Vascularized bone graft pedicled on the volar carpal artery from the volar distal radius as primary procedure for scaphoid non-union

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Introduction

Five to 30\% of scaphoid fractures evolve towards non-union [1,2]. Without treatment, this leads to periscaphoid arthritis and carpal collapse with dorsal intercalated segment instability (DISI) deformity of the lunatum [3]. Non-vascularized bone graft gives non-union in up to 20\% of cases [4–6], and in more than 50\% in case of proximal pole necrosis [7]. Vascularized bone graft seems to be associated with a better rate of consolidation, but is generally restricted to secondary intervention or proximal pole necrosis [5,8].

KEYWORDS
Scaphoid non-union; Vascularized bone graft

Summary

Introduction: The treatment of scaphoid non-union with non-vascularized bone graft leads to non-union in 10 to 20\% of cases and up to 50\% in case of proximal pole necrosis. Vascularized bone graft improves consolidation rates, but is generally restricted to secondary scaphoid non-union.

Hypothesis: This study assessed the value of a primary vascularized bone graft pedicled on the transverse volar carpal artery from the volar aspect of the distal radius as donor site.

Patients and methods: This retrospective study included 111 cases of vascularized bone graft for scaphoid non-union as primary procedure in 73 cases and secondarily in 38. The procedures were performed through a single incision.

Results: Mean delay before surgery was 25.5 and 33 months respectively, with union rates of 96\% and 89.5\%. Results showed improvement in both groups, but were better in primary surgery in terms of range of motion, strength, pain, function, satisfaction and return to work. There were more complications with secondary surgery.

Discussion: All reports agree that union is better with vascularized bone graft. This technique performed as a day of admission surgery through a single incision under locoregional anesthesia seems feasible as a primary intervention.

Level of evidence: IV – retrospective study.

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Several vascularized grafts have been described [9–18], including graft pedicled on the palmar carpal artery [19]. Mathoulin [14,19] adopted Kuhlmann’s graft harvested from the volar radius [16], vascularized by the volar carpal artery with anastomosis between the radial and ulnar arteries [20], following a cadaver study [19] (Fig. 1).

This retrospective study compared results of vascularized bone graft from the volar radius for scaphoid non-union as a primary intervention in 73 cases and secondarily in 38 cases.

**Patients and method**

**Inclusion and exclusion criteria**

This retrospective single-surgeon series included patients operated on for scaphoid non-union between January 1994 and September 2008. Non-unions of grade 1 or 3B or grade 4 with necrosis were excluded.

**Homogeneous patient groups**

Two homogeneous groups of vascularized bone graft from the volar radius were identified.

Group 1 comprised 73 patients with primary vascularized graft for non-union. Thirty-three were initially managed conservatively by 1—24 weeks’ immobilization (mean 10.3 weeks). Non-union was classified using the Alnot classification (Table 1), as grade 2A, 2B, or 3A. Associated radial styloidectomy was performed in the same sitting.

Group 2 comprised 38 patients with secondary vascularized graft. The primary treatment was non-vascularized iliac crest bone graft in 14 cases (37%), revised in two cases; a screw in 21 cases (55%); and staples in three cases (8%). Non-union was grade 2A, 2B, or 3A, with associated styloidectomy.

Table 2 shows data for the two groups.

**Surgical technique [14,21]**

Surgery was performed as a day case procedure under locoregional anesthesia, through a single incision: the Henry approach was extended by a distal lateral limb towards the scaphoid tubercle (Fig. 2).
### Table 2  Patient characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Primary treatment patients (n = 73)</th>
<th>Secondary treatment patients (n = 38)</th>
</tr>
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<tbody>
<tr>
<td><strong>Sex</strong></td>
<td>89% ♂ (65), 11% ♀ (8)</td>
<td>87% ♂ (33), 13% ♀ (5)</td>
</tr>
<tr>
<td><strong>Mean age (years)</strong></td>
<td>30.41 ± 11.2 (15 to 61 yrs)</td>
<td>31.16 ± 8.6 (19 to 47 yrs)</td>
</tr>
<tr>
<td><strong>Dominant involvement</strong></td>
<td>64% (47)</td>
<td>66% (25)</td>
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<tr>
<td><strong>Occupation</strong></td>
<td>26% manual workers (19)</td>
<td>71% manual workers (27)</td>
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<tr>
<td></td>
<td>74% sedentary (54)</td>
<td>29% sedentary (11)</td>
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<tr>
<td><strong>Fracture-surgery interval (months)</strong></td>
<td>20.51 (4 to 120)</td>
<td>23.38 (10 to 72)</td>
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<tr>
<td><strong>Initial treatment</strong></td>
<td>55% non-diagnosed</td>
<td>92% (35) immobilization (15.4 weeks)</td>
</tr>
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<td></td>
<td>45% (33) conservative treatment (10.3 weeks immobilization)</td>
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<tr>
<td><strong>Type of fracture</strong></td>
<td>26% proximal pole (19)</td>
<td>13% proximal pole (5)</td>
</tr>
<tr>
<td></td>
<td>74% waist (54)</td>
<td>87% waist (33)</td>
</tr>
<tr>
<td><strong>Type of non-union (Alnot classification)</strong></td>
<td>2A: 67% (49)</td>
<td>2A: 39.5% (15)</td>
</tr>
<tr>
<td></td>
<td>2B: 30% (22)</td>
<td>2B: 52.5% (20)</td>
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<tr>
<td></td>
<td>3A: 3% (2)</td>
<td>3A: 8% (3)</td>
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</table>

