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ARTICLE

Treatment of unstable scaphoid waist nonunion with cancellous bone grafts and cannulated screw or Kirschner wire fixation

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ABSTRACT

We compared two methods of fixation for unstable scaphoid waist nonunions regarding rate of scaphoid union, union time, deformity correction, clinical outcomes (pain, range of motion, and grip strength), and QuickDASH scores. Eighty-nine patients who undergo cancellous iliac bone grafting and internal fixation either with a Herbert screw ($n = 46$) or multiple Kirschner wires ($n = 43$) were evaluated. The rate of scaphoid union in the K-wire group was 98% ($n = 42$) versus 89% ($n = 41$) in the screw group. The mean union time and duration of surgery for K-wire group versus screw group were 12 versus 15 weeks and 45 versus 66 min respectively. There was no significant difference between the two groups with respect to deformity correction, clinical outcomes, and QuickDASH scores. Despite there was no significant difference in the rate of scaphoid union between the two fixation methods, the K-wires procedure had the advantages of short union time, less demanding, and less expensive than the screw implant.

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Introduction

The natural history of the untreated scaphoid waist fracture is nonunion that often involves apex dorsal angulation with bone loss and collapse resulting in scaphoid nonunion advanced collapse (SNAC) which characterized by humpback or flexion deformity of the scaphoid [1,2]. The humpback deformity characterized by an increased lateral intrascaphoid angle because of the shortening of the volar cortical length of the scaphoid. The deformity can cause dorsal intercalated segmental instability (DISI) because of the extension of the lunate with the proximal scaphoid fragment [3,4]. Surgical treatment is directed at correction of the deformity, restoration of normal carpal alignment, promotion of bone union, and improvement of wrist function [4]. The reference internal fixation and bone grafting is one of the most frequently used surgical procedures for scaphoid nonunion [5]. However, many other techniques are to be considered still valid and effective [6–10]. The purpose of this study was to compare the impact of Herbert screw [11] versus multiple Kirschner wires [12] fixation method on the scaphoid union, union time, deformity correction, clinical outcomes (wrist pain, grip strength, and range of motion [ROM]), and the Disabilities of the Arm, Shoulder, and Hand (QuickDASH) [13] score in adults with unstable scaphoid waist nonunions.

Methods

Our institutional review board (IRB) was approved this retrospective observational study (Level of evidence III) and informed consents was obtained from each patient. Between January 2013 and December 2018, 89 consecutive patients with scaphoid nonunions were treated with open reduction, cancellous iliac bone grafting and internal fixation by Herbert screw or multiple Kirschner wires evaluated. Inclusion criteria were age above 18 years with unstable scaphoid waist fractures that had not healed 6 months after the initial injury. The unstable scaphoid waist nonunions had to have a lateral intrascaphoid angle (LISA) $>35°$, and/or height length ratio (HLR) >0.65 [14]. Exclusion criteria were bilateral scaphoid fractures, history of open fractures of the wrist, transscaphoid perilunate or lunate dislocations, associated fractures in the hand or upper extremities, previous surgical treatment of the affected wrist, stage II or higher scaphoid nonunion advanced collapse (SNAC), and/or scaphoid nonunions with avascular necrosis (AVN). Patients who had less than 24 months follow up also were excluded. Nonunions were diagnosed on the basis of posteroanterior and lateral radiographs of the wrist, CT scan of the wrist along the longitudinal axis of the scaphoid, and the MRI of the wrist to exclude AVN. Patients were managed at the department of orthopaedic surgery in our university hospitals. Forty-six patients who were seen in one hospital received Herbert screw fixation (screw group), and 43 patients who were seen in the other hospital received Kirschner wire fixation (K-wire group). The patients' demographics are listed in Table 1.

Pre- and postoperative the clinical parameters (pain, ROM, and grip strength) and QuickDASH were taken. Pain analysis was performed according to the self-reported VAS score [15]. The score was determined by measuring the distance (mm) on the 10 cm line between the 'no pain' anchor and the patient's mark, providing a range of scores from 0 to 100. A hand Jamar dynamometer (Sammons Preston, Bolingbrook, Chicago, IL) was used to evaluate the single maximal effort of grip strength with correction for limb dominance [16]. The total and differential arcs of motion of the wrist (extension/flexion, ulnar/radial deviation, and pronation/

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Table 1. Patient demographics.

