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Treatment of nonunion of the scaphoid with pronator quadratus pedicled bone graft

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SUMMARY

Background. We report our experience with the operative treatment of six ununited scaphoid fractures with pronator quadratus pedicle bone graft.
Methods. We made a prospectively study between 2011-2013 upon six patients with ununited scaphoid fractures and treated with pronator quadratus pedicled bone graft and Herbert-screw (4) or Kirschner-wires fixation (2). There were recorded: age, sex, ethiology, the location of fracture, time from fracture to diagnosis of nonunion, initial treatment, type of fixation, time to union, range of wrist motion, subjective complains, complications, grip strength, Mayo clinical wrist score, duration until return to work. The radiological criterion for ossous union was trabeculation across the site of the fracture on all three radiographs.
Results. The final evaluation was made using subjective and objective criteria, the patient satisfaction, chronic pain, active range of motion, grip strength and ability to work. All the 6 cases presented radiographic consolidation after an average of 9,8 weeks. The mean period of evaluation was 14 month. The range of motion of the affected wrist averaged 61° flexion, 59° extension, 13° radial deviation and 25° ulnar deviation compaired with an average of 73° flexion, 65° extension, 16° radial deviation and 29° ulnar deviation of the contralateral wrist. The grip strength showed an average of 39 kilograms-force on the operated site compaired with an average of 41 kilograms-force on the contralateral site. All the patients returned to work after an average of 17 months. The final results according to Mayo Clinic Wrist Score was excellent in 3 cases and good in 3 cases.
Conclusions. The pronator quadratus vascularised bone graft procedure is technically easy, optimal because of his good structural integrity as well as a robust blood supply and can be harvested with minimal donor site morbidity.
Keywords: scaphoid nonunion, pronator quadratus, bone graft

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BACKGROUND

Misdiagnosis or delayed diagnosis of fracture of the carpal scaphoid or its unproper indication for conservative treatment may lead to delayed union or non-union. [1] Due to poor prognosis of conventional bone grafts, vascularised bone grafts have been found as the primary treatment when pseudarthrosis or avascular necrosis is diagnosed. [2]

The ideal treatment of scaphoid nonunions remains controversial. Osteoarthritis may become progressively worse in association with long-standing nonunion of the scaphoid and avascularity of the proximal fragment. The rate of osseous union seems to depend also on the stability and vascularity of the proximal fragment. [3]

The purpose of the study was to evaluate the outcomes in a series of scaphoid waist nonunions to determinate if the pronator quadratus pedicle bone graft is effective in the treatment of these fractures. We report our experience with the operative treatment of six ununited scaphoid fractures with pronator quadratus pedicle bone graft and Herbert-screw or Kirschner-wire fixation.

MATERIAL AND METHODS

We made a prospectively study between 2011-2013 upon six patients who came to our Orthopaedic-Traumatology Department with old ununited scaphoid fractures and treated with pronator quadratus pedicled bone graft and Herbert-screw (4 cases) or Kirschner-wires fixation (2 cases).

All the patients had symptomatology for minimum 8 month before the surgery. One patient was diagnosed with avascular necrosis of the proximal fragment established by specific radiographic and clinical criteria. The radiologic criteria were increased bone density, loss

of normal trabecular appearance, collapse of the subchondral bone, cystic changes and deformity of the osseous segment. Clinically a finding of sclerotic bone without visible punctate bleeding points after debridement of the proximal segment on Tourniquet release was necessary to confirm the diagnosis of avascular necrosis. [4]

Medical records and radiographs were reviewed. There were recorded pacient demographies: age, sex, ethiology, 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. (table 1, table 2, table 3)

The dominant hand was affected in five patients and the average duration of the nonunion of the scaphoid was 13 month. Follow-up was from 8 to 24 month.

