Four-corner arthrodesis using distal radius bone grafting

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Purpose
The aim of the study was to review the clinical and radiographic results of four-corner arthrodesis for stages 2 and 3 scapholunate advanced collapse and scaphoid nonunion advanced collapse wrist using 3 Kirschner-wires (3K-wires) and bone graft from distal end of the radius.

Patients and methods
Twenty patients (scaphoid nonunion advanced collapse, $n = 14$; scapholunate dissociation, $n = 6$) underwent four-corner arthrodesis using 3K-wires and distal end radius bone graft and were evaluated for radiographic and clinical success using standard posteroanterior and lateral wrist radiographs and according to modified Mayo Wrist Scoring Chart at 6 and 12 months after surgery. Wrist pains, range of the wrist motion, and grip strength were evaluated at final follow-up. A total of 12 men and eight women were included and their average age at surgery was 38 years. In all, 14 wrists were right and six were left.

Results
Radiographic film assessment revealed union in all cases after an average period of 7 weeks, a well-preserved radiolunate articular interval at all stages of follow-up examination. Pain classification scores showed that 10 patients were pain free, nine patients complained slight pain with vigorous activities, and only one patient complained moderate pain with vigorous activities. The mean flexion improved from 42 to 70% of the normal side. The mean extension improved from 29 to 65% of the normal side. The mean ulnar deviation improved from 28 to 43% of the normal side. The mean radial deviation improved from 30 to 45% of the normal side. Grip strength significantly improved from 28% of opposite side preoperatively to 61% postoperatively. Complications occurred in three cases, radial impingement in one patient, ulnar neuritis in one patient, and superficial infection in one patient.

Conclusion
We have shown that four-corner arthrodesis using K-wires effectively achieves union, provides satisfactory pain relief, restores grip strength, allows return to original job, and preserves functional motion.

Keywords:
arthrodesis, four-corner, scapholunate advanced collapse, scaphoid nonunion advanced collapse

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Introduction

Stability of the wrist is provided by the tight-fitting anatomic design of the individual carpal bones and the ligamentous interconnections that control movement of one bone relative to another [1]. Wrist instability results from soft tissue or bony disruption, leading to pathologic carpal orientation [2]. Motion and load-bearing capacity are lost. Pain occurs secondary to abnormal shear forces, synovitis, and ultimately cartilage degeneration [2].

Arthritic changes begin at the radial styloid articulation with the scaphoid and progress to the proximal radioscaphoid joint. Degeneration then moves to the midcarpal capitolunate joint. This is the final common pathway for a variety of degenerative disorders of the wrist [3], the most common being scapholunate dissociation. It is also seen in scaphoid nonunion, avascular necrosis of the scaphoid, rheumatoid arthritis, and calcium pyrophosphate deposition disease (pseudogout) [4].

As a result of its concentric design, the radiolunate joint is unloaded and preserved regardless of the etiology or stage of degeneration [2]. Four-corner fusion of the midcarpal joint (lunate, triquetrum, capitate, and hamate) with scaphoid excision is based on maintenance of this relationship. Successful arthrodesis results in isolated radiocarpal motion with force transmission through the radiolunate articulation and the triangular fibrocartilage complex. There are several methods of fixation including multiple headless screws, circular plates, Kirschner-wires (K-wires), and conventional staples [5]. However, there is no agreement on the best technique [6].

We present our experience using simple method of fixation (3K-wires) and bone graft from distal end of the radius.

Patients and methods

Twenty patients with advanced radioscaphoid and midcarpal osteoarthritis underwent four-corner arthrodesis using K-wires and distal radius bone graft. The study protocol was approved by the Ethics Committees of Faculty of Medicine, Benha University. An informed consent was obtained from all study subjects prior to their inclusion in this study.

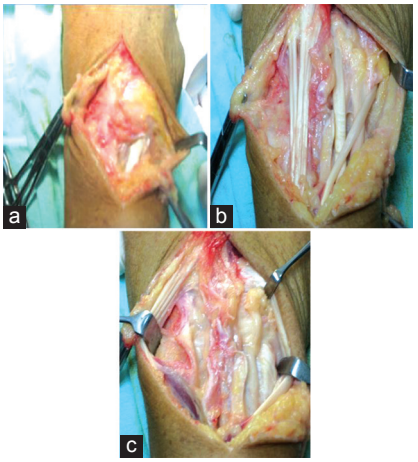
General anesthesia and a tourniquet were used in all patients. A dorsal lazy S longitudinal incision centered over the third metacarpal–capitate-lunate–radius axis was used for exposure of the corpus. The skin flaps were raised, and the superficial branch of the radial nerve was identified and protected. The extensor retinaculum over the second, third, and fourth extensor compartment was divided in line with the tendons.

