Scaphoid excision and four-corner fusion in the treatment of scaphoid nonunion advanced collapse

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Background
Four-corner arthrodesis with scaphoidectomy is a time-tested, motion-sparing wrist procedure and biomechanically sound intercarpal fusion that results in near-normal load transmission through the radiolunate articulation that has evolved over the past 20 years.
Aim
The aim of the present study was to evaluate the results of scaphoid excision and four-corner fusion with fixation by K wires in the treatment of stage II and III scaphoid nonunion advanced collapse.
Patients and methods
A prospective study was conducted from March 2013 to November 2014 at the Al-Azhar University Hospital in Damietta. The study included 20 patients with established scaphoid nonunion advanced collapse grade II and III. All patients were males, and all cases involved the dominant hand (right hand). Their average age was 35 (25–48) years. Their occupations in terms of wrist loading were as follows: 10 patients were heavy manual workers and 10 patients were light manual workers. The mechanism of injury was 'fall on an outstretched hand' in 16 cases and 'hit by heavy object' in four cases.
Results
A total of 20 cases were included in this study – 14 of them had good results, four patients had fair results, and two patients had poor results. On reviewing all patients, the following points were checked with each patient: pain and tenderness, range of motion, grip strength, and patient satisfaction. In all patients, we found that there was soft tissue (synovium) interposition, instability, and deformity. Ten patients had 40–100% satisfaction, four patients had 0–100% satisfaction, four patients had 0–80% satisfaction, and the last two patients had 0–40% satisfaction. All patients showed radiological solid fusion by the end of the follow-up period. The mean time to achieve fusion was 10 (9–12) weeks. There were no intraoperative complications. Postoperatively, two patients presented with superficial wound infection that resolved completely with local measures and IV antibiotics (third generation cephalosporin). Two patients showed dorsal impingement of the capitate and the radius. Four patients developed reflex sympathetic dystrophy that also resolved within 6 months after cast removal with physiotherapy and active hand exercise. None of the patients showed deep infection, nonunion, or de Quervain tenosynovitis.
Conclusion
Patient satisfaction was high, and the procedure offered good-to-excellent pain relief. Advances in surgical exposures, fixation techniques, and implants have allowed for rigid fixation that enables rapid union and commencement of early range of motion. Failure rates and complication rates are relatively low, and the long-term outcomes are promising.

Keywords:
advanced collapse, four-corner fusion, nonunion, scaphoid

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Introduction

Scaphoid fractures are among the most common traumatic injuries to the upper extremity and altogether account for 50–80% of carpal injuries with an annual estimated incidence of 38 fractures per 100 000 men [1].

They are most prevalent among active, young adults, who fall on an outstretched hand with the wrist forced into extension (dorsiflexion). Prompt diagnosis and timely treatment decrease the occurrence of nonunion of these fractures, and failure to diagnose these fractures

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can lead to inadequate healing, avascular necrosis, and ultimately the development of osteoarthritis and limited range of wrist motion [2].

The incidence of scaphoid nonunion may range from 5% to as high as 12%. Once nonunion of the scaphoid is established, the natural course is carpal collapse [3].

Longstanding scaphoid nonunion, scaphoid malunion, and chronic scapholunate dissociation result in malalignment of the carpal bones, instability, and osteoarthritis of the wrist leading to progressive carpal collapse followed by radiocarpal osteoarthritis known as scaphoid nonunion advanced collapse (SNAC) or scapholunate advanced collapse. They are common patterns of wrist arthritis. It is caused by trauma and also from pseudogout and can appear bilateral without a clear history of injury [4].

Lichtman classified scaphoid nonunions into five types, of which grade IV is characterized by SNAC with arthritis in the radioscaphoid and midcarpal joint. Three distinct time-related degenerative changes occur in SNAC/scapholunate advance collapse (SLAC) wrists: (a) stage I consists of joint-space narrowing between the tip of the styloid process of the radius and the distal outer aspect of the scaphoid; (b) stage II consists of degenerative changes along the entire articular surface between the radius and the scaphoid; (c) stage III includes narrowing of the capitolunate joint space; (d) stage IV includes SNAC with arthritis in the radioscaphoid and midcarpal joint; and (e) stage V includes stage V+arthritic change in the radiolunate joint [5].

