



## Functional outcome of four-corner arthrodesis for treatment of grade IV scaphoid non-union

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Functional limitations and pain are end results of scaphoid nonunion with progressive carpal collapse and radiocarpal arthritis. The aim of this study was to assess the functional outcome of four-corner arthrodesis with scaphoidectomy for the treatment of grade IV scaphoid nonunion with Scaphoid Nonunion Advanced Collapse (SNAC) stages II and III.

Ten patients with symptomatic grade IV non union of the scaphoid and a mean duration of non unions of  $12.1 \pm 2.81$  months were treated using the four-corner arthrodesis technique. A dorsal midline longitudinal approach centered over the third metacarpal-capitate-lunate-radius axis, excision of the scaphoid, neutral alignment of the remaining carpal bones, and arthrodesis of the capitate, hamate, lunate, and triquetrum, were performed. Kirschner wires were used to secure the arthrodesis in all cases. A below-elbow thumb spica cast was applied for 3 months. Follow up period ranged from 8 to 24 months, with a mean of  $16 \pm 4.7$  months. All patients were assessed both functionally for pain, range of motion and grip strength, and radiographically for evidence of fusion and carpal alignment.

Good results were achieved in 7 patients (70%) according to the modified Mayo Wrist Scoring Chart. There were no intraoperative complications. Postoperatively, one patient suffered superficial wound infection One patient showed dorsal impingement of the capitate and radius. Also, two patients suffered reflex sympathetic dystrophy. No patients showed deep infection or nonunion.

The Four-corner arthrodesis technique is a motion-sparing, limited arthrodesis that reliably results in

**pain relief, improved grip strength, and overall patient satisfaction with low associated non union and complication rates.**

**Keywords :** SNAC (Scaphoid Nonunion Advanced Collapse) ; SLAC (Scapholunate Advanced Collapse).

### INTRODUCTION

Scaphoid fractures accounts for 60% to 70% of all carpal bone fractures. Despite proper treatment, the incidence of scaphoid nonunion may range from 5% to as high as 12% (7,11). Once nonunion of the scaphoid is established, the natural history is one of progressive carpal collapse followed by radiocarpal osteoarthritis known as scaphoid

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nonunion advanced collapse (SNAC) or scapholunate advanced collapse (SLAC) (8). Lichtman classified scaphoid nonunions into five types, of which grade IV is characterized by SNAC with arthritis in the radioscaphoid and midcarpal joint (5). Three distinct time-related degenerative changes occur in SNAC/SLAC wrists; these consist of joint-space narrowing between the tip of the styloid process of the radius and the distal outer aspect of the scaphoid in stage I, degenerative changes along the entire articular surface between the radius and the scaphoid in stage II, and narrowing of the capitulate joint space in stage III. 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 (1,10). Of different salvage procedures, excision of the scaphoid, neutral alignment of the carpal bones and fusion of the capitate, hamate, lunate and triquetrum; known as the four-corner arthrodesis technique, is said to be the procedure of choice for Stage III SNAC/SLAC lesions. Although it is a more demanding technique, it is still preferred by some authors over other salvage procedures for stage II lesions (1,6,9,10). The present study was conducted to assess the functional outcome of four-corner arthrodesis technique with scaphoidectomy for the treatment of grade IV scaphoid nonunion with SNAC/SLAC stages II and III.

#### PATIENTS AND METHODS

This prospective study included 10 patients with grade IV traumatic scaphoid nonunion with stage II or III SNAC/SLAC wrists. All patients were men. The mean age of the patients was  $31 \pm 7.48$  (21-46) years. The mean duration of nonunion was  $12.1 \pm 2.8$  (8-17) months. All patients were assessed before surgery both functionally for pain, grip strength, and wrist range of motion, and radiologically for signs of grade IV scaphoid nonunion with stage II SNAC (degenerative changes along the entire radioscaphoid articulation), and stage III SNAC (narrowing of the capitulate joint space). General anaesthesia and a tourniquet were used in all patients.

A dorsal midline longitudinal incision centered over the third metacarpal-capitate-lunate-radius axis was used

for exposure of the carpus. The skin flaps were raised, and the superficial branch of the radial nerve was identified and protected. 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 longitudinally on the ulnar aspect of the 4<sup>th</sup> compartment to expose the carpal bones. The radiolunate articulation was inspected for degenerative wear and if normal, the scaphoid was excised either piecemeal with a rongeur or in its entirety sharply. The articular surfaces of the capitulate, capitate-hamate, triquetrohamate and lunotriquetral joints were denuded of articular cartilage, using a high-speed burr throughout the surfaces to be arthrodesed.

