Evaluation of treatment of nonunited middle third scaphoid fractures using threaded Kirschner wires fixation with iliac bone grafting

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Objectives
To evaluate the results of iliac bone grafting with threaded Kirschner wires (K-wires) fixation in treating of nonunited middle third scaphoid fractures.
Background
Scaphoid nonunion is a common complication after scaphoid fractures as it is an intra-articular fracture with high fracture mobility and instability. In addition, the scaphoid is devoid of periosteum along with impaired vascularity. Scaphoid nonunion results in carpal collapse with secondary osteoarthritis. To avoid that, the aim of treatment should be to enhance the biology of fracture through bone grafting and provide adequate stability of the fracture in an anatomic alignment.
Patients and methods
This study is a prospective case series of 30 patients with nonunited middle third scaphoid fractures admitted to an academically supervised trauma center from June 2018 to June 2020. They were managed by open reduction, refreshment of the scaphoid nonunion site with iliac crest bone grafting, and threaded K-wires fixation in an anatomical alignment. The mean age was 28.58 ± 4.47 years. Postoperative clinical outcomes were evaluated using the Quick disabilities of arm, shoulder and hand (DASH) score, and modified Mayo wrist score. Postoperative radiological union and scaphoid alignment were assessed. The minimum period of follow-up was one year.
Results
One year postoperatively, the mean modified Mayo wrist score was 81.67 ± 9.39 and the mean Quick DASH score was 25.67 ± 14.97. Radiologically, the union was achieved in 86.7%. The mean union time was 11.92 ± 1.54 weeks.
Conclusions
Threaded K-wires fixation with iliac bone grafting is an effective method for treating nonunited middle third scaphoid fractures.

Keywords:
iliac bone graft, middle third scaphoid, nonunited scaphoid, threaded K-wire

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Introduction

The scaphoid is the most fractured carpal bone in adults. Scaphoid fractures mainly occur in adult males with high incidence in the age group from 20 to 29 years (151/100,000), in females, from 10 to 19 years (46/100,000). The fracture occurs in the middle third of the scaphoid in 60-69% of the patients. The incidence of scaphoid nonunion in adults is 5% and reaches up to 30% in non-treated patients [1].

Delayed Union is considered if the healing cannot be achieved at an average of 4–6 months and nonunion is considered after 6 months [2]. It can be classified according to Filan and Herbert [3] classification into D1: fibrous nonunion with preserved scaphoid shape, D2: complete nonunion with significant bone resorption and highly mobile bone fragments, D3: sclerosis at the nonunion site with humpback deformity and D4: bony necrosis with loss of normal bony architecture. It can also be classified according to Slade and Geissler [4] classification into Type; 1: delayed presentation of scaphoid nonunion for 4–12 weeks, 2: fibrous union with minimal fracture line, 3: minimal sclerosis less than 1 mm, 4: cystic formation of 1-5 mm, 5: cyst more than 5 mm with humpback deformity, 6: wrist osteoarthritis.

Middle third scaphoid nonunion results in flexion deformity of the scaphoid with humpback deformity. This leads to progressive carpal collapse with dorsal intercalated segment instability (DISI), and secondary

peri-scaphoid osteoarthritis. Consequently, to prevent such complications, the goal of surgical treatment should be the correction of humpback deformity, enhancing the biology of fracture through bone grafting along with providing adequate stability of the fracture in an anatomic alignment [5].

There are different methods of internal fixation of scaphoid middle third fractures including Herbert screws, plating, and K-wires fixation. Herbert screw fixation can occupy more space that decreases the amount of bone graft that can be placed and affect the weak blood supply which may decrease bone healing [6]. Plate fixation can provide greater stability more than Herbert screw fixation, but it requires extensive dissection for placement that may affect the tenuous blood supply of the scaphoid and bone healing [7].

The aim of this study was to evaluate the functional and radiological outcomes of open reduction of the middle third scaphoid nonunion site with correction of humpback deformity, refreshment of nonunion site, iliac bone grafting, and threaded K-wires fixation.

Patients and methods

This study is a prospective case series of 30 patients with nonunited middle third scaphoid fractures that had been admitted to an academically supervised trauma center from June 2018 to June 2020. The study was approved by Institutional Review Board (IRB) and the ethical committee. Written consent about the procedure and possible complications was taken. All patients were managed by open reduction, refreshment of the scaphoid nonunion site with iliac crest bone grafting, and threaded K-wires fixation in an anatomical alignment.

