

# Cancellous bone graft and Kirschner wire fixation as a treatment for cavitory-type scaphoid nonunions exhibiting DISI

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Published online: 17 November 2011  
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## Abstract

**Background** Cavitory-type scaphoid non-unions represent one of the most difficult treatment challenges amongst all scaphoid non-unions as they exhibit bone loss, scaphoid shortening, flexion ('humpback') deformity and dorsal intercalated segmental instability (DISI), creating altered carpal mechanics which may proceed to the degenerative changes of scapholunate advanced collapse of the wrist. Our technique and its rationale are presented in the largest-to-date series on cavitory scaphoid non-unions exhibiting DISI.

**Methods** Our technique for treatment of these cavitory non-unions is presented through a series of 27 patients.

**Results** Union was achieved in (26/27) 96% of cases, with no complications. Carpal mechanics was restored, with an average carpal height index of  $1.52 \pm 0.06$ , and an average scapholunate angle was  $46 \pm 9^\circ$ . Average follow-up was 2.2 years.

**Conclusion** In this subset of patients, we believe this technique is less technically demanding than the use of either cortico-cancellous grafts or various compression screws. Our success equals or betters that of other published techniques, with all patients enjoying a full return to work, even in occupations demanding heavy labour. We believe that scaphoid union, coupled with the often difficult restoration of carpal height and intra-carpal angles, has produced very good functional outcomes in the management of these challenging cases.

**Keywords** Scaphoid non-union · Scapholunate angle · Carpal height index · Distal radius cancellous autograft · Kirschner wires

## Introduction

Amongst all wrist injuries, the incidence of scaphoid fractures is second only to that of fracture of the distal radius [5, 19]. Despite proper treatment, it has been estimated that non-union occurs in between 5% and 10% [10, 20, 22, 23, 31], resulting in a total of 17,250 to 34,500 non-unions per year in the USA [28]. Non-unions have been attributed to a number of risk factors including smoking, delay in beginning treatment, inadequate immobilisation, displacement of the fragments, instability due to ligamentous injury and inadequate blood supply of the proximal fragment [9]. Patients with scaphoid non-unions are likely to develop traumatic arthritis with increasing pain, decreased wrist mobility and weakness [17, 32].

Given the relatively high incidence of non-union of scaphoid fractures and their poor prognosis, it is not surprising that a number of treatments have been advocated for un-united fractures of the scaphoid [3, 7, 11–13, 15, 16, 21, 24, 25, 29, 30, 33–36, 38]. Traditionally, the most popular surgical treatments include bone grafting, vascularised bone grafting and internal fixation. While each method achieves a high predictability of bone union (80–90%) [26], many disadvantages emerge among the techniques. Technical difficulties arise with the routine use of cortico-cancellous bone grafts and screw fixation when dealing with cavitory defects in established scaphoid non-unions [1]. Problems present when attempting to obtain the correct shape when using solid bone grafts and then also when keeping the graft reduced during screw insertion [1].

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Compression screw devices can further split the graft material or cause the graft to displace [36]. With cancellous grafts, compression devices can also cause the scaphoid to shorten, which is undesirable for subsequent wrist mechanics.

In the published literature, the most successful and reliable procedure for obtaining bone healing in established scaphoid non-union has been internal fixation with Kirchner wires and cortico-cancellous iliac crest bone graft (97% success rate in 151 patients) [35]. Of these 151 patients, only 25 had established dorsal intercalated segmental instability (DISI) [35]. Our technique and experience in the management of difficult cases of scaphoid fracture cavity-type non-unions exhibiting DISI with non-vascularised cancellous bone graft from the dorsum of the distal radial metaphysis and Kirschner wire fixation in the largest-to-date series is presented.

## Patients and Methods

### Study Population

A retrospective analysis was performed of 27 patients with scaphoid non-union exhibiting DISI presenting from 2004 to 2010 who underwent the following operative procedure.

### Technique and General Set-Up

A general anaesthetic was used with patients positioned supine with a tourniquet and Esmarch bandage applied around the upper arm for exsanguination. A radiolucent hand table was used for intra-operative fluoroscopy. The procedure was performed as outpatient surgery, with all patients treated with the following protocol.

