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Treatment for proximal pole scaphoid nonunion with capsular-based vascularized distal radius graft

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Abstract

Purpose We retrospectively reviewed the results of 89 patients with proximal pole scaphoid nonunion, 58 with avascular necrosis, treated with a capsular-based vascularized distal radius graft.

Methods Seventy-one male and eighteen female patients with symptomatic nonunion at the proximal pole of the scaphoid were included in this study. No patient had a humpback deformity. In all patients, the vascularized bone graft was harvested from the dorsum of the distal radius and was attached to a capsular flap of the dorsal wrist capsule. After fixation of the scaphoid with a small cannulated screw, the graft was inserted press-fit into the scaphoid trough in the nonunion site. Supplementary fixation of the graft with a microsuture anchor into the scaphoid was used in 66 patients.

Results At a mean time of 12.3 weeks (range 6–24) after surgery, solid union was achieved in 76 of 89 patients (49 of 58 with avascular necrosis). Eleven patients had persistent nonunion and two fibrous union as determined by CT scan. Sixty-six of the patients with solid bone union were completely pain free, and ten complained of slight pain with strenuous activities. No donor site morbidity was observed.

Conclusions The capsular-based vascularized bone graft from the distal radius is a reliable alternative technique for scaphoid nonunions. It is a simple and expedient harvesting technique without the need for a microsurgical anastomoses. The supplemental fixation with a microsuture anchor eliminates the risk of graft displacement.

Keywords Scaphoid avascular necrosis · Scaphoid nonunion · Scaphoid proximal pole · Vascularized bone graft

Introduction

Fractures of the proximal pole of the scaphoid are associated with higher rate of nonunion than the more distal fractures because of the retrograde interosseous blood supply of the scaphoid, which leads to tenuous vascularity of the proximal part of the scaphoid [1]. Furthermore, avascular necrosis of the proximal pole of the scaphoid further impairs bone healing [2]. Treatment for proximal pole scaphoid nonunion especially with avascular necrosis is a reconstructive challenge. Persistent nonunion is the main complication of treatment.

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Various techniques have been described for the treatment for scaphoid proximal pole nonunion, but there is no current consensus on optimal treatment [3]. Proposal treatment options vary from excision of the scaphoid proximal pole to open reduction and internal fixation with or without non-vascularized bone graft and vascularized bone graft. Clinical studies have demonstrated that vascularized bone grafts (VBGs) lead to a higher union rate than the conventional bone grafts likely due to superior biologic and mechanical properties [3–5].

Many types of vascularized bone grafts have been described. These include the VBG from distal radius based on the 1,2 intercompartmental supraretinacular artery (1,2 ICSRA) [6], the VBG based on the palmar carpal artery [7] or the ulnar artery [8] and free VBG from the iliac crest [9–11] and the medial femur condyle [12].

To avoid the need for dissection of small-caliber vessels in pedicled VBGs or microsurgical anastomoses in free VBGs, Sotereanos et al. [13] have previously reported promising early results of a dorsal capsular-based VBG from the distal

radius for proximal pole scaphoid nonunions. This graft is harvested from the dorsal distal radius and is attached to a wide distally based flap of the dorsal wrist capsule [13, 14]. It is supplied by the fourth extensor compartment artery (4 ECA) as latex injection studies have shown [15].

The purpose of this study was to evaluate mid- to long-term outcome of dorsal capsular-based VBG from the distal radius for proximal pole scaphoid nonunions.

Materials and methods

Between 2000 and 2016, eighty-nine patients with symptomatic nonunion at the proximal pole of the scaphoid were treated with a capsular-based vascularized distal radius graft by the senior author (D.G.S.). The medical data of these patients were reviewed retrospectively after obtaining institutional review board approval. Eighteen patients were females, and seventy-one were males. The mean patient age was 28 years (range 19–44 years), and the mean period from injury to surgery was 24 months (range 12–51 months). The dominant arm was involved in seventy-two patients (81%). Fifty-seven patients were users of tobacco products (64%). No patient had a previous surgery to the dorsal wrist. Patients with incomplete medical records or radiographs and a follow-up less than 2 years were excluded from the study.

