

PRONATOR QUADRATUS MUSCLE PEDICLED BONE GRAFT FOR DELAYED UNION SCAPHOID

By

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ABSTRACT

Background: The human scaphoid bone is one of the carpal bones of the wrist. Its fracture is the most common type of carpal bone fracture. Scaphoid nonunion is a well-known and common problem. Both clinical and biological factors contribute to the development of nonunion. Several techniques of bone grafting have been used in the management of scaphoid fracture nonunion. The union rate achieved with standard nonvascularized bone grafts was poor, especially in case of avascular necrosis and pseudarthroses, whereas the use of vascularized bone grafts results in better union rates. Pronator quadratus pedicled bone graft is described as one of the successful techniques that treat delayed union of the scaphoid fracture.

Objective: To evaluate the outcomes and results of pronator quadratus muscle pedicle bone graft for patients who were suffering from delayed union or nonunion of scaphoid bone fracture.

Patients and Methods: Ten patients suffering from delayed and non-united scaphoid fractures, seven males and three females, aging from 17 to 54 years old. We used the pronator quadratus muscle pedicled bone graft to treat all these patients.

Results: Complete union was achieved in seven patients, 6 patients of them were suffering from waist non united scaphoid fracture, and one patient of four patients suffering from non-united proximal pole scaphoid fracture.

Conclusion: The use of the pronator quadratus pedicled bone graft in delayed union of the scaphoid waist fractures achieved a high rate of union with excellent and good functional outcomes. A poor result occurred on using the pronator quadratus pedicled bone graft in delayed union of the scaphoid proximal pole fracture.

Keywords: Scaphoid fracture – nonunion – pronator quadratus pedicled graft – internal fixation.

INTRODUCTION

The scaphoid is the most common carpal to fracture with an estimated incidence is 4.3 per 10,000 people. Misdiagnosis and improper treatment can result in potentially devastating complications such as delayed union, avascular necrosis, and instability and ultimately osteoarthritis (Nassiri, 2016).

People with scaphoid fractures generally have snuff box tenderness. Focal

tenderness is usually present in one of three places: 1) volar prominence at the distal wrist for distal pole fractures; 2) anatomic snuff box for waist or midbody fractures and 3) distal to Lister's tubercle for proximal pole fractures (Yin , 2010).

Scaphoid nonunion is a well-known and common problem in trauma and hand surgery. Nonunion occurs in 10% to 15% of patients if a scaphoid fracture is not detected and treated. Nonunion of

proximal pole fractures can range of up to 30% (*Werdin, 2014*).

Both clinical and biological factors contribute to the development of nonunion. Biological factors include the degree of fracture displacement, the fragile vascular supply of the scaphoid, and its complex anatomy. Clinical factors include variable patient symptoms such as minimal pain and swelling, compliance with immobilization, lack of medical and radiological diagnosis, and delays in treatment (*Wong and von Schroeder, 2011*).

When a massive free bone graft must be incorporated into a large bone defect in the presence of a poor vascular recipient bed, the risks of absorption and failure of the graft to revascularize are high. Studies have confirmed that a bone graft that is transferred to a recipient site with an intact pedicle of blood supply remains viable. In addition, it unites directly with the recipient bone without necessity of revascularization or replacement by creeping substitution. It also provides a live bone bridge for reconstruction of a massive bone defect and is a ready source of vascular osteogenic tissue, which sprouts new outgrowths to revascularize avascular recipient bone tissue (*Rashed, 2015*).

The usage of a pronator quadratus pedicled vascularized bone graft of the distal radius to revascularize the non-united scaphoid fractures was described as one of the most successful, less complex, and quite elegant procedures (*Lee et al, 2015*).

The aim of this study was to evaluate the outcomes and results of pronator quadratus muscle pedicle bone graft for

patients who are suffering from delayed union or nonunion of scaphoid bone fracture.

PATIENTS AND METHODS

This was a prospective study involving 10 patients with delayed or non-united scaphoid fractures underwent at the orthopedic outpatient clinic of Al-Azhar University Hospitals and Ain Shams General Hospital between the period of October 2017 till March 2020. Patients were checked with X-rays, clinical evaluation, and functional assessment.

Inclusion criteria:

Patients with delayed or non-united scaphoid fracture for more than 3 months of primary intervention, with or without avascular necrosis, without severe arthritis, bone resorption and marked carpal instability, and not suffering any general comorbidities or neurological disease affecting the diseased wrist.

