was used to prepare the plate insertion surface. We performed reaming until the reamer edge was seated below the dorsal cortex of the lunate. Cancellous bone graft was packed tightly into the fusion surfaces. In two cases, we used only morselized scaphoid bone graft. In 13 cases, an eight-hole standard plate was used, and in two cases, a six-hole plate was used. We inserted 2.4-mm screws for fixation. The center of the plate was packed with additional bone graft. Fluoroscopy was used again to confirm appropriate alignment of bones and length of screws. Passive extension of the wrist was performed to clinically and radiographically check for dorsal hardware impingement. After removal of the Kirschner wires, we repaired the capsule and skin closure was completed (Fig. 2).

A plaster forearm-based thumb spica splint was applied and maintained for 2 weeks. This was followed by 2 additional weeks wearing a fiberglass short arm thumb spica cast. All patients received a minimum of 12 weeks of

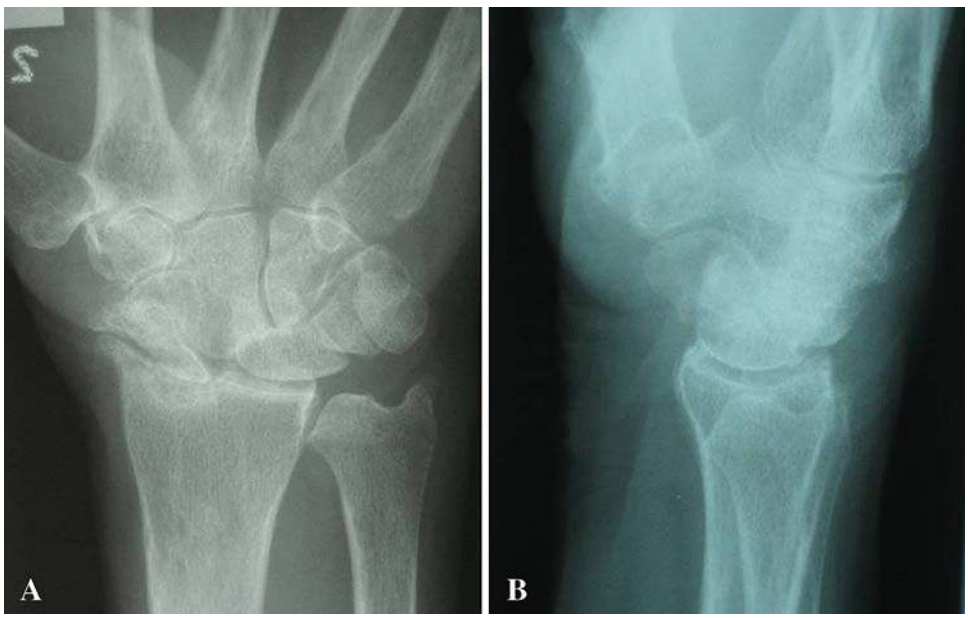

Fig. 1A–B (**A**) AP and (**B**) lateral radiographs show the wrist of a patient with symptomatic scaphoid fracture nonunion advanced collapse.