All the patients had a history of a dorsiflexion injury of the wrist. 2 patients had sustained the fracture in a simple fall, 3 during sports activity and 1 in a traffic accident with a motorbike. In 2 cases the fracture was missed on

Tab. 1. Preoperative data on the 6 patients

Case	Sex/ Age	Side	Initial treatment	Site of nonunion	Duration of nonunion (months)
1.	M/36	Right	Bellow the elbow cast	Proximal third	16
2.	M/28	Right	Bellow the elbow cast	Proximal third	12
3.	M/22	Right	None	Waist	16
4.	M/19	Left	Bellow the elbow cast	Waist	9
5.	M/33	Right	Bellow the elbow cast	Proximal third	14
6.	M/31	Right	None	Proximal third	15

Tab. 2. Postoperative data on the 6 patients

Case	Osteosynthesis / Herbert screw	Time to union (weeks)	Duration until returns to work (weeks)	Mayo clinic wrist score (points)	Results
1.	Kirschner-wires	9	12	80	Good
2.	Herbert screw	12	18	80	Good
3.	Herbert screw	11	19	90	Excelent
4.	Kirschner-wires	8	14	100	Excelent
5.	Herbert screw	9	23	80	Good
6.	Herbert screw	10	17	100	Excelent

Tab. 3. Postoperative clinical results

Case	Pain	Last follow-up (degrees)				Grip strength (affected/ normal) (Kg/F)
		Flexion	Extension	Radial deviation	Ulnar deviation	
1.	—	65/75	50/60	10/20	35/35	42/45
2.	Mild	50/70	65/70	15/15	25/25	40/40
3.	—	70/70	65/70	20/20	25/25	35/38
4.	—	50/70	40/75	10/20	20/30	42/52
5.	—	65/80	70/80	15/15	20/30	42/36
6.	Mild	70/75	65/70	10/10	30/30	37/35

the initial radiographs and for 4 cases was applied conservative treatment. (figure 1)

Radiographs were made preoperatively, postoperatively and every 6 weeks till consolidation. Radiographic determination of union was performed by musculoskeletal radiologists blinded to the study. Each time were made three standard radiographs: anteroposterior, lateral and scaphoid with the affected wrist in full ulnar deviation and the forearm in 30 degrees of supination. The criterion for ossous union was trabeculation across the site of the fracture on all three radiographs. [5] There were no preoperative osteoarthritis changes

Surgical procedure

A linear or a zig-zag incision was made over the scaphoid tuberosity and the distal radius. The radioscaphocapitate ligament is splitted by incision and later is repaired. 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. The bleeding points are seen even with the tourniquet inflated.

Then, at the level of distal radius, the pronator quadratus is identified and a parallelipiped block of bone graft of 15-20 mm long is outlined at its distal insertion close to abductor pollicis longue tendon. (figure 2) Along the margin of the graft were made holes with Kirschner-wire to facilitate separation with a fine osteotome. It must be take care that the pronator quadratus is not detached from the bone graft and the muscle is dissected towards the ulna to secure a pedicle 20mm thick. If the muscle is too tight to allow easy transfer of the pedicled bone, the ulnar origin of the pronator quadratus is dissected subperiostally from the ulna through an additional incision over the distal ulna.

The proximal and distal segments of the scaphoid are aligned as a traction force is applied to the thumb. This maneouvre 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-