The inclusion criteria were age between 16 and 45 years, middle third scaphoid nonunion fracture more than 6 months from the initial injury. The patients had to complete at least one-year of follow-up to be included in this study. The exclusion criteria were previous surgical intervention, associated wrist fractures or ligamentous injuries, fractures of scaphoid tubercle or proximal pole, peri-scaphoid osteoarthritis, avascular necrosis, chronic illness, and smokers.

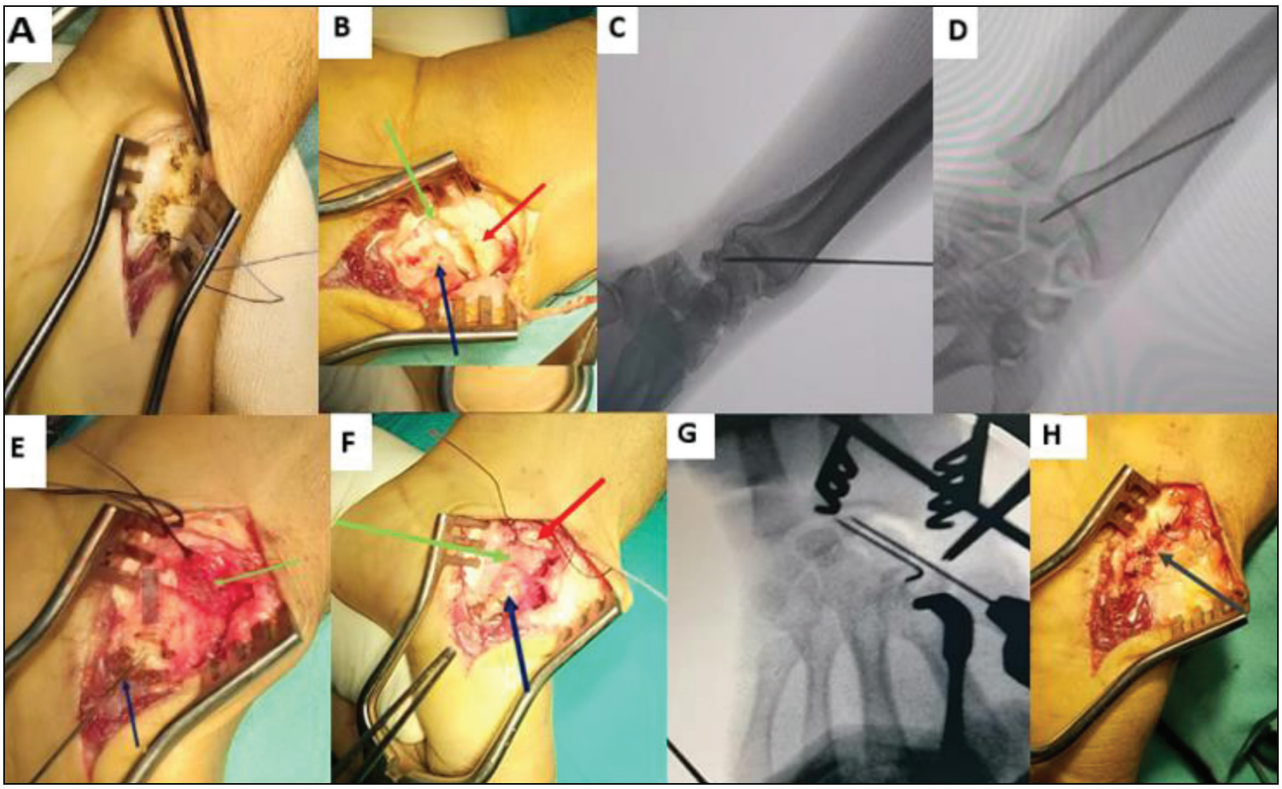
Preoperative evaluation: full detailed history about duration passed from the initial injury, mechanism of injury, presence of chronic illness, and any previous associated wrist injuries. Preoperative DASH and Mayo wrist scores were recorded. Radiological evaluation in the form of plain Radiography wrist anteroposterior (AP), lateral and scaphoid views. Computed tomography (CT) evaluation to assess the amount of bone loss (Gap size), scaphoid cyst, humpback deformity, and carpal alignment. Eight patients had a gap size of less than 5 mm whereas 22 patients had a gap size of more than 5 mm. Scaphoid cyst was present in five patients. Twenty-two patients had humpback deformity with DISI deformity of the lunate. MRI was done to exclude avascular necrosis. Routine preoperative laboratory investigations were done. In all patients, a single prophylactic antibiotic was administered 2 hours before surgery in the form of a third-generation cephalosporin injection, and the dose was adjusted according to the weight of the patient.