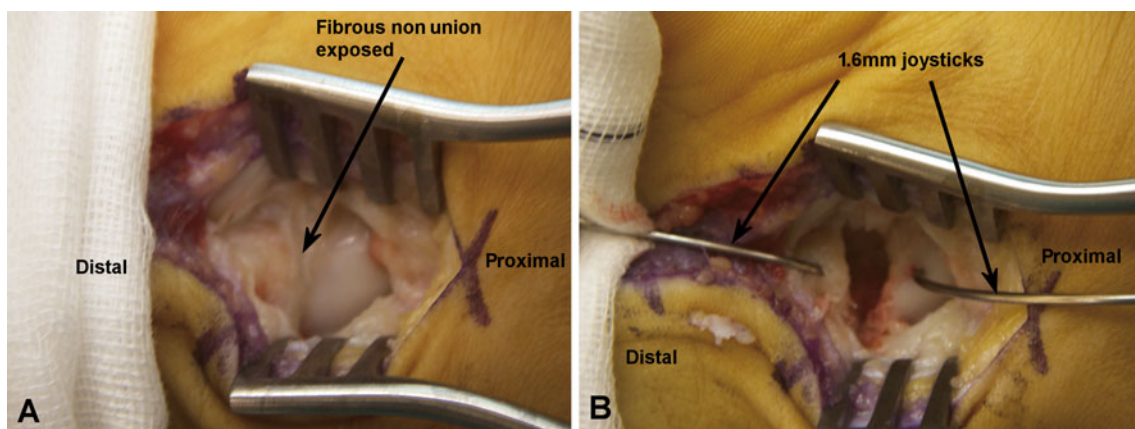
### Approach

A volar approach is used going down through the bed of flexor carpi radialis (FCR) tendon. The FCR tendon is retracted ulnarly using a small self-retaining retractor. The wrist capsule and radioscaphoid capitate (RSC) ligament are carefully incised by making a longitudinal incision parallel with the long axis of the scaphoid, from the volar tip of the radius to the proximal tubercle of the trapezium, thus enabling repair of the RSC ligament at closure of the operation (Fig. 1a).

### Preparation of Non-union Site, Restoration of Alignment and Insertion of Wires

Two temporary 1.6 mm Kirschner wires were inserted, one into the proximal fragment and one into the distal fragment, and used as ‘joysticks’, allowing greater manipulation of the fragments and greater exposure of the interior surfaces of the scaphoid. They were removed during the procedure once the definitive Kirschner wires were in place.

The non-union site was identified with a needle. If in doubt, an X-ray was taken to confirm the correct location. The fibrous non-union was resected with a beaver 69 scalpel blade. Fibrous tissue and any dead bone were removed using small sharp curettes, a beaver 69 scalpel and a Kirschner wire driver. We deliberately avoided using power burr instruments to avoid thermal necrosis of bone. Careful attention was made to preserve as much viable bone as possible. Bony resection was continued until both fragments showed solid healthy looking and feeling bone. There was usually no punctate bleeding, given that the tourniquet was still on, but the viable bone had a relatively obvious appearance (Fig. 1b). If it was sclerotic, more bone was resected. Humpback deformity or flexion deformity was corrected in order to eradicate any DISI of the wrist.



**Fig. 1** Volar approach demonstrating **a** exposure of fibrous non-union and **b** decortication of sclerotic, reactive bone at bone ends, creating two bleeding fragments with Kirschner wires used as joysticks

Lunate tilt was corrected with temporary Kirschner wires and confirmed with lateral X-rays, thus helping to align the proximal pole of the scaphoid from its dorsiflexed position and determine the true scaphoid height by restoring the scaphoid–lunate angle.

Two 1.25-mm diameter Kirschner wires were used to internally fixate the scaphoid. The wires were driven distally to proximally and generally parallel to each other using fluoroscopic guidance. The entry point was either percutaneous at the thenar eminence or through the skin incision. The entry point was determined by whichever looked to give the best position on fluoroscopy. It was acceptable for wires to cross the scapho–trapezo–trapezoidal joint and purchase upon the trapezium if that achieved the best Kirschner wire alignment on the anteroposterior X-ray view (Fig. 2).

Once the two definitive wires were in place and fluoroscopic X-rays had confirmed that the position of bone and hardware was satisfactory, then the wires were cut off 1–2 mm below the skin and left within the muscle of the well padded thenar eminence. This was a relatively comfortable place for wires to be buried as skin complications were minimal and they were easy to retrieve 12 weeks later.