In some cases where the scaphoid showed a "humpback" deformity, reduction was performed using a chisel and maintained by temporary pins. The volar carpal artery lies between the palmar periosteum of the radius and the distal part of the superficial aponeurosis of the pronator quadratus, the last distal centimeter of which was opened; then the periosteum was sectioned using a knife for about 1 cm on either side of the pedicle. The lateral half of the pedicle was released subperiosteally up to the radial artery (Fig. 3).

The graft was harvested from the radius using a chisel. The pedicle was then dissected up to the origin of the volar carpal artery (Fig. 4). The scaphoid was screwed from distal to proximal. The bone graft was fitted to fill the defect on the volar aspect of the scaphoid (Fig. 5), and stabilized by tightening the screw (Fig. 6) or using a temporary pin (Fig. 7). The capsule was sutured without compressing the pedicle, and the radioscapohapiticate ligament was repaired. A palmar splint with the wrist in 40° extension was kept until consolidation was achieved. The pin was removed at 3 weeks.

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**Figure 3** Dissection of the volar carpal artery.

**Figure 4** Harvesting pyramidal graft and exposure of scaphoid bone defect. Drawing and photograph.
Evaluation methods

Range of motion, force and pain were measured preoperatively and at last follow-up. Motion was measured in flexion, extension and radial and ulnar inclination. Muscle force was measured in kilogram using a Jamar dynamometer. Consolidation time was determined using control X-rays. Complications, return to work, functional recovery on the Mayo Wrist Score and overall patient satisfaction were recorded. All data were collected by a single observer (C.M.).

Results were evaluated using descriptive statistical analysis.

Results

None of the patients were lost to follow-up. Mean follow-up (FU) was 25.5 months (10—65 months) in group 1 and 33 months (10—63 months) in group 2. Table 3 shows data for the two groups.

Complications

There were six complications (8%) in group 1. Three patients (4%) showed non-union; two had proximal pole (PP) fractures (10.5% of PPs) initially and the third a waist fracture (W) (1.8% of Ws). Three patients (4%) showed stiffness requiring tenoarthrolysis; they had proximal pole fracture (15.8% of PPs).

There were 10 complications (26%) in group 2. Four patients (10.5%) showed non-union; one PP (20% of PPs) and three Ws (9% of Ws). Two underwent secondary four-corner arthrodesis and scaphoidectomy, and were not satisfied by their operations. The other two refused further surgery. One patient (2.5%) with waist fracture initially (3% of Ws) showed stiffness requiring tenoarthrolysis. Three patients (8%) had complex regional pain syndrome.

Subjective and functional results

There was significant pain relief. In group 1 with PP, pain passed from severe in 10.5% of cases and moderate in 89.5% initially, to 10.5% moderate and 89.5% pain-free. In W, pain passed from severe in 7.4% of cases and moderate in 92.6% initially, to 1.8% moderate and 98.2% pain-free.

In group 2, pain levels were markedly higher, both pre- and postoperatively. In PP, pain was initially severe in 60% of cases and moderate in 40%, and decreased to 60% moderate and 40% pain-free. In W, pain was initially severe in 60.6% of cases and moderate in 39.4%, and decreased to 3% severe, 39.4% moderate and 57.6% pain-free. Although there was clear improvement in pain, these results were less satisfactory than for first-line treatment.

In group 1, the functional results on the Mayo Wrist Score were excellent or good in 94.5% of cases; 98.5% of patients were completely satisfied or had only minor reservations. One patient with initial PP fracture was dissatisfied. He had a poor functional score, showed non-union, and was the only one who would not have the operation again.

In group 2, the functional results were 73.2% excellent or good and 26.5% moderate or poor (PP: 40% excellent, 40% good, 20% poor; W: 42.5% excellent, 30.3% good, 18.2% moderate and 9% poor). Overall, functional results were worse than in group 1. Seventy-six percent of patients were completely satisfied or had only minor reservations, 16% had
Table 3  Clinical and radiological results per group.

