

Original Research Article

Clinico-radiological assessment of vascularized muscle pedicle bone graft in scaphoid non-union

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ABSTRACT

Background: The aim of this study was to assess the clinico-radiological outcome of vascularised muscle pedicle bone graft in scaphoid non-union.

Methods: 16 men and 8 women with non-union of the scaphoid involving the proximal pole (n=6), waist (n=14), and distal pole (n=4) were randomly assigned to receive a vascularized muscle pedicle bone transplant with Herbert screw fixation. Their ages ranged from 18 to 45 (mean 32). Eight months was the average non-union period (range: 4–12 months).

Results: The mean follow-up duration was 18 months. 20 out of 24 were united. In 16 out of 24 cases, the scapholunate and radiolunate angles were corrected. 4 of 24 did not achieve union, and 3 of those were associated with proximal pole absorption. During pedicle dissection, there was no iatrogenic fracture or hardware malfunction.

Conclusions: Scaphoid non-union has been successfully treated with vascularized bone grafts, particularly in cases where the non-union has an avascular proximal pole or has not healed following prior surgery.

Keywords: Scaphoid non-union, Avascular proximal pole, Muscle pedicle bone graft

INTRODUCTION

Almost 10% of scaphoid fractures that are treated non-operatively may not heal, leading to carpal collapse and ultimately radiocarpal osteoarthritis.¹⁻³ Success rates for surgical fixations for scaphoid non-union range from 70 to 90%.^{4,5} A 90% success rate can be achieved with Russe inlay bone grafting or iliac crest bone grafting with screw fixation.⁶ Because of impaired vascularity, non-union is more likely in proximal pole fractures. Conventional bone grafting may not work in cases where the fracture site is entirely avascular, exhibits necrotic bone, and shows no signs of bleeding.^{4,5,7,8}

The non-union site may get a source of angiogenic and osteogenic factors from vascularized bone grafts.^{6,7} Vascularized pedicled bone grafts have been utilized to treat non-union of the scaphoid, pronator quadratus, and

anterior side of the wrist and forearm.⁹⁻¹¹ Additional salvage operations consist of posterior and anterior interosseous neurectomy or radial styloidectomy along with partial scaphoid excision. Limited intercarpal fusion, proximal row carpectomy, scaphoid excision and 4-corner fusion, and whole wrist fusion are among the more intricate treatments.¹²

METHODS

In a sample of 24 cases of non-union scaphoid between 2022 and 2024, 16 of the cases involved men and 8 involved women, ages 18 to 45 (mean 32 years), with non-union of the scaphoid involving the proximal pole (n=6), waist (n=14), and distal pole (n=4). A vascularized muscle pedicle bone graft with Herbert screw fixation was randomly assigned to them. Informed consent of each patient was obtained. The mean duration of non-union was

8 months (4-12 months). There was a reduction in mean range of motion. Dorsiflexion and radial deviation were the most impacted motions. Radiographs in lateral, antero-posterior, and 30° ulnar-deviation were obtained. The scapholunate angle, radiolunate angle, and intrascaphoid angle were measured.

Technique

To reveal the non-union, a volar incision was given over the scaphoid tuberosity and the distal radius (Figure 1). The radio-scapho-capitate ligament complex was split, although it was kept for potential future restoration of the muscle pedicle. Using a power burr, the ends of the sclerotic bone were freshened to create an oval cavity that was 10 to 20 mm long and parallel to the scaphoid axis. After identifying the pronator quadratus, a block of bone graft measuring 15 to 20 mm long was formed at the graft's distal insertion on the distal radius, near the abductor pollicis longus tendon. Kirschner wire holes were delineated around the graft's perimeter to aid in separation using a fine osteotome. To ensure a 20 mm thick pedicle, the pronator quadratus muscle was dissected toward the ulna with caution to avoid severing it from the obtained bone graft. The ulnar origin of the pronator quadratus was freed subperiosteally from the ulna through an extra incision over the distal ulna if the muscle was too tight to permit easy transfer of the pedicled bone. With the thumb under traction, the proximal and distal scaphoid segments were meticulously positioned. By using this technique, any intercalated segment instability is fixed and the grafted bone can be carefully placed into the scaphoid cavity (Figure 2). A Herbert's screw was inserted at the scaphoid tuberosity to secure the graft and the proximal and distal scaphoid segments, avoiding the radiocarpal joint (Figure 3). A long-arm thumb spica cast was placed after the skin closure.



