Four corner fusion for the management of scaphoid nonunion advanced collapse – A new technique

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Background
There are several techniques to achieve four corner fusion to provide pain relief in cases of scaphoid nonunion advanced collapse (SNAC) wrist while preserving a function, but can be complicated with malunion, nonunion, hardware impingement or incomplete correction of the lunate extension. We evaluate a new time preserving and simple technique to achieve four corner fusion for the management of nonunion scaphoid with painful arthritis of the wrist.

Patients and methods
A prospective study was conducted on 16 patients with SNAC of the wrist. Their mean age was 31 years, and the average duration of symptoms was 21 months (range 5–60 months). Through a dorsal approach using a tubular osteotome, the junction between the capitate, lunate, hamate and triquetrium was excised down to the volar capsule and replaced with a core of cancellous iliac bone graft extracted using the same tool.

Results
The preoperative mean range of wrist flexion was 53° (30°–80°), the mean range of wrist extension was 56° (30°–80°), the mean visual analogue score was 3.2 and the Mayo score was poor in five, fair in three and good in six patients. The postoperative mean range of wrist flexion was 44° (10°–60°), the mean range of wrist extension was 49° (20°–70°), the visual analogue score was 0.7 and the Mayo score was excellent in eight patients, good in seven and poor in one patient. Only one patient proceeded to nonunion.

Conclusion
This new simple technique can be performed to achieve four corner fusion in the management of SNAC.

Keywords:
fusion, nonunion, scaphoid

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Introduction

As scaphoid fracture accounts for up to 60% of carpal fractures and has a nonunion rate as high as 12%, it will remain a hot study topic for hand surgeons and researchers. Historically, scaphoid nonunion leading to carpal collapse and osteoarthritis, known as scaphoid nonunion advanced collapse (SNAC), were treated with total wrist arthrodesis to provide pain relief, but at the expense of wrist motion. In 1924, Thoronton [1] reported the first limited wrist arthrodesis after fusing the scaphoid, lunate, capitate, and hamate. In 1948, Steele fused the scaphoid, lunate, capitate and trapezium. He used this procedure as a treatment modality for scaphoid fractures. In 1952, Heflet [2] reported fusing both fragments of a scaphoid nonunion to the capitates. Scaphoid excision was first introduced in the literature by Watson and Ryu [3]. The biomechanical principle on which scaphoid excision was introduced is that after the scaphoid has been excised, the wrist load falls solely on the preserved radial lunate and ulnocarpal articulation [3]. The addition of the hamate and triquetrium to the carpal fusion was reported to improve the rate of union. A silastic prosthesis was first used to replace the excised scaphoid, but its use has been discontinued [4]. Since the 1980s, scaphoid excision and four corner fusion has become a popular option for the treatment of SNAC wrist [5,6]. Pioneered by Watson and Ballet more than 25 years ago, four corner fusions (capitate–lunate–hamate–triquetrum) has been a widely acceptable treatment for SNAC wrist, preserving motion. It involves scaphoid excision, removal of articular surfaces of the bones, packing with bone graft and fixation with Kirschner-wires (K-wires) [3]. Later publications report the use of staples, Herbert screws or plates. Despite its success as a management option for SNAC wrist and its wide use, complications such as hardware impingement, incomplete correction and deep infection have been reported [7].

We hypothesized that using a tubular osteotome to remove a central osteochondral portion of the four bones will remove the articular cartilage and subchondral dense bone, thus allowing fusion. Moreover, leaving the peripheral rim of the capitolunate and the triquetrohamate articulations will maintain the relationship between the carpal bones, thus preventing

collapse and maintaining carpal height with a disc-shaped iliac bone graft.

Patients and methods

A prospective study was conducted on 16 patients (12 male and four female patients), with 10 dominant hands and six nondominant hands, having scaphoid nonunion and advanced collapse of the wrist. Their mean age was 31 years, and the average duration of symptoms was 21 months (mean 5–60 months). The preoperative mean range of wrist extension was 53° (30°–80°), the mean range of wrist extension was 56° (30°–80°), the mean visual analogue score was 3.2 and the Mayo score was poor in five, fair in three and good in six patients. Approval have been taken verbally from the patients.

