Resection arthroplasty for treatment of nonunion and avascular necrosis of the distal scaphoid

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Background
Posttraumatic osteonecrosis of distal pole of scaphoid is extremely rare, with only few reported cases so far. The purpose of this study was to evaluate the clinical and radiographic results of treatment of distal scaphoid nonunion and avascular necrosis with resection arthroplasty in adult patients.
Patients and methods
From 2008 to 2013, seven patients presented to the authors for treatment of nonunion and avascular necrosis of the distal part of the scaphoid following distal pole fracture. Pain was evaluated by means of the visual analog scale. The time to return to previous activities and work status were documented. Wrist function was measured according to the Mayo Modified Wrist Score. Carpal height index (Nattrass modification) and radiolunate angle were recorded.
Results
Follow-up period ranged from 24 to 60 months. Three patients had an excellent result (43%), and four had a good result (57%). There is significant postoperative improvement of pain, range of wrist motion, and Mayo Modified Wrist Score. All patients returned to their previous occupations within 2 months. There were statistically significant increases in the radiolunate angle and no significant decrease in Nattrass carpal height.
Conclusion
Resection of the distal scaphoid appears to be a valid technique and to constitute an alternative to vascularized bone graft or limited intercarpal arthrodesis for the treatment of scaphoid nonunion with avascular necrosis of distal pole.
Level of evidence: level IV, case series.

Keywords:

avascular necrosis of distal scaphoid pole, resection arthroplasty, scaphoid nonunion, surgical treatment

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Introduction

Scaphoid is the most common carpal bone to fracture, and its diagnosis is frequently delayed and is more prone to osteonecrosis and nonunion [1]. The incidence of osteonecrosis following fractures of the scaphoid was reported between 13 and 50% with higher chances in fractures of proximal one-fifth of the scaphoid, and it usually occurs in proximal pole [2–5]. Only few published reports could be traced in the literature reporting posttraumatic osteonecrosis of distal pole of scaphoid [6,7].

Treatment of scaphoid nonunion remains a challenging problem, especially in the setting of avascular necrosis. Theoretically, the use of pedicled vascularized bone grafts, which help revascularize ischemic bone, should improve the union rate and time to union [8,9].

Studies in the literature on vascularized bone grafts [10–12] are not only characterized by considerable variability in union rates (27–100%) but are also limited by the small number of patients, the inadequate assessment of vascularity, the variable proportion of avascular necrosis, and the lack of postoperative imaging studies to confirm radiographic findings.

The purpose of this study was to evaluate the clinical and radiographic results of treatment of distal scaphoid nonunion and avascular necrosis with distal scaphoid resection arthroplasty in adult patients.

Patients and methods

From 2008 to 2013, seven patients presented to the authors for treatment of nonunion and avascular necrosis of the distal part of the scaphoid following distal pole fracture. The study was approved by the

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institutional ethics committee in the Department of Orthopedic Surgery, Faculty of Medicine, Minia University, Minia, Egypt. All patients had an established nonunion of the scaphoid for more than 6 months. Patients with systematic inflammatory disease (rheumatoid arthritis) or idiopathic avascular necrosis (Preiser's disease) and patients who had already developed scaphoid nonunion advanced collapsed wrist were excluded.

The mean age at the time of the surgery was 47 years (30–66 years). There were two woman and five men. The dominant wrist was affected in three patients, and the nondominant wrist was affected in the other four (Table 1).

The mechanism of injury was a sports injury in two patients, and a ground-level fall on the outstretched hand in five patients.

Two types of scaphoid fracture have been outlined by Nakamura *et al.* [13]. One is the volar type, in which the fracture line runs perpendicular to the scaphoid axes and is located at the waist and more distally in the scaphoid. The other is the dorsal type, in which the fracture line displays a horizontal orientation, and the fracture line runs perpendicular to the forearm axes and is positioned more proximally. All our patients were volar type.

Preoperative evaluation

The preoperative clinical evaluation included assessment of pain by means of a visual analog scale and documentation of wrist motion in terms of flexion, extension, and ulnar and radial deviation. The data were summarized with the Mayo Modified Wrist Score. Imaging of the scaphoid included radiographic examination of both wrists (posteroanterior views in neutral rotation, lateral, and special scaphoid views). All patients had enhanced MRI scans before surgery for detection of avascular necrosis (AVN) of the distal pole, which was confirmed by postoperative histopathological examination of excised distal pole.