Item	K-wire group ($n = 43$)	Screw group ($n = 46$)	p-value
Age	35 (11)	32 (13)	0.55
Sex male/female	31/12	33/13	0.83
Occupation (no. of patients)			0.94
Manual labour	18	21	
Office workers	10	9	
Students	6	7	
House wife	7	7	
Retired	2	2	
Injured side (no. of patients)			0.79
Right	31	33	
Left	12	13	
Dominance (no. of patients)			0.42
Dominant	32	33	
Nondominant	11	13	
Mechanism of injury (no. of patients)			0.52
Fall	31	34	
Twisting	9	7	
Punch	1	3	
MVA	2	0	
Uncertain	0	2	
Herbert classification			0.76
D2 (fibrous nonunion)	29	33	
D3 (sclerotic nonunion)	14	13	
Initial treatment			0.82
No treatment	13	15	
Splint immobilization	18	20	
Cast immobilization	12	11	
Time from initial injury to surgery (months)	11 (8)	11 (6)	0.69

No.: number; K-wire: Kirschner wire. Data given as mean (SD).

supination) were measured using a two-arm goniometer [17]. The LISA and HLR were measured pre- and postoperative on the sagittal CT scan of the wrist. An orthopaedic surgeon with level 3 experience [18] evaluated and interpreted the preoperative clinical and radiographic parameters of all patients. Another orthopaedic surgeon with level 3 experience [18] who was blinded to the preoperative data evaluated and interpreted the postoperative clinical and radiographic outcomes of all patients. The clinical and radiographic parameters were evaluated and interpreted preoperative and after 24 months postoperative.

Surgical technique

Surgery was performed under general anaesthesia with upper arm tourniquet control. Through a 4 cm longitudinal volar incision was centred over the tuberosity of the scaphoid lateral to the flexor carpi radialis (FCR) tendon. The bed of the FCR was incised in line with the skin incision and the radioscaphocapitate ligament was incised longitudinally to expose the fracture. The scaphoid was inspected, and the fibrous tissue and sclerotic bone were resected up to normal-looking bone. Generous curettage of each scaphoid pole was done to expose the healthy bleeding cancellous bone and prepare an adequate cavity to accept the graft. The scaphoid was reduced, and its length was restored by introducing a lamina spreader in the gap. A cancellous graft was harvested from the ipsilateral iliac crest and packed into the prepared cavity. Satisfactory scaphoid and lunate alignment with the correction of the DISI were confirmed by a C-arm image intensifier. In patients with K-wires fixation, the scaphoid was fixed with three 1.1 mm K-wires under image intensify guidance in a retrograde manner with convergent K-wire placement (Figures 1 and 2), and the K-wires were cut off beneath the skin. In patients with cannulated screw fixation, the Herbert screw (Zimmer, Swindon, Wiltshire, UK) was placed in a retrograde manner (Figure 3). With nonstructural graft, the screw simply drew the fracture fragments closer together without creating compression

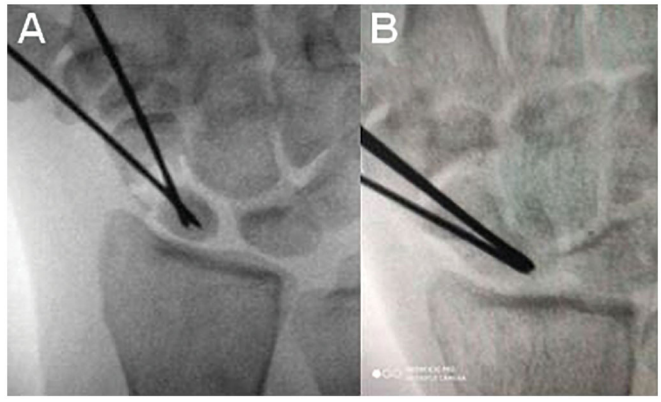

Figure 1. Fluoroscopic PA view shows the K-wires are inserted in a convergent direction. (A) Before grafting and (B) after grafting.