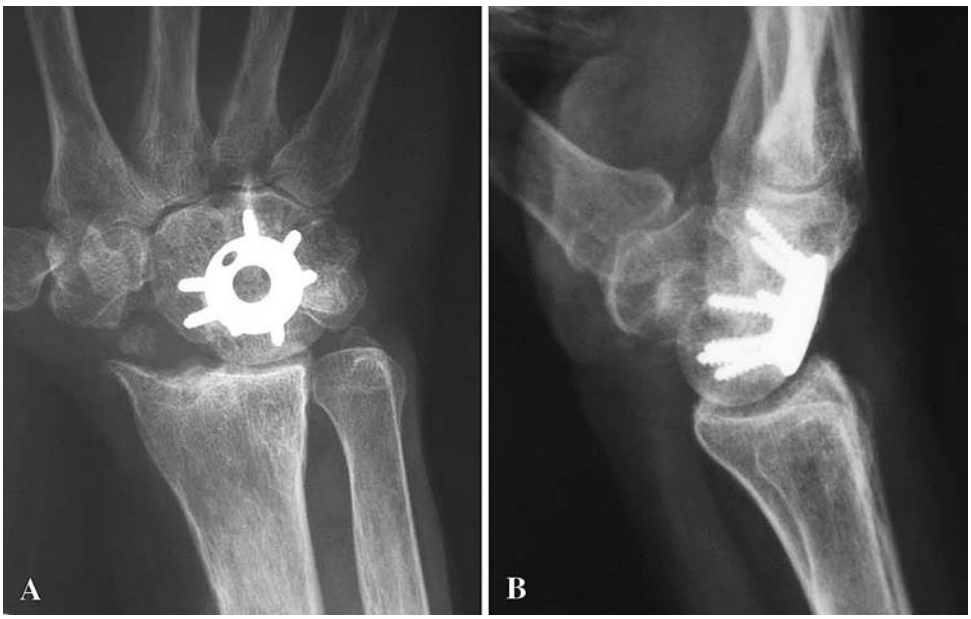

Fig. 2A–B (**A**) A postoperative AP radiograph shows the scaphoid excision and four-corner fusion using the circular plate for fixation. (**B**) The lateral view shows the plate inset below the dorsal cortex of the lunate.

Table 1. Modified Mayo Wrist Score

Classification	Fusion	Pain	Motion*	Grip strength*
Excellent	Solid	None	> 50%	> 50%
Good	Solid	Slight	> 30%	50%–70%
Fair	Solid	Moderate	> 20%	30%–50%
Poor	Failed	Severe	< 20%	< 30%

* Injured/uninjured × 100. (Published with the permission of Elsevier from Minami A, Kato H, Iwasaki N, Minami M. Limited wrist fusions: comparison of results 22 and 89 months after surgery. *J Hand Surg Am.* 1999;24:133–137.)

occupational therapy afterward. Supervised sessions with an occupational therapist took place twice a week, and a home therapy program was performed by the patient every day.

Patients then were seen monthly until they were discharged. We recorded objective measurements such as grip strength using the Jamar dynamometer in the second handle position (Sammons, Bolingbrook, IL), and wrist ROM using a goniometer. These measurements were compared with those of the opposite normal wrist. All patients were asymptomatic in their contralateral wrists and hands. We asked patients to subjectively grade their level of pain as none, slight (minimal with activity, none at rest), moderate (moderate with activity, occasionally at rest), or severe (constant and significant). For a comparison with the literature, we used the Modified Mayo Wrist Score [7, 8], which takes into account fusion, pain, ROM, and grip strength (Table 1).

Radiographs were taken immediately postoperatively and then at 2 weeks, 4 weeks, 8 weeks, and at the last followup. The treating surgeon (SSY) used radiographs to confirm successful fusion and to rule out hardware problems and signs of nonunion. Successful arthrodesis was determined by solid trabeculation across the intercarpal articulations and no persistent joint lines visible on the radiographs. The films were inspected for lucency around the implant, metallic failure or screw backout, joint-line narrowing, marginal osteophytes, subchondral cystic changes, and carpal malalignment.

Results

Radiographic union was achieved by all 15 patients at last followup. The final followup radiographs showed no signs of lucency around the implant, loose hardware, broken screws, or loss of carpal alignment. There were no signs of progression of arthrosis.

One patient had a postoperative complication: dorsal hardware impingement that necessitated plate removal 6.5 months after the index procedure. At the time of her second surgery, this patient had a solid fusion (Fig. 3). Another patient had carpal tunnel syndrome develop 13 months after surgery; the symptoms were resistant to nonoperative treatment and she underwent carpal tunnel release surgery with complete resolution of her symptoms. There were no postoperative infections. No pisotriquetral joint problems were encountered.