<table>
<thead>
<tr>
<th></th>
<th>Primary treatment patients (n = 73)</th>
<th>Secondary treatment patients (n = 38)</th>
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<tbody>
<tr>
<td><strong>Follow-up (months)</strong></td>
<td>25.5 ± 14.5 (10 to 65)</td>
<td>33 ± 18.3 (10 to 63)</td>
</tr>
<tr>
<td><strong>Radiologic consolidation</strong></td>
<td>96%</td>
<td>89.5%</td>
</tr>
<tr>
<td><strong>Mean time to consolidation (weeks)</strong></td>
<td>9.7 ± 4.9 (6 to 24)</td>
<td>10.8 ± 4.2 (6 to 24)</td>
</tr>
<tr>
<td><strong>Flexion (degrees)</strong></td>
<td>+10.6 ± 13.7 (−30 to 40)</td>
<td>+11.3 ± 12.2 (−10 to 40)</td>
</tr>
<tr>
<td><strong>Extension (degrees)</strong></td>
<td>+7.8 ± 10.4 (−5 to 40)</td>
<td>+16.3 ± 14.6 (0 to 50)</td>
</tr>
<tr>
<td><strong>Radial deviation (degrees)</strong></td>
<td>+5.3 ± 5.5 (−8 to 20)</td>
<td>+6.3 ± 6.3 (−5 to 15)</td>
</tr>
<tr>
<td><strong>Ulnar deviation (degrees)</strong></td>
<td>+5.6 ± 5.9 (−5 to 20)</td>
<td>+7.4 ± 6.8 (0 to 20)</td>
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<tr>
<td><strong>Muscle force (Kg)</strong></td>
<td>+16.4 ± 9.5 (0 to 35)</td>
<td>+18.2 ± 12 (−6 to 45)</td>
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<thead>
<tr>
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<th>Preoperative</th>
<th>Postoperative</th>
<th>Preoperative</th>
<th>Postoperative</th>
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<tr>
<td><strong>Pain</strong></td>
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<tr>
<td>Severe</td>
<td>8% (6)</td>
<td>0%</td>
<td>60.5% (23)</td>
<td>2.5% (1)</td>
</tr>
<tr>
<td>Moderate</td>
<td>92% (67)</td>
<td>4% (3)</td>
<td>39.5% (15)</td>
<td>42% (16)</td>
</tr>
<tr>
<td>None</td>
<td>0%</td>
<td>96% (70)</td>
<td>0%</td>
<td>55.5% (21)</td>
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<tr>
<td><strong>Complications</strong></td>
<td></td>
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<tr>
<td>Non-union</td>
<td>4%</td>
<td></td>
<td>10.5%</td>
<td></td>
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<tr>
<td>Stiffness</td>
<td>4%</td>
<td></td>
<td>2.5%</td>
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<tr>
<td>CRPS</td>
<td>0%</td>
<td></td>
<td>8%</td>
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<td><strong>Functional results (Mayo Wrist score)</strong></td>
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<tr>
<td>Excellent</td>
<td>83.5% (61)</td>
<td></td>
<td>42% (16)</td>
<td></td>
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<tr>
<td>Good</td>
<td>11% (8)</td>
<td></td>
<td>31.5% (12)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>4% (3)</td>
<td></td>
<td>16% (6)</td>
<td></td>
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<tr>
<td>Poor</td>
<td>1.5% (1)</td>
<td></td>
<td>10.5% (4)</td>
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<td><strong>Overall satisfaction</strong></td>
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<tr>
<td>Completely satisfied</td>
<td>85% (62)</td>
<td></td>
<td>44.5% (17)</td>
<td></td>
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<tr>
<td>Minor reservations</td>
<td>13.5% (10)</td>
<td></td>
<td>31.5% (12)</td>
<td></td>
</tr>
<tr>
<td>Major reservations</td>
<td>0%</td>
<td></td>
<td>16% (6)</td>
<td></td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>1.5% (1)</td>
<td></td>
<td>8% (3)</td>
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</table>

major reservations and 8% were dissatisfied. The three dissatisfied patients had poor functional results and non-union on X-ray, and were the only patients to say they would not have the operation again; two had had W fractures (6% of Ws) and one PP (20% of PPs).

In group 1, patients returned to work at a mean 9.7 ± 5.7 weeks, except for one patient who never returned and remained on disability benefit for work accident. Three patients (4%) had to change jobs (5.3% of PPs and 3.7% of Ws). In group 2, patients returned to work at a mean of 17.5 ± 12 weeks (PP, 14.6 weeks; W, 18 weeks), except for one patient who never returned and who was one of the four showing non-union. Six patients (16%) had to change jobs; two PPs (40% of PPs); four W (12.1% of Ws).

