Base of Hamate as a reconstruction for proximal pole scaphoid fractures

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Background
Scaphoid fracture nonunion is a troublesome complication that if untreated will lead to avascular necrosis (AVN) of proximal pole, then carpal collapse, and degenerative arthritis. The proximal pole of the scaphoid vascular status is an important factor in determining the type of bone graft used whether vascularized or nonvascularized.
The purpose of this study was to evaluate the results of a new technique in the reconstruction of AVN proximal pole scaphoid fracture nonunion by using proximal Hamate as an autograft to restore the shape of scaphoid and scapholunate mechanics and the effect of graft size on wrist mechanics.
Patients and methods
This was an interrupted time-series clinical trial (quasi-experimental) study that included 20 patients with nonunited proximal scaphoid fractures with AVN of the proximal part treated with excision of the proximal pole of scaphoid and reconstruct with the proximal pole of Hamate and reconstruction of scapholunate ligament.
Results
All fractures united, except two fractures, with a mean period of 10.2 weeks, the mean follow-up period was 11 months, there was an improvement in visual analog scale score from 8 (7–9) preoperative to 2 (0–5) postoperative and the final Mayo wrist score was 93.1 (range, 79–98).
Conclusion
The use of proximal hamate as an autograft to reconstruct the proximal osteocartilaginous surface of the scaphoid nonunited fractures with AVN of the proximal pole is a promising technique.

Keywords:
avascular necrosis, Capito-Hamate ligament, scaphoid nonunion, Triquetro-Hamate ligament

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Introduction

Proximal pole scaphoid fractures usually present with mild-to-moderate radial-sided wrist pain. Due to the mildness in complaints and difficulty in visualizing the fracture line in radiograph, the diagnosis may have been missed at the time of injury, and led to fracture nonunion at the time of detection [1].

Nonunion of proximal pole scaphoid fractures has a lot of difficulties to reconstruct due to poor blood supply, the need to reconstruct the scapholunate ligament, and fragmentation [2].

The proximal pole vascular status is an important factor in decision-making when treating proximal pole fracture nonunion, so accurate preoperative vascular status assessment is important [3].

A lot of studies reported that unenhanced MRI was accurate for detecting proximal pole scaphoid avascular necrosis (AVN) in patients with fracture nonunions [3]. Cerezal and colleagues divided the patients into four groups based on the T1-weighted and T2-weighted fat-suppressed imaging appearance. Group 1 had a signal in the proximal pole isointense to normal carpal bones on T1 images and T2 images (normal-to-minimal ischemia). Group 2 had a slightly low signal in the proximal pole on T1 images and homogeneously increased signals on T2 images (moderate ischemia). Group 3 had variably low signals on T1 images and heterogeneous signals on T2 images (severe ischemia). Group 4 had a low signal on T1-weighted and homogeneously decreased signal on T2 images (AVN) [4].

The purpose of this study was to evaluate the results of a new technique in reconstruction of AVN proximal pole

scaphoid fracture nonunion by using proximal Hamate as an autograft to restore the shape of scaphoid and scapholunate mechanics and the effect of graft size on wrist mechanics.

Patients and methods

This was an interrupted time-series clinical trial (quasi-experimental) study that included 20 patients with nonunited proximal scaphoid fractures with AVN of the proximal part, who attended Benha University Hospital between January 2021 and July 2022, after approval of the Research Ethics Committee at Faculty of Medicine, University (REC-FOMBU).

Skeletally mature patients with nonunited proximal pole scaphoid fracture with AVN of the proximal part were included in this study. Exclusion criteria included patients with systemic disorders (e.g. anemia, coagulation disorders, diabetes, or rheumatoid arthritis), local wrist conditions (arthritis, previous trauma or surgery, nerve entrapment, infection, or malignancy), cervical spine pathology, psychiatric disorder, or pregnancy.

The diagnosis was made by full clinical examination and radiological assessment (radiograph, computed tomography scan, and MRI) for all patients. AVN was assessed according to Cerezal *et al.* [4]. MRI classification system and grade-4 patients were included in this study (had low signal on T1-weighted and homogeneously decreased signal on T2-weighted fat-suppressed images).