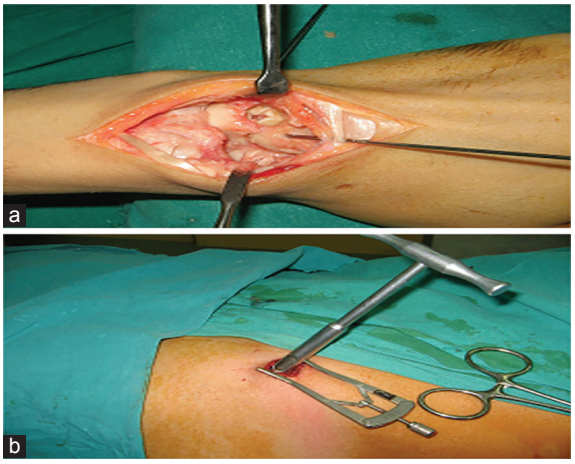
Under general anaesthesia and the patient placed supine and the forearm extended and pronated on an arm board, the limb is exsanguinated and tourniquet inflated. The ipsilateral iliac crest is prepared and draped. A 4–5 cm dorsal skin incision is made starting from the Lister's tubercle and is directed to the base of the third metacarpal parallel to the extensor carpi radialis brevis tendon. Subcutaneous dissection is performed while protecting the terminal branch of the radial nerve. The tendon sheath of the extensor carpi radialis brevis is opened and the tendon is retracted radially. The extensor pollicis longus tendon was extracted from its sheath and retracted radially. The capsular incision was performed longitudinally in the bed of extensor carpi radialis brevis down to the carpal bones including the dorsal intercarpal ligament (that is later repaired) from the third metacarpal proximally to the distal radius. The articular surface of the lunate and the lunate fossa of the distal radius was inspected and probed for exclusion of arthrosis. The capsular incision is extended ulnarly by sharp dissection, freeing the dorsal capsule from the dorsal rim of the radius to the level of the distal radioulnar joint without opening the sheath of the fourth compartment; it is also extended radially to the level of the radial styloid, and further dissection of the capsule from the carpal bone is performed. The scaphoid is excised in a piece-meal manner. The capitate is pushed ulnarly so as to align its radial border with that of the lunate and volarly to correct the DISI deformity (Fig. 1).

A K-wire under image intensifier guidance is inserted from the radial part of the base of the capitate parallel to its radial border, holding the lunate short of its articular cartilage. Using a 12 mm diameter tubular ostetome, the junction between the capitate, lunate, hamate and triquetrium was excised down to the volar capsule. This removes the proximal portion of the capitohamate articulation, the radial portion of the triquetro hamate articulation, the distal portion of the lunotriquetral articulation and most of the lunocapitate articulation except its far radial portion.

A second K-wire is inserted percutaneously from the hamate, directed towards the lunate to cross the excised defect, but held short at its border for further readvancement. A third and fourth K-wires are inserted in a likewise manner from the triquetrum towards the lunate and from the capitate towards the triquetrum (Fig. 2).

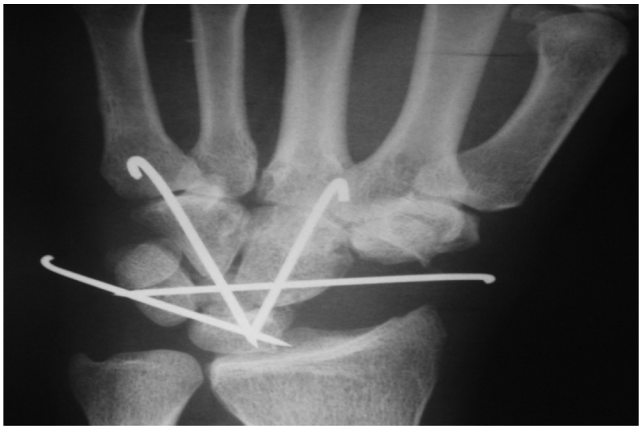
An incision of 2–3 cm is performed over the iliac crest 4 cm posterior to the ipsilateral anterior superior iliac spine and dissection of subcutaneous tissue is performed by sharp dissection of the muscular attachment, thus freeing 2 cm of the (top) of the iliac crest. Using the same tubular osteotome, a core of cancellous bone

Figure 1



(a) Intraoperative images showing the defect after excision. (b) Iliac crest graft harvesting using the tubular osteotome.

Figure 2



Anteroposterior radiograph postoperatively.

graft is extracted between the tables of the iliac crest. If needed, parts of the articular surfaces between the carpal bones involved may be excised using a rongeur to ensure adequacy of surface area for fusion. The excised core graft is inserted in the defect, removing any excess from the graft to ensure an even dorsal surface. The previously inserted K-wires are advanced through the core graft. The position of the K-wire is checked with image intensifier, and the range of motion is also assessed for normality. The vertical limb of the capsular incision is sutured and the transverse limb of the incision is reattached to the periostium of the dorsal rim of the radius, followed by subcutaneous and skin closure. A short arm cast is applied in slight wrist dorsiflexion for 8 weeks, after which the K-wires are removed and a short arm cast is applied for an additional 4 weeks, followed by a range of motion and strengthening rehabilitation.

Results

The postoperative mean range of wrist flexion for all patients was 44.1° (10°–60°), the mean range wrist extension was 48.8° (20°–70°), the mean visual analogue score was 0.7 and the Mayo score was excellent in eight patients, good in seven and poor in one patient. Only one patient proceeded to nonunion and was scheduled for revision. The nonunion rate was 6.25%. Superficial pin tract infection in one patient (6.25%) resolved by oral antibiotics and pin removal. Reflex sympathetic osteodystrophy in one patient (6.26%) resolved by physiotherapy (Fig. 3) (Table 1).