Figure 1: Skin incision.

Postoperative care

After one month, the long arm thumb spica cast is removed and replaced with a short arm cast for an additional month. Radiographs and, if in question, tomograms are used to assess the union after two months. After another month or

two of bracing the wrist in a functioning position, physical activities are started.



Figure 2: Intra-op clinical photograph showing scaphoid being stabilized with guide wire with vascularized pedicle bone graft fitted snugly in the cavity.



Figure 3 (a & b): Post-op x-ray showing fixation with Herberts screw.

RESULTS

Table 1 presents the demographic data, clinical characteristics, and outcomes of the study participants. The mean age of the participants was 29.46 ± 6.95 years, and the average duration of non-union was 9.67 ± 3.38 months. Regarding fracture site distribution, the majority of fractures occurred in the waist (58.33%), followed by the proximal pole (25.00%) and distal pole (16.67%). These findings provide an overview of the participant characteristics and fracture patterns in the study cohort.

Table 1: Demographic data, clinical characteristics and outcome of the study participants.

Characteristics	Values
Age (mean $\pm$ SD)	29.46 $\pm$ 6.95
Duration of non-union in months (mean $\pm$ SD)	9.67 $\pm$ 3.38
Site of fracture (frequency/percentage)	
Waist	14 (58.33)
Proximal pole	6 (25.00)
Distal pole	4 (16.67)

Table 2 compares the pre-operative and post-operative findings of scaphoid non-union. Significant improvements were observed in all range of motion parameters following surgery. Dorsiflexion increased from $49.83 \pm 4.48^\circ$ pre-operatively to $59.42 \pm 4.41^\circ$ post-operatively ($p < 0.001$). Palmar flexion improved from $53.04 \pm 3.44^\circ$ to $57.13 \pm 3.14^\circ$ ($p < 0.001$), radial deviation increased from $9.71 \pm 1.52^\circ$ to $14.21 \pm 1.53^\circ$ ($p < 0.001$), and ulnar deviation improved from $23.17 \pm 2.60^\circ$ to $28.17 \pm 2.06^\circ$ ($p < 0.001$). All changes were statistically significant, indicating positive outcomes following surgical intervention.

Table 2: Comparison of pre-op and post-op findings of scaphoid non-union.

Range	Pre-op range (mean $\pm$ SD)	Post-op range (mean $\pm$ SD)	P value
Dorsiflexion	49.83 ± 4.48	59.42 ± 4.41	<0.001
Palmar flexion	53.04 ± 3.44	57.13 ± 3.14	<0.001
Radial deviation	9.71 ± 1.52	14.21 ± 1.53	<0.001
Ulnar deviation	23.17 ± 2.60	28.17 ± 2.06	<0.001

Table 3 presents the comparison of the percentage change in different range of movements following surgery. Significant improvements were observed in all movement parameters, with dorsiflexion showing an average change of $18.88 \pm 3.28\%$ ($p < 0.001$). Palmar flexion increased by $7.82 \pm 3.67\%$ ($p < 0.001$), radial deviation showed a substantial change of $48.06 \pm 16.39\%$ ($p < 0.001$), and ulnar deviation improved by $21.32 \pm 8.74\%$ ($p < 0.001$). All changes were statistically significant, indicating considerable functional improvement post-operatively.

Table 3: Comparison of percentage of change in the different range of movements.