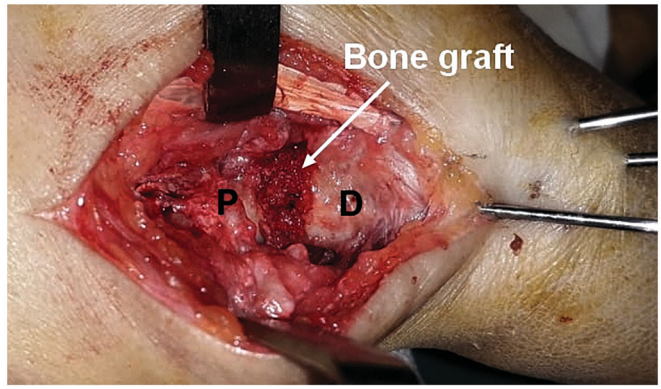

Figure 2. Cancellous bone graft in the prepared cavity after reduction and K-wire placement. P: proximal pole; D: distal pole.

to avoid scaphoid length shortening. The final screw position was checked and confirmed with the use of an image intensifier. Finally, the capsule and radioscaphocapitate ligament were

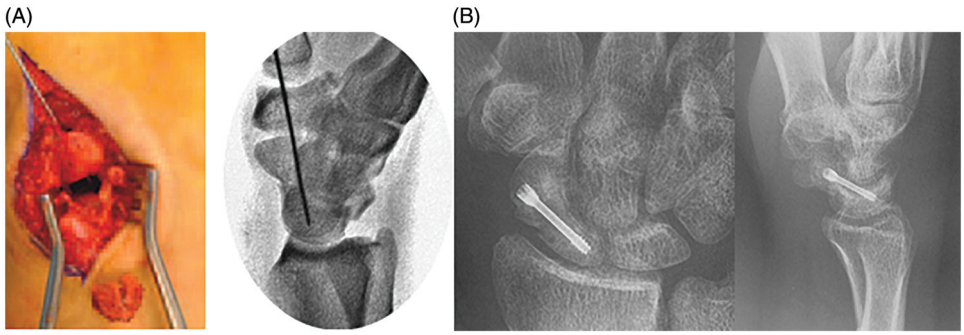

Figure 3. (A) Intraoperative photo and radiographic image of guide wire insertion. (B) PA and lateral radiographs 12 weeks postoperative shows graft incorporation.

Table 2. Preoperative clinical and radiographic data.

Parameter	Screw group ($n = 46$)	K-wire group ($n = 43$)	p-value
VAS score (mm)	60 (10)	60 (15)	0.94
ROM % of healthy side	60% (10)	65% (12)	0.26
Grip strength % of healthy side	60% (10)	60% (10)	0.88
QuickDASH score	70 (4)	69 (6)	0.17
LISA	70° (11)	68° (17)	0.72
HLR	0.77 (0.08)	0.79 (0.09)	0.67

VAS: visual analogue scale score; mm: millimetres; ROM: range of motion; DASH: Disabilities of the Arm, Shoulder, and Hand; LISA: lateral intrascaphoid angle; HLR: height length ration; K-wire: Kirschner wire. Data given as mean (SD).

repaired and the skin sutured. All procedures were performed either by senior author with level 4 experience [18] or under his direct supervision.

Follow-up

A dorsal above elbow plaster splint was applied. Patients were advised to elevate their arms as much as possible throughout the day to reduce swelling. Active finger motion and shoulder exercises were allowed immediately after surgery several times a day. Skin sutures were removed two weeks postoperative, and then a short arm thumb spica cast had to worn until eight weeks postoperative. After the cast removed, gentle hand and wrist exercises, and light activities were permitted with the assistance of a removable wrist splint for an additional 8 weeks then aggressive wrist exercises and heavy activities were allowed after scaphoid union under the supervision of a specialised hand physiotherapist. In the K-wire group, the wires were removed after radiographic union. Gradual return to an office job was allowed within the confines of the cast but manual work was allowed after scaphoid union and within the limits of pain. Full return to work and recreational activities were allowed after union and pain relief. Four radiographic views of the wrist (standard PA, lateral, 45° pronation oblique, and PA with ulnar deviation) were obtained at 2-week intervals until union. Scaphoid union was defined on the radiographs (in at least three of the four views [19]) as the absence of adverse features such as a gap at nonunion site, lucency around or shifting of the implant, or displacement of the graft. Patients underwent CT scans of the wrist along the longitudinal axis of the scaphoid at the follow-up visit when the adverse features disappeared on the radiographs to confirm the union. Union time was recorded when the CT demonstrated >50% trabecular bridging across the nonunion site. Nonunion was defined when adverse features on the radiographs or <50% trabecular bridging on CT scan was identified at 24 weeks after surgery.