The consistent sparing of the radiolunate joint in wrists with SNAC/SLAC has served as the anatomical basis for several of the most widely used treatment methods over the past three decades [6].

Four-corner fusion is a classic surgical procedure, described by Krista E. Weiss, involving excision of the scaphoid with fusion of the capitates, hamate, triquartum, and lunate with the distal radius bone graft to decrease pain, improve strength, and preserve motion [7].

Indications include chronic carpal instability, perilunate instability, grade II and III of the Lichtman classification, and nondissociative carpal instability after failed soft tissue repair [8].

Complications such as arthritic changes in the rediolunate joint and ulnar translocation of the carpal bones are also observed [9].

Four-corner fusion can be performed with K wires, staples, or circular plate or screw fixation [10].

K wires: these wires are placed from the capitate to the lunate, from the hamate to the lunate, and from the triquertum to the capitate [11].

Placement of staples increases the accuracy and biomechanical properties [12].

Headless compression screw fixation is a method that results in immediate stable fixation that allows for early range of motion (ROM) [13], and a circular plate is specially designed for limited wrist arthrodesis called the spider limited wrist fusion plate [14].

Complications includes dorsal impingement of the capitate and the radius, sympathetic dystrophy, infection, and de Qurervain tenosynovitis [15].

Aim

The aim of this study was to evaluate the results of scaphoid excision and four-corner fusion with fixation by K wires in the treatment of stage II and III SNAC.

Patients and methods

This prospective study was carried out from March 2013 to November 2014 at the Al-Azhar University Hospital in Damietta. This study approved by the Ethical committee of Al-Azhar University, Damietta, Egypt. We included 20 patients with established SNAC to collapse grade II and III. All patients were males, and the right hand was involved in all cases, which was the dominant hand in all patients.

Their average age was 35 (25–48) years. Their occupations in terms of wrist loading were as follows: 10 patients were heavy manual workers and 10 patients were light manual workers. The mechanism of injury was 'fall on an outstretched hand' in 16 cases and 'hit by a heavy object' in four cases. Four cases were misdiagnosed from the start, two patients were previously operated with bone grafting and K wire fixation, and two patients received no treatment earlier. The follow-up period was from 6 months to 1 year.

The mean time between trauma and surgery was 5 (3–10) years, except in two patients (since 1986), and

the site of fracture was in the middle-third in all patients as shown in Table 1.

Assessment

All 20 patients underwent preoperative clinical and radiological assessment. Clinical assessment recorded the mechanism of injury, previous treatment, symptoms, and work disability. Clinical examination included assessment of swelling, tenderness, active and passive range of movement in both wrists, and grip strength.

All patients with established nonunion complained of recurrent swelling in the wrist, mainly in the anatomical snuff box. Pain and tenderness in the volar–radial aspect of the wrist and inability to continue their job after 5 min were the most common complaints. The methods used for the clinical assessment of function were ROM and grip strength tests.

To test ROM, the injured wrist was placed facing the normal one, and patients were asked to dorsiflexion and palm flexion both wrists. Next, the hand was placed on the table, and the patients were asked to ulnar deviate and radial deviate the hand. By this method, the degree of motion was calculated. In addition, grip strength was measured by asking the patient to squeeze as hard as he could an inflated, rolled sphygmomanometer cuff at 20 mm of mercury.

Radiological assessment included standard four-view radiographs of both wrists preoperatively. The same technique was used at the follow-up examination (anteroposterior view of both wrists including the third metacarpal and anteroposterior view in full ulnar and radial deviation to determine the amount of displacement between the two fragments of the fractured scaphoid).

Operative technique

A total of 16 patients were operated under regional anesthesia (supraclavicular injection), and four patients were operated under intravenous injection through a dorsal approach and a tourniquet was applied.