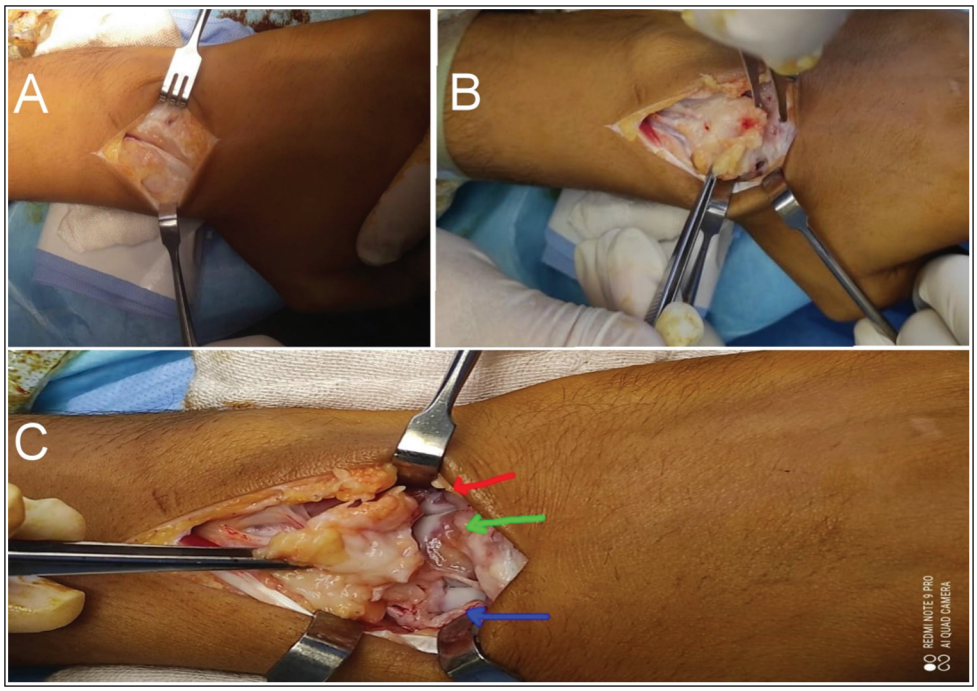
Informed consent was obtained from all patients after giving detailed information about the study. All patients have painful wrist motion that affects their daily activity and functional tasks, the pain is assessed according to the visual analog scale (VAS) pain score. The preoperative average VAS score was 8 (range, 6–10), the grip strength was assessed by using a handheld dynamometer, and the grip average was 53.7% of the sound side (range, 48–65%).

Surgical technique

After regional or general anesthesia, the patient is placed supine on the operative table with the upper limb extended on a board with an upper arm tourniquet. A dorsal approach of the wrist is used via dorsal longitudinal wrist incision, then the third extensor compartment is opened, and radial retraction of the extensor pollicis longus tendon is done. The fourth extensor compartment is entered, and a proximal-based retinacular flap of the capsule is raised (Fig. 1).

The proximal pole of scaphoid is removed with keeping the remaining scapholunate ligament freed off it and attached to the lunate, then the distal scaphoid proximal surface was prepared by curettage and osteotome till

Figure 1



(a) Dorsal approach and open third compartment EPL tendon. (b) Retraction of EPL and a proximal-based flap. (c) Elevation of flap, red arrow on Hamate base, green arrow on capitate, blue arrow on scaphoid and fracture site.

identifying punctate bleeding while the tourniquet was deflated (Fig. 2).

Then, the length, depth, and width of the defect and the excised pole measured to detect the graft size will harvest.

From the same incision, the base of Hamate was marked as the same size as the defect and separated with a small osteotome keeping the volar Capito-Hamate ligament attached to the graft and separate it from the capitate, at this step, attention should be directed to take care of distal Triquetro-Hamate ligament not to be injured to prevent future midcarpal instability, so if it was injured, repair should be done via suture anchor. After harvesting the graft, size checks in comparison with excised scaphoid pole, then the graft was rotated 180° before fixation to make the attached ligament of the Hamate base dorsal, to reconstruct the detached scapholunate ligament (Fig. 3).