#### Harvesting and Packing of Distal Radius Bone Graft

Morsellised cancellous autograft was harvested via a separate 1 cm dorsal skin incision from the ipsilateral distal radius adjacent to Lister's tubercle. The graft was packed around the Kirschner wires into the created cavity (Fig. 3). Fluoroscopy was again used to ensure placement of wires, reduction of scaphoid and carpal angles and implantation of autograft before closure.

#### Closure of Joint and Wound

The tourniquet was let down and haemostasis was achieved with a bipolar diathermy. The volar capsule and RSC

ligament was closed securely with 4–0 absorbable, braided suture, thus reconstituting the RSC ligament. Skin incisions were closed with an interrupted 4–0 nylon suture. The wounds were then dressed with Vaseline gauze. Additional bupivacaine was injected into the wrist wound for post-operative pain relief. A short-arm, full cylindrical, Gypsona scaphoid cast was applied. The use of waterproof casts or backslabs in the first 2 weeks was avoided in an attempt to maximise patient compliance.

#### Post-operative Management

##### *Zero to 2 Weeks*

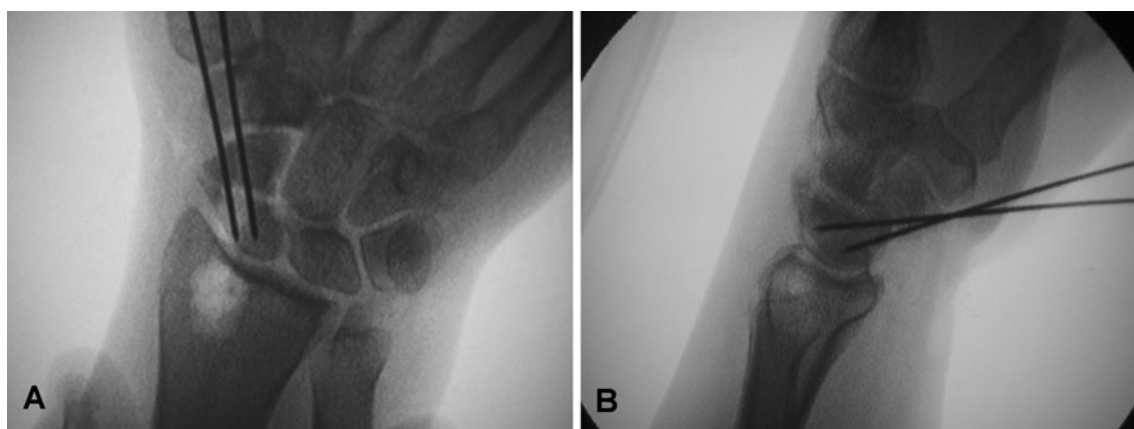
A short-arm full cylindrical Gypsona scaphoid plaster was applied for 2 weeks, thus allowing pronation and supination of the forearm. Active finger movement was encouraged. Patients were instructed that a sling was optional and to avoid any lifting or twisting with the operated hand. The length of the cast at the thumb was determined by the patients expected level of compliance, with longer thumb casts for less compliant patients in an attempt to minimise movement of the non-union site.

##### *Two to 6 Weeks*

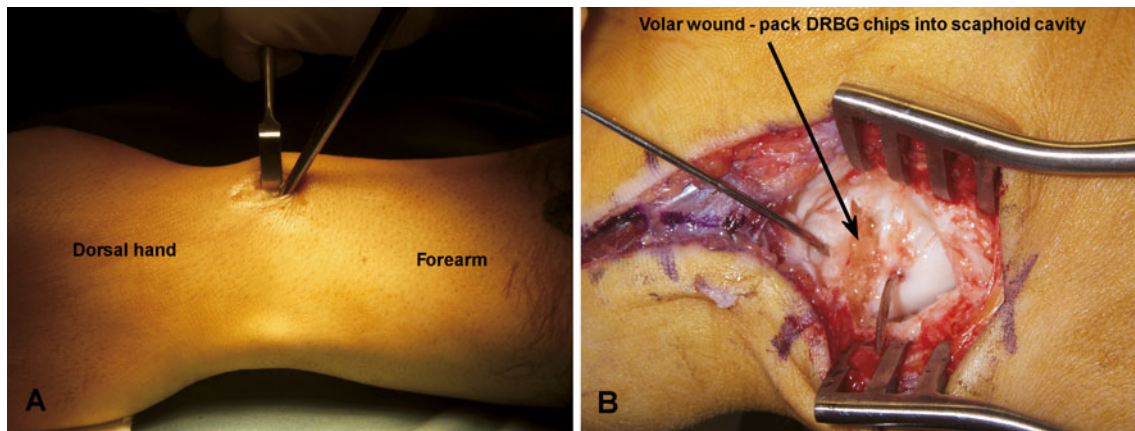
The short-arm cast and sutures were removed. X-rays were deliberately not taken at this time to minimise radiation of the immature bone graft. The Gypsona cast was changed to a waterproof Gore-tex and fibreglass cast in order to allow showering. Casts were carefully applied by certified hand therapists to avoid pressure over wires.