Surgical technique

All operations were performed under local intravenous anesthesia (Bier block). The patient is positioned supine with the extremity on a radiolucent arm table. The arm was cleansed with antimicrobial solution and draped in a sterile manner. Exsanguination was performed with an Esmarch bandage with a pneumatic tourniquet applied to the upper arm.

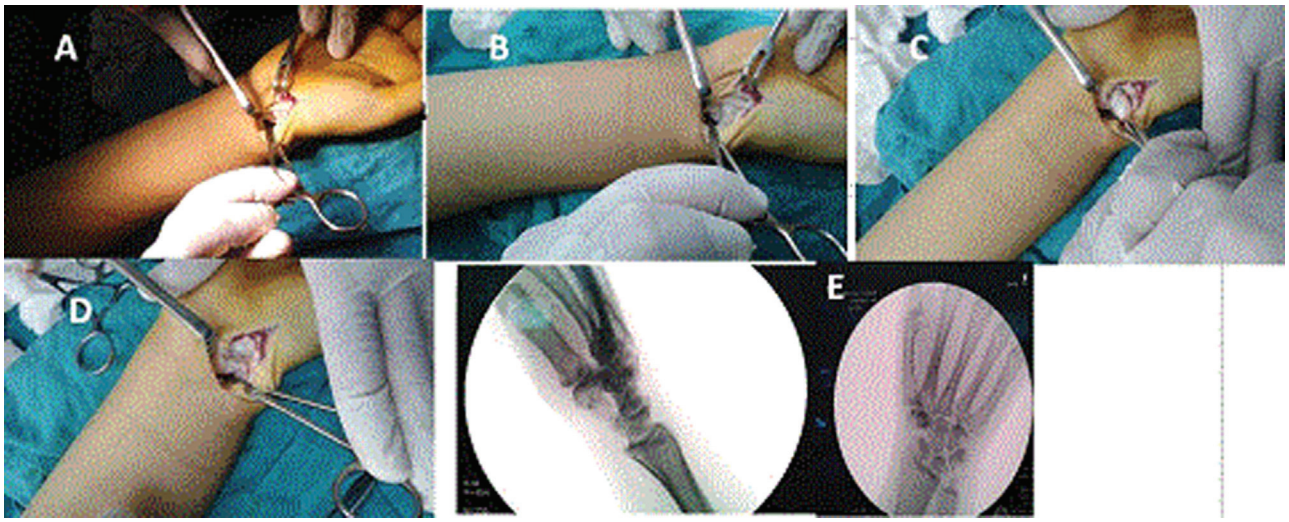
A standard volar approach was used, through a reversed L-shaped skin incision (Fig. 1a). The nonunion and

Table 1 Functional outcome

Patients	Sex	Age	Side	VAS score		Return to work (months)	F/E arc (deg.)		U/R arc (deg.)		Grip strength (kg)		RL angle (deg.)		MMWS		Outcome
				Pre	Postop		Pre	Postop	Pre	Postop	Affected	Normal	Pre	Postop	Pre	Postop	
1	F	30	R	5	1	2	57	95	30	47	38	52	20	30	70	80	Good
2	M	44	L	7	0	1.5	77	130	28	62	65	68	8	13	20	100	Excellent
3	M	51	L	3	0	3	93	104	43	55	34	45	14	23	70	85	Good
4	M	36	R	2	0	2	121	133	45	63	50	55	9	14	65	100	Excellent
5	F	54	L	3	0	2	95	105	45	48	35	48	13	20	60	80	Good
6	M	66	L	7	0	1.5	116	124	56	60	47	57	12	15	65	95	Excellent
7	M	48	R	6	1	2	96	125	48	62	42	55	8	18	60	90	Good

All postoperative measurements were obtained during the patient's latest follow-up (24–48 months after the procedure). F/E, flexion-extension; MMWS, Mayo Modified Wrist Score; Postop, postoperatively; Pre, preoperatively; RL angle, radiolunate angle; U/RD, ulnar-radial deviation; VAS, visual analog scale.