Bone grafts were taken from the distal radius when a bone graft was likely required.

A dorsal approach, midline, longitudinal incision centered over the third metacarpal–capitalunate–radius axis was used for exposure of the carpus. The skin flaps were raised.

The extensor retinaculum over the extensor pollicis longus was divided in line with the tendon. The extensor tendons were retracted, and the dorsal wrist capsule was exposed and incised longitudinal on the ulnar aspect of the fourth compartment to expose the carpal bones. The radiolunate articulation was inspected for degeneration wear, and if normal the scaphoid was excised either piecemeal with a rongeur or in its entirety sharply.

Table 1 Full history of patients

Case number	Mechanism of trauma	Previous treatment	Age	Side	Sex	Occupation	Dominant
1	FOOSH	Cast for 8 weeks	45	Right	Male	Heavy manual	Right
2	FOOSH	Cast for 5 weeks	48	Right	Male	Light manual	Right
3	Hit by heavy object	Cast for 7 weeks	25	Right	Male	Heavy manual	Right
4	FOOSH	K wire fixation	30	Right	Male	Heavy manual	Right
5	FOOSH	Cast for 6 weeks	27	Right	Male	Light manual	Right
6	FOOSH	No treatment	33	Right	Male	Heavy manual	Right
7	FOOSH	No treatment	35	Right	Male	Heavy manual	Right
8	Hit by heavy object	Cast for 8 weeks	40	Right	Male	Light manual	Right
9	FOOSH	Cast for 6 weeks	29	Right	Male	Light manual	Right
10	FOOSH	No treatment	31	Right	Male	Light manual	Right
11	FOOSH	Cast for 9 weeks	46	Right	Male	Heavy manual	Right
12	FOOSH	Cast for 4 weeks	47	Right	Male	Light manual	Right
13	Hit by heavy object	Cast for 8 weeks	26	Right	Male	Heavy manual	Right
14	FOOSH	K wire fixation	29	Right	Male	Heavy manual	Right
15	FOOSH	Cast for 5 weeks	28	Right	Male	Light manual	Right
16	FOOSH	No treatment	32	Right	Male	Heavy manual	Right
17	FOOSH	No treatment	33	Right	Male	Heavy manual	Right
18	Hit by heavy object	Cast for 8 weeks	41	Right	Male	Light manual	Right
19	FOOSH	Cast for 6 weeks	31	Right	Male	Light manual	Right
20	FOOSH	No treatment	30	Right	Male	Light manual	Right

FOOSH, fall on an outstretched hand.

The articular surface of the capitolunate, capitohamate, triquetrohamate, and lunotriquetral joints were denuded of articular cartilage, using a high-speed burr throughout the surface to be arthrodesed. Autologous bone graft obtained from the distal radius was packed into the interstices of the denuded articular surface. Next, the capitolunate axis was reduced, and 1.2-mm K wires were placed across the capitates to the lunate to maintain the alignment.

K wires were placed from the hamate to the triquetrum and the hamate to the lunate; an additional bone graft was placed to fill the gap. Capsulotomy was repaired with nonabsorbable sutures, the extensor tendons were replaced, and the extensor retinaculum was repaired with the extensor pollicis longus dorsally transposed.

The tourniquet was deflated, hemostasis was obtained, and the skin edges were reapproximated. A bulky hand dressing and a thumb Spica immobilized the wrist in a neutral position without drain.

All patients were encouraged to commence digital ROM, tendon-gliding exercises, and edema control measures starting on the first postoperative day. Approximately 1 week after surgery (in first visit), the bulky hand dressing was changed, the suture was removed after 2 weeks, and a well-fitting thumb spica was applied.

