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A review of scaphoid fracture, treatment outcomes, and consequences

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Abstract

Purpose Scaphoid fractures are the most common carpal fracture and can lead to severe complications like carpal collapse and osteoarthritis. This study reviewed scaphoid fracture patterns, outcomes, and consequences in conservative and surgical management.

Methods Sixty-four patients with scaphoid fracture who attended the hand clinic at King Hussein Medical City from January 2022 to December 2022 were included and reviewed regarding the anatomical fracture site, the associated injury, the treatment modality (conservative versus surgical), the healing time, and fracture sequelae such as nonunion and scaphoid nonunion advanced collapse.

Results Most patients were males (62 patients, 96.9%), and most (47, 73.4%) fell within 25 to 40 years. Scaphoid waist fracture was the most common location (40, 52.5%). Most patients (47, 73.4%) received conservative treatment and 17 (26.6%) were fixed acutely. However, nonunion complicated 53 fractures (82.8%).

Notably, there were no differences in the union rate or time between cases of scaphoid nonunion treated with vascularized or nonvascularized grafts. Furthermore, there were no variations in union rates among genders, extremities, age, fracture locations, or among smokers. However, a higher union rate was noted in office workers and those who received conservative treatment.

Conclusion Nonunions were higher in our study than in the literature, as our department is a referral center for established nonunion cases. For conservative treatment, we recommend aggressive management and follow-up with a clinical and CT scan at three months and early referral of non-united fractures to the hand clinic to avoid the advanced collapse of the scaphoid.

Keywords Scaphoid · Nonunion · Carpal bone · Fracture · Graft · Jordan

Introduction

Scaphoid fractures are the most common carpal fractures, accounting for 60% of all carpal fractures. Due to the complex three-dimensional structure of the scaphoid, diagnosis and treatment may not be straightforward [1]. The scaphoid forms an essential mechanical link between the proximal and distal carpal rows; therefore, it is subjected to high mechanical stress, which explains the highest incidence of carpal fractures. Cartilage covered approximately 80% of the scaphoid surface. The scaphoid articulates with the distal radius, lunate bone, capitate, trapezoid, and trapezium [2]. The blood supply arises dorsally from the dorsal carpal branch of the radial artery, accounts for 70–80% of the blood supply to the scaphoid, and enters the bone from distal to proximal. Vessels of the superficial palmar artery of the radial artery account for 20–30% of the scaphoid blood supply and exclusively supply the distal scaphoid. Therefore, the proximal scaphoid has a sparse blood supply, which explains a longer healing time and a higher nonunion rate [3].

Scaphoid fractures mainly affect young males after a fall on their outstretched hands, resulting in wrist hyperextension [1]. There are many classification systems for scaphoid fractures to guide treatment and support expected outcomes. However, the most commonly adopted system is based on the fracture site. The scaphoid waist accounts for two-thirds of fractures, followed by the distal pole, which

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accounts for 25%, while the proximal pole accounts for 5–10%. Healing of scaphoid fractures varies according to fracture location, where approximately 90% of scaphoid waist fractures healed. However, proximal pole fracture secondary to the scanty blood supply, 10–14% of nondisplaced fractures, and up to 50% of displaced fractures may be complicated by nonunion. Scaphoid nonunion progresses to carpal collapse and secondary osteoarthritis and consequently can lead to disabling consequences for patients [4].

This study aims to review scaphoid fracture patterns, risk factors, outcomes, and consequences to identify treatment outcomes in conservative or surgical treatment and assess the association of scaphoid fractures union with different parameters.

Method

All patients attending the Hand Clinic at the Royal Rehabilitation Center at King Hussein Medical City from January 2022 to December 2022 with a history of a scaphoid fracture were included. Patients' medical history and sociodemographic characteristics were collected, and their records and radiographs were reviewed using a Picture Archiving and Communication System (PACS) to define the fracture characteristics such as anatomical site, associated injury, treatment modality (conservative versus surgical), healing time, and fracture consequences such as nonunion and Scaphoid Nonunion Advanced Collapse (SNAC). Vascularized and nonvascularized scaphoid nonunion grafting and fixation outcomes were compared. SNAC treatment modalities were reviewed according to the management; this included grafting, distal pole excision, four-corner fusion, proximal raw carpectomy, and wrist arthrodesis.