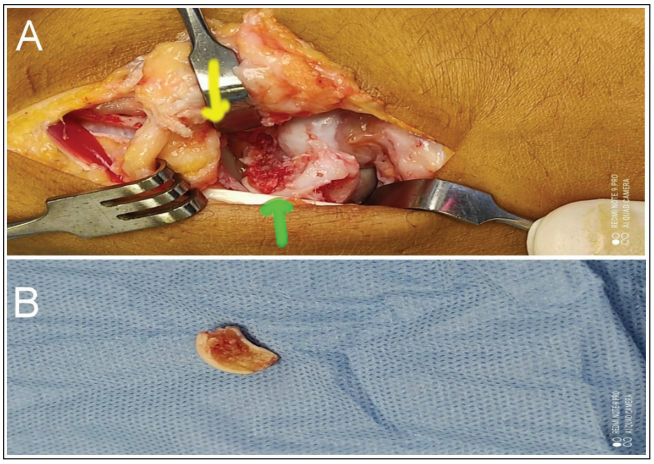
The graft was fixed in its position via preliminary k-wire after image intensifier check fixation is done with a headless screw through dorsal or volar entry according to surgeon preference.

Alignment of scapholunate interval and midcarpal relation should be checked before scapholunate ligament repair, and Lunate reduced to a neutral position and stabilized with Capitolunate wire (Fig. 4).

Reconstruction of the scapholunate ligament by suturing the remnant of lunate attachment to capito-Hamate ligament on the graft that rotated and became dorsal, then dorsal capsulodesis was used to augment the repair by suture anchor fixed in scaphoid (Fig. 5).

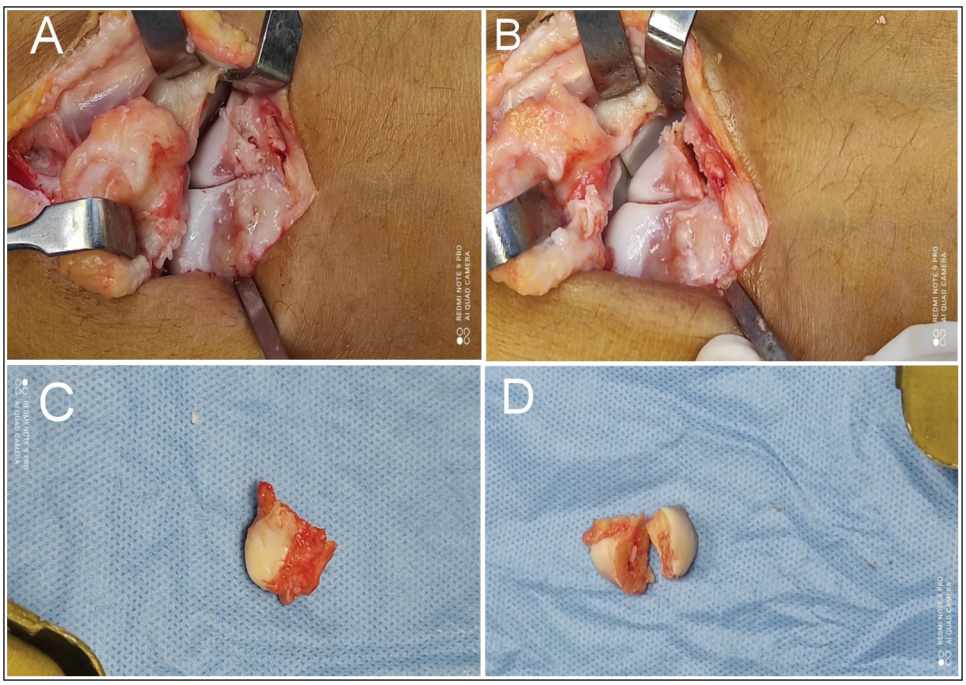
During scaphoid pole excision, if sufficient scapholunate ligament could not be kept attached to lunate, a suture anchor fixed in lunate can be used to augment the repair (Fig. 6).