The average total arc of motion of the wrist was 84° (SD ± 15.8; range, 60°−125°). This was 71% of the opposite normal wrist. Grip strength averaged 26 kg (SD ± 8.1; range, 180–45 kg), which was 78% of the

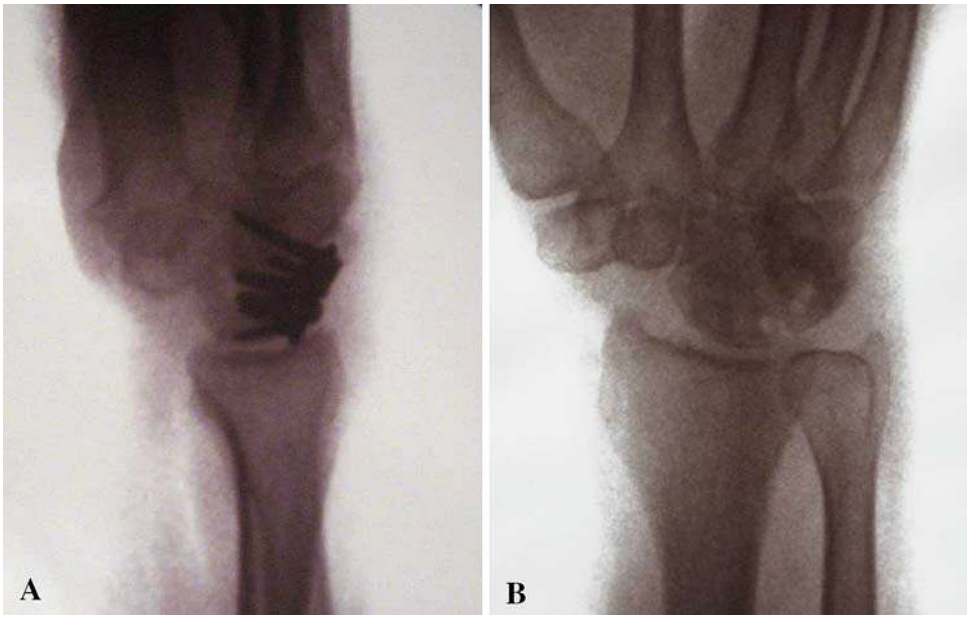

Fig. 3A–B (**A**) This lateral radiograph shows dorsal impingement of the plate against the lip of the distal radius. (**B**) After removal of the plate, the patient achieved a good result and solid fusion.

opposite normal side. Six patients reported no pain at followup. Seven patients had slight pain, and two patients had moderate pain. None described severe pain.

Discussion

Scaphoid excision, four-corner fusion is a well-accepted salvage surgical procedure for advanced scapholunate collapse arthrosis of the wrist. Various implants have been used to achieve intercarpal fusion. We reviewed our experience with the circular plate implant. We evaluated the clinical and radiographic outcomes of scaphoid excision four-corner fusions using a nonlocking circular plate. Radiographs were reviewed to determine successful union of the fusion mass, surgical complications, and functional outcomes (including ROM, grip strength, and pain).

There are shortcomings to our study. First, we did not have sufficient preoperative functional measurements such as ROM and grip strength with which to compare our outcomes. Instead, we compared our results with those of the contralateral limb. Second, judging the success of fusions radiographically is difficult, especially around metallic hardware, and we did not obtain CT scans to verify union. There is intraobserver and interobserver variability in determining radiographic fusion, and we were unable to use multiple blinded observers to ascertain the variability statistics. Nonetheless, no clear signs of nonunion, such as hardware loosening, were detected on final followup radiographs. Finally, we did not use validated outcome instruments at the outset and owing to the retrospective nature of our study we were unable to use such instruments to assess our results.