Preoperative radiographs showed nonunion of the proximal third of the scaphoid in all patients. None of the proximal poles had any fragmentation or collapse. No patient had a humpback deformity. Radiographic evaluation indicated avascular necrosis with sclerotic and cystic changes of the proximal pole of the scaphoid in 58 of the 89 patients. Magnetic resonance imaging (MRI) was performed in 45 of the 58 patients with avascular necrosis of the proximal pole, which showed low-intensity signal in both T1- and T2-weighted sequences at the proximal pole confirming the diagnosis. However, in all 58 patients avascularity was verified during surgery by the lack of punctate bleeding from the proximal pole.

In all patients, the vascularized bone graft was harvested from the distal aspect of the dorsal radius and was attached to a capsular flap of the dorsal wrist capsule. After fixation of the scaphoid with a small cannulated screw, the graft was inserted press-fit into a dorsal trough across the nonunion site. Supplementary fixation of the graft with a microsuture anchor into the scaphoid was used in 66 patients.

Surgical technique

The procedure was performed under general or regional anesthesia with the use of tourniquet control and loupe magnification. A straight dorsal incision to the wrist just ulnar to the Lister tubercle was performed approximately 4 cm in length. Dissection was carried out through subcutaneous tissues, and the extensor pollicis longus (EPL) tendon and the extensor digitorum communis (EDC) tendons were identified. The wrist capsule was exposed by partially release of the extensor retinaculum of the fourth dorsal compartment. The ECD tendons were retracted ulnarly, and the EPL tendon was retracted radially.

The graft was outlined with a marking pen on the dorsal wrist capsule and distal radius. The capsular flap's shape was trapezoidal with length approximately 2 cm and width from 1 cm at the radial bone block to 1.5 cm at its base

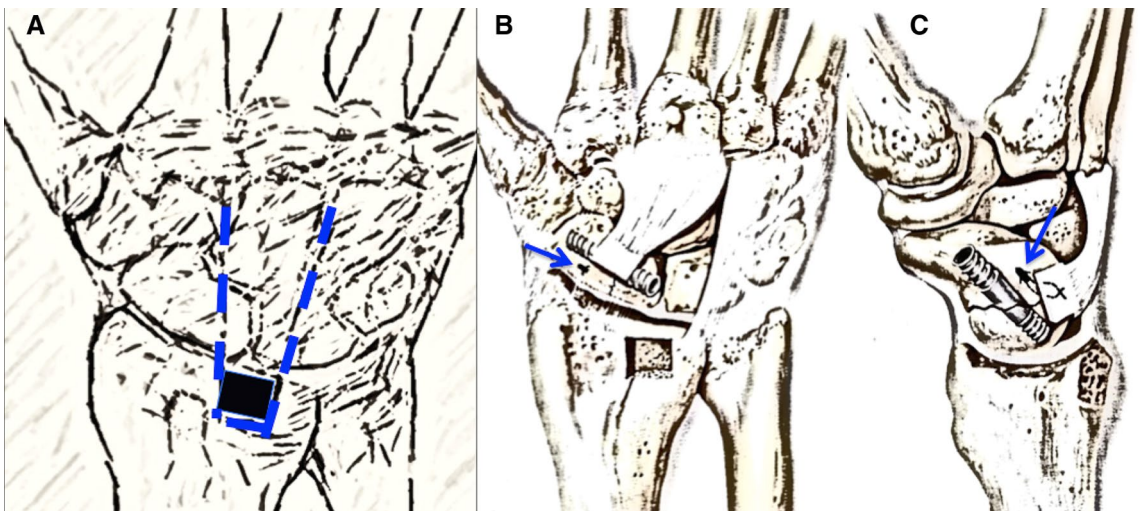

Fig. 1 Schematic view of the dorsal capsular-based vascularized distal radius graft. **a** The capsular graft is outlined with blue dotted line and the bone graft is marked with black color. **b** Anteroposterior and **c** lateral schematic views of the completed dorsal capsular-based vascularized distal radius graft technique. Note the bone anchor (blue arrow) next to the cannulated screw