At 10–14 days, a short arm cast that allowed finger and thumb motion was applied for 4–6 weeks. Serial interval radiographs were taken to ensure arthrodesis. When there was radiological evidence of fusion at 6–8 weeks (in second visit), the cast was discarded and therapy was commenced, with 1–2 weeks of dart thrower's motion followed by 4 weeks of additional flexion-extension and radial–ulnar deviation exercises. Strengthening exercises avoiding heavy activities were then initiated for 4–6 weeks, and no contact sports were permitted for 4–5 months postoperatively. Patients were encouraged for a hand therapy program emphasizing ROM, strengthening, and endurance. At the last follow-up, all patients were functionally assessed according to the modified Mayo Wrist Scoring Chart. The steps of the operation are shown in Fig. 1.

Results

A total of 20 cases were included in this study – 14 of them had good results, four patients had fair results, and two patients had poor results. On reviewing all patients, the following points were checked with each patient: pain and tenderness, ROM, grip strength, and patient satisfaction.

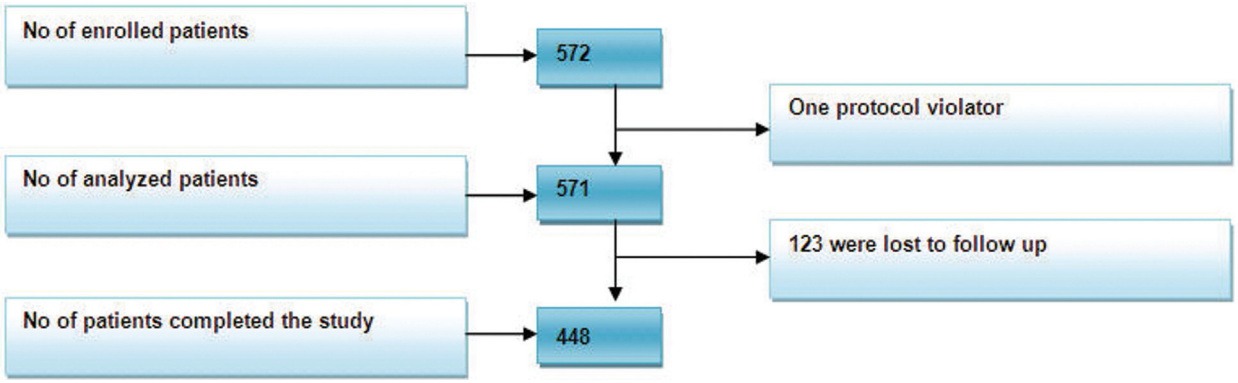
In all patients, we found that there were soft-tissue (synovium) interposition, instability, and deformity.

At the last follow-up, all patients were functionally assessed according to the modified Mayo Wrist Scoring Chart [16].

Pain and tenderness

All patients with good results (14 patients) had no residual pain or tenderness during daily activities – two of them had improved from 60 to 100% and the other 12 patients had improved from 40 to 100%. The other four patients who had fair results, moderate

Figure 1



Steps of the operation: (a) dorsal incision; (b) release of the extensor retinaculum; dissection of the extensor pollicis longus; (d) dissection at fourth compartment; (e) removal of the scaphoid; (f) after scaphoid removal; (g) disarticulation of the lunate; (h) bone graft from the distal radius; (i) cancellous bone graft; (j) placement of the bone graft between the carpal bones; (k) K wire insertion from the capitates to the lunate: (l) K wire insertion from the hamate to the triqurter: (m) anteroposterior view under a fluoroscopy camera; (n) anteroposterior view for the third K wire; (o) closure of the extensor retinaculum; and (p) closure of the radioscapocapitate ligament.

pain on usual activity, and tender snuff box area showed improvement from 20 to 80%. The remaining two patients who had poor results had occasional pain at day and improved from 0 to 80%.

Hand grip strength

In all the patients with good results (14 patients), postoperative hand grip was stronger compared with preoperatively and improved from 40 to 60%, two of them had no improvement (60–60%), and the remaining four patients had improvement from 20 to 60, as compared with the normal hand.

Patient satisfaction

Ten patients had 40–100% satisfaction, four patients had 0–100% satisfaction, four patients had 0–80% satisfaction, and the remaining two patients had 0–40% satisfaction.