Statistical analysis

A power analysis was performed on the rate of scaphoid union which was considered the primary outcome of the study using the G*power 3.1 software [20]. The reported rate of union in the previous literature was 98% for screw fixation and 80% for K-wire fixation [3]. The sample size that was required in each group to provide an 80% power with $p < 0.05$ for the rate of union was 43 patients. Secondary outcomes were operative time, union time, wrist pain, ROM, grip strength, and Quick DASH score. Union time and Quick DASH score had a respective mean ± standard deviation (SD) of 15 ± 5 weeks, and 20 ± 12 points for screw group and 12 ± 4 weeks, and 28 ± 12 points for the K-wire group.[3] The sample size that was required in each group to provide a 90% power with $p < 0.05$ was 40 patients. The outcome measures were compared before surgery and after surgery using the independent t-test for continuous parametric variables and a Mann–Whitney U-test for continuous nonparametric variables. The categorical variables (sex, occupation, injured side, dominance, fracture classification, and complications) were compared using the Chi-square test. The rates of scaphoid union and nonunion were compared using a Fisher's exact test. A p value < 0.05 was considered to be statistically significant.

Results

Both groups were similar in terms of pre-operative demographic, clinical and radiographic parameters (VAS, ROM, grip strength, QuickDASH score, LISA, and HLR) (Tables 1 and 2).

No significant differences were found between the two groups with respect to union rate. Scaphoid union was reported in 42 patients (98%) of the K-wire group versus 41 patients (89%) of the screw group ($p = 0.20$). Nonunion was diagnosed 6 months post-operative in one patient of the K-wire group versus five patients of the screw group ($p = 0.20$). No apparent technical errors were reported in cases of nonunion. The union time was significantly shorter in K-wires group. The mean union time for

Table 3. Follow up data and complications of screw group versus K-wire group.

Parameter	Screw group ($n = 46$)	K-wire group ($n = 43$)	p Value
Time to union (weeks)	15 (4)	12 (3)	0.01
Full return to work (weeks)	24 (5)	23 (5)	0.71
Complications (No. of patients)			0.77
Superficial wound infection	2	4	
Sensitive scar (graft site)	2	1	
Hypertrophic scar (graft site)	3	2	
Complex regional pain syndrome	2	1	

K-wire: Kirschner wire; No: number. Data given as mean (SD).

Table 4. Postoperative clinical and radiographic data.

Parameter	Screw group ($n = 46$)	K-wire group ($n = 43$)	p Value
VAS score (mm)	8 (5)	11 (6)	0.43
ROM % of healthy side	93% (9)	90% (5)	0.12
Grip strength % of healthy side	97 (6)	95 (7)	0.68
QuickDASH score	22 (10)	25 (8)	0.37
LISA	32° (11)	34° (17)	0.81
HLR	0.61 (0.08)	0.64 (0.09)	0.64

VAS: visual analogue scale score; mm: millimetres; ROM: range of motion; DASH: Disabilities of the Arm, Shoulder, and Hand; LISA: lateral intrascaphoid angle; HLR: height length ration; K-wire: Kirschner wire. Data given as mean (SD).

the K-wire group was 12 weeks (SD 3) versus 15 weeks (SD 4) for the screw group ($p = 0.01$). There were no differences with respect to the full return to work, complications (Table 3). After surgery, there were no differences with respect to VAS score, ROM, grip strength, QuickDASH score, LISA, and HLR between the two groups (Table 4).

The mean of the duration of the surgery for the screw group was 66 min (SD 12) and for K-wires group was 45 min (SD 7) ($p = 0.01$). The mean follow-up period for screw group was 27 months (SD 2) and for K-wire group was 28 months (SD 3) ($p = 0.73$).