The extensor tendons were retracted (Fig. 1), and the dorsal wrist capsule was exposed and incised; a rectangular flap based radially was developed to expose both radiocarpal and midcarpal joints (Fig. 2). The radiolunate articulation was inspected for degenerative wear and if normal, the scaphoid was excised either piecemeal or in its entirety sharply. The articular surfaces of the capitolunate, capitohamate, triquetrohamate, and lunotriquetral joints were denuded of articular cartilage throughout the surfaces to be arthrodesed.

Autologous cancellous bone graft obtained from the distal end of the radius was packed into the interstices of the denuded articular surfaces. Thereafter, the capitolunate axis was reduced by two joysticks wires, one inserted in the lunate from posterior to anterior and oblique distally and the other one inserted in the capitate from posterior to anterior and oblique proximally, and two 1.3 mm K-wires placed across the capitate toward the lunate but did not cross the capitatelunate joint, and a 1.3 mm K-wire placed across the hamate to triquetrum but did not cross the hamatotriquetrum joint; bone graft was packed into the interstices of the denuded articular surfaces to fill the gaps. Thereafter, the wires advanced from capitate to lunate and from hamate to triquetrum (Fig. 3).

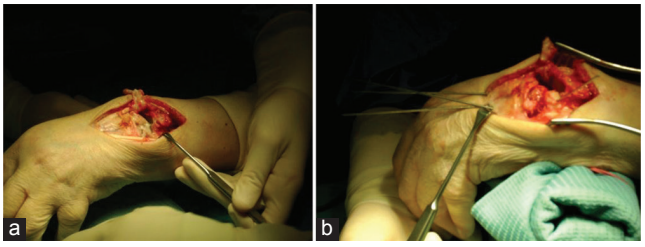
The capsulotomy was repaired with nonabsorbable sutures; the extensor tendons were replaced; and the extensor retinaculum was repaired with the extensor policies longus dorsally transposed. The skin edges were reapproximated. A bulky hand dressing and a thumb spica immobilized the wrist in a neutral position. Approximately 1 week after surgery, the bulky hand dressing and sutures were removed, and a well-fitting thumb spica was applied. Serial interval radiographs were taken to ensure the arthrodesis. When there was radiological evidence of fusion, the cast was discarded, the K-wires were removed after 3 months, and patients were encouraged for hand therapy program.

Figure 1



Surgical approach: (a) midline S-shaped incision, (b) second, third, and fourth extensor compartments opened, (c) wide exposure of dorsal wrist capsule.

Figure 2



(a) Rectangular flap based radially developed, (b) two K-wires inserted through capitate and one through hamate.

Figure 3

Two K-wires connect capitate to lunate and one connect hamate to triquetrum.

Evaluation

Radiological union

Patients were assessed radiologically every 2 weeks postoperatively for evidence of union.

The hand function

Patients were assessed preoperatively and postoperatively (at 6 months and at 12 months). Range of motion of both wrists was measured in extension, flexion, ulnar deviation, and radial deviation. Testing grip strength, the examiner pumps a blood pressure cuff to 200 mmHg (about 26.7 kPa) and asks the patient to squeeze it together as tightly as possible. Patients with normal hand function should attain a value of 200 mmHg (about 26.7 kPa) or more.

Pain was evaluated by the Modified Mayo Wrist Scoring Chart (Table 1).

Complications

Patients were evaluated for any complication through the period of follow-up.

The Mann–Whitney *U*-test was used to verify the differences in healing index (HI). Differences were considered significant when *P* value is less than 0.05.

Results

All patients achieved radiological union after a period ranging from 6 to 9 weeks (average 7 weeks); nonunion did not occur in any case (Figs. 4–6).

With respect to the hand function, the range of motion and the grip strength increased gradually postoperative and reached the maximum after 1 year; the grip strength significantly improved from 28% of opposite side preoperatively to 61% postoperatively. The mean flexion improved from 42 to 70% of the normal side. The mean extension improved from 2 65% of the normal side. The mean ulnar deviation improved from 28 to 43% of the normal side. The mean radial deviation improved from 30 to 45% of the normal side (Table 2).

Pain classification scores showed that 10 patients were pain free, nine patients complained slight pain with vigorous activities, and only one patient complained moderate pain with vigorous activities.