Figure 2



(a) After excixion of proximal pole and keep scapholunate ligament attached to lunate (yellow arrow), and prepare the distal scaphoid till punctate bleeding (green arrow). (b) Proximal pole post excision shows unhealthy bone and its diameters were taken.

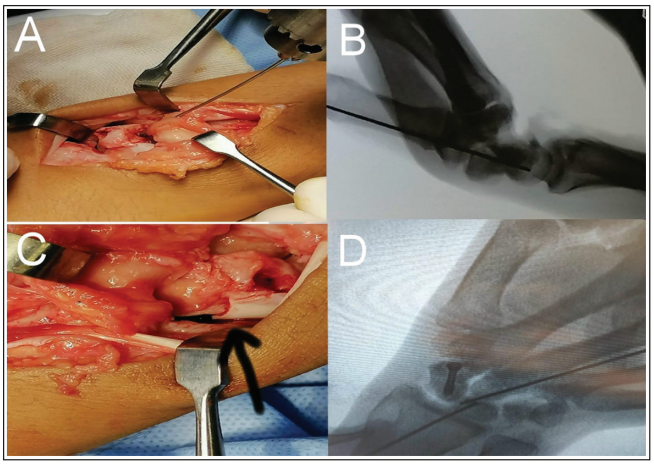
Figure 3



(a) Mark the base of Hamate to fit the defect size. (b) Osteotomy done keeping the volar CH ligament intact. (c) Harvested graft with attached volar CH ligament. (d) Compare graft size and rotate it 180°. CH, Capito-Hamate ligament.

The capitolunate wire was cut under the skin, then after skin closure, a below-elbow thumb splint was done and changed with thumb spica with suture removal 2 weeks postoperative, then follow-up done every 2 weeks, and computed tomography scan done at 6–8 weeks to assess bony union by the presence of bridging trabecular bone more than 50%. When the union was achieved, k-wire and cast were removed and physiotherapy is initiated.

Figure 4



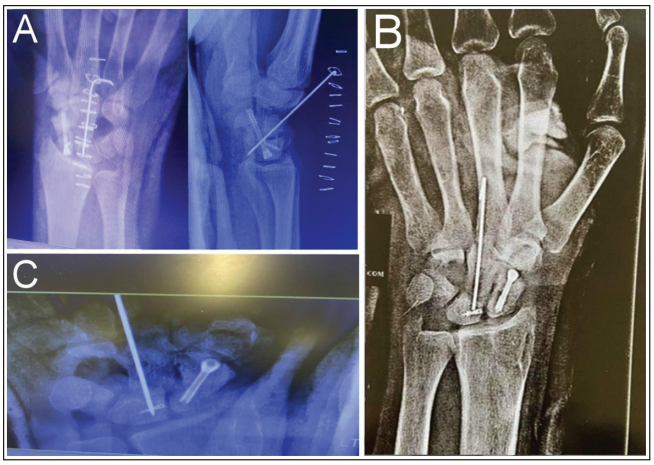
(a) Reduction of graft and fixation by k-wire. (b) Intraoperative lateral view. (c) Fixation and compression of the graft via Herbert screw, black arrow shows the site of fracture compressed. (d) Graft well positioned and reduction of lunate and fixation by k-wire through capitate.

The functional outcomes were assessed by VAS score for pain and Modified Mayo wrist score.