(Fig. 1). The capsular flap was outlined sharply with a knife. The bone graft was harvested from the distal aspect of the dorsal radius just ulnar and distal to Lister tubercle including the dorsal ridge of the distal radius (Fig. 1). The bone graft's size was approximately 1 × 1 cm, and its depth was approximately 7 mm. With the use of a 1.0-mm side-cutting drill bit, the bone graft was outlined on the distal radius cortex with multiple drill holes. Then the bone graft was gently elevated with a thin osteotome with care to maintain 2–3 mm of the distal radius cortex intact to minimize the risk of propagation onto the articular cartilage of the radiocarpal joint. The capsular flap was elevated along with the bone graft from the underlying tissues in a proximal-to-distal direction. Care was taken to prevent detachment of the dorsal scapholunate ligament.

After the flap was elevated, the scaphoid proximal pole nonunion site was identified with wrist flexion. If a pseudarthrosis was present with disruption of the cartilage shell, the nonunion was cleaned with a dental pick and small curettes. Then attention was directed to the fixation of the scaphoid proximal pole nonunion with a small cannulated screw. Under fluoroscopic control, two 1-mm smooth Kirschner-wires were inserted into the scaphoid with the wrist in extreme flexion. The Kirschner-wires oriented from the proximal pole of the scaphoid toward the base of the thumb. One of these Kirschner-wires served as a guide wire for a cannulated screw, and the other served as a derotational wire. The guide wire for the screw was placed perpendicular to the fracture site and as volar as possible to enable dorsal trough and placement of the VBG. After the size of the cannulated screw was determined, the screw was inserted into the scaphoid and the derotational wire was then removed (Fig. 1b, c). Care was taken to bury the screw underneath the articular surface by approximately 2 mm.

At the completion of the nonunion fixation, a dorsal trough was created across the scaphoid nonunion site with a side-cutting burr in a nonarticular location. Care was taken to create a trough slightly smaller than the bone graft to allow press-fit impaction. All nonvascular viable tissue was curetted out and excavated from the nonunion site. Then the harvested bone graft with its capsular attachment was gently inserted into the scaphoid trough with minimal rotation (10°–30°) due to the close proximity of the graft donor site. In 66 patients, a microsuture anchor was placed at the floor of the trough to avoid dislodgement of the graft (Fig. 1b, c). A mattress stitch, from the suture anchor, was passed through the perimeter of the graft periosteum to secure the graft into the trough. The stitch was tied over the graft with care not to compress the pedicle of the graft. Hemostasis was obtained; the wound was irrigated and closed in layers.

Postoperative evaluation

Postoperatively, a short-arm thumb spica splint with the wrist in neutral position was applied for 2 weeks, followed by a short-arm thumb spica cast for another 4 weeks. Then a removable forearm-based thumb spica splint was used until solid union occurred. In all patients, radiographs were obtained with the cast removed in 6 weeks and monthly thereafter to assess union progression. The immobilization period was followed by physiotherapy to restore the range of motion of the wrist and the grip strength. Weight bearing was allowed after there was clinical and radiographic evidence of osseous union.

All patients underwent clinical and radiographic evaluations before and after the surgery. The wrist range of motion was assessed with a goniometer. Grip strength was measured using a Jamar dynamometer (Preston Corp, Clifton, NJ), and the values were recorded as a percentage of the strength on the contralateral (unaffected) side. Wrist function was assessed using the Mayo Modified Wrist Score (MMWS). Union was defined radiographically (posteroanterior, lateral, oblique views) as trabecular crossing the nonunion site and absence of sclerosis at the union site. Additional computed tomography (CT) scans at the longitudinal axis of the scaphoid were obtained in patients with doubtful healing based on radiographs.

The clinical data of all patients were statistically analyzed using the Wilcoxon signed-rank test.

Results

The mean follow-up period was 36 months with a minimum of 24 months (range 24–58 months). Solid union was achieved in 76 of 89 patients (85.4%). It was noted that 49 of the 58 patients with avascular necrosis of the proximal pole of the scaphoid went on to union (84.5%). The mean time to union was 12.3 weeks (range 6–24 weeks) after surgery. At the final follow-up, sixty-six of the patients with union were completely pain free and ten complained of slight pain with strenuous activities.