Table 1 Modified Mayo Wrist scoring chart

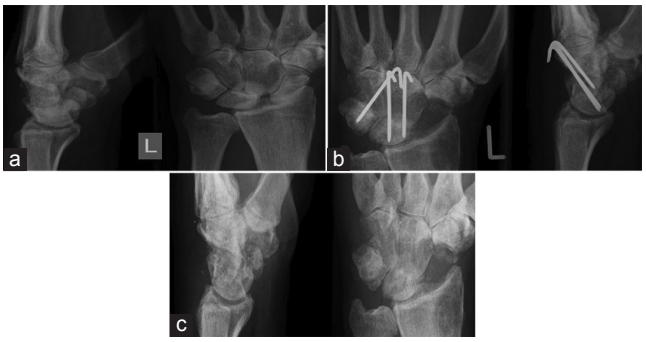
Findings	Score
No pain	25
Mild pain with vigorous activities	20
Pain only with weather changes	20
Moderate pain with vigorous activities	15
Mild pain with activities of daily living	10
Moderate pain with activities of daily living	5
Pain at rest	0

Radial impingement occurred in one patient. It was treated by radial styloidectomy.

Ulnar neuritis occurred in one patient; it was due to improper placement of one K-wire, which was too long causing irritation of the ulnar nerve, early removal of the K-wires after 10 weeks, and wrist splint for 2 weeks.

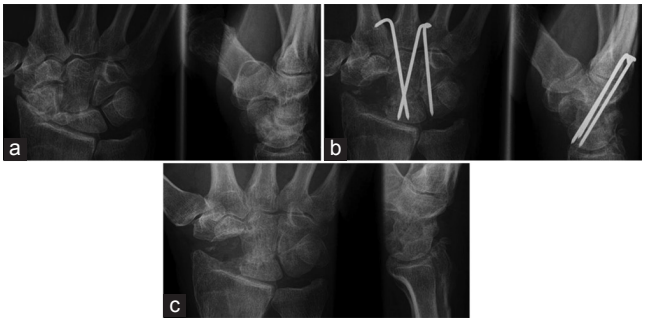
Superficial skin infection occurred in one patient, which was improved with systemic antibiotic for 3 days and oral antibiotic for 1 week.

Figure 4



Advanced SLAC wrist: (a) at time of operation, (b) after 3 months, (c) after 6 months. SLAC, scapholunate advanced collapse.

Figure 5



Advanced SNAC wrist: (a) at time of operation, (b) after 3 months, (c) after 6 months. SNAC, scaphoid nonunion advanced collapse.

Figure 6

Advanced SLAC wrist: (a) at time of operation, (b) after 3 months, (c) after 6 months. SLAC, scapholunate advanced collapse.

Table 2 Patient's data

N	Age	Side	Sex	Diagnosis	Preoperative						Postoperative						Union achieved after weeks	Complications
					Grip strength (mmHg)	Pain score	Wrist flexion	Wrist extension	Ulnar deviation	Radial deviation	Grip strength (6–12 m)	Pain score	Wrist flexion (6–12 m)	Wrist extension (6–12 m)	Ulnar deviation (6–12 m)	Radial deviation (6–12 m)		
1	35	D	M	SNAC	70	5	30	30	20	10	60/110	25	40/65	35/60	15/25	10/20	6	No
2	50	D	M	SNAC	50	0	35	25	15	5	50/100	20	35/50	35/50	10/25	0/20	7	Radial impingement
3	21	D	M	SNAC	40	5	30	20	10	5	65/125	25	40/70	35/60	10/25	5/20	8	No
4	55	D	F	SNAC	30	5	30	20	5	5	25/80	20	30/50	30/55	5/15	5/10	6	No
5	38	D	M	SNAC	40	0	20	50	15	10	70/130	20	35/65	45/70	15/20	10/15	7	Ulnar neuritis
6	60	D	F	SNAC	30	0	40	20	10	10	45/105	15	30/55	30/50	10/15	5/10	9	No
7	27	D	F	SLAC	45	0	45	20	10	10	50/115	20	30/55	30/55	10/20	5/10	6	No
8	31	N	F	SLAC	60	5	35	15	10	5	55/120	25	35/50	20/45	10/15	5/10	7	No
9	36	N	M	SNAC	55	5	30	52	5	5	60/130	25	25/45	25/55	5/20	10/15	8	No
10	31	D	M	SNAC	65	10	40	35	20	15	70/135	20	30/40	35/50	10/25	15/20	8	No
11	26	D	F	SLAC	55	5	30	30	15	10	65/115	25	35/45	30/60	10/25	10/10	7	No
12	45	D	M	SNAC	70	5	35	25	15	15	80/140	20	40/55	35/60	15/25	5/10	6	No
13	48	N	F	SNAC	60	10	25	20	5	5	75/135	20	35/50	20/45	10/10	5/10	6	No
14	29	D	F	SLAC	80	10	45	40	20	15	75/135	25	50/60	30/50	15/25	10/15	9	No
15	39		M	SLAC	75	5	30	35	15	15	80/145	25	40/55	25/55	15/20	5/10	7	No
16	46	D	M	SNAC	65	5	35	20	10	10	70/130	25	40/55	35/60	10/15	5/15	7	No
17	33	N	M	SNAC	60	0	40	35	15	15	65/120	25	45/65	40/55	10/20	10/20	8	No
18	31	N	M	SNAC	40	0	25	20	10	5	50/120	20	35/55	30/40	5/15	5/10	6	Superficial infection
19	28	D	F	SNAC	50	5	30	15	15	5	70/130	25	40/60	25/35	10/15	10/10	6	No
20	46	D	M	SLAC	60	5	35	20	15	5	65/120	20	45/70	35/50	15/15	5/10	6	No
Average	38	6 N14 D	8 F12 M	14 SNAC6 SLAC	5528%	4	3342%	2629%	1328%	930%	62/12231/61%	22	37/5646/70%	31/5835/65%	11/2024/43%	7/1423/45%	7	15 — No3 — complications