Figure 1



(a) A standard volar approach through a reversed L-shaped skin incision. (b) The nonunion and the scaphotrapeziotrapezoid joint were exposed. (c) The distal fragment was removed by inserting a key periosteal elevator in the scaphotrapeziotrapezoid joint and lifting the distal fragment using the trapezium and trapezoid as a fulcrum while incising the soft-tissue attachments. (d) Distal scaphoid pole was excised. (e) A fluoroscopy unit was used to confirm complete excision of distal scaphoid.

the scaphotrapeziotrapezoid joint were exposed (Fig. 1b). The distal fragment was removed by inserting a key periosteal elevator in the scaphotrapeziotrapezoid joint and lifting the distal fragment using the trapezium and trapezoid as a fulcrum while incising the soft-tissue attachments (Fig. 1c, d). A fluoroscopy unit is used to confirm complete excision of distal scaphoid (Fig. 1e). The wound was closed in layers.

The patients were immobilized in a short arm thumb cast for 3 weeks, after which all patients participated in physiotherapy program during postoperative rehabilitation. Motion is the early goal followed by graduated strengthening.

Outcome measures

Postoperative posteroanterior, lateral, and scaphoid view radiographs were obtained at 6 and 12 weeks, at 6 and 12 months, and at the latest follow-up.

Carpal height index (Nattrass modification) [14] was recorded from both the preoperative and the latest follow-up radiographs (a minimum of 2 years apart) when the functional and radiographic result was adequately established. In addition, the radiolunate (RL) angle was measured from both the preoperative and the latest follow-up radiographs (Fig. 2).

Pain was evaluated by means of the visual analog scale, with scores ranging from 0 (no pain) to 10 (very severe pain). The ranges of wrist motion and grip strength were assessed in both the affected and normal hands. The time to return to previous activities and work status were documented. Wrist function was measured according to the Mayo Modified Wrist Score, which consists of pain rating, work status, range of motion, and grip strength, and the functional outcome was ranked as excellent (91–100), good (80–90), fair (65–79), or poor (<65).

The differences between the results evaluated preoperatively and at final follow-up were tested by the Student's t test and the χ^2 test. The results were considered to be significant if P value less than 0.05.

Results

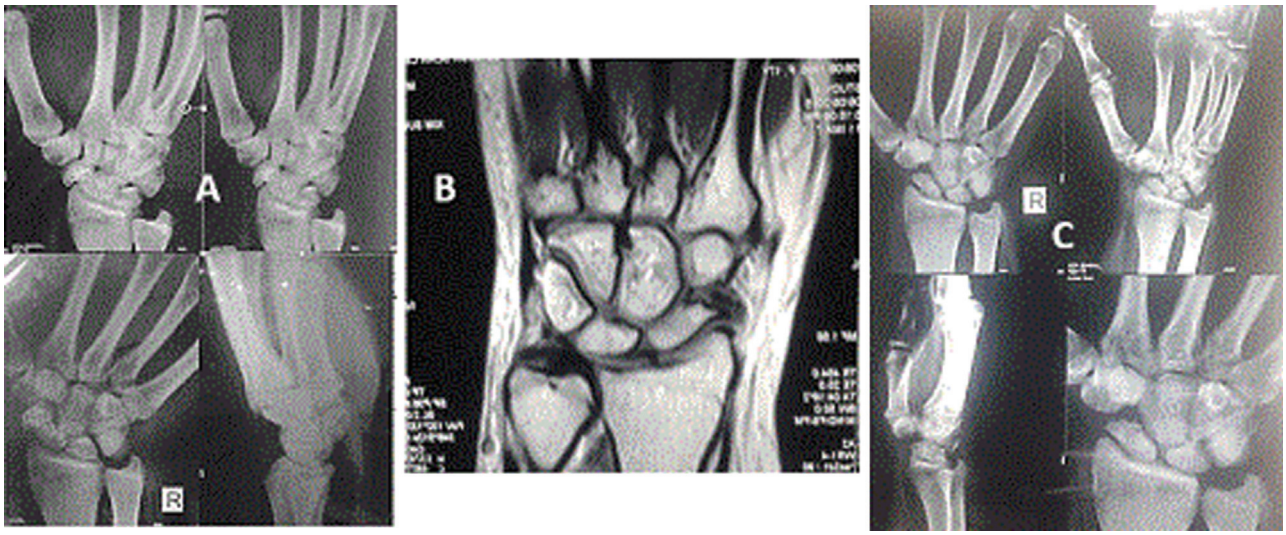
Follow-up period ranged from 24 to 60 months, with a mean of 36 months.