Range	Change in percentage	P value
Dorsiflexion	18.88 ± 3.28	<0.001
Palmar flexion	7.82 ± 3.67	<0.001
Radial deviation	48.06 ± 16.39	<0.001
Ulnar deviation	21.32 ± 8.74	<0.001

The follow-up period was 18 months on average. Union was achieved in 20 of 24 cases. Correction of the scapholunate and radiolunate angles was attained in 16 out of 24 cases (union). The scapholunate and radiolunate angles were not fully corrected in 8 of 24 cases (union). 4 of 24 cases landed in non-union, 3 of those were associated with proximal pole absorption. During pedicle dissection there was no iatrogenic fracture or hardware malfunction.

The average ROM of the wrist improved after operation. Dorsiflexion increased from 50 degrees to 59.4 degrees, planter-flexion from 55 degrees to 62 degrees, radial

deviation from 9.3 degrees to 14 degrees and ulnar deviation marginally improved from 25 to 28 degrees after surgery. If average percentage of increase in range of motion after surgery is taken into consideration, dorsiflexion was increased by 19%, palmar flexion was increased by 7.8%, radial deviation was increased by 48% and ulnar deviation was increased by 21.3%.

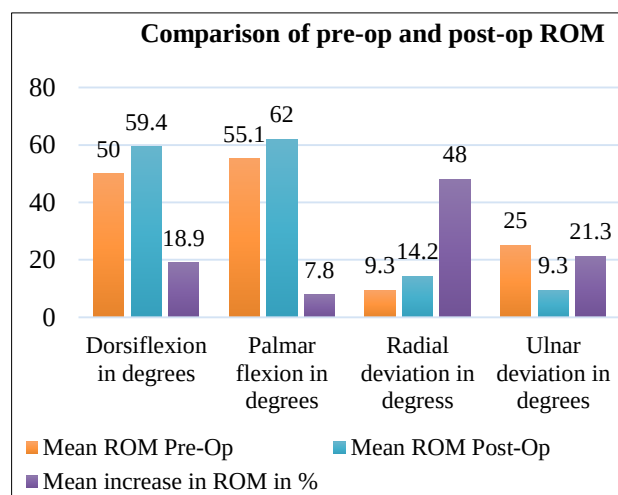


Figure 4: Comparison bar graph of pre-op and post-op ROM.

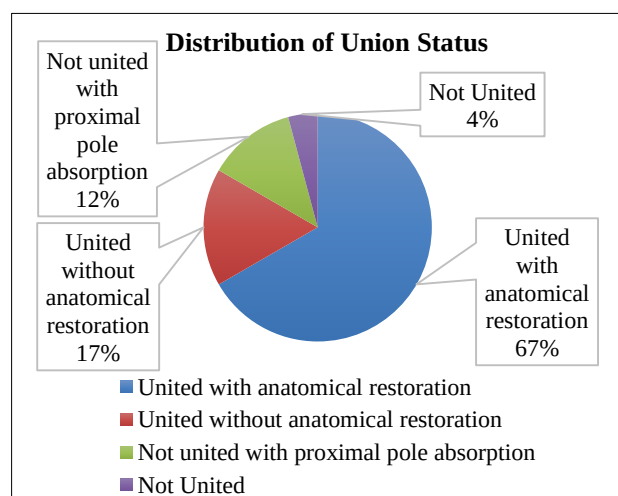


Figure 5: Pie chart showing the distribution of union status.

Table 4 shows the distribution of union status across different fracture sites. The total number of fractures was 24, with fractures in the distal pole (4), proximal pole (6), and waist (14). Union status was categorized as "not united," "not united with proximal pole absorption," "united with anatomical restoration," and "united without anatomical restoration." For the distal pole, 2 fractures were united with anatomical restoration, and 2 were united without anatomical restoration. In the proximal pole group, 3 fractures were not united with proximal pole absorption, and 1 was united with anatomical restoration. The waist group had the highest number of fractures, with

9 united with anatomical restoration, and 4 united without anatomical restoration. The p value of 0.04 suggests a statistically significant association between union status and fracture site.