Statistical analysis

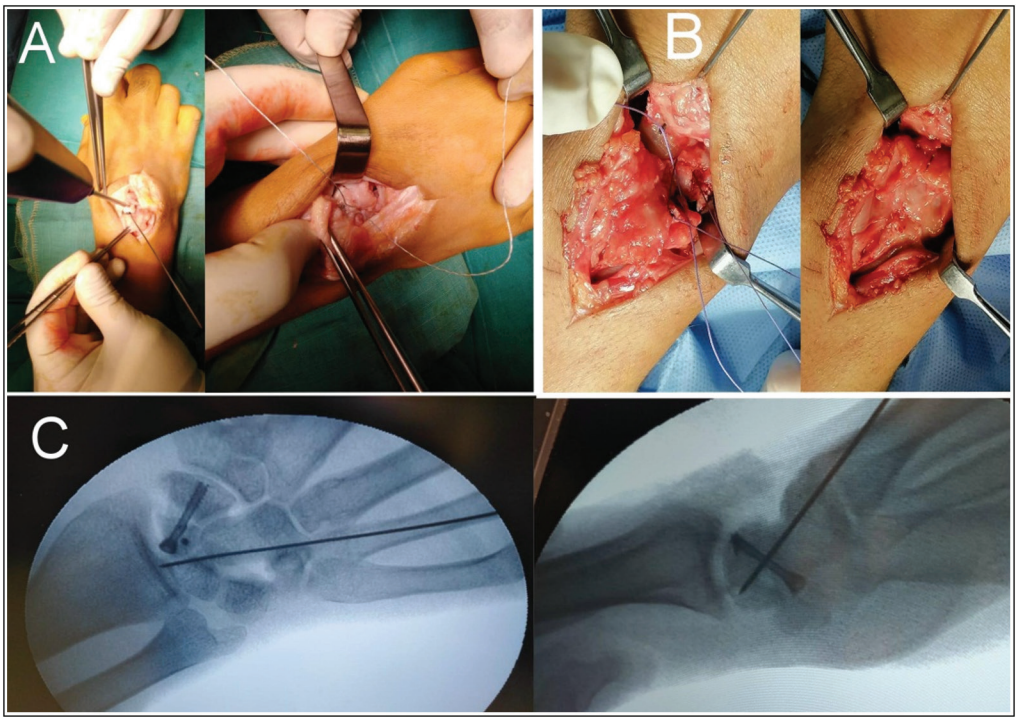
Data were analyzed by the Statistical Package of Social Science (SPSS) software package for Windows (Standard version 16; SPSS Inc., IBM Corp, Armonk, NY, USA). The normal data distribution was tested by Shapiro test. Qualitative data were described by relative frequency (number of occurrences) and percentages.

Figure 6



(a) Postoperative adiograph of a case that we used suture anchor in scaphoid. (b, c) Postoperative radiographs of cases we used suture anchors in lunate to augment scapholunate repair.

Figure 5



(a) Suture anchor used to augment the scapholunate ligament repair. (b) Dorsal capsulodesis to scaphoid to augment ligament repair. (c) Intraoperative final image shows proper graft and screw position, anchor, and capitolunate wire.

The association between categorical variables was tested using Chi-square test or its equivalent when the cell count was less than 5. Continuous variables were presented by the arithmetic mean (for central tendency) and SD.

Results

All fractures went on to clinical and radiological union, except for two cases where nonunion of the fractures and radioscaphoid arthritis occur. The mean union rate was 10.2 weeks (range, 9–14 weeks) (Fig. 7).

The mean follow-up period was 11 months (9–14), there was a significant improvement in VAS score than in preoperative state with a mean value of 2 (range, 0–5), also, there was a significant improvement in hand grip from 53.7% preoperative to 89% of the healthy side at the final follow-up (range, 80–95%), according to Mayo wrist score; 16 patients were excellent, two good, and two poor results with mean 93.1 (range, 79–98). There was no significance according to the size of the graft harvested on the final results, size range (4–9 mm) (Table 1).

Three patients had attrition of finger extensor tendons due to capitolunate wire that healed with wire removal. Two patients have nonunion and radioscaphoid arthritis, one of them was treated with limited wrist fusion and the other refused this option and was satisfied with his results as his job was an office worker.

Discussion

The scaphoid nonunited fractures, especially with AVN of the proximal pole, represent a challenging problem. This is due to the lack of efficiency of bone healing associated with AVN. Not only fracture healing was the main problem but also fragmentation of the proximal pole and loss of cartilaginous cap and scapholunate ligament disruption. All these problems should be in mind when treating such problematic cases.

The management strategy was to achieve union and restore the scapholunate ligament with cartilage-capped graft, with decreased graft donor site morbidity.