Autologous bone graft obtained from the anterior iliac crest was packed into the interstices of the denuded articular surfaces. Then, the capitulate axis was reduced, and a 1.2 mm K wire placed across the capitate and triquetrum maintained the alignment. K wires were placed from the capitate to the lunate, hamate to lunate, triquetrum to capitate, and triquetrum to lunate. Additional bone graft was placed to fill the gaps.

The capsulotomy was repaired with nonabsorbable sutures, the extensor tendons were replaced, and the extensor retinaculum was repaired with the extensor pollicis longus dorsally transposed. Tourniquet was deflated, haemostasis was obtained, and the skin edges were reapproximated. A bulky hand dressing and a thumb spica immobilized the wrist in a neutral position.

All patients were encouraged to commence digital range of motion, tendon-gliding exercises, and oedema-control measures starting on the first postoperative day. Approximately one 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, and patients were encouraged for hand therapy program emphasizing range of motion, strengthening and endurance.

At the last follow-up all patients were functionally assessed according to the modified Mayo Wrist Scoring Chart (table I). Data was statistically analyzed using a computer program (SPSS for windows, release 10).

#### RESULTS

Functionally, seven patients had good results (70%), two had fair results, and only one had a poor result. The scores for pain, range of motion (ROM)

Table I. — Modified Mayo Wrist Scoring Chart (Smith and Cooney 1996)

Category	Score	Findings
<i>Pain (25 points)</i>	25	No pain
	20	Mild pain with vigorous activities
	20	Pain only with weather changes
	15	Moderate pain with vigorous activities
	10	Mild pain with activities of daily living
	5	Moderate pain with activities of daily living
<i>Satisfaction (25 points)</i>	0	Pain at rest
	25	Very satisfied
	20	Moderately satisfied
	10	Not satisfied, but working
<i>Range of motion (25 points)</i>	0	Not satisfied, unable to work
		Percentage of normal
	25	100%
	15	75%-99%
	10	50%-74%
	5	25%-49%
<i>Grip strength (25 points)</i>	0	0%-24%
		Percentage of normal
	25	100%
	15	75%-99%
	10	50%-74%
	5	25%-49%
<i>Final result</i>	0	0%-24%
		points
	Excellent	90-100
	Good	80-89
	Fair	65-79
Poor	< 65	

of the wrist, grip strength, patient satisfaction, and the total score of each patient preoperatively are shown in table II. 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 follow-up period are shown in table III. All patients showed radiological solid fusion by the end of follow-up period. The mean time to achieve fusion was  $10 \pm 0.94$  (9-12) weeks.

There were no intraoperative complications. Postoperatively, one patient presented superficial wound infection that resolved completely with local measures and IV 3<sup>rd</sup> generation cephalosporin antibiotics. One patient showed dorsal impingement of the capitate and radius. Two patients developed reflex sympathetic dystrophy that also resolved within 6 months after cast removal with

physiotherapy and active hand exercises. No patients showed deep infections, nonunion, or de Quervain's tenosynovitis.

### Case presentation

#### Case N° (1)

A 22-year-old manual worker presented with grade IV scaphoid nonunion of 11 months duration with stage II SNAC wrist of the dominant hand as shown in figure 1 (A & B). Preoperative functional assessment revealed a total score of 25 points. Scaphidectomy and four-corner arthrodesis were performed as shown in figure 1 (C & D). At final follow-up, solid fusion was achieved, but with extensive dorsal fusion mass with resultant dorsal

Table II. — Preoperative functional scores and total scores of each patient

Case N°	Pain	Score	Wrist ROM		Grip Strength		Patient Satisfaction		Total Score
			Severity	Score	% of Normal	Score	% of Normal	Score	
1	Moderate pain with daily living activities	5	55	10	50	10	Not Satisfied- Unable to work	0	25
2	Moderate pain with vigorous activities	15	75	15	75	15	Not Satisfied but working	10	55
3	Moderate pain with daily living activities	5	45	5	50	10	Not Satisfied- Unable to work	0	20
4	Mild pain with daily living activities	10	60	10	50	10	Not Satisfied but working	10	40
5	Mild pain with daily living activities	10	50	10	45	5	Not Satisfied- Unable to work	0	25
6	Moderate pain with daily living activities	5	45	5	50	10	Not Satisfied- Unable to work	0	20
7	Mild pain with daily living activities	10	55	10	55	10	Not Satisfied but working	10	40
8	Mild pain with daily living activities	10	60	10	65	10	Not Satisfied but working	10	40
9	Pain at rest	0	40	5	40	5	Not Satisfied- Unable to work	0	10
10	Mild pain with daily living activities	10	60	10	60	10	Not Satisfied but working	10	40

impingement of the capitate and radius (fig 1 : E & F). A functional score of 80 points was reached, corresponding to a good result.