Functional outcome

Preoperatively, with the use of the visual analog scale, all patients had experienced pain ranging from 2 to 7 (mean, 4.7) during daily activities. At the latest follow-up, the mean visual analog scale score was 0.3 (range, 0–1), which was significantly better than the preoperative score (P=0.0001) (Tables 1 and 2).

At the latest follow-up, the flexion-extension arc was 116.6° and the ulnar-radial deviation arc was 56.7°. There was statistically significant difference between the postoperative and preoperative values of the flexion-extension or radial-ulnar deviation arc (P=0.04 and 0.008, respectively) (Table 2).

Figure 2



(a) Preoperative scaphoid views of a patient showing nonunion with avascular necrosis of distal pole of scaphoid (patient 1) (Table 1). (b) MRI confirms diagnosis of avascular necrosis distal scaphoid pole. (c) At the latest follow-up (after 3 years), she had almost complete resolution of pain (visual analog scale score of 1), flexion-extension arc at 76% of normal, 73% of his normal contralateral grip strength, and a good outcome according to Mayo Modified Wrist Score (80 points).

Table 2 Statistical analysis of preoperative and postoperative values

	Preoperative value	Postoperative value	*P* value
VAS score	4.7±2	0.3±2.7	0.0001
Flexion-extension arc (deg.)	93.6±21.9	116.6±21.6	0.04
Ulnar-radial deviation arc (deg.)	42.1±9.9	56.7±11.1	0.008
Mayo Modified Wrist Score	58.6±17.5	90±21	0.001
RL angle	12±4.3	19±6.2	0.03
Nattrass carpal height index	1.62±0.1	1.59±0.1	0.06

[a]Values are presented as mean±SD. All postoperative measurements were obtained during the patient's latest follow-up (24–60 months after the procedure). RL, radiolunate angle; VAS, visual analog scale.

Grip strength was 81.8% of that of the normal hand, which was not significantly reduced (*P*=0.1) (Table 1).

All patients returned to their previous occupations within 1.5–3 months (average, 2 months) of their surgery (Table 1).

The Mayo Modified Wrist Score was used for summarizing the subjective and objective data. The average score increased significantly from 58.6 preoperatively to 90 at the final follow-up (*P*=0.001) (Table 2). Three patients had an excellent result (43%), and four had a good result (57%) (Table 1).

Radiographic evaluation

The mean RL angle was 12° (range, 8–20°) preoperatively and 19° (range, 13–30°) postoperatively. The increase in the RL angle was statistically significant (*P*=0.03) (Tables 1 and 2). There was no significant decrease in Nattrass carpal height index (*P*=0.06) (Table 2).

Discussion

The osteonecrosis of proximal pole and nonunion are common complications of scaphoid fractures owing to its precarious blood supply. Blood supply to scaphoid comes mainly (70–80%) through the dorsal ridge vessels, which arise from the radial artery or the intercarpal artery and supply the scaphoid from distal to proximal direction after entering small foraminas on the dorsal aspect of its waist. Smaller contribution (20–30%) comes from the laterello-volar vessels, branches from radial artery, or its superficial palmer branch, which enters the scaphoid through the tubercle and again supplies the proximal pole from distal to proximal direction [4,15].

Hence, any fracture through the waist tends to leave the proximal fragment avascular, resulting in high rates of avascular necrosis of proximal pole. The site of entry of the dorsal vessels is variable – they enter distal to the waist in 14%, at the waist in 79%, and proximal in 7% [16]. If all the dorsal vessels enter the bone proximal to the waist, a fracture through the waist can lead to

osteonecrosis of the distal fragment [17]. Even then, posttraumatic avascular necrosis of distal pole of scaphoid is an extremely rare occurrence, with only few reported cases so far [6,7].

Scaphoid nonunions are challenging cases that first must be identified and then treated based on stability, collapse, and vascularity. Unstable nonunions are identified on the basis of collapse of the scaphoid into the 'humpback' deformity, with increased intrascaphoid and scapholunate angles [18].