Table 4: Distribution of union status.

Union status	Site of fracture			
	Distal pole	Proximal pole	Waist	Total
Not united	0	0	1	1
Not united with proximal pole absorption	0	3	0	3
United with anatomical restoration	2	1	9	12
United without anatomical restoration	2	2	4	8
Total	4	6	14	24

P value=0.04

DISCUSSION

Vascularized bone grafting (VBG) is indicated for proximal pole non-union and AVN of the proximal pole. Both the presence of AVN on MRI and the lack of punctate bleeding sites from the proximal pole after surgery are indicators of AVN.

It is difficult to place the Herbert screw accurately with a free-hand technique; implant malposition may be avoided by bending the wrist and using the thumb's axis as a guide. All non-union cases in an early Herbert screw fixation were unable to achieve union without bone grafting.¹³ However, the position of the guidewire cannot be confirmed by fluoroscopic means because of the bent wrist. By combining bone transplantation with Herbert-screw fixation, 25 of the 26 patients with scaphoid non-union were able to achieve union. The follow-up period was short, nevertheless, and trabeculation above the fracture line was identified as union on two of the four radiographs.¹⁴

After an average follow-up of 14 months, the mean palmar flexion, dorsiflexion, radial deviation, and ulnar deviation of 33 scaphoid non-union patients treated with Herbert screws, bone grafting, or both were 8°, 61°, 20°, and 35°, respectively, and the grip strength was the same as the uninjured hand.¹⁵

One safe and effective treatment for symptomatic nonunion of the scaphoid is the Russe inlay bone grafting operation.¹⁶ The volar technique helps to rectify any flexion deformity and reduces harm to the blood supply.

Russe in 1960 reported union rates to be 20/22.¹⁶ Jiranek et al, Stark et al and Cooney et al revealed union in 21 out

of 26 (in 7 to 18 years), 147 out of 151 (in one to 10 years), and 38 out of 44 (in 12 to 163 months) respectively.¹⁷⁻¹⁹

Vascularized bone grafts can maintain the carpus's natural structure, maximizing anatomic motion and lowering the chance of collapse and degenerative change. There is very little morbidity because the grafts can be acquired with just one incision. The volar carpal artery begins its journey along the volar aspect of the radius at the level of the radial styloid, branches off from the radial artery at the distal edge of the pronator quadratus, and culminates in a T-shaped anastomosis. During dissection, this branch's location is constant and noticeable. In our study we studied the outcome of vascularized pedicle bone graft on non-union scaphoid fracture in 24 patients. The average mean follow-up was 18 months. We found that majority of patients achieved union with or without anatomical restoration. This suggests that the treatment protocols are generally effective in promoting bone healing. Of those which achieved union majority were waist type fractures. Some patients have not achieved union, particularly those with fractures at the proximal pole or where proximal pole absorption is noted. This may indicate challenges in treatment efficacy for specific fracture types. Overall, there is a notable improvement in range of motion post-operatively across all measured parameters (dorsiflexion, palmar flexion, radial deviation, ulnar deviation). This indicates that despite the challenges in union for some patients, the surgical interventions have generally been successful in restoring functional mobility of the wrist.

The limitation of this study is that it lacks detailed information on the specific surgical techniques used, patient comorbidities, or complications, which could further influence outcomes.

So, in brief the outcomes suggest that this surgical intervention is generally effective in promoting fracture healing and improving wrist function. Fractures located at the waist of the scaphoid generally have better outcomes compared to those at the proximal pole or with proximal pole absorption, which may require more tailored treatment approaches. While age and duration of non-union are noted, their specific impact on outcomes would require further statistical analysis to determine correlations with union and functional outcomes.

CONCLUSION

A combination of Herbert screw fixation and bone graft always produces superior results than either technique alone. To further enhance vascularity in handling such a complex scenario, vascularized muscle pedicle bone graft might be added. Overall, there is a notable 85% union rate and a significant improvement in range of motion.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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