Two patients had fibrous union as determined by CT scan with pain only with strenuous activities. Eleven patients had persistent nonunion (nine patients were users of tobacco products). Two of these eleven patients had constant pain and nine had pain during activities.

The mean wrist flexion significantly improved from 34° before surgery to 47° after surgery ($p < 0.05$), and mean wrist extension significantly improved from 45° preoperatively to 70° postoperatively ($p < 0.05$). The mean grip strength at the final follow-up was 84% of the contralateral arm, compared with 67% before surgery ($p < 0.05$). The mean MMWS significantly improved from 42 preoperatively

to 87 postoperatively ($p < 0.05$). Seventy-eight patients were employed before their injuries. Sixty-nine of those patients returned to their previous occupations, five returned to light duty work and four were unemployed after surgery.

In our series, no patient developed a postoperative infection or donor site morbidity. No graft extrusion was observed. At the final follow-up, no arthritic changes were noted at the dorsal ridge of the radius. No other complications were noted.

Discussion

Scaphoid nonunion represents a challenging clinical problem. Untreated scaphoid nonunion over time results in progressive degenerative changes in the wrist leading up to scaphoid nonunion advanced collapse. Numerous techniques with bone grafts have been described in the treatment for scaphoid nonunion with avascular necrosis of the proximal pole showing higher union rate with the use of VBGs than the use of non-VBGs [3–5]. However, many of these VBGs require technically demanding dissection of small vessels such as dissection of the 1,2 ICSRA (mean diameter is 0.3 mm) or microsurgical anastomoses in free VBGs.

The concept of capsular-based vascularized distal radius graft was designed to overcome the difficulties with graft harvesting and to avoid the need for microsurgical anastomoses. This VBG is nourished by the artery of the fourth extensor compartment, and the pedicle is included with the strip of dorsal capsule that is attached to the bone graft, without the need for a microvascular dissection of the pedicle. It is harvested from a position that allows easy access to the proximal scaphoid pole with minimal rotation 10°–30°, thus minimizing the risk of nutrient vessel kinking.

In the reported studies for treatment for scaphoid nonunions using VBGs, although the primary goal was the bone union, the results have not been uniform [6, 7, 16–24], making the comparison difficult. Most of these studies evaluated a mixed population with proximal pole scaphoid nonunion and scaphoid waist nonunions, using a variety of methods to evaluate the vascularity of the proximal pole (radiographic appearance, MRI, surgical findings). In contrast, our current study included only proximal pole scaphoid nonunions, most of them with avascular necrosis (58 of 89 patients).

In the current cohort, the overall union rate with the capsular-based VBG was 85.4% (76 of 89 patients) at a mean time of 12.3 weeks (Figs. 2, 3). Solid union was achieved in 49 of 58 (84.5%) nonunions with an avascular proximal pole (84.5%). No donor site morbidity was observed from graft harvesting, as shown by maintenance of wrist stability and improvement of the range of motion. Moreover, no arthritic changes were observed at the harvest site at final follow-up evaluation.

Our results compare favorably with other techniques for the treatment for scaphoid proximal pole nonunion reported in the literature. A meta-analysis study reported an overall union rate of 88% with the use of vascularized bone graft with internal fixation for scaphoid proximal pole nonunion with an avascular necrosis [4]. In contrast, the authors reported union in only 47% of nonunions treated with non-vascularized graft with internal fixation [4]. More recently, another systematic meta-review demonstrated a union rate of 89% (84–93) with the use of vascularized bone graft from the distal radius and 87% (80–93) with the use of iliac crest grafts in patients with scaphoid nonunions [3]. The authors