Operative technique

The patient was placed in a supine position and the affected wrist was placed over a radiolucent arm board. General anesthesia was used in all patients. The iliac crest was also exposed and draped to harvest the iliac crest bone graft. A pneumatic tourniquet was applied over smooth padding at mid-arm. After sterilization and draping of the affected limb, a sterile Esmarch bandage was used to exsanguinate the limb followed by inflation of the pneumatic tourniquet to a pressure 100 mmHg more than the systolic blood pressure.

A volar approach to the scaphoid was used. The skin incision was 3 cm vertically centered over the flexor carpi radialis tendon till the wrist crease then deviated toward the scaphoid tubercle in line with the thumb about 2 cm. The deep fascia in line with the skin incision was incised and the radial artery was retracted to the radial side of the wound. The tendon of the flexor carpi radialis muscle was retracted to the ulnar side to expose the volar aspect of the wrist joint. The palmar capsule was opened in Z-shaped fashion. The distal transverse limb was horizontal over scapho-trapezium-trapezoid (STT) joint then curved obliquely toward the radial styloid parallel to radio-scapho-capitate ligament then curved again along radio-scaphoid joint (Fig. 1a). This creates two triangular flaps that should be adequately repaired at the end of the procedure to avoid flexion deformity of the scaphoid. The scaphoid fracture was identified (Fig. 1b). The nonunion site was refreshed by curettage of sclerotic bone on proximal and distal fragments using high-speed bur till reaching viable bone surface with preservation of the cartilaginous framework. The DISI deformity of the lunate was corrected by palmar flexion of the wrist and temporarily fixed by a radio-lunate wire (Fig. 1c, d). Two small k-wires 0.8 mm were inserted in the proximal and distal pole of the scaphoid to be used as joysticks to manipulate the bone fragments to restore proper alignment and length of the scaphoid. Gap size was assessed. The cavitation created after

Figure 1



(a) The palmar capsule over the scaphoid was opened in Z-shaped fashion **(b)** Exposure and curettage of the scaphoid nonunion site. Proximal fragment (red arrow), distal fragment (blue arrow), nonunion site (green arrow). **(c, d)** The DISI deformity of the lunate was corrected by palmar flexion of the wrist and temporarily fixed by radio-lunate wire. **(e)** The cavitation created after proper curettage inside the proximal and distal poles was managed first by impaction of cancellous bone graft (green arrow). Threaded K- wire was inserted into the distal fragment before impaction of the trapezoidal iliac bone graft in the nonunion site (blue arrow). **(f, g)** The trapezoidal-shaped tricortical iliac crest bone graft (green arrow) was impacted between the proximal (red arrow) and distal (blue arrow) fragments then the advancement of two parallel 1.4 mm threaded K-wires guided by fluoroscopy started at the distal pole of the scaphoid passing through the bone graft and reaching to engage the proximal pole the cut short and bent over the volar surface of the scaphoid. **(h)** closure of the capsule (black arrow).

proper curettage inside the proximal and distal poles was managed first by cancellous bone graft impaction in the cavities then a trapezoidal-shaped tricortical iliac crest bone graft was impacted between proximal and distal fragments to restore the length and alignment of the scaphoid (Fig. 1e, f).

The wrist was hyperextended on a folded towel followed by exposure of scapho-trapezium joint and the distal pole of the scaphoid was exposed. Fixation of the fracture was done using two parallel 1.4 mm threaded K-wires guided by fluoroscopy started at distal pole of the scaphoid passing through the bone graft and reaching to engage the proximal pole (Fig. 1g). The threaded wires were bent first then cut short and twisted over the scaphoid tubercle. The radio-lunate wire was removed.

Deflation of the pneumatic tourniquet followed by proper hemostasis was done. The two triangular flaps of the capsule were properly repaired (Fig. 1h). The skin was closed, and a dressing was applied. Thumb slab was done.

Postoperative care and functional assessment

Immediate postoperative plain Radiographys were done. After two weeks, surgical sutures were removed and a thumb spica was done. Radiological evaluation was done at four, eight, twelve weeks, and one year to assess the union and scaphoid alignment. After complete union, removal of spica and starting physiotherapy was done till reaching the full range of wrist motion and powerful grip (Fig. 2).