Since it was first popularized by Watson and Ballet in the 1980s [12], the four-corner fusion has been established as an effective treatment for scapholunate and scaphoid fracture advanced collapse patterns of degenerative arthritis of the wrist [1, 5, 14]. Kirschner wires, staples, and then compression screws are the traditional forms of bone fixation. In 1999, a metallic circular plate was introduced to provide a simple and sturdy method of internal fixation that might tolerate earlier mobilization of the wrist while also resulting in higher rates of fusion. Early enthusiasm for the implant, however, was dampened by reports of high rates of complications [2, 4, 9, 11]. The results of our study are more in line with the more recently published results of Merrell et al., with a 100% rate of union with low morbidity and good function [6].

The incidence of nonunion using traditional forms of fixation for four-corner fusion range from 3% to 9% [1, 3, 5, 11]. A review of the literature by Siegel and Ruby showed the average rate of nonunion to be 4.3% [10]. With circular plate fixation, Kendall et al. reported in 2005 on their first 18 cases performed by four surgeons [4]. Only eight patients were available for followup. Seven of these 18 patients had nonunions develop. They used the excised scaphoid for grafting in 16 of the 18 patients and another patient received an allograft. Vance et al. reported a nonunion rate of 26% in a series of 27 patients [11]. In 20 of these patients, the scaphoid was used for bone grafting. Shindle et al. reported a nonunion rate of 25% in their series of 16 patients [9]. In contrast to these early reports,

Table 2. Comparison of studies of circular plate fixation for four-corner fusion

Study	Nonunion	Impingement, dorsal or styloid	Hardware, breakage or back-out	Motion (% of normal)*	Grip (% of normal)*
Kendall et al. [4]	7/18 (39%)	0/18 (0%)	0/18 (0%)	46%*	56%*
Vance et al. [11]	7/27 (26%)	6/27 (22%)	0/27 (0%)	48%*	70%*
Shindle et al. [9]	4/16 (25%)	4/16 (25%)	2/16 (13%)	N/A	N/A
Chung et al. [2]	0/11 (0%)	0/11 (0%)	3/27 (27%)	73.8°	17.3 kg
Merrell et al. [6]	0/28 (0%)	1/28 (4%)	2/28 (7%)	45%*	82%*
Current study	0/15 (0%)	1/15 (7%)	0/15 (0%)	70%*	78%*

Merrell et al. recently reported good results in 28 consecutive patients who underwent four-corner fusion using the circular plate [6]. They had no nonunions. The senior author (AW) advocates the use of distal radius bone grafting exclusively and only eight-hole standard plates allowing two screws for fixation in each carpal bone [13]. All our patients also obtained successful fusion. Although we used morselized scaphoid graft in two patients and a six-hole plate in two, timely union also was achieved by these patients.

Complications reported by Vance et al. include hardware impingement in 22% [11]. Shindle et al. reported radial styloid impingement in 6% and dorsal hardware impingement in 25% of their 16 patients [9]. Broken screws in three of 11 patients using the circular plates were reported by Chung et al. [2]. Although none of the patients in the study by Merrell et al. experienced nonunion, one patient did have screw backout and one had plate breakage. Two patients required reoperation, one for radial styloid impingement and another for capsular release for stiffness. In our series, one patient had dorsal plate impingement that required a second surgery for hardware removal (Table 2).

ROM of the wrist, grip strength, and pain scales have been used to measure the quality of outcomes in previous studies. Using traditional forms of internal fixation, the total arc of motion after four-corner fusion was reported as 47% of the opposite normal wrist by Wyrick et al. [14, 15] and 58% by Cohen and Kozin [3]. With the circular plate, ROM was reported as 46% by Kendall et al. [4], 48% by Vance et al. [11], and 45% by Merrell et al. [6]. In our series, we found 70% ROM compared with the opposite side. Traditional fixation resulted in a grip strength of 74% of the opposite side according to Wyrick et al. [14, 15], and 79% according to Cohen and Kozin [3]. Using the circular plate, Kendall et al. [4] reported grip strength of 56%, Vance et al. [11] reported 70%, and Merrell et al. [6] reported 82%. We found the grip strength was 78% of the opposite side. Postoperative immobilization was between 6 and 8 weeks in the traditional fixation protocols, whereas the circular plate studies began motion between 4 and 6 weeks. We casted the wrists for no more than 4 weeks, and this perhaps could have contributed to our better final ROM.