Exclusion criteria:

Patients with acute scaphoid fracture, or those who developed severe arthritis, bone resorption and marked carpal instability and those who were suffering any general comorbidities or neurological disease affecting the diseased wrist.

After approval by hospital ethics committee, informed consents were obtained from all the patients.

Preoperative and postoperative clinical and radiographic evaluation was carried out. Clinical evaluation involved assessment of pain, range of motion of the wrist, and grip strength. The range of motion was measured with a goniometer, including flexion, extension, and radial and ulnar deviation. The grip strength was

measured with a dynamometer. Postoperatively, clinical, and functional results were reported according to the modified Mayo wrist scoring system.

The radiographic evaluation involves plain radiograph posteroanterior, scaphoid view and lateral views preoperatively and postoperatively. The scapholunate (SL) angle was measured. The presence of AVN was diagnosed using MRI.

All operations were carried out under general anesthesia, and under an image intensifier control. The patients were lying in supine position with supinated forearm. A pneumatic tourniquet was applied to minimize bleeding.

A classic anterior incision (Henry's incision) was given and the radioscaphocapitate ligament was splitted by incision and later is repaired. The site of the nonunion was exposed, and the fibrous material was curetted until normal bone was visible. The surface of the proximal fragment was carefully inspected for bleeding points. The bleeding points were seen even with the tourniquet inflated. Then, at the level of distal radius, the pronator quadratus was identified, and a parallelepiped block of bone graft of 15-20 mm long was outlined at its distal insertion close to abductor pollicis longue tendon. Along the margin of the graft, holes were made with Kirschner- wire to facilitate separation with a fine osteotome. The pronator quadratus was not detached from the bone graft, and the muscle was dissected towards the ulna to secure a pedicle 20 mm thick. The proximal and distal segments of the scaphoid were aligned as a traction force was applied to the thumb. This maneuver allowed the bone graft to be inserted firm, into the

space between the two fragments. The scaphoid with the bone graft inserted was firmly fixed with a Herbert-screw or with two 1.2 mm Kirschner- wires introduced at the scaphoid tuberosity. Screw fixation was preferred, but occasionally Kirschner wires were used if the bone fragments were too small. The skin incision was closed without tension, and a short arm slap was applied.

Patients were instructed for movement of fingers. Thumb motor and sensory examinations were done to evaluate neurovascularity.

In the postoperative follow-up, 14 - 21 days after surgery, the sutures were removed and patients were immobilized in a short arm cast including the wrist and thumb for 4 - 10 weeks, and all Kirschner wires were removed within 8 - 10 weeks of operation. The patients were encouraged to do physiotherapy to improve the mobility and regain strength. Nonunions were considered healed after radiographic evidence of bone consolidation (bridge trabeculae on both sides of the graft, with attenuation of the continuity solution lines in the scaphoid).

Range of motion (flexion, extension, and radial and ulnar inclination), force and pain are measured preoperatively and at last follow-up. Consolidation time was determined using control X-rays. Complications, return to work, functional recovery on the Mayo Wrist Score and overall patient satisfaction were observed.

Statistical methods:

All data were collected, tabulated, and subjected to statistical analysis. Statistical analysis was performed by SPSS in general (version 20). Microsoft office

Excel was used for data handling and graphical presentation.

Quantitative variables were described by the Mean, Standard Deviation, and the Range (Maximum – Minimum). Independent samples t-test was used for comparing means of the two groups.

Qualitative categorical variables are described by numbers and percentages.

Fisher exact test was applied to assess association.

Significance level was considered when $P \leq 0.05$. Two tailed tests were assumed throughout the analysis for all statistical tests.

RESULTS

The average operative time was 90 min (range: 70–110 min). The results were evaluated according to the fracture union, functional results, and complications.

In our study we used the pronator quadratus muscle pedicled bone graft for 10 patients, aging from 17 years old to 54 years old (the mean is 32.5 years). According to sex distribution, there were 7 males (70%) and 3 females (30%). According to side distribution, the injuries were in the right side in 6 patients (60 %), were in the left side in 4 patients (40 %). According to site distribution, the nonunion was in the proximal pole in 4 patients (40 %), was in the waist in 6 patients (60 %). According to Mode of trauma distribution, it was due to fall on

the outstretched hand in 5 patients (50%), RTA in 3 patients (30%), direct blow trauma in 1 patient (10%) and fall from height in 1 patient (10%). According to Herbert classification: The fracture was type C in 6 patients (60 %) and was type D1 in 4 patients (40 %). According to presence of pre-operative avascular necrosis, there were 6 patients not developed AVN (60%) and 4 patients developed AVN (40%). According to intraoperative tool of fixation of the fracture and the graft, we used k-wires in 6 patients (60%), and used Herbert screw in 4 patients (40%). According to the duration of preoperative nonunion it was ranging from 3 months to 11 months (mean 4.9 months) (**Table 1**).