Fig. 1. Radiological aspect of scaphoid nonunion

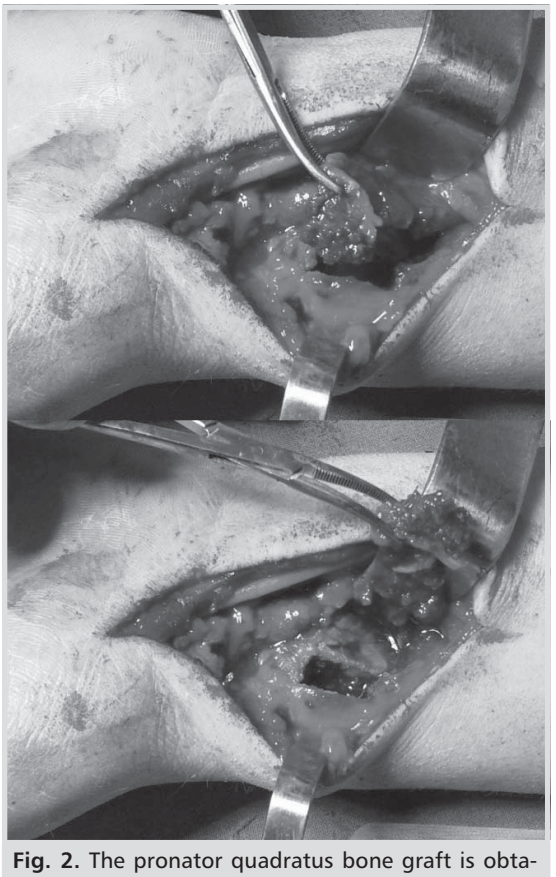

Fig. 2. The pronator quadratus bone graft is obtained from the distal radius

wires introduced at the scaphoid tuberosity (figure 3). The bone graft is inserted volarly and is placed as a wedge in the scaphoid nonunion site. Screw fixation is preferred, but occasionally Kirschner wires are used if the bone fragments are too small. [6]

The supply of blood to the bone graft is verified by inspection of bleeding from the graft after the tourniquet is deflated.

The skin incision was closed without tension and a long armcast with the thumb in opposition is applied for one month, followed by a short cast for a further month, then the union is evaluated radiografically. The wrist is braced in a functional position for another one month (or longer is necessary) and phisiotherapy and active exercises are then started. (figure 4, 5, 6) We were conservative in deciding when the fracture had healed, believing that is better a longer immobilization than to risk an unsatisfactory result. When the bone is consolidated, the Kirschner-wires are removed (at least 8 months after operation). The Herbert-screw doesn't need to be removed (we used titanium screw). [7]

RESULTS

The final evaluation was made using subjective and objective criteria, the patient satisfaction, chronic pain, active range of motion, grip strength and ability to work. The patient«s satisfaction was assessed by asking if the status of wrist was better than before the operation. 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 appear during daily activities and at rest. The range of motion was meassured using a goniometer and was compaired with the contralateral hand. (table 2)

The grip strength was measured with a dynanometer (Physisc Faculty Lab, "Ovidius" University of Constanta, Romania) and was expressed as an absolute value of kilograms-force and compared with contralateral wrist.

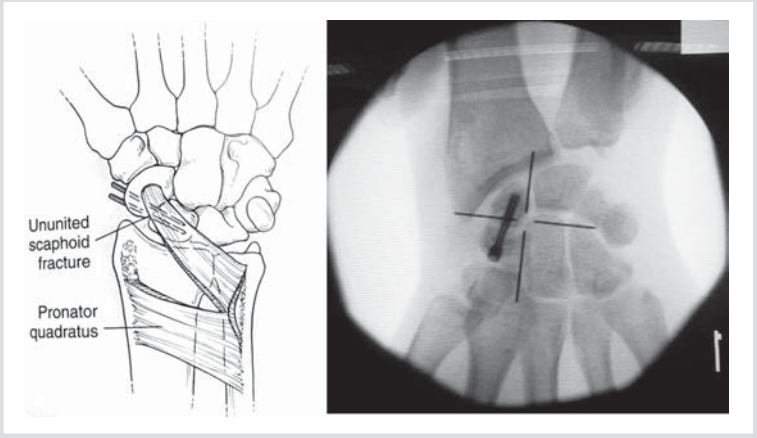

Fig. 3. The graft fill the site of nonunion [7] and then is fixed with Herbert-screw