Discussion

The standard surgical procedure for unstable scaphoid nonunion is internal fixation and bone grafting. The goals of surgical management are deformity correction, scaphoid union, pain relief, improvement of wrist function, and prevention of subsequent joint arthritis. The surgeon must decide upon the method of internal fixation and type and source of graft. Regardless of fixation systems, surgery should provide stability and living bone at the nonunion site [21]. In recent years, there is a general trend toward using screw fixation over K-wire fixation. The present study demonstrated that no significant differences were found between the two methods regarding to scaphoid union, deformity correction, clinical outcomes, and QuickDASH. However, the K-wire group had a shorter time to union than the screw group. Sometimes smooth and non-locked implants (such as K-wires and rush nails), also with additional bone grafts, have demonstrated to be superior to more 'technological' ones (screw and plates). Union does not depend on the kind of fixation but it depends on the stability. Axial forces (e.g. due to the movement of the fingers) generate proper compressive forces at the fracture site, while torsion forces are just about null through the fracture. In addition, the shape of the bone graft plays an important role [21]. The orientation of the K-wires is important. The use of multiple convergent K-wires is the most favourable. This allows the K-wires to pass through more surface area of the scaphoid and allows for a more targeted placement into the proximal pole, thus increasing the fracture reduction stability and accelerating the union. Our study reported nonunion in five patients of the screw group versus one patient of the K-wire group ($p = 0.20$). The explanation is better control for rotation of fragments with multiple K-wires as opposed to a single screw. In contrast to K-wires, a cannulated screw is capable of resisting bending forces but is unable to withstand cyclical multiaxis loading or rotation [22,23]. Therefore, we prefer to continue immobilization until 8 weeks postoperative. However, this can adversely affect the short term ROM. Some studies recommended a 3 weeks immobilization with bone graft alone (modified matti-russe technique) [6,7]. However, other studies recommended a short arm cast for a shorter time (3–4 weeks) when the scaphoid is stabilized using a plate or a staple respectively [7,8]. Park et al. [24] reported 88.5% union rate in 31 patients with unstable scaphoid nonunion who were treated with cancellous iliac bone grafting and K-wire fixation. They stated that the K-wire fixation allowed more space for bone grafting than a screw. Panchal et al. [25] showed that wires were less strong compared to compression screws; however, the trade-off to be that more scaphoid volume is occupied by the screw, which decreases the amount of bone graft that can be placed. Additionally, screw fixation is technically more demanding than K-wires, and the incidence of technical errors may play a role in the occurrence of nonunion. Merrell et al. [26] made a meta-analysis of 36 publications and demonstrated that the time to surgery and fracture location affected the union rates. When the time to surgery was less than 12 months, the union rates were 90%, as compared to 80% when the time to surgery was more than 12 months. In our study, the mean time from the initial injury to surgery was 11 months, with an overall union rate of 93%. Munk and Larsen [27] systematically reviewed 147 publications and found that in the K-wire analysis, there was a higher union rate in patients who had fracture characteristics associated with poorer prognosis, such as avascular necrosis and proximal pole fractures, as compared to the groups fixed with screws. The K-wire group had a higher incidence of union than the screw group (91% versus 88%, respectively), a difference that persisted when used with vascularised grafts (K-wire 94% versus screw 87%).

Cancellous iliac bone graft had a higher concentration of osteoblasts and osteocytes that giving superior osteogenic properties as compared to the corticocancellous graft. Additionally, its large trabecular surface area encourages revascularisation and incorporation at the recipient site [28]. Schnitzler et al. [29] compared bone biopsies from the iliac crest and the distal radius used in the bone grafting procedures of the wrist and concluded

that the distal radius has a lower bone volume, more slender trabecular architecture, thinner cortices, and lower bone turnover than the iliac crest, and the osteoblasts in the distal radius showed a lower range of functional activity. However, other studies compared non-vascularised iliac crest and distal radial bone grafts using the same fixation techniques and concluded that there was no difference between the choices of bone graft [30,31].

No differences found between the two groups regarding time to return to work. We think the time taken to return to work is dependent on multiple factors including the patient's occupation and the attitudes of the patient, employer, and insurance company, which makes the time taken to return to work a questionable outcome measure. The limitations of this study include its retrospective nature and absence of randomization. In conclusion, there was no significant difference between the two fixation methods with respect to scaphoid union and outcomes. However, the K-wires fixation provided a shorter operative and union time than the screw fixation. Additionally, it was technically less demanding and less expensive than the screw implant.

Ethical approval

Our institutional review board approved this study.

Consent

All patients were given an information sheet, the risks, and benefits of operative treatment were discussed and full written consent was obtained.

Disclosure statement

The authors whose names are listed above certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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