Range of motion of the wrist

Fourteen patients with good results had ROM that improved from 50 to 75%, whereas the other six patients had improvement in ROM from 40 to 75%, as compared with the normal hand. Functionally, 14 (70%) patients had good results, four had fair results, and two had a poor results. The scores of pain, ROM of the wrist, grip strength, and patient satisfaction as well as the total score of each patient preoperatively are shown in Table 2.

The scores for pain, ROM of the wrist, grip strength, patient satisfaction, the total score, and the final result of each patient at the end of the follow-up period are shown in Table 3.

All patients showed radiological solid fusion by the end of the follow-up period. The mean time to achieve fusion was 10 (9–12) weeks. There were no intraoperative complications.

Postoperatively, two patients presented with superficial wound infection that resolved completely with local measures and intravenous antibiotics (third generation cephalosporin). Two patients showed dorsal impingement of the capitate and the radius. Four patients developed reflex sympathetic dystrophy that also resolved within 6 months after cast removal with physiotherapy and active hand exercise. None of

Table 2 Preoperative functional scores and total scores each patient

Case number	Pain		Wrist ROM		Grip strength		Patient satisfaction		Total score	Final result
	Severity	Score	Normal (%)	Score	Normal (%)	Score	Degree of satisfaction	Score		
1	No pain	25	75	15	75	15	Very satisfied	25	80	Good
2	No pain	25	78	15	76	15	Very satisfied	25	80	Good
3	Moderate pain with vigorous activity	15	76	15	75	15	Moderately satisfied	20	65	Fair
4	No pain	25	77	15	80	15	Very satisfied	25	80	Good
5	No pain	25	75	15	75	15	Very satisfied	25	80	Good
6	Mild pain with vigorous activity	20	75	15	75	15	Moderately satisfied	20	70	Good
7	No pain	25	79	15	78	15	Very satisfied	25	80	Fair
8	No pain	25	75	15	75	15	Very satisfied	25	80	Good
9	Mild pain with vigorous activity	20	77	15	76	15	Not satisfied but working	10	60	Poor
10	No pain	25	75	15	75	15	Very satisfied	25	80	Good
11	No pain	25	78	15	76	15	Very satisfied	25	80	Good
12	Moderate pain with vigorous activity	15	76	15	75	15	Moderately satisfied	20	65	Fair
13	No pain	25	77	15	80	15	Very satisfied	25	80	Good
14	No pain	25	75	15	75	15	Very satisfied	25	80	Good
15	No pain	25	75	15	75	15	Very satisfied	25	80	Good
16	Mild pain with vigorous activity	20	77	15	76	15	Not satisfied but working	10	60	Poor
17	No pain	25	75	15	75	15	Very satisfied	25	80	Good
18	Mild pain with vigorous activity	20	75	15	75	15	Moderately satisfied	20	70	Good
19	No pain	25	79	15	78	15	Very satisfied	25	80	Fair
20	No pain	25	75	15	75	15	Very satisfied	25	80	Good

ROM, range of motion.