Clinical results

Range of motion and force improved, with greater gain in the primary group.

In group 1, mean flexion rose from 51.4° to 62°, gain = 10.6° (PP, 11.3°; W, 0.4°), extension from 61.2° to 69.3°, gain = 7.8° (PP, 10°; W, 7.4°), radial deviation from 15.5° to 20.2°, gain = 5.3° (PP, 4.5°; W, 4.8°), and ulnar deviation from 24.6° to 30°, gain = 5.6° (PP, 5.8°; W, 5.3°). There was clear improvement in force on the Jamar, from a mean 26.8 to 42.3 kg (compared to the contralateral control values which remained stable at a mean 46.3 and 45.4 kg, respectively): i.e., a gain of 16.4 kg (PP, 15.4 kg; W, 16 kg).

Results for motion and force showed similar improvement in secondary grafting, but at lower levels. Mean flexion rose from 35° to 46.3°, gain = 11.3° (PP, 8°; W, 11.9°), extension from 41.6° to 58.5°, gain = 16.3° (PP, 22°; W, 16.2°), radial deviation from 13.3° to 19.8°, gain = 6.3° (PP, 1.7°; W, 6.9°), and ulnar deviation from 14.8° to 22°, gain = 7.4° (PP, 5°; W, 7.4°). There was clear improvement in force on the Jamar, although less than in group 1, from 20.4 kg to 39.5 kg (compared to the contralateral control values which remained stable at a mean 45.3 and 45 kg, respectively; similar to in group 1): i.e., a gain of 18.2 kg (PP, 18.7 kg; W, 19.5 kg).

Radiology results

In group 1, radiologic consolidation was achieved in 70 cases i.e., 96% (PP, 89.5%; W, 98.2%) at a mean of 9.7 weeks (PP 11.3 weeks; W 9.2 weeks).

In group 2, radiologic consolidation was achieved in 34 cases i.e., 89.5% (PP, 80%; W, 91%) at a mean of 10.8 weeks (PP, 17 weeks, W, 10 weeks).

Discussion

Bone graft from the volar radius vascularized by the volar carpal artery is a good treatment for moderate scaphoid...
defects (Alnot grades IIa, IIb or IIIa). The anterior approach allows graft harvesting and treatment of the non-union to be performed as a single procedure. Although harvesting may seem difficult at first, it is in fact a simple technique that provides excellent results. The surgery is performed under locoregional anesthesia through a single incision with reduced surgery time as a day case, thus reducing hospital stay and overall costs. It was first described for failure of classical techniques. However, given the quality of the functional results and the speed of consolidation, we recommend it as primary treatment of scaphoid non-union. The present study is the first to report results of vascularized grafts as a primary treatment for scaphoid non-union. It shows improvement for all evaluation criteria in these cases.

Various factors seem to affect consolidation. The mean age of patients who failed to show union after primary non-union treatment was 40 years, versus 30 in case of successful union. Age has been identified as a factor of poor prognosis by other authors [7,22]. Likewise, the greater the delay between fracture and surgery the poorer is the consolidation. The mean delay in patients without consolidation was 48.3 months, versus 19 months in case of consolidation. Several studies [22,23] correlated smoking and non-consolidation. A study conducted in 2008 [24] reported a lower consolidation rate (73%) with vascularized grafts from the volar radius; these findings highlight the difficulties encountered in harvesting and osteosynthesis, especially for less experienced surgeons. There was notably a risk of perioperative articular fracture of the radius [24,25], which seemed greatest at the beginning of the learning curve.

Although the conventional Matti-Russe graft remains an excellent option, many studies reported better consolation rates using vascularized bone graft: union was achieved in 70% to 90% of non-vascularized grafts [26,27] and more than 90% of vascularized grafts [2,16,19,28—34]. Munk and Larsen [35] confirmed these findings in a meta-analysis of 5,246 cases of scaphoid non-union, with an 80% consolidation rate (78—82) for non-vascularized bone graft without osteosynthesis, 84% (82—85) with osteosynthesis, and 91% (87—94) for vascularized graft. In non-union with avascular necrosis of the proximal pole, however, surgeons seem to agree that a primary vascularized graft is the best conservative management [7,36—38], due to the very poor consolidation rate obtained with non-vascularized grafts (< 50%). Dailiana [39] reported that union on MRI was achieved faster with a vascularized graft. Some authors recommend other vascularized free grafts, from the supracondylar region of the femur [40,41], base of the third metatarsal [42], iliac crest [43], rib [44], etc.

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. The present retrospective findings should be confirmed with longer follow-up. A larger trial is required to validate the use of vascularized graft for primary treatment of scaphoid non-union.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