Free vascularized and pedicled grafts have been described in treating this problem [5,6]. Also, medial femoral condyle-vascularized bone graft was demonstrated [7], iliac bone graft was a widely used method [8], another trial with an osteochondral graft from the rib was done [9–11], and finally proximal scaphoid allograft was used [12]. Most of these methods need longer time operation due to microvascular anastomosis or have graft donor site morbidity such as paraesthesias or numbness in the saphenous nerve distribution [13]. Last, most of these grafts do not address the reconstruction of the scapholunate ligament [14].

In our study, we used the proximal Hamate to reconstruct the proximal pole of scaphoid by a nonvascularized autograft that has cartilaginous surfaces nearly similar to that of scaphoid, restore scapholunate ligament by capito-Hamate ligament attached to the graft, and also addresses the donor site morbidity issues by using the same operative approach without compromising carpal stability.

A study by Kakar *et al*. [15] was done to quantify the similarity of the topology of the articulating surfaces of the Hamate and scaphoid. They found that there were similarities between the two articular surfaces: 60% of the Hamate autografts had over 90% surface correspondence to the scaphoid.

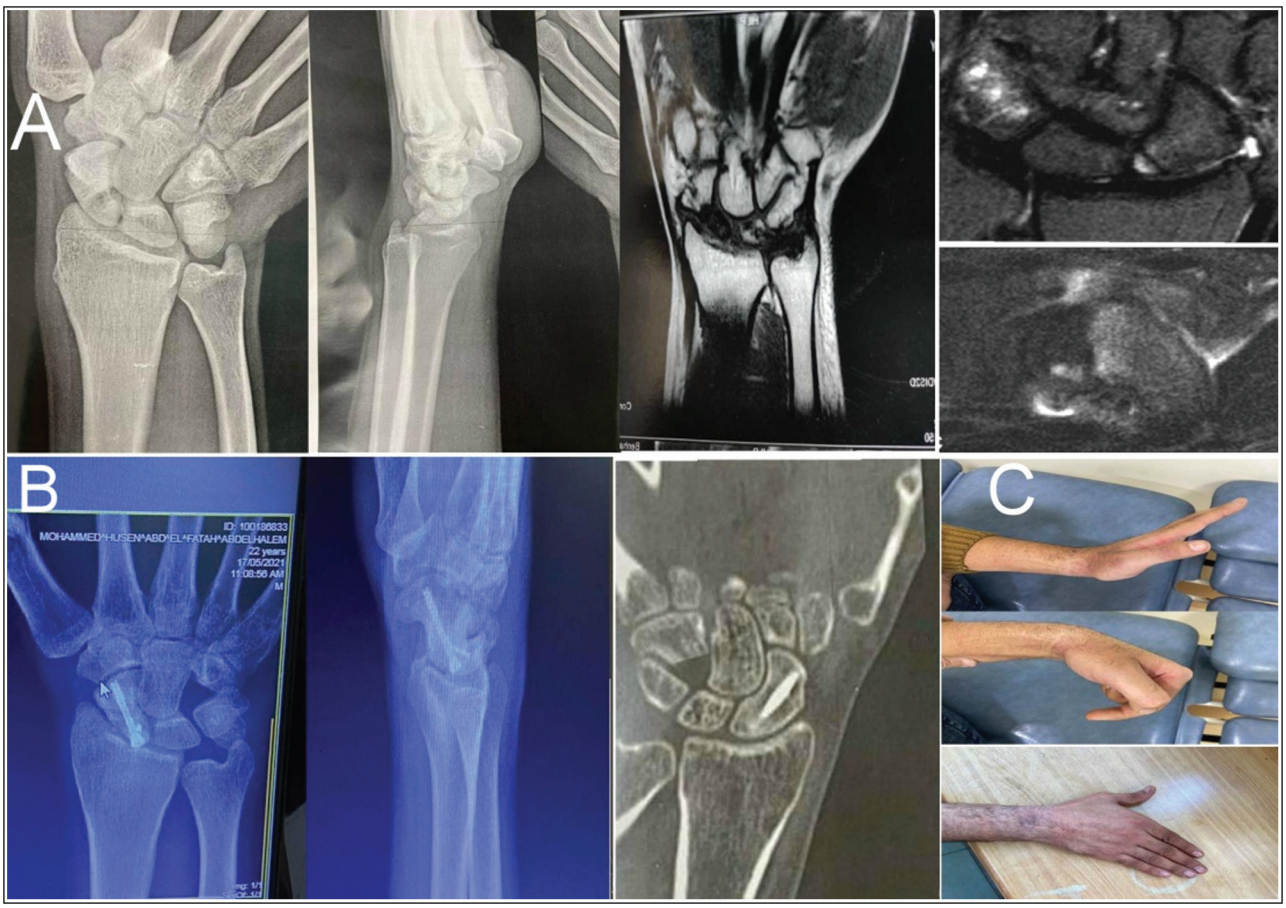
Wu *et al*. [16] performed an anthropometric analysis of the scaphoid proximal pole to the proximal Hamate on 29 cadaveric studies, their results were 70% similar.