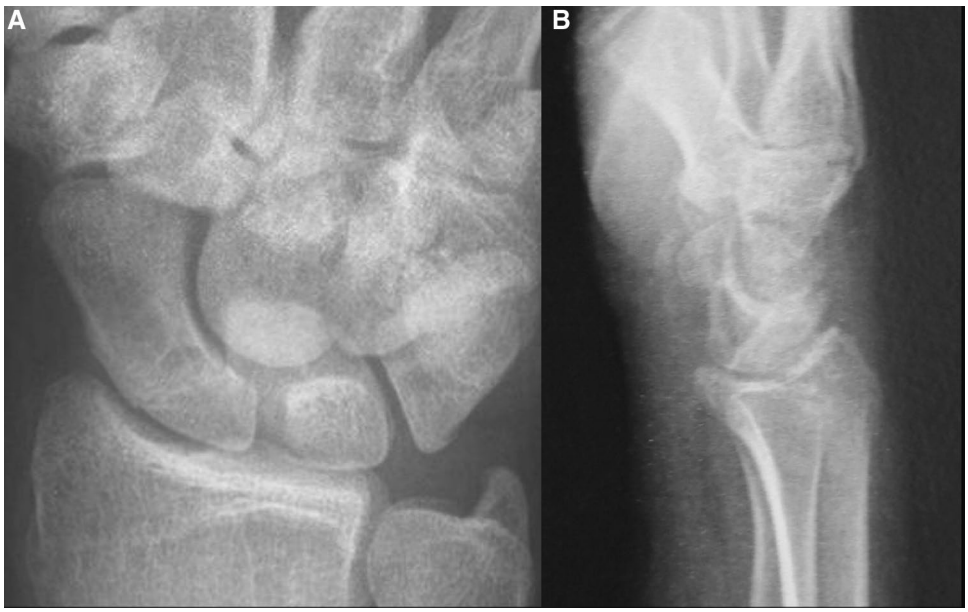

Fig. 2 Anteroposterior (**a**) and lateral (**b**) radiographs of the right wrist showing a nonunion of the proximal pole of the scaphoid

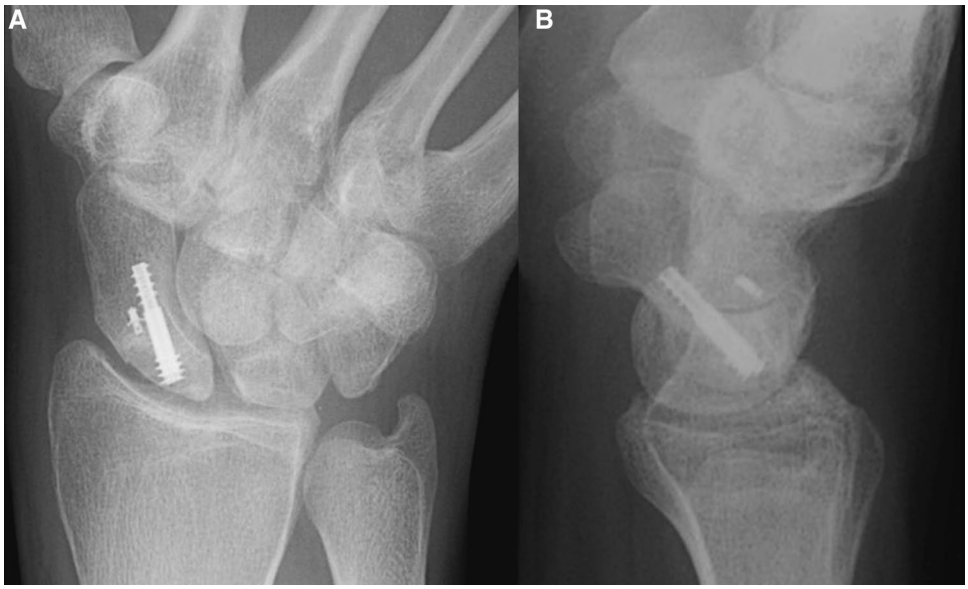

Fig. 3 Anteroposterior (**a**) and lateral (**b**) radiographs of the right wrist joint at 24 months postoperative showing no evidence of scaphoid necrosis or arthritic changes of the radiocarpal joint. Note the bone anchor next to the cannulated screw

found higher complication rates with the use of the iliac crest graft [3]. However, this study did not demonstrate a significantly superior technique for the management of scaphoid nonunion [3].