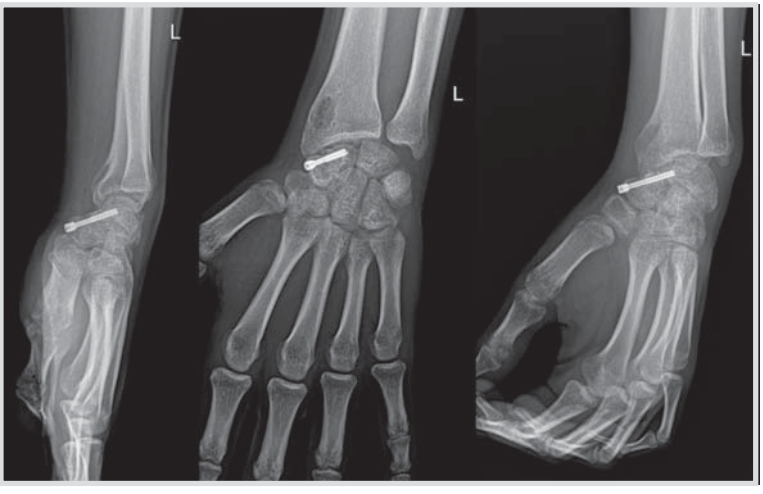

Fig. 4. Radiological aspects after 4 weeks

The capacity to work was made on the fact the pacient returned or not to work and capacity to work full-time (100%) or was restricted (25-50% of the normal working time).

The pshysical examination included inspection and palpation of the wrist for tenderness, osteophytes os instability.

The radiologic criterion of consolidation were: dissapearance of fracture line, bridging bone trabeculae, restoration of normal bone density.

For the evaluation of the late results we used Mayo Clinic Wrist scoring system with residual pain, functional status, range of motion and grip strength, each of them beeing a maximum of 25 points. A score of 90 to 100 points indicates an excellent result, 80-90 points a good result, 65-79 points a fair result and under 65 points a poor result. (figure 7, 8)

There were no early complications as pin-track infection, sensory disturbances in the area of the radial nerve, hematomas or problems with the healing of the wound. There were also none late septic complications.

At the moment of the surgery, 4 cases had fibrous nonunions and 2 cases had sclerotic pseudarthrosis. The length of the bone graft was from 8 to 21 mm. All the 6 cases presented radiographic consolidation after an average of 9,8 weeks (range 8 to 12) and normal aligment after operation (tabel II). The mean period of evaluation was 14 month (range 8 to 24 months). All the patients were satisfied with the late clinical and functional results.

Fig. 5. Radiological aspects after 8 weeks

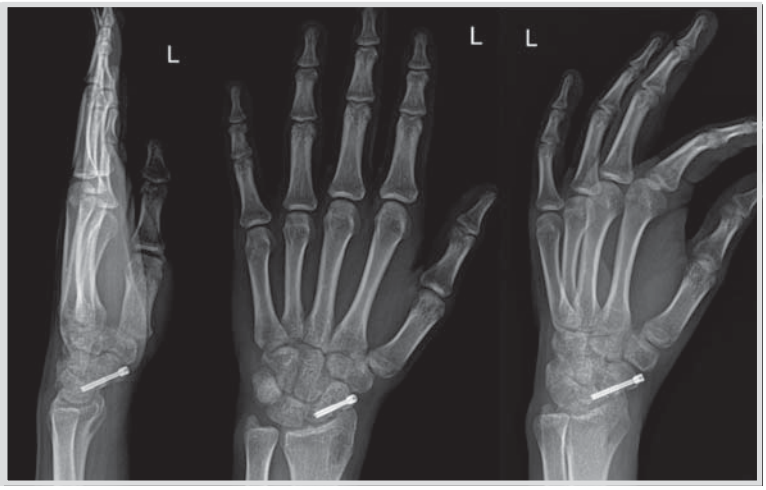

Fig. 6. Radiological aspects after 12 weeks – fracture consolidated

The cast immobilisation was removed when radiologic union was achieved. 4 patients had no pain after the immobilisation was removed and 2 patients had milde pain, but all the patients were able with no problems to follow the phisyotherapic and rehabilitation protocol.