##### *Six Weeks*

The cast was removed, and the first post-operative X-rays were taken. A removable splint consisting of a rigid



**Fig. 2** Radiograph showing insertion of two 1.25 mm Kirschner wires from distal to proximal, highlighting **a** entry at the thenar muscles and avoidance of the trapezium, and **b** it is not necessary that the wires be parallel to each other



**Fig. 3** **a** Harvesting autologous dorsal radius bone graft via 1 cm skin incision adjacent to Lister's tubercle, and **b** cancellous bone graft packed around the Kirschner wires into the created cavity

thermoplastic gauntlet was applied. Patients commenced supervised hand therapy sessions, with special emphasis of gentle short arc active radiocarpal flexion and extension.

#### *Ten to 12 Weeks*

Patients were changed from a thermoplastic splint to a much softer nylon or neoprene style of splint that offered less rigid support. If X-rays looked satisfactory, then Kirschner wires were removed under either local or general anaesthesia in the operating theatre. After removing these wires, real-time dynamic fluoroscopy was used to determine if the scaphoid was moving as one united bone or two un-united fragments, in addition to assessing carpal mechanics. If the fracture was united, the patient continued gentle active motion but wore the splint for most of the day and night. After removal of Kirschner wires, patients continued to wear soft (reinforced nylon or neoprene) splints on average for a further 3 weeks.

#### *Twelve to 15 Weeks*

Patients were often discharged from all medical follow-up. They were advised to continue with hand therapy until they had maximised range of motion and grip strength to that of the uninjured hand. Sports were not permitted until at least 6 months after the operation date.

#### Follow-Up Assessment

The case notes and pre-operative, post-operative and follow-up radiographs of each patient who presented to our unit from 2004 to 2010 were reviewed. All pre-operative radiographs were classified according to the criteria of Herbert [14]. All final radiographs were assessed for union using defined criteria [6]. We measured the scapholunate angle and Carpal Height Index using the modified Bouman's carpal height

index ratio, as described in Greens' textbook [8]. The average follow-up period of patients ranged from 6 months to 4 years (average, 2.2 years). Functional assessment included range of motion (ROM) and grip strength compared with the uninjured hand was performed on 26 patients as part of regular follow-up. One patient was unable to attend. Subjective responses regarding limitations in activities of daily living or sports and hobbies, and general satisfaction were obtained by an independent researcher.

#### Results

Of the 27 male patients with scaphoid fractures, 12 had occurred in road traffic accidents, six in falls, five during sport and four during assault. Only one patient's injury was worker-compensation-related. The dominant wrist was involved in 63% of the patients. The average age at operation was 25 years (range, 16–43 years). No patients had evidence of avascular necrosis radiologically or at the time of surgery. All fractures of the scaphoid were at the waist, with no proximal or distal pole fractures seen. Nine patients were treated previously with screw fixation; four patients were treated with screw fixation plus bone graft, while seven were previously treated with a plaster cast, and seven had no previous treatment. The average time from original scaphoid fracture to surgery was 20 weeks (range, 6–156 weeks; Table 1).

Twenty-six of the 27 (96%) fractures united, in an average of 9.7 (range, 8–12) weeks postoperatively. The average carpal height index was  $1.52 \pm 0.07$  while the average scapholunate angle was  $46 \pm 10^\circ$ . Union was judged to be present when, on plain radiographic examination, there were definite trabeculae across the site of the fracture and the fracture gap had disappeared (Fig. 4). The sole non-union was a patient who continued to smoke two packs of cigarettes per day despite repeated counselling to abstain.

