Vascularised bone graft from the base of the second metacarpal for refractory nonunion of the scaphoid

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A vascularised bone-graft procedure from the base of the second metacarpal was performed in 14 patients with nonunion of the scaphoid. There were 11 men and three women with a mean age of 22 years. In eight patients, who had dorsiflexed intercalated segment instability (DISI), an open wedge was formed at the site of nonunion, and the vascular pedicle was grafted from the volar side. In the six patients without DISI, transplantation was carried out through the same dorsal skin incision.

Complete bony union was obtained in all patients after a mean post-operative period of 10.2 weeks, and DISI was corrected in all affected patients. According to Cooney’s clinical scoring system, the results were excellent in five, good in six, and fair in three patients. Because of its technical simplicity and the limited dissection needed, the procedure should be considered for the primary surgical treatment of patients with nonunion of the scaphoid.

Although the results of the treatment of nonunion of a fractured scaphoid have improved with new devices for internal fixation and improvements in the techniques of bone grafting, the optimal methods of treatment remain controversial.1-4

Union may be difficult to achieve, and several operations may be required for patients who develop avascular necrosis of the proximal pole. There may be stiffness and reduced grip strength because of the prolonged time to bony union. When nonunion is complicated by dorsiflexed intercalated segment instability (DISI), the rotation of carpal bones must be corrected at the time of surgery, and a large bone graft from the volar side is required. Since Foucher and Braun5 reported the use of bone grafts using the first dorsal metacarpal artery as a pedicle in patients with refractory nonunion, various methods of vascularised bone grafting have been described.6-14 However, they have often posed problems, such as a large scar on the hand or forearm and difficulty in identifying or elevating the pedicle because of the small diameter of the vessels. Makino13 described a vascularised bone graft from the base of the second metacarpal using the same dorsal skin incision. In 2002, we reported that this technique could be performed from the volar side in patients with DISI.15 We now show that it can be applied either to the volar or dorsal side depending on the site and state of the nonunion and we present the clinical results.

Patients and Methods
Between March 1999 and February 2003 we treated 14 patients with nonunion of the scaphoid including two with transscaphoid perilunate dislocation and one with a pathological fracture through a bone cyst. There were 11 men and three women with a mean age of 22 years (13 to 32) at the time of surgery. The affected side was the right in eight and left in six, and the mean time interval from injury or the onset of symptoms to surgery was 10.1 months (4 to 20).

No clear history of trauma was noted in the patient with the pathological fracture. In three patients the fracture had been overlooked at the time of initial treatment. Five patients had undergone prolonged immobilisation in a cast and previous surgery for the fracture or nonunion using a Herbert screws had failed in five patients. There was pain, restricted movement, and reduced strength of grip in all patients.

Radiography at the initial examination showed the site of nonunion to be in the middle third of the scaphoid in nine patients...
and the proximal third in five. There was sclerosis at the site of nonunion in five, and mild degenerative changes in two. There was a wide area of low-signal-intensity indicative of bone in the proximal bone fragment in T1-weighted and T2-weighted MR scans in ten patients. According to the criteria of Filan and Herbert\textsuperscript{16} for nonunion of the scaphoid, the condition was D2 (pseudarthrosis, early deformity) in three, D3 (sclerotic pseudarthrosis, advanced deformity) in four, and D4 (avascular necrosis, fragmented proximal pole) in seven patients. Nonunion was complicated by DISI in ten of the 14 patients.

In the first three patients, pre-operative angiography was performed to confirm the site and size of the blood vessel which might be used as the pedicle. It was performed again two weeks post-operatively in one patient to confirm the patency of the vessel.