#### Case N° (7)

A 25-year-old manual worker presented with grade IV scaphoid nonunion of 16 months duration with stage III SNAC wrist of the dominant hand as shown in figure 2 (A & B). Preoperative functional assessment revealed a total score of 40 points. Scaphoidectomy and four-corner arthrodesis were performed as shown in figure 2 (C & D). At final follow-up, solid fusion was achieved (fig 2 : E & F) and a functional score of 80 points was reached, reflecting a good result.

## DISCUSSION

Despite the best efforts in diagnosis and treatment, failure of persistent scaphoid nonunion to

heal may occur. With grade IV and V scaphoid nonunion with SNAC/SLAC wrists, a salvage procedure is likely to be necessary. Among different salvage procedures, excision of the scaphoid and four-corner arthrodesis, although technically demanding, results in greater patient satisfaction and good to excellent relief of pain, especially in younger patients and working men (4,10). The present study was conducted to assess the functional outcome of 10 patients with grade IV scaphoid nonunion and stage II or III SNAC/SLAC wrists treated with excision of the scaphoid and four-corner arthrodesis.

The choice of the four-corner arthrodesis technique for management of stage III SNAC/SLAC wrists is consistent with other studies (1,3,4,10,14). 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 (7,10,14) arguing that the lat-



**Fig. 1.** — A & B : Preoperative AP and lateral views. C & D : Postoperative AP and lateral views. E & F : AP & lateral views showing solid fusion with dorsal bony fusion mass resulting in dorsal impingement of the capitate and radius.

ter 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. On the other hand, other studies recommend the four-corner arthrodesis for stage II SNAC/SLAC lesion especially in younger patients and working men (1,4,6,10) 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 are young working men for whom the four-corner arthrodesis technique seems a reasonable choice.

Excision of the scaphoid was performed for all patients in the present study. A cadaveric study performed by Kobza *et al*, 2003 (2) proved that scaphoid excision with four-corner arthrodesis allows significant greater ROM at the wrist compared with scaphoid retention or inclusion.

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. Also the average time needed to achieve fusion differs with different methods of fixation. It was estimated that for K wires, approximately 8 to 10 weeks are needed to achieve



**Fig. 2.** — A & B : Preoperative AP and lateral views. C & D : Postoperative AP and lateral views. E & F : AP & lateral views showing solid fusion.

arthrodesis (10). In the present study, K wires were used to secure arthrodesis in all patients. The mean time to achieve fusion was  $10 \pm 0.94$  weeks which is similar to other studies (1,7,10).

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). From the results of the present study shown in table III, it is obvious that both the percentages of wrist ROM

and grip strength scores 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 result as noticed that the three patients with fair and poor results had mild to moderate pain with activity, and consequently affect the degree of patient satisfaction. No excellent results were obtained in the present study because the scoring system needs 90-100 points to give excellent results which could be achieved only if the recovery of ROM of the wrist or the grip strength or both reaches 100% of normal. This is not expected with

Table III. — Functional scores, total scores, and final results at the last follow-up

Case N°	Pain	Score	Wrist ROM		Grip Strength		Patient Satisfaction		Total Score	Final Result
			% of Normal	Score	% of 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-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-Vigorous activity	20	75	15	75	15	Moderately 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-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

a salvage procedure at the wrist. Other studies report 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 (4,6,10). The improvement of the wrist ROM and grip strength in the present study ranged from 75%-79% and 75%-80% respectively. These results are higher than those reported in the aforementioned studies. This can be explained by the small number of patients in the present study.

No significant complications occurred in the present study. Solid fusion was achieved in all patients. These results are better than many published studies (1,4,6,10,11,13). This can be explained by the small number of patients with strict adherence to surgical technique, good preparation of graft bed, and relatively long period of postoperative immobilization adopted in the present study. Dorsal impingement of the capitate and radius occurred in one patient and resulted in reduction of the degree of dorsiflexion. However, it did not affect the final total score or the end result. Two patients suffered reflex sympathetic dystrophy, which resolved completely with physiotherapy

and active hand exercises, and did not affect the final total score or end result. One patient suffered superficial wound infection that resolved completely with local measures and antibiotics ; also, this did not affect the final total score or end result. The overall complication rate in the present study (40%) is significantly higher than published in other studies (13.5%) (10). This is explained again by the small number of patients in the present study. Despite the apparently high rate of complications, they were non significant, resolved completely without further intervention, and did not affect the final score or the end result.

## CONCLUSION

Four-corner arthrodesis with scaphoidectomy is a motion-sparing and biomechanically sound intercarpal fusion that results in near-normal load transmission through the radiolunate articulation. Patient satisfaction is high, and the procedure offers good to excellent pain relief. The range of motion after 4-corner arthrodesis ranged from 75% to 79% of the normal contralateral wrist, and up to 80% of normal grip strength can be expected.

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