In individuals undergoing treatment for nonunion with grafting, we utilized a one to two intercompartmental supraretinacular artery-based vascularized graft obtained from the distal dorsal radius in all cases. In cases where a nonvascularized graft was used, we harvested cortical graft from the distal radius. The decision to harvest from the volar or dorsal aspect depended on the specific surgical approach for addressing scaphoid nonunion.

Results

Our review included 64 patients evaluated for scaphoid fractures and receiving primary or salvage treatment. Males represent the majority (62 patients, 96.9%), while only two females (3.1%) were included. The mean age of the patients was 31.95 years (±7.53). The left hand was more commonly affected (37 patients, 57.8%), and most patients (47, 73.4%) were between 25 and 40 years old. Forty-eight patients (75%) of patients were manual workers, and 38 patients (59.4%) were smokers, Table 1.

When evaluating the location of scaphoid fractures location, scaphoid waist fractures were the most common (40, 62.5%); proximal scaphoid fractures occurred in 18 patients and accounted for 28.1%, and distal pole fractures were reported in six patients (9.4%).

Most fractures (44, 68.8%) were treated initially by general orthopaedic surgeons, while the remaining (20, 31.2%) received initial treatment by hand surgeons. Conservative

Table 1 Descriptive analysis of scaphoid fracture ($N = 64$)

	Number	Percentage
Gender		
Male	62	96.9
Female	2	3.1
Affected extremity		
Right	27	42.2
Left	37	57.8
Age group		
< 25	9	14.1
25–40	47	73.4
> 40	8	12.5
Occupation		
Manual worker	48	75
Office work	6	9.4
Driver	5	7.8
Others	5	7.8
Smoking		
Yes	38	59.4
No	26	40.6
Fracture location		
Proximal	18	28.1
Waist	40	62.5
Distal	6	9.4
Initial treatment		
Conservative	47	73.4
Surgery	17	26.6
Surgical approach ($N = 17$)		
Dorsal	10	58.8
Volar	4	23.5
Percutaneous	3	17.6
Initial treatment provider		
Upper limb surgeon	20	31.2
General orthopedic surgeon	44	68.8
Initial treatment outcome		
Union	11	17.2
Nonunion	53	82.8
Part of perilunate fracture dislocation	8	12.5

treatment was the initial treatment in 73.4% (47 patients) of fractures. 26.6% (17 patients) of fractures were treated surgically with acute fixation. In the surgically treated group, the dorsal approach was the most common (10 patients, 58.8%). However, only 11 patients (17.2%) presented to the hand clinic developed union during follow-up, and 53 patients (82.8%) were complicated by nonunion. Scaphoid fractures were part of a perilunate fracture-dislocation in eight cases (12.5%).

Radiographs of referred non-united scaphoid fractures showed that only ten patients (18.9%) were not complicated by scaphoid nonunion advance collapse. However, the remaining demonstrated a nonunion sequel on the radiographs with the following distribution: fifteen patients (28.3%) showed radio-scaphoid arthritic changes (SNAC I); SNAC II and III accounted for 11.3% and 32.1%, respectively. Moreover, wrist arthritis was noticed in 9.4% of nonunion cases, Table 2.

During follow-up, only 32 patients (61.4%) in the nonunion category received treatment through fixation, grafting, or salvage surgeries. However, the remainder were either waiting for surgery because of the long waiting list or did not require intervention at the presentation time. Fracture grafting and fixation (either vascularized or nonvascularized) were performed in 20.7%, and proximal carpectomy was the most common intervention (20.8%). Four corner and total wrist arthrodesis accounted for 5.7% and 7.5%, respectively, and distal pole excision was done in 5.7%.