Table (1): Demographic data of studied cases

Case Parameter	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
AGE	47	23	29	32	19	54	41	25	17	38
Sex	M	M	F	M	M	M	F	M	F	M
Comorbidity	D.M	No	No	B.A, D.M	No	H.T.N, D.M	No	No	Epilepsy	No
Mode of trauma	Fall on outstretched hand	Fall on outstretched hand	R.T. A	Fall on outstretched hand	Direct blow	Fall on outstretched hand	Fall on outstretched hand	R.T. A	Fall from height	R.T. A
Site of fracture	Lt. Proximal pole	Rt. Proximal pole	Lt. Proximal pole	Rt. Proximal pole	Lt. waist	Rt. Waist	Rt. waist	Lt. waist	Rt. Waist	Lt. waist
Classification	Type C	Type D1	Type C	Type C	Type D1	Type D1	Type C	Type C	Type C	Type D1
Initial treatment	B.E scaphoid cast	Neglected	B.E scaphoid cast	Neglected	B.E scaphoid cast	B.E scaphoid cast then neglected	B.E scaphoid cast	A.E scaphoid cast for 1.5 mo. Then below for 2 mo.	Neglected	B.E scaphoid cast then neglected
Duration of non-union	3 mo.	7 mo.	4 mo.	3.5 mo.	3 mo.	11 mo.	3 mo.	3.5 mo.	5 mo.	6 mo.
AVN	No	AVN	AVN	No	No	AVN	No	No	No	AVN
Operation	PQPBG	PQPBG	PQPBG	PQPBG	PQPBG	PQPBG	PQPBG	PQPBG	PQPBG	PQPBG
Tool of fixation	k-wires	k-wires	k-wires	k-wires	Herbert screw	Herbert screw	K-wires	Herbert screw	Herbert screw	K-wires
Post-operative complications	Pin tract infection	No	No	No	No	*sensory disturbance *delayed wound healing	No	No	No	No
Result after 5 months of follow up	Not united	Not united	Not united	united	united	united	united	united	united	united
Mayo score	55 (poor)	65 (fair)	45 (poor)	75 (fair)	85 (good)	80 (good)	85 (good)	90 (excellent)	95 (excellent)	80 (good)

M = male, F = female, B.A = bronchial asthma, D.M = diabetes mellitus, H.T.N = hypertension, R.T.A = road traffic accident, B.E = below elbow, A.E = above elbow, P.Q.P.B.G = pronator quadratus pedicled bone graft.

Increase of the flexion and extension angles means post-operative improvement. The wrist range of motion improved significantly. The mean preoperative wrist extension was 58.5° (range = 55–65°) and improved to 72° postoperatively (range = 60–80°). The mean preoperative flexion was 57.5°

(range = 55–65°) and improved to 71° postoperatively (range = 60–80°). The hand grip strength also improved, with the average preoperative grip strength being 18.2 kg (range = 16–20 kg) and the average postoperative grip strength being 26.2 kg (range = 22–30 kg), (Table 2 and 3).

Table (2): Results of the 10 patients with nonunion of fracture of the scaphoid

Cases Parameters		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Pain	Pre-operative	+	+	+	+	+	+	+	+	+	+
	post-operative	+/-	+/-	+	-	-	+	-	-	-	-
Flexion (angle in degree)	Pre-operative	55	60	55	55	60	55	55	65	60	55
	post-operative	60	65	60	75	80	60	75	80	80	75
Extension (angle in degree)	Pre-operative	60	55	55	60	60	55	60	65	55	60
	post-operative	65	60	65	75	80	65	75	80	80	75
Grip strength (In Kg)	Pre-operative	18	17	16	20	19	17	18	20	19	18
	post-operative	24	25	23	26	28	22	28	29	30	27
Time of union (weeks)		Not united	Not united	Not united	16	14	Not united	15	12	10	12
Clinical results (Mayo wrist score)		55 poor	65 fair	45 poor	75 good	85 good	45 poor	85 good	90 Excellent	95 Excellent	80 good