The range of motion of the affected wrist averaged 61 degrees of flexion, 59 degrees of extension, 13 degrees of radial deviation and 25 degrees of ulnar deviation compaired with an average of 73 degrees of flexion, 65 degrees of extension, 16 degrees of radial deviation and 29 degrees of ulnar deviation of the contralateral (non-affected) wrist.(table 3)

The evaluation of the grip strength showed an average of 39 kilograms-force on the operated site compaired with an average of 41 kilograms-force on the contralateral site.

All the patients returned to their initial work-place at an average of 17 months after the surgery. Degenerative changes on the late radiographs were noted in one case and these changes were mild, with slight narrowing of the joint space and formation of osteophytes.

The final functional result according to Mayo Clinic Wrist Score was excellent in 3 cases and good in 3 cases.

DISCUSSIONS

There is no standard treatment of chronic nonunion of the scaphoid, but the technique we used is an accessible method to treat any recurrent pseudarthrosis. The main advantage of this preocedure is that it respects the normal principles of fracture-healing better than a simple placement of a non-vascularised bone graft, in an unfavorable low-vascular bed. [8]

The healing potential of an ununited scaphoid depends on two factors: vascularity and stability. Because of its vulnerable blood supply and the loss of retaining ligamentous support, unstable and proximal non-unions of the scaphoid have been associated with decreased rates of union after conventional bone-graft procedures. The rate of succes with conventional grafting is lower when the proximal pole of the scaphoid is completely avascular. [4, 9, 10, 11]

Grafts of vascularised autogenous 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. [8]

Fig. 7. 14 weeks postoperatively: flexion/extension

Fig. 8. 14 weeks postoperatively: radial/ulnar deviation

Revascularisation seems to be faster promoted by the use of vascularised bone grafts than conventional autogenous graft from the iliac crest. Vascularised bone grafts obtained from the distal radius and pedicled by the pronator quadratus have been described by Braun, Leung and Hung, Kawai and Yamamoto. [4, 7, 12, 13]

Kulhman et al reported the successful use of a radial bone graft pedicled on the radial branch of the volar carpal arch for the tratment of scaphoid nonunion, previousely treated by Matti-Russe operation. [14]

Zaindenberg et al reported success with the use of vascularised bone graft from radial styloid process after the Matti-Russen procedure has failed. [15] Grimberteau and Panconi used a vascularised bone graft, obtained from ulna and based on the ulnar artery, to treat recurent non-union of the scaphoid, in some cases of whom previos procedures has failed. [8]

Harph et al reported a rate of union of 90% after using of a free vascularised iliac-crest wedge graft for the treatment of scaphoid nonunion with an avascular proximal pole. [6, 16] Doi et al described the treatment of scaphoid nonunions with a free vascularised medial femural condyle inlay graft and the rate of union was 100 percents. [17]

Boyer et al reported unions in six of ten patients treated with distal radial graft based on a 1,2 intercompartimental supraretinacular artery pedicle. In that series, four persistent nonunions had been previously treated with a nonvascularised graft which had failed. [18] Henry reported a successful graft based on a 1,2 intercompartimental supraretinacular artery pedicle in the treatment of scaphoid collapse and osteonecrosis. [19]

Chacha reported the use of bone graft with a vascular pedicle from the pronator quadratus on two patients with nonunion of scaphoid with avascular necrosis, but he did not comment the results because of short follow-up. [3, 20] Rath et al obtained a bone graft from the pronator quadratus with a six centimeter long pedicle. [21] Mathoulin et Haerle achieved unions in all cases they treated with vascularised bone graft with a pedicle from the palmar carpal artery. Ten from seventeen patients from his group had a failure of a previous surgery. [22] Zaidemberg et al reported successfuly union in all the patients with long-standing symptomatic scaphoid nonunions treated with a vascularised bone graft from the radial aspect of the distal part of the radius. In half of the patients was a failure of Russe bone grafts procedure. These procedure was primary recomended for the treatment of non-union, cystic degeneration of scaphoid. [23]