**Operative technique.** The operation is undertaken using either general anaesthesia or an axillary nerve block, and after exsanguination a pneumatic tourniquet is applied. The scaphoid is approached through a curved dorsal incision about 4 cm long from the anatomical snuffbox to the shaft of the second metacarpal bone (Fig. 1). The superficial branch of the radial nerve is identified, dissected, and carefully retracted. The dorsal intercarpal arch and the second dorsal metacarpal artery, which originates from the radial artery in the anatomical snuffbox,\textsuperscript{17} are then identified. This vessel is dissected to the level of the shaft of the second metacarpal. This is facilitated by identifying it on the periosteum at the ulnar margin of the tendon of extensor carpi radialis and advancing the dissection proximally and distally. Since the dorsal intercarpal arch passes under the tendons of extensor pollicis longus and extensor carpi radialis and the superficial branch of the radial nerve, dissection is advanced by retracting these tendons and sequentially ligating the dorsal intercarpal and basal metacarpal arches (Fig. 2). Thereafter, this vessel is elevated *en bloc* with periosteum, and cortical and cancellous bone from the base of the second metacarpal bone. This is done by cutting a square of periosteum on the base of the second metacarpal with a scalpel and making a hole in the bone at each corner of the square with a 1.0 mm Kirschner wire (K-wire). The cortico-cancellous graft is then carefully detached in one piece using an osteotome (Fig. 3a). After the pedicle graft has been detached and elevated, the tourniquet is released temporarily to confirm whether the blood flow is adequate. The site of nonunion is then exposed on the dorsal side through the same skin incision. It is curetted until cancellous bone is exposed, and the moulded graft inserted (Fig. 3b). If there is a gap, further cancellous bone is collected from the base of the second metacarpal and incorporated as a free graft. The graft is fixed with a Herbert screw or K-wires inserted from the proximal side.

For scaphoid nonunion with DISI, a curved incision about 3 cm long is also made over the scaphoid from the volar side. The site of nonunion is exposed and curetted until cancellous bone has been exposed. As described by
Nakamura et al., a K-wire is inserted into the lunate from the dorsal side, the lunate and the proximal part of the scaphoid are rotated distally en bloc to correct DISI as an open wedge, and the size and shape of the required graft are measured. The pedicle graft is then temporarily elevated to the snuffbox (Fig. 4a) and transferred to the site of nonunion, which has been exposed on the volar side, by passing it beneath the tendons of abductor pollicis longus and extensor pollicis brevis subcutaneously. The graft is shaped into a wedge which matches the site of nonunion and is inserted. Finally, it is fixed with a Herbert screw or K-wires (Fig. 4b).

Plain radiographs were obtained every two weeks after surgery, and bony union was considered to have been achieved when continuity was observed across the site of nonunion. In the patients with DISI, the radiolunate angle was measured on plain lateral radiography before and after operation.

The results were evaluated using the clinical scoring system of Cooney et al based on four categories of pain, function, range of movement and grip strength (Table I). The results were rated as excellent, good, fair, and poor when the total score was 90 to 100, 80 to 90, 65 to 80, and 65 or less, respectively. The mean follow-up period was 11.9 months (7 to 25).

**Results**

Detailed profiles of the 14 patients are shown in Table II. The graft was fixed using a Herbert screw in ten patients and K-wires in four. A spica cast including the thumb was applied for a mean of 7.5 weeks (6 to 10) after surgery. Complete bony union was obtained in all patients. The mean time interval until radiological confirmation of union was 10.2 weeks (6 to 15) and the K-wires used for fixation were removed after a mean period of 12 weeks (7 to 19).
On post-operative angiography which was undertaken in one patient, the second dorsal metacarpal artery showed spasm, but the blood flow around the graft was maintained (Fig. 5). In one patient, the second dorsal metacarpal artery was mistakenly separated during surgery, and a bone graft from the base of the third metacarpal with a pedicle from the third dorsal metacarpal artery was transplanted as an emergency alternative.

In the eight patients with pre-operative DISI, in whom a volar approach had been used, the mean radiolunate angle decreased from 17.1° (8 to 26) before to -3.1° (0 to -9) after surgery, indicating correction of the DISI, but overcorrection was observed in one patient. Pain persisted during forced dorsiflexion of the wrist such as during push-ups in two patients, and another complained of pain during strenuous gripping, but all resumed the work in which they were engaged before injury. The mean range of movement of the wrist was 58° (38 to 75) in palmar flexion and 58° (40 to 70) in dorsiflexion. The grip strength improved by a mean of 35% (0 to 60) after surgery. Although neurapraxia of the superficial branch of the radial nerve was noted post-operatively in three patients, it resolved within three months. In the two patients who had degenerative changes before surgery, there was no progression of these changes at follow-up, and no new degenerative changes occurred in the other 12 patients. The outcome according to the clinical scoring was excellent in five, good in six, and fair in three patients. An illustrative case is shown in Figure 6.

**Discussion**

Recently, the results of treatment of nonunion of the scaphoid have improved, and the rate of union has been reported to have reached 90%. However, the rate of healing of nonunion remains lower than for nonunion of fractures at other sites.