Of our 64 patients, only 11 (17.2%) developed scaphoid fracture healing in the initial treatment with conservative or surgical methods. The mean union time was 6.82 (±6.49) months. However, 11 patients (20.8%) from the nonunion group were treated by fixation and grafting by either vascularized or nonvascularized graft. However, union occurred in 66.6% of patients treated with fixation and nonvascularized grafts and 80% of patients treated with fixation with vascularized grafts. Nevertheless, there were no statistical differences in union time and rate between the two groups, Table 3.

Table 4 compares union in different categories. The analysis demonstrated no difference in union rate between genders, age groups, or extremity involvement. There was also no difference in union with smoking, scaphoid fracture anatomic location, and whether the initial treatment was provided by upper limb or general orthopaedic surgeons. However, manual workers and drivers were at higher risk of nonunion, while office workers' fractures were more likely to develop union. Similarly, surgically treated fractures were more likely to develop nonunion.

Table 2 Nonunion consequences and treatment ($N = 53$)

	Number	Percentage
Nonunion consequences		
No changes	10	18.9
SNAC I	15	28.3
SNAC II	6	11.3
SNAC III	17	32.1
SNAC IV	5	9.4
Nonunion and nonunion consequences treatment		
Vascularized graft	5	9.4
Nonvascularized graft	6	11.3
Four corner arthrodesis	3	5.7
Proximal raw carpectomy	11	20.8
Wrist arthrodesis	4	7.5
Distal pole excision	3	5.7
Waiting surgery	21	39.6

Discussion

There is much controversy surrounding the treatment of scaphoid fractures, including conservative and surgical options. Many studies compared scaphoid casts above the elbow to those below the elbow and found no differences in healing and complication rates [5, 6]. Similarly, there is no difference in healing rate between the scaphoid and Colles cast. However, the Colles cast is more comfortable for patients and therefore is preferred by many surgeons [7]. Likewise, there is no difference in union rate when the wrist is immobilized in flexion or extension. However, the cast in a flexed position is associated with more complications, such as reduced wrist extension and grip strength [8]. Adjunct ultrasound treatment with a standard scaphoid cast results in faster healing [9]. Comparing the operative and non-operative treatment of undisplaced fractures showed no difference in the healing rate with higher complications in the operative group. Yet,

Table 3 Nonunion fixation and grafting

	Number (%)	*P*-value
Nonvascularized graft	6	0.504
Union	4 (66.6)	
Nonunion	2 (33.3)	
Vascularized graft	5	
Union	4 (80)	
Nonunion	1 (20)	
Mean union time in months (±SD)		0.839
Nonvascularized graft	5.75 (±0.96)	
Vascularized graft	6 (±2.16)	

Numbers within brackets represent the percentage within the same category

Table 4 Bivariate analysis of union with different variables ($N = 64$)

	Union	Nonunion	*P*-value
Gender			
Male	11 (17.7)	51 (82.3)	0.381
Female	0	2 (100)	
Affected extremity			
Right	6 (22.2)	21 (77.8)	0.564
Left	5 (13.5)	32 (86.5)	
Age group			
< 25	2 (22.2)	7 (77.8)	0.867
25–40	8 (17)	39 (83)	
> 40	1 (12.5)	7 (87.5)	
Occupation			
Manual worker	5 (10.4)	43 (89.6)	0.029
Office work	4 (66.6)	2 (33.3)	
Driver	1 (20)	4 (80)	
Others	1(20)	4 (80)	
Smoking			
Yes	6 (15.8)	32 (84.2)	0.983
No	5 (19.2)	21 (80.8)	
Fracture location			
Proximal	1 (5.6)	17 (94.4)	0.188
Waist	8 (20)	32 (80)	
Distal	2 (33.3)	4 (66.6)	
Initial treatment			
Conservative	5 (29.4)	12 (70.6)	0.041
Surgery	6 (12.8)	41 (87.2)	
Initial treatment provider			
Upper limb surgeon	5 (25)	15 (75)	0.448
General orthopedic surgeon	6 (13.6)	38 (86.4)	

Numbers within brackets represent the percentage within the same category

for displaced fractures, fixation results in a higher healing rate [10–12]. However, the open technique is superior to percutaneous fixation in the union rate, although percutaneous fixation is associated with less soft tissue disruption [13].