Treatment options for salvage of scaphoid nonunion presenting with dorsal intercalated segment instability (DISI) deformity and/or arthritis have included proximal-row carpectomy, scaphoid excision accompanied by intercarpal arthrodesis, or total wrist arthrodesis. Malerich *et al.* [19] introduced distal scaphoid resection arthroplasty as a simple and effective procedure. They reported favorable outcomes with 2–8 years of follow-up, except in patients with preoperative lunate-capitate joint arthritis, who experienced aggravation of arthritic changes. Excision arthroplasty by removal of the distal pole of the scaphoid is an alternative to scaphoid-trapezium-trapezoid fusion.

All our patients were volar type according to Nakamura *et al.* [13]. In a biomechanical study by Matsuki *et al.* [20], in the volar-type nonunion model (V model), the fracture line runs perpendicular to the scaphoid axes. Both the dorsal intercarpal (DIC) ligament and the dorsal scapholunate interosseous ligament attach to the proximal fragment. In the dorsal-type nonunion model (D model), the fracture line runs perpendicular to the forearm axes, the DIC ligament attaches to the distal fragment, and the dorsal scapholunate interosseous ligament attaches to the proximal fragment.

In the VR model, overall force transmission through the radioulnocarpal joint was unchanged after fragment resection, as the DIC ligament stabilizes the proximal fragment. However, pressure concentration at the dorsal ridge of the scaphoid fossa slightly decreased without any significant alterations in an MC joint pressure distribution pattern. They recommend resection of the distal fragment for volar-type nonunion, which can resolve the abnormal pressure concentration on the scaphoid fossa without overloading the capitate.

Pain relief was a major benefit in this series. At the final follow-up, 100% of patients had improvement in their visual analog scale score and 71.5% of patients had complete resolution of pain. The postoperative wrist range of motion in our series showed significant improvement in relation to the preoperative values. Grip strength did not significantly decrease when compared with the contralateral normal wrist.

In the present series, distal scaphoid resection arthroplasty resulted in a significant improvement of wrist function, as assessed by the Mayo Modified Wrist Score, with 100% of patients achieving an excellent or good outcome. All patients returned to their previous level of activities and work status within 2 months.

Vance *et al.* [21] had an excellent study; they followed up the exact same cohort of patients in the original publication by Malerich and colleagues in New York in 1999. Amazingly, 18 of the 19 patients were available for follow-up. At an average follow-up of 14 years, only two patients required a salvage procedure and the others were pain free and satisfied. Flexion-extension was 80% of the normal wrist, and grip strength remained good at 76% of the normal wrist. Although there were some progressive arthritic changes on radiography, clinical intervention was not necessary.

There is significant increase in the RL angle in the current study. Although this malalignment appeared to cause no symptoms, its long-term consequence is unknown.

Malerich and colleagues evaluate the long-term results of distal scaphoid excision for degenerative arthritis secondary to scaphoid nonunion in 19 patients from 1987. The mean follow-up was 15 years. The outcomes of this procedure include increased grip strength and total arc of motion, a small decrease in revised carpal height ratio, and a small increase in RL angle. Two patients failed distal scaphoid resection arthroplasty necessitating proximal-row carpectomy (one) and wrist arthrodesis (one) for recalcitrant pain. More than half of the remaining patients developed midcarpal arthritis on radiographs that was asymptomatic. No patients developed RL arthritis. This study showed that distal scaphoid resection arthroplasty produced favorable, long-term clinical results and did not result in noteworthy wrist collapse. Midcarpal arthritis, which may develop after the procedure, did not cause appreciable deterioration in patient outcomes [22].

Garcia-Elias *et al.* [23] reported that excisional arthroplasty might worsen instability and cause DISI deformity in patients with dorsal midcarpal instability owing to the termination of the flexion moment

exerted on the scaphoid and the unopposed extension movement on the lunate caused by the resection of the distal pole of the scaphoid.

Conclusion

Resection of the distal scaphoid appears to be a valid technique and to constitute an alternative to vascularized bone graft or limited intercarpal arthrodesis for the treatment of scaphoid nonunion with avascular necrosis of distal pole. This technique helps to avoid complications such as nonunion, impingement, motion limitation, secondary instability, and mechanical stress with consequent arthritic changes. Distal scaphoid resection is a great option because it burns no bridges, and the usual salvage procedures can still be done later.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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