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Pronator quadratus pedicled bone graft for scaphoid non-unions

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Abstract
Introduction: Nonunion rate is especially high in proximal pole fractures of the scaphoid due to tenuous retrograde blood supply and is a challenging situation for Orthopaedic surgeons. Pronator quadratus pedicled vascularized bone graft is an option for the treatment of scaphoid non-unions. The aim of this study was to evaluate the clinical results of the treatment of scaphoid non-unions using a pronator quadratus pedicled bone graft.
Materials and Methods: In this study a total of 12 patients with non-united scaphoid fractures and were treated with pronator quadratus pedicled bone graft, Herbert-screw and K- wire were enrolled. Clinical outcomes were assessed using the modified Mayo Wrist Score and Disabilities of Arm, Shoulder and Hand score.
Results: All the patients achieved bony consolidation after an average of 8.9 (range 6 to 12) weeks. The range of motion of the affected wrist averaged 60 degrees of flexion, 61 degrees of extension, 14 degrees of radial deviation and 24 degrees of ulnar deviation compared with non-affected wrist, an average of 71 degrees of flexion, 67 degrees of extension, 16 degrees of radial deviation and 30 degrees of ulnar deviation. The evaluation of the grip strength showed an average of 38 kilograms-force on the operated site compared with an average of 42 kilograms- force on the contralateral site.
Conclusion: Pronator quadratus pedicled bone grafting is proved to be effective for bone union, increased wrist joint motion.

Keywords: Scaphoid, non-unions, pedicled pronator quadratus, vascularized bone graft

Introduction
Scaphoid fractures frequently present to a hand surgeon's clinic usually as an undiagnosed wrist pain or a problem fracture following trauma. It is seen in young and physically active adults. Due to the unique blood supply of the scaphoid, periscaphoid arthritis and proximal pole necrosis are common sequalae, with upto 30% progressing to non-union [1]. Other reason for nonunion is its peculiar anatomy, is that it lacks periosteal covering. More than 80% of the scaphoid surface is covered by articular cartilage while the remaining surface acts as sites for vascular supply. Due to absence of periosteum, union in scaphoid fracture occurs by primary bone healing resulting in minimal callus formation and biomechanically weak early union [2]. The most prominent symptom of scaphoid nonunion is pain during wrist motion but if left untreated, it can cause osteoarthritis, decrease in grip strength and limitation in wrist range of motion. The natural history of scaphoid nonunion progresses to scaphoid nonunion advanced collapse (SNAC) which is characterized by advanced collapse and progressive arthritis of the wrist leading to less favorable clinical results [3].
Although conservative methods have been described in literature for the treatment of non-unions, the management is usually surgical. Bone grafting is the procedure of choice, which can be non-vascularized or vascularized. Due to poor prognosis of conventional bone grafts, vascularized bone grafts have been found as the primary treatment when pseudarthrosis or avascular necrosis is diagnosed [4].
Braun in 1983 first reported good healing using the pronator pedicled bone graft for scaphoid non-union [5]. In this study we present our experience of pedicled pronator quadratus bone graft for treatment of scaphoid fracture non-unions.

Materials and Methods

This prospective study was conducted in Govt. Bone and Joint Hospital, an associated hospital of Govt. Medical College Srinagar from January 2021- December 2021. In this study a total of 12 patients with non-united scaphoid fractures and were treated with pronator quadratus pedicled bone graft, Herbert-screw and K- wire were enrolled.

All the patients had symptoms for minimum 8 months before the surgery. Demographic data as, age, sex, etiology, the location of fracture, time from fracture to diagnosis of nonunion, initial treatment, operative details, type of fixation, time to union, range of wrist motion, subjective complains, complications, grip strength, Mayo clinical wrist score, duration until return to work were noted.

Procedure

A linear incision was made over the scaphoid tuberosity and the distal radius. The site of the nonunion was exposed and the fibrous material was curetted until normal bone is visible. The surface of the proximal fragment is carefully inspected for bleeding points with use of a loupe magnification. Then, pronator quadratus muscle's distal insertion over the radius was identified and bone block of 5x10 mm was outlined close to abductor pollicis longus tendon. Graft was separated with a fine osteotome taking utmost care not to detach the muscle from it. The muscle was then dissected towards the ulna to secure a 10mm thick pedicle. In cases, where the muscle was too tight to allow easy transfer of the pedicled bone, the ulnar origin of the muscle was dissected subperiostally from the distal ulna through an additional incision. The proximal and distal segments of the scaphoid were aligned as a traction force was applied to the thumb. This allows the bone graft to be inserted firm, into the space between the two fragments. The scaphoid with the bone graft inserted are firmly fixed with a Herbert-screw or with two 1, 2 mm Kirschner wires introduced at the scaphoid tuberosity. The bone graft is inserted vulgarly and is placed as a wedge in the scaphoid nonunion site. The wound was closed without tension and a long arm cast was applied for one month.