**Table 1** Results in patients according to previous treatment

Case	Group	Age, years	Mechanism of injury	Time to operation, weeks	Stage (Herbert)	Time to union	Carpal height index	Scapho-lunate angle
	Previous conservative treatment							
1	POP	16	RTA	20	D2 S2	10	1.51	44
2	POP	18	RTA	8	D2 S3	9	1.49	38
6	POP	32	RTA	9	D2 S3	10	1.60	65
7	POP	20	RTA	14	D2 S2	9	1.5	40
8	None	31	Fall	6	D2 S2	11	1.59	60
12	None	23	Assault	20	D2 S4	N	1.28	25
14	POP	25	Fall	8	D2 S3	8	1.55	59
15	POP	37	RTA	14	D2 S3	10	1.62	62
16	None	27	Sport	11	D2 S2	9	1.53	44
18	None	27	RTA	21	D2 S3	9	1.49	41
19	None	43	Assault	17	D2 S3	8	1.60	49
22	None	24	RTA	11	D2 S2	8	1.48	48
23	None	18	Fall	16	D2 S2	9	1.49	52
26	POP	22	RTA	19	D2 S2	12	1.49	46
	Previous surgery							
3	Screw	19	RTA	12	D2 S3	10	1.51	45
4	Screw	24	Sport	13	D2 S3	10	1.48	55
5	Screw	17	Fall/WC	8	D2 S2	8	1.54	50
9	Screw	17	Sport	12	D2 S3	12	1.46	36
10	Screw	17	Sport	24	D2 S3	11	1.52	41
11	SBG	28	RTA	156	D2 S4	11	1.46	36
13	Screw	24	Fall	23	D2 S2	9	1.53	43
17	Screw	33	RTA	10	D2 S2	10	1.55	39
20	SBG	21	RTA	23	D2 S2	10	1.54	54
21	SBG	27	Assault	11	D2 S4	11	1.59	44
24	SBG	33	Sport	20	D2 S2	10	1.50	42
25	Screw	24	Assault	22	D2 S3	10	1.54	47
27	Screw	26	Fall	21	D2 S3	8	1.52	44
Mean		25±7		20±27		10±1	1.52±0.06	46±9

POP plaster of Paris, SBG screw and bone graft, RTA road traffic accident, WC workers compensation

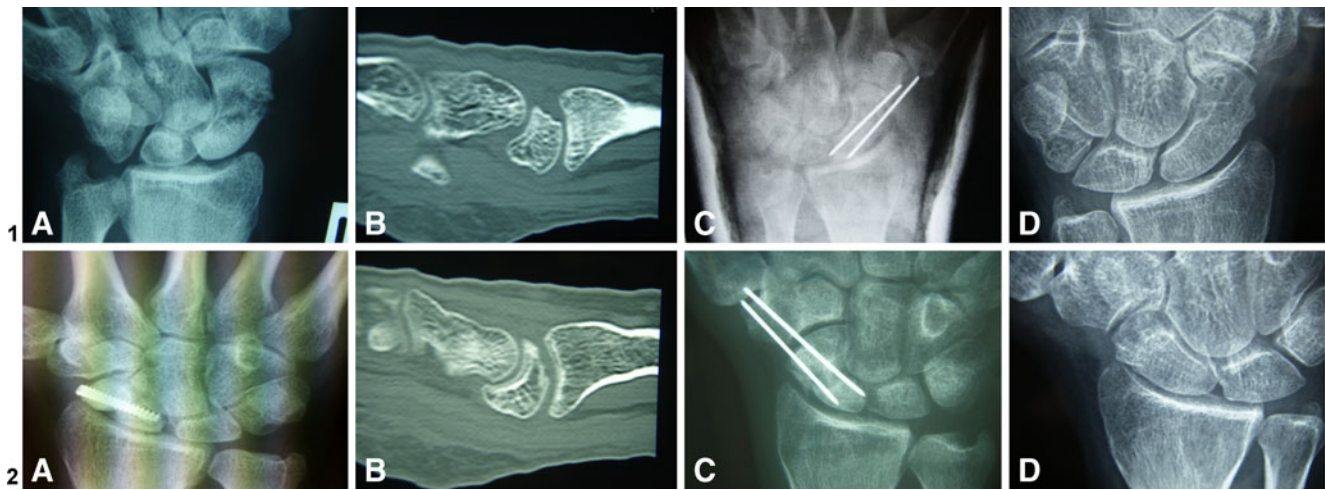
The same patient also admitted to smoking daily marijuana and relatively frequent use of intra-nasal amphetamines and other illegal drugs. He was unable to attend final follow-up due to being incarcerated in prison and was considered to be of very low compliance. Of the 26 patients whose fracture united, all returned to work—including all 17 manual labourers and tradesmen. All 26 patients had excellent ROM, strength and function compared with their uninjured wrist and able to resume their pre-injury level of functioning and usual activities (Table 2). No patients required a further procedure.