Many clinical studies have shown good to excellent results with the use of the vascularized bone graft from distal radius based on the 1,2 ICSRA with a union rate from 60 to 100% [6, 17–21]. However, as with all dorsally harvested grafts, the 1,2 ICSRA graft cannot correct a humpback deformity. In a large clinical series with the 1,2 ICSRA pedicled VBG, union was achieved in 71% of cases with proximal pole scaphoid nonunion (34 of 48 patients) [18]. However, union was noted in only 50% of nonunions with an avascular proximal pole (12 of 24 patients) [18]. Furthermore, a failure rate of 64% was noted in patients (9 of 14) with scaphoid nonunion with avascular necrosis of the proximal pole and concomitant humpback deformity [18]. The authors found that screw fixation had a better union rate than other techniques of fixation (Kirschner-wires, no fixation of the graft) [18].

Another potential disadvantage of the 1,2 ICSRA pedicled VBG is that its vascular pedicle may be kinked with the rotation, requiring a radial styloidectomy to avoid tension on the vascular pedicle. In a clinical study, the authors evaluated the outcomes of the 1,2 ICSRA pedicled VBG in 30 patients with scaphoid nonunion, 11 proximal pole with avascular necrosis and 19 scaphoid waist [20]. The investigators reported union in 28 of the 30 patients (93%) at a mean of 5.5 months for nonunions of the proximal pole and 4.1 months for nonunions of the waist [20]. In order to accomplish higher union rate and decrease tension on the vascular pedicle of the graft, cannulated screw fixation and a concomitant radial styloidectomy were performed in all patients [20]. Additionally, the authors placed the 1,2 ICSRA pedicled VBG in a volar direction in all scaphoid waist nonunions to correct the humpback deformity [20]. The extra step of radial styloidectomy is not necessary with the capsular-based vascularized distal radius graft technique because of its short arc of rotation.

In our study, there was no case of failure due to extrusion of the graft. The graft was inserted press-fit into the scaphoid trough; however, a mismatch size difference between the graft and the trough may lead to graft dislodgement in the early postoperative period. To eliminate the risk of graft extrusion, we currently use a microsuture anchor at the floor of the trough as a supplementary fixation to secure the graft to the scaphoid. A microsuture anchor was used in the last 66 patients of the current series.

The current study was limited by its retrospective nature. The absence of a control group was another limitation of the study. However, this cohort included a large series of 89 proximal pole scaphoid nonunions (58 with avascular necrosis) with a mean follow-up of 36 months. A relative contraindication of the capsular-based vascularized bone graft from the distal radius is previous surgery or injury to the dorsal aspect of the wrist or distal radius due to possible damage of the blood supply to the dorsal capsule. Another limitation of this graft is the inability to correct a concomitant humpback deformity, as with all dorsally harvested VBGs. None of the patients in the current study had a humpback deformity.

The humpback deformity in scaphoid nonunions can be corrected with the use of bone graft from the iliac crest or the volar radius pedicled VBG following by fixation with a screw [7, 25, 26]. In the Fisk-Fernandez technique, an anterior wedge-shaped corticocancellous graft from the iliac crest is inserted at the scaphoid nonunion site restoring the

length and the alignment of the scaphoid [25, 26]. The volar radius pedicled VBG is based on the radial carpal artery just distal to the pronator quadratus and is interposed press-fit in a volar direction to correct the humpback deformity [7]. Union rates of 80% to 100% have been reported with these techniques [7, 25, 26].

Conclusion

In summary, the capsular-based vascularized bone graft from the distal radius is a simple and expedient harvesting pedicled VBG avoiding meticulous pedicle dissection or microsurgical anastomoses. The supplemental fixation with a microsuture anchor eliminates the risk of graft displacement. The capsular-based vascularized bone graft from the distal radius is a reliable alternative technique for proximal pole scaphoid nonunions, even with avascular necrosis, providing successful clinical outcomes.

Compliance with ethical standards

Conflict of interest All the authors have no conflict of interest.

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