A vascularised bone graft, which is more reliable and less invasive than a conventional graft allows union more consistently and rapidly. Reports regarding vascularised bone grafting for the treatment of refractory scaphoid nonunion have appeared sporadically, but no method has been adapted as the standard. Kuhlman et al. described the results of bone grafting from the palmar side of the distal end of the radius with a pedicle of the palmar carpal artery. Zaidenberg et al. described a bone graft from the radial side of the distal end of the radius with a pedicle of the ascending irrigating branch of the radial artery, and Yajima et al. applied this vascularised bone graft to the palmar side. Since the diameter of the vessels used by these methods is small, identification of the vessels is often difficult after exsanguination.

Moreover, because the vessels cross the mobile wrist, kinking is likely to occur. In the method of Guimberteau and Panconi in which bone graft is taken from the ulna...
using the ulnar artery as the pedicle, a large vessel is used, but the incision extends over 10 cm from the carpal area to the middle of the forearm. In the method of Yuceturk et al,⁹ in which the first dorsal metacarpal artery is used as the pedicle, and that of Mathoulin and Brunelli,¹¹ in which the second dorsal metacarpal artery is used, there is insufficient cancellous bone which can be elevated en bloc with the graft because it is taken from the shaft of the metacarpal. Sakai, Doi and Kawai²¹ and Doi et al²² reported the use of free vascularised periosteal bone grafts from the femoral region, but the method involved damage to healthy parts of the body, and a microsurgical technique was required.

Radiographs of a 26-year-old man in whom the initial surgery for transscaphoid perilunate dislocation had failed. Figure 6a – Anteroposterior (AP) view six months after the initial surgery. The bone at the site of the fracture had been resorbed, but no radiolucent area was noted around the Herbert screw. Figure 6b – The second dorsal metacarpal artery was sufficiently identifiable on the periosteum even after exsanguination (at the tip of the forceps). Figure 6c – The tourniquet was released temporarily, and the blood flow confirmed to be adequate. However, no circulation was detected in the proximal pole during surgery. The original screw was replaced by a longer one. Figure 6d – AP view two months after surgery showing union.
Therefore, it is more reasonable to perform these procedures as salvage operations after vascularised bone grafting has failed.

The dorsal intercarpal arch and its branch, the second dorsal metacarpal artery, which are used as the pedicle of the graft, run over the periosteum, have a large diameter, and are easy to identify and elevate. Also, the base of the metacarpal is advantageous as a donor site, because it is cortical bone and is of sufficient thickness, and is rich in cancellous bone which can also be used to fill bony defects at the site of nonunion. A skin incision of 3 to 4 cm suffices for the dissection of the graft so that the procedure is less invasive than other methods. Makino reported this procedure and performed it from the dorsal side for nonunion of scaphoid fractures and Kienböck’s disease. We also performed this procedure on patients with DISI approaching the nonunion from the volar side for its correction. A pedicle with a sufficient length could be obtained in all patients, and kinking did not occur because the pedicle did not cross the wrist. In addition, because many vascular buds form a network on the dorsal side of the carpal region, the adjacent third dorsal metacarpal artery could be used when the elevation of the second dorsal metacarpal artery failed. Moreover, from the experience of being unable to identify the ascending irrigating branch when the method of Zaidemberg et al was previously attempted, we performed angiography on the first three patients who underwent this procedure to study the position and the size of the dorsal radiocarpal arch and second dorsal metacarpal artery. However, since these vessels are by readily identified intra-operatively, we do not now perform angiography. We also performed angiography post-operatively on one patient. Doi et al reported that thrombi formed in blind-loop peripheral arteries and veins immediately after a pedicle bone graft, but we noted no obstruction of vessels in our patients despite the narrowing of their lumina compared with the pre-operative level.

In many reports, vessels have not been completely exsanguinated to ensure their identification during surgery, but the dorsal radiocarpal arch and second dorsal metacarpal artery can be readily identified because they have a diameter of 1 mm or more, and because pooling of blood in vessels can be confirmed visually during surgery even with complete exsanguination. Currently, we perform dissection with complete exsanguination, and confirm the blood flow by releasing the tourniquet after elevation of the pedicle.

There are some reports which suggest that conventional bone grafting should be the first choice for the treatment of nonunion of the scaphoid and that, when union has not been achieved by the first operation, vascularised bone grafting should be attempted. However, because of its technical ease and low invasiveness, we also recommend it as a primary surgical procedure for nonunion of the scaphoid.

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References