Table (3): Change in mean values in flexion, extension, and grip strength

Parameters	Values	Minimum	Maximum	Mean	SD
Flexion (in degree)					
Flexion Pre		55.00	65.00	57.50	3.54
Flexion Post		60.00	80.00	71.00	8.76
Flexion Difference (Post - Pre)		5.00	20.00	13.50	7.47
Extension (in degree)					
Extension Pre		55.00	65.00	58.50	3.37
Extension Post		60.00	80.00	72.00	7.53
Extension Difference (Post - Pre)		5.00	25.00	13.50	6.26
Grip strength (in Kg)					
Grip strength Pre		16.00	20.00	18.20	1.32
Grip strength Post		22.00	30.00	26.20	2.66
Grip strength Difference (Post - Pre)		5.00	11.00	8.00	1.94

The mean preoperative scapholunate angle angles were 61° (range = 50–70°)

and postoperatively it improved to 46.5° (range = 40–50°) (Table 4 and 5).

Table (4): Preoperative and postoperative assessment of the scapholunate angle

Cases Parameters	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Preoperative SL angle	55	60	60	55	70	65	65	60	70	50
Postoperative SL angle	50	45	45	50	45	45	50	45	40	50

Table (5): Change in mean values in scapho-lunate angle

Parameters	Values	Minimum	Maximum	Mean	SD
	Scapho-lunate angle Pre		50.00	70.00	61.00
Scapho-lunate angle Post		40.00	50.00	46.50	3.37
Scapho-lunate angle Difference (Post - Pre)		-30.00	0.00	-14.50	9.26

The overall union rate after 5 months was 70% (7 patients). The time of union for only 7 united cases ranged from 10 weeks to 16 weeks (mean 13.57). Functional results according to wrist mayo scoring system, ranged from 45 to 95

(mean 75.5), 2 patients had poor score (20%), 2 patients had fair score (20%), 4 patients had good score (40%), and 2 patients had excellent score (20%) (Tables 6, 7, and 8).

Table (6): Result after 5 months of follow up

	Frequency	Percent
Not united	3	30%
United	7	70%

Table (7): Time of union after the operation for only the 7 cases united (in weeks)

Minimum	Maximum	Mean	SD
10.00	16.00	13.57	2.30

Table (8): Mayo score

Minimum	Maximum	Mean	SD
45.00	95.00	75.50	15.89

According to the relation of results after 5 months of follow up and site of fracture, 3 of cases who suffered proximal pole nonunion were not united and all cases who suffered waist nonunion were

united. (Fisher exact p value 0.0333) (P <0.05 significant). The association between results after 5 months of follow up and site of nonunion is considered to statistically significant (Table 9).

Table (10): Relation between results and site of fracture

Group Result	Proximal pole nonunion	Waist nonunion	Fisher Exact test P Value
Not united	3	0	0.0333
United	1	6	

DISCUSSION

Scaphoid nonunion is a challenging and complex problem which results owing to multiple factors. Over the last years, different methods for scaphoid nonunion

reconstruction have been described. Because of the frequency of the disease, a successful method for daily operative practice is necessary.

In our study, we used the pronator quadratus muscle pedicled bone graft for 10 patients suffering from delayed union and nonunion of proximal pole and waist scaphoid fracture. The main advantage of this procedure was that it respects the normal principles of fracture-healing. The volar approach provides an excellent access to the volar part of the cortex of the scaphoid which can be easily reconstituted with a vascularized bone graft from distal radius and internally fixated with an implant (Herbert screw or Kirschner wires).

We achieved complete union and satisfactory functional results in 7 patients from all the 10 patients. When we compared the results according to site of nonunion, we found that the results were statistically significantly higher in waist fractures compared to proximal pole fractures, as we achieved a complete union in 6 patients suffering from waist non united scaphoid fracture (union rate 100 %) and just 1 patient of 4 patients suffering from non-united proximal pole scaphoid fracture (union rate 25%). According to Mayo score system of the wrist function, we achieved excellent and good results in 6 patients with waist scaphoid non unions, fair results in 2 patients with proximal pole scaphoid nonunion and poor results in 2 patients with proximal pole scaphoid nonunion.