Normal hand grip power (200 mmHg), wrist flexion/extension (80/90°), ulnar/radial deviation (45/30°); D, dominant; F, female; M, male; N, nondominant; SLAC, scapholunate advanced collapse; SNAC, scaphoid nonunion advanced collapse.

Discussion

Four-corner arthrodesis is a valuable option for treating stages 2 and 3 scapholunate advanced collapse and scaphoid nonunion advanced collapse wrist; however, controversy exists regarding the method of fixation and surgical technique [7].

In this study, a simple method of fixation was used (3K-wires), cancellous bone graft from distal end radius; there was 0% nonunion and radiological union achieved after 7 weeks. These results are encouraging when considered against other reports in the literature in which K-wires, staples, plates, and multiple Herbert screws were used. Watson *et al.* [8] showed 3% nonunion in 252 patients treated with K-wires. However, Krakauer *et al.* [9] described two painful nonunions in 23 patients (with K-wires, multiple Herbert screws, and staples). In a group of 19 patients all treated with K-wires [1], one patient had a nonunion. Three of 17 patients fixed with K-wires and staples had nonunion [5], 63% nonunion in 18 patients treated with circular plates [10], 26% nonunion in 27 patients treated with circular plates [7], and 25% nonunion in patients treated with circular plate [11]. These results were first due to the choice of bone graft. It is critical to the long-term success of arthrodesis that the source of the bone graft is of high quality. Cancellous bone graft from Lister's tubercle in the distal radius is one of the best sources. Cancellous bone graft has been shown to be superior to cortical bone graft in many orthopedic applications, including intracarpal arthrodesis [12]. A common pitfall is substituting the excised and morcellized scaphoid for the distal radius in the graft. Bone graft taken from the excised scaphoid is both of reduced quantity (little cancellous bone can be obtained from within the scaphoid cortical shell) and more sclerotic in consistency than bone taken from the distal radius [13], which has never been exposed to the compressive forces experienced by the scaphoid under pathologic conditions. In the Kendall and colleagues' study with a 63% nonunion rate, 16 of 18 patients received cancellous bone graft from the excised scaphoid. In the Vance and colleagues' study with a 26% nonunion rate, 20 of 27 patients received cancellous bone graft from the morcellized scaphoid. Use of excised scaphoid bone graft should be avoided. Second, an adequate quantity of bone graft is important. We exhaust the bone graft accessible from the distal radius in all directions by a curette. Graft tissue is packed not only into the areas between carpals, but also placed over the top of the carpals. Third, denude all the cartilage down to bleeding cancellous bone from at least the dorsal two-third of the articulation between all four bones before using the autogenous bone graft. Fourth, after reaming, debris must again be removed from the carpal spaces, using a tiny curette, so that cartilage remnants do not get stuck there. With respect to the hand function, the hand grip strength reached 61% of other side, wrist flexion became 70% of the normal side, wrist extension reached 65% of normal side, and most of the patients were pain free or had mild pain with vigorous activities except one patient with moderate pain in vigorous activities; these results are considered very good in comparison with other studies. These results were due early range of motion exercises, which were helped by early union [14]. Complications occurred in three patients only and they were mild complications that minimally affect the results of those three patients; hence, the overall results were not affected so much. Radial impaction occurred in one of our earlier patients; currently, we examine with finger probing the space between the radial styloid and the trapezium after the K-wires have been placed and the wrist is moved. If this space appears tight in radial deviation, we perform a radial styloidectomy, to avoid postoperative radial impingement. The limitations of this study were nonrandomized selection of the patients, the number of cases was relatively small, and the short period of follow-up. A longer follow-up period will better help to define the functional expectations, especially with respect to development of secondary arthrosis.

Conclusion

Despite development of many options for fixation, the four-corner arthrodesis (plates, screws, and staples) fixation with K-wires is still safe and reliable method to achieve union. Cancellous bone graft obtained from distal end of the radius is better than graft obtained from scaphoid or iliac crest.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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