Postoperative clinical outcomes were evaluated using the Quick disabilities of arm, shoulder and hand (DASH) score, and the modified Mayo wrist score had been done three months and one year postoperatively. Radiological evaluation of the union was done after three months and one-year postoperatively according to Kumar *et al.* [8] criteria in which grade 1 (excellent): complete union with no osteopenia, grade 2 (good): union with osteopenia, grade 3: nonunion but a good clear outline of the scaphoid with no evidence of necrosis, grade 4 (Poor): nonunion and a poor outline with evidence of necrosis. Radiological assessment of scapholunate (SL) and radio-lunate (RL) angles were measured.

Figure 2

(a, b) Preoperative plain-Radiography AP and lateral view of the wrist with scaphoid nonunion and cyst formation. **(c)** Preoperative CT showing nonunion of the middle third scaphoid with cyst formation less than 5 mm. **(d, e)** two weeks postoperative Radiography AP and lateral views after bone grafting and internal fixation by two threaded K-wires. **(f, g)** one-year postoperative radiography with the complete union. **(h, i)** one-year postoperative range of wrist flexion and extension.

Statistical analysis

At the end of the study, the data were collected, tabulated, and statistically analyzed by IBM SPSS 157 (statistical package for social science) version 23. Shapiro–Wilk test was used to verify the normality of distribution and the Pearson $\chi 2$ test was used to compare means. The significance level was set at P values less than 0.05.

Results

Demographics and baseline characteristics

A total of 30 patients were included, 26 (86.66%) males and 4 (13.33%) females with an average age of 28.58 ± 4.47 (range, 17–42) years. The dominant hand was right in all patients. Twenty-one patients had right-side injuries, whereas nine had left. According to Filan and Herbert's classification of scaphoid nonunion, eight patients were type D2, whereas 22 type D3 with DISI deformity of the lunate. Eight patients had a gap size of less than 5 mm whereas 22 patients had a gap size of more than 5 mm. Scaphoid cyst was present in five patients. The mean time from injury to surgery was 17.30 ± 7.88 (range, 8–25) months. The mechanism of injury was a fall on the outstretched hand in 25 patients and a road traffic accident in five patients (Table 1).

The mean union time was 11.92 ± 1.54 weeks. The union rate was 86.67%. Radiological evaluation of the union was done according to Kumar *et al.*

Table 1 Demographics and baseline characteristics

Variables	*N* = 30 (%)	*P* value
Age (mean±SD)	26.60 ± 5.58	0.71
Sex (male/female)	26/4 (86.66)/(13.33)	1
Side (right/left)	21/9 (70)/(30)	0.705
Nonunion type (D2/ D3)	8/22 (26.67)/(73.33)	1
Time from injury to surgery/months (mean±SD)	17.30 ± 7.88	0.497
Mechanism of injury (Fall on outstretched hand/road traffic accident)	25/5 (83.33)/(16.67)	1

Table 2 Comparison between the studied periods according to the Modified Mayo and Quick DASH scores: (*n*=30)

	Preoperative		Postoperative	Friedman test	*P* value
	3 months	One-year			
Modified Mayo score					
Min. – Max	60–75	50–85	55–90		
Mean±SD	67.67 ± 3.72	74.67 ± 9.54	81.67 ± 9.39	22.933	0.0000116
Quick DASH score					
Min. – Max	38–74	19–58	8–52	19.48	0.0000478
Mean±SD	51.47 ± 8.59	35.85 ± 11.48	25.67 ± 14.97		

criteria: 20 patients 66.7% (grade 2), ten 33.3% (grade 3) three months postoperatively. At the final one-year postoperative radiological evaluation, there was significant improvement of the radiological union whereas 21 patients (70%) achieved complete union without osteopenia (grade 1) with excellent results and five patients (16.67%) achieved union with osteopenia (grade 2) with good results. Unfortunately, four patients (13.33%) progressed to nonunion with the poor outline of the scaphoid and osteonecrosis (grade 4) with poor results. There was no statistically significant relationship between gap size at the nonunion site (whether less or more than 5 mm) and delay of time to union.

The mean preoperative SL angle was 55.81 (range,47-72) ° and the RL angle was −3.8 (range, −16–8) °. Three months postoperatively, the mean RL angle was statistically significantly improved to 45.78 (range,41–55) ° (*P* =0.001), and RL angle to 0.57 (range,4–3) ° (*P* = 0.001). One-year postoperatively the mean SL angle was statistically significantly improved to 43.78 (range,41- 51) ° (*P* = 0.001) and the mean RL angle was 0.33 (range,1–2) ° (*P* = 0.001).