Discussion

Nonunion and complication rate were reported at 4.3% (the lowest rate) by Seigel and Ruby [8] in a literature review of intercarpal fusions between 1924 and 1994. Larsen *et al.* [9] in a similar review between 1946 and 1993 reported a nonunion rate ranging from 9 to 50%. Shin's review of eight case series including 431 cases of four corner fusions highlighted this procedure's common complications at 13.5%. An overall 3% of cases reported reflex sympathetic dystrophy, 3% reported superficial infection, 0.5% reported deep infection and 2% reported failure requiring further intervention in the form of total wrist arthrodesis [7]. Range of motion following four corner fusions in the previous literature was reported by Ashmead *et al.* [4] in 100 patients at 44 months follow-up with 32° extension and 42° flexion, which is 53% of the other wrist, and grip strength was 80% of other wrist. Cohen and Kozin [10] found that the mean range of motion was 49° extension and 31° flexion, which is 58% of other wrist, and grip strength was 79% of other wrist. In a case series of 20 wrists, at an average follow-up of 3 years, Watson and Ryu [3] reported a 60% flexion–extension and radial deviation average of the other wrist.

Another viable option for the management for SNAC wrist is proximal row carpectomy (PRC), which was compared with four corner fusion in several studies. Both PRC and four corner fusions achieve similar results in the flexion–extension arc and pain relief, but PRC is considered superior in sagittal plane range of motion, whereas four corner fusion provides better coronal range of motion. Although PRC is considered a technically easier operation over the conventional four corner fusion, it converts the wrist joint with its normal two centres of rotation into a simple one centre joint. Therefore, the motion occurring at the wrist following PRC has a component of anteroposterior and lateral translation, leading to early degeneration and questionable long-term results. In a study by Tomaino *et al.* [11], a 20% failure rate due to persisitant pain after PRC was reported. In one study by Wyrick *et al.* [12], four out of 12 patients showed radiocapitate space narrowing at 50 months follow-up, whereas Cohen and Kozin [10] reported radiocapitate space narrowing in three of 12 at 2-year follow-up.

Several implants have been used in the procedure of four corner fusion. They have all been evaluated and tested by clinical and radiological outcome postoperatively. However, to our knowledge, no published report to date shows a faster time to union and rates of nonunion comparing K-wires, staples or circular plate fixation. In 1999 the circular plate was introduced amid enthusiasm that it allows early mobilization, but was soon criticized following reports of high rates of associated complications such as nonunion, hardware impingement, screw breakout, screw breakage and plate breakage [13–15].

Figure 3

Anteroposterior radiographs showing union at the fusion site.

Table 1 Demographic data and final results

Case number	Age (years)	Sex	Hand dominance	Duration of symptoms (months)	Preoperative ROM wrist (deg.)				Postoperative ROM wrist (deg.)				VAS	Night pain	Mayo score	Radiographs
					Flexion	Extension	VAS	Night pain	Mayo score	Occupation	Flexion	Extension				
1	25	Male	D	36	30	40	5	+	Poor	Manual	40	40	1	–	Good	Union
2	26	Male	ND	21	35	45	1	+	Poor	Manual	40	50	1	–	Good	Union
3	23	Female	ND	16	50	60	3	+	Fair	Housewife	40	60	0	–	Good	Union
4	30	Male	D	22	40	30	1	+	Fair	Manual	30	30	1	+	Good	Union
5	22	Male	ND	12	60	70	2	–	Good	Manual	45	40	0	–	Excellent	Union
6	30	Female	D	8	70	60	6	–	Good	Housewife	50	60	1	–	Excellent	Union
7	38	Female	D	30	50	60	7	+	Good	Housewife	60	60	2	+	Excellent	Union
8	40	Female	D	12	75	80	3	–	Good	Housewife	60	60	1	–	Excellent	Union
9	36	Male	D	8	80	60	2	+	Good	Manual	50	70	1	–	Excellent	Union
10	27	Male	D	60	60	50	1	–	Fair	Manual	30	40	0	–	Good	Union
11	23	Male	ND	20	50	70	1	–	Poor	Manual	50	50	1	–	Good	Union
12	33	Male	D	12	60	60	2	+	Poor	Manual	60	50	1	+	Good	Union
13	31	Male	ND	16	50	50	3	+	Poor	Manual	50	50	0	–	Excellent	Union
14	32	Male	D	18	40	50	4	+	Fair	Manual	50	50	1	–	Excellent	Union
15	39	Male	ND	5	50	60	5	+	Good	Manual	40	50	0	–	Excellent	Union
16	39	Male	D	40	50	60	5	+	Poor	Manual	10	20	0	+	Poor	Nonunion
Mean	30.88			21.00	53.13	56.56	3.19				44.06	48.75	0.69			

D, dominant; ND, nondominant; ROM, range of motion; VAS, visual analogue score.

Our procedure is a simple technique using a tubular osteotome for the excised area from the carpus and the iliac bone graft, thus ensuring maintenance of carpal height and relations. The use of K-wires provides an easy economic option for treatment of SNAC wrist. We reported nonunion in one of 16 patients at a rate of 6.25%, which is consistent with that reported in previous studies of four corner fusions; yet, our rate of complication was very low. Limitations of our study are that no computed tomographic scans were performed during follow-up to verify union. Further study on larger case series is required to prove this technique valuable.

Conclusion

This new simple technique can be performed to achieve four corner fusions in the management of SNAC.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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