The longer the duration of the nonunion and the previously failed fixation, the greater the side effects [14]. Treatment of scaphoid nonunion aims to achieve healing, correct deformity, prevent osteoarthritis, and relieve symptoms [15]. Many options to treat nonunions, including percutaneous screw fixation for stable nonunions of less than six months [16]. Nonvascularized bone grafting is associated with an 80–90% union rate. Failed treatment of nonunion and presence of osteoarthritis can be managed with salvage options, including wrist denervation, radial styloidectomy, excision of the distal scaphoid pole, proximal row carpectomy, and scaphoid excision, as well as four corner and total wrist arthrodesis.

The high rate of nonunions in our cohort can be explained by our hand unit being a referral for complicated cases. Therefore, the included patients were already those who developed nonunion. In our practice, we switched from four-corner arthrodesis to proximal row carpectomy because of more complications and lower patient satisfaction in the four-corner arthrodesis group.

Acute scaphoid fracture treatment

In the case of undisplaced or minimally displaced (0.5 mm) scaphoid waist fractures, healing can be achieved in 90% after six weeks [17]. However, displaced and comminuted fractures are associated with instability and increased time to union [18].

However, there is a trend among many surgeons to treat minimally displaced scaphoid waist fractures through the minimally invasive technique of percutaneous fixation to expedite the patient's return to work or sport. However, fixation is associated with a high complication rate in the form of protruding hardware, infection, and an increased risk of scaphotrapezial osteoarthritis [13, 19].

A 0.5–1.5 mm fracture displacement requires prolonged immobilization for eight to ten weeks. Fracture instability requires surgical fixation, such as a comminuted fracture, Dorsal Intercalated Segment Instability (DISI), lateral intrascaphoid angle > 35°, or associated perilunate injury. Displaced scaphoid waist fractures (1.5 mm) are unstable and require fixation. Many surgeons consider a fracture displacement of > 1 mm for fixation [17, 20].

Fractures of the proximal pole are prone to an increased risk of nonunion and require a longer time to heal due to poor blood supply and the inherent instability of a small fracture fragment. A nondisplaced fracture is associated with a nonunion rate of 10–14%, while a displaced fracture can reach up to 50%. Therefore, a CT scan is recommended for such fractures to measure displacement. Conservative management requires prolonged immobilization for 10 weeks, while surgical fixation is performed through a dorsal approach to achieve reduction and secure fixation [21, 22].

The distal scaphoid fractures are often not displaced or only minimally displaced and with good vascularity, heal without complications after conservative treatment. A radiovolar tip tuberosity avulsion is treated with four weeks of immobilization, while an intra-articular distal scaphoid fracture requires longer immobilization of six weeks. Surgical treatment is considered for displaced fractures. However, it is difficult to determine the degree of displacement on an X-ray, and CT is required [23, 24].

The scaphoid union is usually evaluated by clinical and radiological examinations. However, persistent tenderness over the snuffbox can persist for years after healing. Like other intra-articular fractures, scaphoids heal by primary

bone healing without callus formation, which is sometimes difficult to assess on radiographs, making CT the study of choice to assess healing. Most scaphoid fractures unite after ten to 12 weeks of immobilization, which should be weighed against the risk of surgical treatment if early surgery is contemplated [24, 25, 13].

Dias et al. [13] conducted a randomized clinical trial comparing two treatment groups for acute scaphoid fractures. Eighty-eight patients with bicortical scaphoid fractures were randomized to treatment in two groups; the first group (44 patients) with early internal fixation using a Herbert screw without a cast, and the second group (44 patients) with conservative treatment for eight weeks with immobilization in a below-elbow cast with the thumb left free. The study found no clear overall benefit of early fixation of acute scaphoid fractures beyond a decrease in the rate of treatment change due to delayed healing at 12 weeks. However, early internal fixation of minimally displaced or undisplaced scaphoid waist fractures that would heal in a cast could lead to overtreatment of many such fractures and expose these patients to avoidable surgical risk. Therefore, they instituted a program of so-called aggressive conservative management, in which fracture healing was assessed after six to eight weeks of cast immobilization with plain radiographs and CT if necessary, and they recommended surgical fixation with or without bone grafting at a time if, at the fracture site, a gap is identified. This approach should result in fracture healing in over 95% of these patients.