Several other pedicled vascularised grafts have been described for the treatment of persistent scaphoid nonunion, but the use of vascularised graft from the volar and ulnar aspect of the distal part of the radius supplied by the palmar carpal artery has been reported to have excellent rates of union. [6, 22]

Viability and stability of the fragments are essential for obtaining consolidation of pseudarthrosis. The base principle is to treat avascular necrosis by increasing the vascularity of the bone. It is unclear if enough osteogenic bone survives after a nonvascularised bone graft method. Laboratory studies of vascularised and nonvascularised grafts have demonstrated that the former are associated with earlier union and with greater strength and stiffness between six weeks and six month postoperatively. [3]

Shaffer et al, in a controlled experiment involving on dogs, found that bone repair happened faster for the vascularised bone grafts than nonvascularised grafts, allthough the characteristisc of bone repair were similar. [24]

The volar approach that was popularised by Russe provide excellent access to the volar part of the cortex of the scaphoid which can be easily reconstituted with a vascularised bone graft from distal radius and stable fixated with an implant (Herbert – screw or Kirschner-wires).

The osteosynthesis has been used to increase the stability of bone fragments and bone graft. The use of the Herbert-screw was initially reported by Herbert and Fischer, who also reported higher success of nonunions treatment in association with bone graft. Numerous studies have reported the better results of Herbert-screw fixation with bone grafting with increased rates of union and range of motion. [5, 25, 26]

Insertion of Herbert screw requires special equipment and high technical skills. Another disadvantages is that it violates scaphotrapezial joint, but the great advantage is that it provides more rigid fixation, promotes early active motion and compression than Kirschner wires. [1] We preffered the use of Kirschner-wires in case of small fragments when the use of Herbert-screw was not possible. To supplement fixation, we use a cast immobilisation for minimum 2 month.

The patients who had union did not report pain, but motion of the wrist and grip strength were slightly decreased compared with the

other (normal) wrist. Incipient osteoarthritis remains limited to the radioscaphoid joint, with no significant functional implications and there was no carpal collapse.

It is reported that use of a volar approach may lead to more capsular adhesions than use of a dorsal approach, but the postoperative stiffness was treated with early intensive rehabilitation, after the removal of the cast, which substantially improved the range of motion of the wrist.

All the patients from our study had union and we assessed bone union according to strict criteria: trabeculation had to be visible across the site of the fracture on all three radiographic projections. Early radiographies following a scaphoid vascularised graft may be inacurrate and could show a delay union or nonunion inspite of a united fracture. Scaphoid vascularised grafts may have a markedly delayed radiographic healing time. [2]

We think that good results in our small group of patients were due to that we achieved the two important factors that promote bone healing in nonunions: stability and vascularity in same time. The revascularisation and consolidation were obtained through two sources of capillary ingrowth: the vascular pedicle and the inlay cancellous bone graft from distal part of the radius. Stable internal osteosynthesis provides a mechanically favourable enviroment for the bone healing.

The limitation of our study was that we had a relatively small number of patients.

CONCLUSIONS

The principal advantages of the method were that: the vascular anatomy are constant and identifiable by a simple volar approach (donor and receptor sites are in same operating field), the blood supply of the graft is excellent and flexible enough to be manipulated to the new location, the donor site is accesible and provides enough bone quantity and short operation time.

The pronator quadratus vascularised bone graft is optimal because of his good structural integrity as well as a robust blood supply and can be harvested with minimal donor site morbidity. This procedure is relative easy and attractive alternative to other vascularized bone-grafting procedures and to the methods of inlay bone-grafting with the implementation of avascular bundle which are more difficult technically.

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