The mean preoperative Modified Mayo score was 67.67 ± 3.72 (range, 60–75); three months postoperatively was 74.67 ± 9.54 (range, 50–85); one-year postoperatively was 81.67 ± 9.39 (range, 55–90). There was no statistically significant difference between preoperative and three months post-operative (*P* = 0.068). There was a highly statistically significant difference between preoperative and one-year post-operative scores (*P* = 0.0000116). According to the modified Mayo score, 20 (66.67%) patients were excellent, six (20%) good, three (10%) fair, and one (3.33%) poor after one-year postoperatively (Table 2).

The mean preoperative Quick DASH score was 51.47 ± 8.59 (range, 38–74); three months postoperatively was 35.85 ± 11.48 (range, 19–58); one-year was 25.67 ± 14.97 (range, 8–52). There was no statistically significant difference between preoperative and three months post-operative scores (*P* = 0.062). There was a highly statistically significant difference between preoperative and one-year post-operative scores (*P* = 0.0000478) (Table 2).

Postoperative complications were seen in four (13.33%) patients who presented with scaphoid nonunion. Two of them presented with protrusion of the k-wires through the skin with pin tract infection. They were managed by early removal of the threaded K-wires, daily dressing, and antibiotic therapy.

Discussion

Middle-third fracture scaphoid nonunion is a common problem. If it is left untreated, it will eventually lead to wrist osteoarthrosis. The proper treatment of such fracture nonunion is to provide adequate stability by internal fixation in a proper alignment and to enhance the biology of fracture healing through bone grafting. The aim of this study is to evaluate whether the threaded K-wires fixation and iliac bone grafting provide adequate stability till healing occurs or not.

In this study, the mean age was 28.58 ± 4.47 (range, 17–42) years. This is comparable to Kumar *et al.* [8], where it was 29.6 years, Hamed *et al.* [9] 29.15 ± 6 years and in Engel *et al.* [10] 28.2 ± 10.3. The age in the previous studies locates almost in the same range. This could be explained by that most scaphoid nonunion occurs at a younger age.

In this study, the mean union time was 11.92 ± 1.54 weeks, and the union rate was 86.67%. Meisel *et al.* [11] reported excellent union rates (97%) with K-wires fixation and iliac bone graft in the treatment of middle third scaphoid nonunion compared with other techniques. Hamed *et al.* [9], reported a higher union rate with K-wires fixation (80%) than with Herbert screw fixation (60%). Engel *et al.* [10] reported (80%) union rate with k-wires fixation and in Merrell *et al.* [12] study, it was 77%. A higher rate of union with K-wires fixation than Herbert screw fixation may be explained as the Herbert screw can occupy more space that decreases the amount of bone graft that can be placed and affect the weak blood supply which may decrease bone healing.

In this study, the mean preoperative modified Mayo score was 67.67 ± 3.72 (range, 60–75), at 3 months postoperatively 74.67 ± 9.54 (range, 50–85), and at one-year 81.67 ± 9.39 (range, 55–90). There was a highly statistically significant difference between preoperative and one-year post-operative scores (P = 0.0000116). Twenty (66.67%) patients were excellent, six (20%) good, three (10%) fair, and one (3.33%) poor after one-year postoperatively. Engel *et al.* [10] reported that the modified Mayo wrist score improved to 71.2 ± 21.9 with the K-wires fixation. Kim *et al.* [13] reported that with K-wires fixation, this score was significantly improved from 64.0 ± 8.3 preoperatively to 87.5 ± 9.7 postoperatively. Excellent results were obtained in six (46.2%) patients, good five (38.5%), and fair two (15.3%). Our results are comparable with these studies.

In this study, the final radiological evaluation was done one-year postoperatively, 21 patients (70%) were grade 1 with (excellent) results, five (16.67%) grade 2 (good) and four (13.33%) grade 4 (poor). There was no statistically significant relationship between gap size at the nonunion site (whether less or more than 5 mm) and delay of time to union. Kumar *et al.* [8] reported the radiological outcomes at 6 months follow-up were: 27 (90%) patients were grade 1 (excellent), two (6.7%) (good), and one (3.3%) (fair). Our results are comparative to Kumar *et al.* [8] results, which explain improved radiological outcomes after K-wires fixation with bone grafting in the treatment of nonunion of middle third scaphoid fractures.

Conclusion

Threaded K-wires fixation with iliac bone grafting is an effective method for treating nonunited middle third scaphoid fractures.

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Conflicts of interest

No conflict of interest.

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