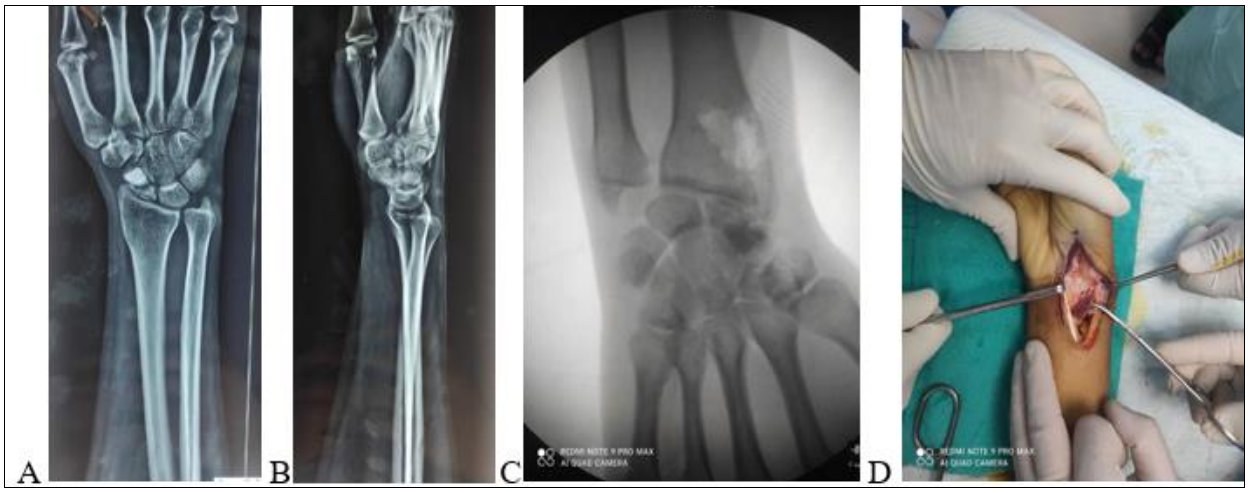

Fig 1: A and B (Radiological aspect of scaphoid non-union), C (Intra-operative radiograph) and D (Obtaining pronator quadratus bone graft from the distal radius)

Follow-up

At the follow-up of one month patients were followed by a short cast for a next month. Physiotherapy and active exercises were started at the follow-up of 3 months.

The final evaluation was made using radiological, subjective and objective criteria, the patient satisfaction, chronic pain, active range of motion, grip strength and ability to work. Fracture union was confirmed by absence of fracture line radiologically averaging at 3-6 months and by absence of tenderness in anatomical snuff box and scaphoid tubercle. Pain was considered mild if it occurred at the extremes of active range of motion of the wrist, but the patient wasn't disturbed. The pain was considered severe if it appears during daily activities and at rest. The range of motion was measured using a goniometer and was compared with the contralateral hand. Clinical outcomes were assessed using the modified Mayo Wrist Score and Disabilities of Arm, Shoulder and Hand score.

Results

The mean age of the study population was 29.2 ± 3.4 (range 20-43) years. Among 12 enrolled patients 9 (75%) were males and 3 (25%) were females (Table 1). The mean time from injury to surgery was 9.7 (range 8-13) months.

Table 1: Demographic characteristics of the study population (N=12)

Demographic characteristics	No. of patients	Percentage
Gender		
Male	9	75.00
Female	3	25.00
Age group		
< 25 Years	5	41.67
25-35 Years	5	41.67
> 35 Years	2	16.66
Injured Side		
Right	8	66.67
Left	4	33.33
Site of non-union		
Waist	3	25.00
Proximal third	9	75.00

All the patients achieved bony consolidation after an average of 8.9 (range 6 to 12) weeks. No deficit in pronation was noted in any of the patients. Limitation in wrist extension was seen in maximum patients postoperatively. All the patients returned to their initial work-place at an average of 13 months after the surgery.

The range of motion of the affected wrist averaged 60 degrees of flexion, 61 degrees of extension, 14 degrees of radial deviation and 24 degrees of ulnar deviation compared with

non-affected wrist, an average of 71 degrees of flexion, 67 degrees of extension, 16 degrees of radial deviation and 30 degrees of ulnar deviation (Table 2).

Table 2: Post-operative clinical results

Parameters	Degrees (Average)/Kilograms force	
	Affected wrist	Non-affected wrist
Flexion	60	71
Extension	61	67
Radial Deviation	14	16
Ulnar Deviation	24	30
Grip Strength	38	42

The evaluation of the grip strength showed an average of 38 kilograms-force on the operated site compared with an average of 42 kilograms- force on the contralateral site (Table 2).