Table 3 Functional scores at the last follow-up

Case number	Pain		Wrist ROM		Grip strength		Pain satisfaction		Total score	Final score
	Severity	Score	Normal (%)	Score	Normal (%)	Score	Degree of Satisfaction	Score		
1	No pain	25	75	15	75	15	Very satisfied	25	80	Good
2	No pain	25	78	15	76	15	Very satisfied	25	80	Good
3	Moderate pain with vigorous activity	15	76	15	75	15	Moderate satisfied	20	65	Fair
4	No pain	25	77	15	80	15	Very satisfied	25	80	Good
5	No pain	25	75	15	75	15	Very satisfied	25	80	Good
6	Mild pain with vigorous activity	20	75	15	75	15	Moderate satisfied	20	70	Fair
7	No pain	25	79	15	78	15	Very satisfied	25	80	Good
8	No pain	25	75	15	75	15	Very satisfied	25	80	Good
9	Mild pain with vigorous activity	20	77	15	76	15	Not satisfied but working	10	60	Poor
10	No pain	25	75	15	75	15	Very satisfied	25	80	Good
11	No pain	25	78	15	76	15	Very satisfied	25	80	Good
12	Moderate pain with vigorous activity	15	76	15	75	15	Moderate satisfied	20	65	Fair
13	No pain	25	77	15	80	15	Very satisfied	25	80	Good
14	No pain	25	75	15	75	15	Very satisfied	25	80	Good
15	No pain	25	75	15	75	15	Very satisfied	25	80	Good
16	Mild pain with vigorous activity	20	77	15	76	15	Not satisfied but working	10	60	Poor
17	No pain	25	75	15	75	15	Very satisfied	25	80	Good
18	Mild pain with vigorous activity	20	75	15	75	15	Moderate satisfied	20	70	Fair
19	No pain	25	79	15	78	15	Very satisfied	25	80	Good
20	No pain	25	75	15	75	15	Very satisfied	25	80	Good

ROM, range of motion.

the patients showed deep infection, nonunion, or de Quervain tenosynovitis.

Discussion

Despite the best efforts in diagnosis and treatment, failure of persistent scaphoid nonunion to heal may occur. With grade II and III scaphoid nonunion with SNAC wrists, a salvage procedure is likely necessary. Among different salvage procedures, excision of the scaphoid and four-corner arthrodesis, although technically demanding, result in greater patient satisfaction and good-to-excellent relief of pain, especially in younger patients and working men. The present study was conducted to assess the functional outcome of 20 patients with stage II or III SNAC/SLAC wrists treated with excision of the scaphoid and four-corner arthrodesis [5]. The choice of the four-corner arthrodesis technique for management of stage III SNAC wrists is consistent with other studies. For stage II lesions, there is controversy in the literature on the appropriate salvage procedure. Some authors prefer proximal row carpectomy over the four-corner arthrodesis, arguing that the latter is technically a more demanding procedure that requires longer postoperative immobilization for bony union, and the differences in the resultant functional outcome are not statistically significant [17].

On the other hand, other studies recommend the four-corner arthrodesis for stage II SNAC lesions, especially in younger patients and working men, arguing that it is a biomechanically sound intercarpal fusion that results in near-normal load transmission through the radiolunate articulation with greater levels of patient satisfaction and grip strength. All patients in the present study were young, working men for whom the four-corner arthrodesis technique seems a reasonable choice [18].

Excision of the scaphoid was performed in all patients in the present study. A cadaveric study was performed, and it proved that scaphoid excision with four-corner arthrodesis allows significantly greater ROM at the wrist compared with scaphoid retention [19]. Different methods of fixation can be used to secure the arthrodesis including K wires, staples, screws, and specially designed plates. The chosen method determines the postoperative care rehabilitation program. In addition, the average time needed to

achieve fusion differs with different methods of fixation. It was estimated that for K wires ~8–10 weeks are needed to achieve arthrodesis [20].

In the present study, K wires were used to secure arthrodesis in all patients. The mean time to achieve fusion was 10 weeks, which is similar to other studies. Using the modified Mayo Wrist Scoring Chart for functional assessment of patients both preoperatively and at the last follow-up, good results were obtained in 70% of patients, fair results in 20%, and poor results in 10% of patients. This scoring chart depends on two subjective categories – pain and patient satisfaction – and two objective categories – ROM of the wrist and grip strength [21].

From the results of the present study, it is obvious that both the percentage of wrist ROM and the grip strength score are nearly constant, despite differences in the percentages of improvement between each patient. This has a very little impact on the final score and result. On the other hand, pain and patient satisfaction affect the final score and results, as noticed in the six patients with fair and poor results who had mild-to-moderate pain with activity that consequently affected the degree of patient satisfaction. No excellent results were obtained in the present study because the scoring system needs 90–100 points to provide excellent results, which could be achieved only if the recovery of ROM of the wrist or the grip strength or both reached 100% of normal. This is not expected with a salvage procedure at the wrist [3]. Other studies have reported the recovery of wrist ROM to range from 41 to 78% of normal and the recovery of grip strength to range from 61 to 76% after scaphoid excision and four-corner arthrodesis. The improvement in wrist ROM and grip strength in the present study ranged from 75 to 79% and from 75 to 80%, respectively. These results are higher than those reported in the previously mentioned studies. This can be explained by the small number of patients in the present study [22].