There were no infections or post-operative haematomas in either operative site, or problems with healing of the

wound, scar tenderness or sensory changes in the hand secondary to surgical trauma.

## Discussion

To gain proper perspective, it is important for readers to appreciate that, in this article, we do not advocate this method exclusively for all scaphoid fractures or for all scaphoid non-unions. We still prefer to use a compression screw when operating on all acute scaphoid fractures (both displaced and undisplaced) and also for undisplaced non-unions at the waist of the scaphoid. However, this article is



**Fig. 4** **a** Pre-operative radiograph and **b** CT 3 months after initial injury showing large cavitory defect and dorsal intercalated segment instability; **c** post-operative radiograph 6 weeks after surgery and **d**

postoperative radiograph 4.5 months after surgery confirming fracture union with restoration of scaphoid height in both groups of patients: (1) previous conservative treatment (2) previous surgery

focused upon the difficult subset of scaphoid non-unions which have (1) displacement, (2) comminution and (3) cavitory defects with bone shortening, flexion, humpback deformity and DISI. Patients with avascular necrosis were not included in this difficult subset as vascularised bone grafts would be our first treatment in these patients [38].

Technical difficulties have been previously noted by many authors in the insertion of compression screws for scaphoid non-unions, especially when there is a cavitory or humpback deformity of the remaining un-united native scaphoid [1, 16, 36]. It is our experience that the insertion of a compression screw device is not necessary to achieve scaphoid union; furthermore, the routine use of such a device might lead to an increased number of bone grafts becoming either displaced (usually in a volar direction) or compressed, with resultant loss of scaphoid height/length and associated disruption to normal carpal mechanics.

The concept of using compression devices to create more rapid bone healing was first proposed by Charnley [4]. It is well known that compression of cancellous bone creates more rapid bone healing [4]. However, that goal needs to be balanced against the competing goal of allowing the bone to heal without shortening or loss of bone graft material. The scaphoid is notorious for both poor blood supply [10] and poor fracture healing [20]. Kirschner wires occupy less of the uniting surface area than a compression screw. We believe this is a significant advantage in the context of difficult fracture healing, such as is seen in cavitory scaphoid non-unions.

While Stark et al. [35] originally advocated treatment of un-united fractures of the scaphoid by iliac crest bone grafts and Kirschner wire (K-wire) fixation, there are notable differences between this technique and ours. We used bone graft from the distal radius as opposed to the iliac crest. The site of bone graft can produce a major difference in morbidity for patients.

Kurz et al. [18] reported a 15% incidence of graft site pain at 3 months, with complications of infection, haemorrhage, lateral cutaneous nerve of thigh problems and ‘gluteal gait’ with iliac crest bone graft. In contrast, no complications associated with distal radius bone graft was seen in our patient cohort. The technique described by Stark et al. [35] included placement of a volar piece of cortical bone in the rectangular window that had been excised from the volar cortex (of the distal fragment). It is not specified in the article [35] how many patients receiving cortical bone were actually in the subset that had a cavitory type of scaphoid non-union. By comparison, in our series, all patients had cavitory non-unions, none of which received cortical bone graft.

A systematic review by Munk et al. [26] found that treatment of scaphoid non-union using non-vascularised bone graft and internal fixation led to a union rate of 84% after an average period of 7 weeks of immobilisation. Stark et al. [35], in their series of 25 patients with DISI, achieved a union rate of 96% over an average of 17 weeks. Our similar excellent union rate (96%) was achieved in a shorter time period of 10 weeks. Cancellous bone is well known to unite more rapidly than cortical bone [36]. Given that our primary goal is to achieve union for these scaphoid non-unions, we believe that cancellous autograft is a superior choice when compared with cortical or cortico-cancellous bone grafts that do not provide the same percentage of surface area with cancellous bone in contact to the un-united fragments. In our series, the sole non-union fracture could be secondary to heavy cigarette smoking and non-compliance, highlighting that patient selection is crucial to surgical success and cigarette smoking is a relative contraindication to the procedure.