Burnier *et al*. [17] used an experimental setup of the wrist stimulator on fresh–frozen mid-forearm cadaver specimens with a wrist simulator to move the wrist through a cyclical motion, to assess restoration of native wrist kinematics after reconstruction of proximal scaphoid by proximal Hamate. They conclude that proximal Hamate grafts restored scapholunate kinematics close to the intact state in both flexion-extension and radial–ulnar deviation.

Our study was held on 20 patients with nonunited proximal pole scaphoid fractures with AVN of the proximal pole, all treated with excision of proximal pole scaphoid and reconstructed with proximal Hamate autograft and repair of scapholunate ligament, we achieved complete union in 18 patients with union rate 10.2 weeks (range, 9–14 weeks), while two patients could not achieve union and this was mostly due to improper compression during fixation and immobilization postoperatively, one of them treated with limited wrist fusion and the other one refused this option. The graft size taken during this study ranged from 4 to 9 mm, and this did not affect the final outcomes and also had no effect on Triquatro-Hamate articulation over the follow-up period. The final Mayo score was 93.1 (range, 79–98).

Our results were comparable to other methods of treatment, a study done with nonvascularized corticocancellous iliac bone graft and Herbert screw

Figure 7



(a) Radiograph and MRI of proximal pole AVN post fracture 8 months ago. (b) Four months postoperative radiographs and computed tomograph scan show complete union. (c) Four months functional range of motion. AVN, avascular necrosis.

Table 1 Demographics and results of the patients

	Data	*P* value
Age (years)		
Range	19–42	NS
Mean±SD	29±2.5	
Gender [*n* (%)]		
Male	12	NS
Female	8	
Size of the graft in mm	4–9	NS
	6±2	
VAS score		
Range	0–5	*P*<0.05
Mean±SD	2±0.5	
Grip strength		
Range	80–95%	*P*<0.05
Mean±SD	89±2.4%	
Union rate		
Range	9–14 weeks	*P*<0.05
Mean±SD	10.2±0.5 weeks	
Mayo score		
Excellent	16	
Good	2	*P*<0.05
Satisfactory	0	
Poor	2	
	93.1 (range 79–98)	

VAS, visual analog scale.

fixation on 11 patients, with union rates 12–24 weeks, and Mayo score 91.4 points postoperatively [1].

Greg Sommerkamp *et al.* [18] treated 15 patients with palmar radiocarpal artery vascularized bone graft, all fractures united with mean 12 weeks, with mean period of immobilization 8.8 weeks.

A retrospective study done by Mark S. Morris *et al.* [19] on patients treated with intercompartmental supraretinacular artery vascularized graft and compression screw fixation, with union rate 100% with mean period 12 weeks.

The results of our study were in line with a study done by Chan *et al.* [14] with the same technique, their follow-up was 3.5 years with Mayo wrist score that was 90.

The limitations of our study were the small number of patients, the lack of a control group, and short follow-up period. Larger-scale studies are needed to assess long-term functional outcomes, with randomized control studies.

Conclusion

The use of proximal Hamate as an autograft to reconstruct the proximal osteocartilaginous surface of the scaphoid nonunited fractures with AVN of proximal pole is a promising technique. Take care of Triquetro-Hamate ligament injury during graft harvesting. Prober graft size and capito-Hamate ligament harvest are one of the important steps to perform the operation successfully.

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Nil.

Conflicts of interest

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

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