Nonunion treatment

The treatment of scaphoid nonunion, especially after failed fixation, presents a challenge for surgeons because a previous operation complicates the evaluation of the patient and increases the technical difficulty of the second procedure. Treatment of nonunion aims to prevent collapse and progressive arthritis. Nonvascularized and vascularized bone grafts with fixation devices such as screws, pins, and plates can achieve reliable union rates. If a fracture does not heal after three months, a possible cause of the delay should be investigated, such as incorrect screw placement, insufficient compression across the fracture, inadequate fixation, and lack of appropriate bone grafting. When such causes are ruled out, immobilization can be continued for six months unless the patient is unwilling to accept prolonged treatment and is unacceptable at the risk of nonunion after prolonged treatment. An average four month application of pulsed electromagnetic fields in addition to immobilization has been shown to achieve union in 69% of cases [26].

Many surgeons consider early surgery after three months of conservative treatment with no evidence of clinical and radiographic healing, but most surgeons consider surgery at six months for fractures that have failed to unite. However, failed fixation was associated with additional reoperation risks, including hardware, reduced bone stock, scarring, prior surgical access, and osteonecrosis of the scaphoid. Nonunion surgical options include nonvascularized bone graft (NVBG), vascularized bone graft (VBG), arterialization, and plate fixation.

Nonvascularized bone graft

Nonvascularized bone graft from the distal radius and iliac crest with revision of screw fixation in cases of technical errors such as fracture malreduction and screw misplacement was the treatment of choice for scaphoid nonunion [27]. Restoring scaphoid length and alignment improves carpal mechanics and subsequently reduces osteoarthritis. Healing of NVBG occurs through insidious substitution and resorption. Therefore, prolonged union time and reduced stability during healing are to be expected [28]. In scaphoid nonunion after prior surgery, Cooney [29] described three different NVBGs; the first is a Russe inlay bone graft, representing a cancellous iliac bone graft placed in a generous groove; this graft is used in patients with preserved bone and minimal humpback deformity and results in a 50% union rate. The second graft is an intermediate wedge graft, representing a bicortical wedge of the iliac crest used to reduce scaphoid shortening. The third graft is the Maltese Cross graft, a tricortical iliac graft that is cruciform in shape and is used to reduce humpback deformity. Cooney reported 83% union in the last two grafts.

Vascularized bone graft

VBG is more technically challenging than NVBG, but it is assumed that VBG improves the biology of healing and aid in the revascularization of the scaphoid in osteonecrosis, particularly the necrotic proximal pole [30]. The most commonly used VBG is from a distal radius and rotated on a pedicle. The vascularized distal radius dorsal graft is based on either the 1,2 or 2,3 intracompartmental supraretinacular artery, while the volar bone graft is based on the volar carpal artery [31]. Other sources for VBG include a graft harvested from the second metacarpal, based on the second dorsal metacarpal artery or the dorsal intercarpal arch. Similar to the distal radius vascularized graft, the vascularized second metacarpal graft can be rotated on its pedicles and it has the advantage that the vascular pedicle does not cross the mobile wrist joint and theoretically has a lower risk of kinking. Vascularized bone grafts from the head of the index and base of the metacarpals have also been described [32, 33].

Free vascular bone grafts such as the medial femoral condyle based on a pedicle from the descending or superior medial geniculate vessels [34] and the iliac bone graft with branches from the deep iliac circumflex vessels as pedicles

[28] have the advantage of greater structural support. However, morbidity at the donor site and a more complex microsurgical technique are disadvantages. The vascularized ulnar bone represents a corticocancellous graft taken with its periosteum from the medial distal third of the ulna, with the ulna based on the ulnar artery as the pedicle [35]. It has the advantages of enclosing a large periosteal layer with the graft and reducing morbidity at the donor site. However, this graft requires sacrificing the ulnar artery and reconstructing it with an interposition vein graft.