It has been recently shown that restoration of carpal height and carpal angles produces a better functional outcome [27]. Arora et al. reported an increased rate of union in patients

**Table 2** Functional results in both groups of patients

Case	Dominant hand	ROM, affected/unaffected	Grip strength, affected/unaffected	Function	Outcome
Previous conservative treatment					
1	No	185/196	47/49	Full	Asymptomatic, plays rugby union
2	Yes	200/200	69/73	Full	Pain when doing heavy bench press
6	Yes	220/200	60/57	Full	Asymptomatic, works as carpenter
7	Yes	185/205	46/49	Full	Asymptomatic, drives motorcycle
8	Yes	190/205	80/84	Full	Asymptomatic, works as bricklayer
12	No	150/200	23/50	Reduced	Reduced ROM, pain when typing
14	Yes	190/215	56/60	Full	Pain when doing one-hand pushups
15	No	170/180	51/48	Full	Asymptomatic, works as builder
16	Yes	200/200	59/65	Full	Asymptomatic, plays squash
18	No	195/200	43/50	Full	Good ROM, works as builder
19	No	200/235	39/43	Full	Reduced ROM, pain-free, works as electrician
22	No	180/190	53/57	Full	Asymptomatic, works as bricklayer
23	Yes	195/210	43/41	Full	Tender scar, no pain, carpenter
26	Yes	195/190	60/62	Full	Asymptomatic, surfer, works as mechanic
Previous surgery					
3	No	200/200	62/60	Full	Asymptomatic, works as plumber
4	Yes	180/190	42/50	Full	Asymptomatic, plays tennis, carpenter
5	Yes	190/195	52/51	Full	Asymptomatic, works as bricklayer
9	Yes	155/185	45/50	Full	Asymptomatic, plays rugby league
10	Yes	195/185	42/40	Full	Asymptomatic, plays tennis
11	No	195/200	63/59	Full	Asymptomatic, works as builder
13	No	200/215	49/54	Full	Asymptomatic, works as bricklayer
17	Yes	150/130	61/58	Full	Pain when doing heavy bench press
20	Yes	180/185	58/60	Full	Asymptomatic, drives motorcycle
21	No	170/170	54/50	Full	Asymptomatic, works as builder
24	Yes	200/200	58/64	Full	Mild ache, plays cricket, carpenter
25	Yes	170/180	72/77	Full	Asymptomatic, works as mechanic
27	Yes	200/190	53/54	Full	Asymptomatic, works as plumber

with recalcitrant avascular non-union of the scaphoid who achieved normal carpal height following vascularised iliac bone graft coupled with K-wire fixation [2]. Our study agrees with Watson et al. [37] that cancellous chip grafts allow the upper limit of carpal mechanics to be achieved by providing a greater surface area to be in contact with un-united fragments. Our high rate of union and excellent patient function adds further evidence that restoration of carpal mechanics is associated with a better functional outcome.

The limitations of the current study include its retrospective design and absence of a corresponding cohort of patients treated by vascularised graft for comparison. While our patient number remains small, there are very few published series that have looked at the use of distal radius cancellous graft and Kirschner wire fixation for scaphoid non-unions [26], and to our knowledge, there have been

none that have looked at the treatment of difficult cases of DISI exclusively. The routine use of computed tomography scans may have allowed for more accurate imaging of scaphoid unions during management and also at their final follow-up assessments. However, we could not justify the financial costs or even convince patients to attend, largely because our patients were already satisfied with pain relief and had returned to full activities.

## Conclusion

Compression screws remain the mainstay of surgical treatment for the majority of scaphoid fractures. However, for patients who present with the more problematic subset of cavitary-type scaphoid non-unions with bone loss, shortening,

flexion and carpal instability, a different approach is required. Our technique of morsellised dorsal radius cancellous autograft is cheap, technically simple, fast and well tolerated with a low rate of complications. Kirschner wires have a low surface area relative to compression screw implants, thus leaving greater surface area of bone graft in contact at fragment interfaces to allow more reliable bone union while simultaneously allowing upper limits of carpal height to be restored by deliberately choosing to avoid compression. With a success rate of 96%, we intend to continue to use this technique in the foreseeable future for this most difficult subset of cavitory scaphoid non-unions.

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