There were no early complications of surgical site infection or sensory disturbances in the area of the radial nerve. There were also none late septic complications. No radiographic progression of arthritis was noted in any patient within the available follow-up time. No arthritic changes were noted at the dorsal ridge of the radius (where the graft had been harvested).

The final functional result according to Mayo Clinic Wrist Score was excellent in 8 (66.67%) cases, good in 3 (25%) cases and fair in 1 (8.33%) cases (Table 3).

Table 3: Results according to Mayo Clinic Wrist scoring system

Grade	Score	No. of patients	Percentage
Excellent	90-100	8	66.67
Good	80-89	3	25.00
Fair	65-79	1	8.33
Poor	< 65	0	0

Fig 2: A (Radiological aspect at final follow-up of one year), B and C (Clinical pictures at final follow-up, flexion/extension)

Discussion

Scaphoid fractures frequently present with the sequala of non-union and proximal pole necrosis. The key to this lies in the unique anatomy of the scaphoid bone. The blood vessels supplying the scaphoid enter the dorsal and the volar surfaces from the distal part and run retrogradely to supply the proximal pole. Hence fractures of the scaphoid can compromise the blood supply of the proximal pole. This clinically results in nonunion and avascular necrosis.

There is no standard treatment of chronic nonunion of the scaphoid. Although conservative methods have been tried, the treatment of scaphoid non-unions is usually surgical [6]. Management of scaphoid nonunion is a challenging task for an orthopaedic surgeon. Many surgical procedures have been employed, which reflects the lack of satisfaction or consistency with any one strategy. In this study we used pronator quadratus pedicled bone graft for scaphoid non-unions, where old fracture site is exposed and a cavity is created at the nonunion site which is filled by bone grafts. In cases of established nonunion, bone grafting is advocated to facilitate healing and correction of any carpal malalignment. Most important intraoperative step in the management of scaphoid nonunion is excision of the pseudoarthrosis and fibrous scar tissue at the non-union site. In doing so, a bony defect is inevitably created. This defect can be filled with either vascularized or non-vascularized bone grafts. When a non-vascularized bone graft is put at the nonunion site, the risks of its absorption and failure of the graft to re-vascularize are high. While a bone graft 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 [7, 8]. It is also a ready source of vascular osteogenic tissue which sprouts new outgrowths to re-vascularize the avascular recipient bone tissue.

Grafts of vascularized bone not only retain a certain amount of the cellular and mineral matrix, but they can also respond to biomechanical stress due to greater strength and rigidity. This was first pointed out by Judet and Roy-Camille, who used the tubercle of the scaphoid pedicled on the lateral head of the abductor pollicis brevis [9]. Vascularised bone grafts provide an additional source of blood supply and hence aid healing, replace deficient bone and re-vascularise ischemic bone [10]. Tu *et al.* in an experimental study determined the bone blood flow following vascularised and non-vascularised bone grafts [11]. They found that the blood flow 2 weeks following a pedicled bone graft was 200% of the normal blood flow as compared to 3% of normal in case of a non-vascularized bone graft. In a meta-analysis of scaphoid fractures by Munk and Larsen, 80% patients had fracture healing following non-vascularized bone grafts and 91% of patients following vascularized bone graft, in the setting of simple non-unions [12]. The difference was stark in the setting of non-unions with proximal pole necrosis. Good union was

reported in 85% of patients with vascularized bone grafts, but in < 50% of patients in non-vascularized bone grafts. Braun in 1983 had described the Pronator Quadratus pedicled bone grafting technique for a variety of indications, including scaphoid non-unions. He reported 100% healing with this technique. Other techniques of harvesting vascularized bone grafts are based on the 1, 2 inter-compartmental supra-retinacular artery, volar carpal artery and from the metacarpal [13-16]. Hemi-hamate has also been reported to be used for scaphoid non-unions [17]. Free microvascular transfer of the medial femoral condyle has also emerged as an option for correction of this deformity [18].

In this study all the patients achieved bony consolidation after an average of 8.9 (range 6 to 12) weeks. No deficit in pronation was noted in any of the patients. Limitation in wrist extension was seen in maximum patients postoperatively. All the patients returned to their initial work-place at an average of 13 months after the surgery. There are some limitations in this study as, less number of patients and short period of follow-up.

Conclusion

Pronator quadratus pedicled bone grafting can be considered to be easily accessible technique on vascularized bone graft for osteosynthesis of scaphoid non-unions. It is proved to be effective for bone union, increased wrist joint motion.

Conflict of Interest

Not available

Financial Support

Not available

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