Four patients had redial palsy due to tourniquet and recovered after 3 months with physiotherapy. Solid fusion was achieved in all patients. These results are better than many published studies. This can be explained by the small number of patients with strict adherence to the surgical technique, good preparation of the graft bed, and a relatively long period of postoperative immobilization adopted in the present study. Dorsal impingement of the capitate and the radius occurred in two patients and resulted in reduction in the degree of dorsiflexion. However, it did not affect the final total score or the end result. Four patients suffered reflex sympathetic dystrophy, which resolved completely with physiotherapy and active hand exercise, and did not affect the final total score or end result. Two patients suffered from superficial wound infections that resolved completely with local measures and antibiotics; moreover, this did not affect the final total score or end result [23].

The overall complication rate in the present study (20%) is significantly higher than scores published in other studies (13.5%). This is explained again by the small number of patients in the present study. Despite the apparently high rate of complications, they were nonsignificant, resolved completely without further intervention, and did not affect the final score or the end result [24].

Pressure-sensitive studies have revealed that areas of increased load coincide with areas that develop joint-space narrowing and arthritis in the clinical setting, and result in the SLAC wrist. Pressure film studies have also revealed a strong correlation between increased load at the distal scaphoid fragment and the radial styloid, coinciding with the area where degenerative changes are seen in a longstanding SNAC. These studies also showed a decrease, or no change, in load under the proximal pole of the scaphoid and the lunate in wrists with scaphoid nonunion, again correlating with clinical findings where the proximal scaphoid fossa and the lunate fossa of the radius are maintained and do not tend to develop degenerative changes, even in a longstanding nonunion of the scaphoid [25].

With this biomechanical study of intact wrists versus four-corner fusion with scaphoid excision, it is demonstrated that there is a statistically significant decrease in the load across the scaphoid fossa. Clearly, in the clinical setting, excision of the scaphoid would be expected to provide relief of pain resulting from bone-to-bone contact in the arthritic scaphoid fossa, and dramatically decrease the load transmitted across the fossa. This finding supports those by Kobza and colleagues, who revealed that after four-corner fusion with scaphoid excision, there is a significant decrease in contact pressure in the scaphoid fossa, and a concomitant increase in mean radiolunate contact pressure compared with the intact specimen. We also found a mean increase in total force within the lunate fossa, although not reaching statistical significance, and a nonsignificant increase in the TFCC area. Clinical studies by Goldfarb CA, and colleagues [26] concluded that pain relief was

equivalent for proximal row carpectomy and four-corner fusion, both methods being motion-preserving options for the treatment of SLAC arthritis. Multiple clinical studies have reported successful pain relief with comparable results in terms of both motion and strength.Four-corner arthrodesis provides a satisfactory option for palmar midcarpal instability. No clinical study so far had made note of a significant increase in ulnar-sided wrist pain, as one may expect, because redistribution of load from that normally would be transferred across the radioscaphoid joint [27]. The findings of this study also suggest that load across the radioscaphoid joint is preferentially redistributed to the radiolunate joint as compared with the ulnocarpal articulation. This finding may help explain why the clinical results after scaphoid excision and four-corner fusion and proximal row carpectomy are so comparable, as reported by Krakauer *et al*. [28].

In short, the results of the present study revealed that patient satisfaction was high and the procedure offers good-to-excellent pain relief. Advances in surgical exposures, fixation techniques, and implants have allowed for rigid fixation that enables rapid union and commencement of early ROM. Failure rates and complication rates are relatively low, and the long-term outcomes are promising.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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