Pain and postoperative functionality were scored differently in each publication and therefore are difficult to compare. The instruments used included the Michigan Hand Outcomes Questionnaire [2], the Disabilities of the Arm, Shoulder and Hand questionnaire [11], the Patient Rated Wrist Evaluation [6], and the Modified Mayo Wrist Score [4]. Using the Modified Mayo Wrist Score in our study, we found 13 of 15 patients had either good or excellent outcomes, whereas in contrast, Kendall et al. had three fair and five poor results [4].

We believe the circular plate is an acceptable implant for four-corner fusions. Although the factors that lead to poor outcomes in four-corner fusion are not entirely understood, our data seem to suggest this implant might not be the source of the problems. A prospective comparative study of larger numbers of wrists during a longer followup would help to clarify the usefulness of the circular plate for intercarpal fusion. Improvements in plate design such as locking screw capability might further enhance the rigidity of the construct.

References

1. Ashmead D IV, Watson HK, Damon C, Herber S, Paly W. Scapholunate advanced collapse wrist salvage. *J Hand Surg Am.* 1994;19:741–750.
2. Chung KC, Watt AJ, Kotsis SV. A prospective outcomes study of four-corner wrist arthrodesis using a circular limited wrist fusion plate for stage II scapholunate advanced collapse wrist deformity. *Plast Reconstr Surg.* 2006;118:433–442.
3. Cohen MS, Kozin SH. Degenerative arthritis of the wrist: proximal row carpectomy versus scaphoid excision and four-corner arthrodesis. *J Hand Surg Am.* 2001;26:94–104.
4. Kendall CB, Brown TR, Millon SJ, Rudisill LE Jr, Sanders JL, Tanner SL. Results of four-corner arthodesis using dorsal circular plate fixation. *J Hand Surg Am.* 2005;30:903–907.
5. Krakauer JD, Bishop AT, Cooney WP. Surgical treatment of scapholunate advanced collapse. *J Hand Surg Am.* 1994;19:751–759.
6. Merrell GA, McDermott EM, Weiss AP. Four-corner arthodesis using a circular plate and distal radius bone grafting: a consecutive case series. *J Hand Surg Am.* 2008;33:635–642.

7. Minami A, Kato H, Iwasaki N, Minami M. Limited wrist fusions: comparison of results 22 and 89 months after surgery. *J Hand Surg Am.* 1999;24:133–137.
8. Minami A, Ogino T, Minami M. Limited wrist fusions. *J Hand Surg Am.* 1988;13:660–667.
9. Shindle MK, Burton KJ, Weiland AJ, Domb BG, Wolfe SW. Complications of circular plate fixation for four-corner arthrodesis. *J Hand Surg Eur.* 2007;32:50–53.
10. Siegel JM, Ruby LK. A critical look at intercarpal arthrodesis: review of the literature. *J Hand Surg Am.* 1996;21:717–723.
11. Vance MC, Hernandez JD, Didonna ML, Stern PJ. Complications and outcome of four-corner arthrodesis: circular plate fixation versus traditional techniques. *J Hand Surg Am.* 2005;30:1122–1127.
12. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J Hand Surg Am.* 1984;9:358–365.
13. Weiss APC. Results of four-corner arthrodesis using dorsal circular plate fixation [Letter]. *J Hand Surg Am.* 2006;31:327–328; author reply 328.
14. Wyrick JD. Proximal row carpectomy and intercarpal arthrodesis for the management of wrist arthritis. *J Am Acad Orthop Surg.* 2003;11:277–281.
15. Wyrick JD, Stern PJ, Kiefhaber TR. Motion-preserving procedures in the treatment of scapholunate advanced collapse wrist: proximal row carpectomy versus four-corner arthrodesis. *J Hand Surg Am.* 1995;20:965–970.