Gras and Mathoulin (2011) reported a retrospective study included 111 cases of vascularized bone graft for scaphoid non-union as primary procedure in 73 cases and secondarily in 38. This study concluded that primary treatment by vascularized graft depending on the series showed equally good or better

consolidation, recovery of motion and pain relief compared to secondary treatment or non-vascularized graft. Vascularized graft from the volar radius is thus a good alternative for primary treatment of scaphoid non-union.

Mathoulin and Gras (2015) reported a case presentation of a 42 years old male patient; he decided to use a vascularized bone graft utilizing a volar pedicled graft based off the volar carpal artery. The union was achieved in 6 weeks. He concluded that vascularized bone grafts seem to be a good option for primary treatment of scaphoid nonunion because the union rate is very high.

Obada et al. (2015) reported on a volar pronator quadratus pedicled bone graft for six patients suffering from non-united waist scaphoid fracture, they achieved union in all six patients, with time range of union 8 – 12 weeks, with functional results varying from good to excellent according to mayo wrist score.

Goel et al. (2017) reported a study that was done on eleven cases of nonunion scaphoid with pronator quadratus vascularized bone graft. Postoperative scaphoid outcome score was excellent in 4 cases, good in 4 cases, fair in 2 cases, and poor in 1 case. One case developed scaphoid nonunion advanced collapse and wrist arthritis.

CONCLUSION

We recommend the use of this approach in the delayed or non-united waist scaphoid fracture as it provided an excellent access to the volar part of the cortex of the scaphoid which can be easily reconstituted with a vascularized bone graft from distal radius and stable fixated

with an implant (Herbert screw or Kirschner wires), in addition to its satisfactory results to the patient.

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استخدام الرقعة العظمية المستخلصة من أسفل عظمة الكعبرة الموعاة بعنق من العضلة الكابة المربعة في الكسور الغير ملتئمة بالعظمة الزورقية

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خلفية البحث: تعد العظمة الزورقية واحدة من العظام المعصمية الصغيرة الموجودة بالرسغ، وتعتبر الكسور بهذه العظمة الأكثر شيوعاً في كسور العظام المعصمية. عدم الالتئام كسر العظمة الزورقية من المشكلات المعروفة والشائعة، وتساهم عوامل إكلينيكية وحيوية في حدوث عدم الالتئام وتطوره. وقد تم استخدام العديد من أساليب الترقيع العظمي لعلاج الكسور الغير ملتئمة بالعظمة الزورقية. نسبة حدوث الالتئام المتحققة عند استخدام الرقعة العظمية الغير موعاة بأوعية دموية كانت ضعيفة وفقيرة وخاصة في حالات النخر العظمي اللاوعائي بالعظمة والتمفصل الكاذب، في حين أن استخدام الرقعة العظمية الموعاة بوعاء دموي قد حقق نتائج أفضل ونسبة التئام أعلى. تم وصف استخدام الرقعة العظمية الموعاة بعنق من العضلة الكابة المربعة كوسيلة ناجحة لعلاج الكسور الغير ملتئمة بالعظمة الزورقية.

الهدف من البحث: تقييم النتائج عند استخدام الرقعة العظمية المستخلصة من أسفل عظمة الكعبرة الموعاة بعنق من العضلة الكابة المربعة في المرضى الذين عانوا من الكسور الغير ملتئمة بالعظمة الزورقية.

المرضى وطرق البحث: قمنا بإجراء جراحة الترقيع برقعة عظمية موعاة بعنق من العضلة الكابة المربعة لعشرة مرضى، سبعة ذكور وثلاث إناث، تتراوح أعمارهم بين السابعة عشر والرابعة والخمسون.

نتائج البحث: حدوث التئام كامل ونتائج وظيفية مرضية في سبعة مرضى، ستة مرضى منهم كانوا يعانون من كسر غير ملتئم بمنتصف العظمة الزورقية، ومريض واحد من ضمن أربعة مرضى كانوا يعانون من كسر غير ملتئم بالقطب البعيد من العظمة الزورقية.

الاستنتاج: استخدام الرقعة العظمية الموعاة بعنق من العضلة الكابة المربعة في الكسور الغير ملتئمة بمنتصف العظمة الزورقية قد حقق نسبة التئام عالية ونتائج وظيفية ممتازة وجيدة، بينما تحققت نتائج ضعيفة عند استخدام الرقعة العظمية الموعاة بعنق من العضلة الكابة المربعة في الكسور الغير ملتئمة بالقطب البعيد بالعظمة الزورقية.