Other techniques

In case of limited VBG due to previous surgeries, arterialization is direct implantation of the second dorsal intermetacarpal artery or the dorsal index artery into the scaphoid has also been described. Such an option can be used in failed previous nonunion surgeries; however, it carries a high reoperation rate [36, 37].

Plate fixation increases torsional stability at the nonunion site, possibly leading to the union. However, plating has several disadvantages, including increased soft-tissue dissection, hardware impingement on articular cartilage, and the potential need for hardware removal [38].

Salvage procedures

Long-term nonunion leads to advanced carpal collapse and subsequent progressive arthritis, defined as scaphoid nonunion advanced collapse (SNAC), which manifests as a painful wrist with a limited range of motion and reduced grip strength. Degenerative changes in long-standing scaphoid nonunion occur first at the radio-scaphoid joint, followed by pan-carpal and mid-carpal arthritis. These conditions are treated based on the location and degree of the arthritic changes. When the arthritis is limited to the radioscaphoid articulation (SNAC I), resection of the distal pole of the scaphoid with radial styloidectomy resulted in satisfactory pain relief, range of motion, and grip strength [39–41].

Two motion-sparing procedures can be performed in more advanced arthrosis involving scaphocapitate (SNAC II) and periscaphoid arthrosis (SNAC III). The first is Proximal Row Carpectomy (PRC) which mandates no arthrosis in that radio lunate articulation, and the second is Four-corner Arthrodesis (FCA), which requires arthrosis sparing of proximal capitate and lunate fossa [42–44]. The outcome of both procedures was compared in many studies and found comparable results in pain reduction and functional outcomes [45, 46]. However, secondary to higher cost and metal impingement in FCA, we shifted from FCA to PRC in our institute. In panarthritis conditions, total wrist arthrodesis is the treatment of choice and the treatment for the progression of FCA and PRC [47].

The study has certain limitations that should be acknowledged. Firstly, the sample predominantly comprises cases involving patients referred with established nonunion, explaining our patients' higher prevalence of nonunion. Consequently, it is essential to recognize that the study sample does not represent all scaphoid patients.

Additionally, it is worth noting that a significant proportion of the patients in our sample are military members with chronic injuries. They regularly attend clinics for medical assessments mandated by their units or to obtain recommendations for their duties, and sometimes even for potential secondary benefits. This unique demographic composition of the sample should be considered when interpreting the study's findings.

Conclusion

Our hand clinic primarily deals with complex scaphoid fracture cases referred from military hospitals, while most acute trauma cases are initially treated at local hospitals. The cases referred to our clinic often involve nonunion or other injuries like perilunate dislocation, which explains the lower number of acute scaphoid fractures treated in this study. Additionally, our study reported a lower union rate compared to the existing literature because it included patients who already had nonunion or delayed union when referred to the hand clinic. Many of these patients required salvage procedures due to advanced arthritis, and some had to wait for treatment due to the hand unit's long waiting list or had tolerable symptoms and did not immediately require treatment at presentation. Consequently, our study results may not accurately represent our population's true incidence of scaphoid fracture and union rates. To gain a more comprehensive understanding of scaphoid outcomes in Jordan, longer-term and multicenter studies are needed.

We recommended early referral of patients with delayed union to decrease the prevalence of SNAC development. Additionally, we recommend aggressive conservative management of the scaphoid fractures by the general orthopaedic surgeon and follow patients with clinical evaluation and CT scan at three months. If there is no sign of healing, we recommend referring the patient to the hand unit.

Author contributions All authors contributed to the study conception and design, material preparation, data collection, and analysis. All authors read and approved the final manuscript.

Data Availability Available upon request.

Declarations

Ethics approval This study has been approved by the local ethical committee of the Jordanian Royal Medical Services under study ID: RMS 6-2022.

Informed consent Not required

Conflict of Interest The authors declare no competing interests.

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