Maniglio et al., J Trauma Treat 2015, 4:3
DOI: 10.4172/2167-1222.1000271

Journal of Trauma & Treatment

Research Article Open Access

Scaphoid Waist Nonunions Treated with Illiac Crest or Vascularized Bone Grafts

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Abstract

We present the results of a retrospective study looking at postoperative outcomes of treatment of scaphoid nonunions following three different techniques: Palmar (nonvascularized) iliac crest, vascularized bone-grafts dorsal and palmar. The purpose is to present the consolidation rates and discover if range of motion, grip strength and pain differ using the different grafts.

Methods: We evaluated 57 cases with a mean follow-up of 6.6 months. 24 patients had nonunion of the proximal scaphoid pole with avascular osteonecrosis. Operative technique were chosen based on the vascularity, location of non-union, previous operations, and pedicle availability. Conventional graft was used in 19 patients, palmar vascularized in 15 and dorsal vascularized graft in 23. We measured and compared

clinical and radiological outcomes.

Results: Out of 57 nonunions 46 united. No significant difference in rate of consolidation was found between the 3 treatment groups. Highest percentage of consolidation, 87%, was in patients treated with a palmar vascularized graft, whereas the consolidation rate of dorsal vascularized graft was 78% and of iliac crest graft 79%. Grip strength improved significantly. The most in iliac crest group (from 70% to 91%) and the least in dorsal vascularized graft group (from 81% to 83%). Best range of motion in flexion/-extension was in the iliac-crest group, although not being significantly. Average Mayo score was 82. 18 patients showed an excellent, 17 a good, 13 a satisfactory and 3 a poor result. No significant difference was found between the groups.

Conclusion: Vascularized grafts had a comparable consolidation rate and outcome in Mayo score as the iliac crest group, even though these cases were more problematic due to the presence of avascular necrosis. Iliac crest grafts afforded the best results concerning grip strength and range of motion. The gain in grip strength and range of motion was less with vascularized grafts.

Keywords: 1,2 intercompartmental supraretinacular artery (1,2 ICSRA) graft; 4th and 5th extensor compartment artery (4th/5th ECA) graft; Avascular necrosis; Illiac crest graft; Mathoulin-graft; Scaphoid waist non-union

Introduction

The aim to treat a scaphoid nonunion is to prevent the degenerative change and scaphoid nonunion advanced collapse (SNAC) [1]. Common reconstruction techniques aim to restore the shape of the scaphoid by filling the resulting defects with bone autograft, either vascularized or non-vascularized. Despite numerous reports and meta-analyses the dispute on the appropriate and most successful technique is ongoing. The basic problem in most studies is that usually one single treatment technique was applied for almost every indication and, even when reporting on cases of avascular non unions the definition of avascularity, besides being difficult and in dispute by principle, is applied variably if not liberally. So the reports on vascularized bone grafts vary in the consolidation rates from 27% [3] up to 100 % [3], thus the conclusions of any meta-analysis are difficult and also the ones of Merell et al. [4] reporting a union rate of 88% in cases with AVN using vascularized bone-grafts compared to 47% in conventional grafting. Despite of these publications concerning this issue, which surgical treatment is indicated in a given situation remains uncertain.

The purpose of this study is to report retrospectively our results of scaphoid reconstructions using the different autografts. Therefore we evaluated the radiographic rate of bone consolidation and the functional and radiological results of our patients in order to determine the answers to the following questions: How are the consolidation rates using the different techniques? What are the advantages and the disadvantage of the different techniques? This may contribute to more precise surgical decision making regarding when to use each graft.

Materials and Methods

We reviewed retrospectively the medical records and radiographs of patients treated between December 2002 and November 2010 by 2 senior surgeons, an expert (experience level 5) and an specialist-expert (experience level 4) [3], at the *Uniklinik Balgrist* in Zurich. Approval for this study was given by the institutional review board (IRB) and the patients have given their informed consent. Patients included in the study were all those with delayed union (2-6 months, n=13) or nonunion (>6 months, n=44) of the scaphoid after a traumatic fracture treated with either a dorsal or volar vascularized bone graft or iliac crest graft. Patients with acute fracture (<2 months) were excluded. Minimum follow-up was 5 months. Treatment failure was defined as a persistence of symptoms with evidence of nonunion on computed tomography (CT).

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Received September 16, 2015; **Accepted** October 23, 2015; **Published** October 30, 2015

Citation: Maniglio M, Schweizer A, Nagy L (2015) Scaphoid Waist Nonunions Treated with Illiac Crest or Vascularized Bone Grafts. J Trauma Treat 4: 271. doi:10.4172/2167-1222.1000271

Statistical evaluation

Statistical analysis was performed using non parametric tests to make a variance analyze (Mann-Whitney, Chi-Square, Kruskal Wallis, Wilcoxon signed Ranks and Mc Nemar-Test) and regression test (Kaplan Meier and Cox Regression) for analyze the consolidation and consolidation time, with the level of significance set at P=0.05

Demographics

Fifty men and 2 women with scaphoid nonunions and delayed unions were followed until union or treatment failure. Of these, 4 patients had a second reconstruction of the scaphoid in our clinic (3 after failure of iliac crest graft and 1 after failure of vascularized bone graft), and 1 patient was treated on both sides with a vascularized graft (once dorsal and once volar). We observe these 5 patients in this study as 10 separate cases, for a total of 57 cases. 44 cases had a scaphoid nonunions and 13 cases a delayed unions. These cases were pooled and considered all to be scaphoid nonunions. In the 48 patients for whom hand dominance was documented, 25 of the fractures occurred in the dominant hand and 23 in the non-dominant. Nineteen patients had undergone prior surgical treatment: 4 patients had more than 1 prior surgical treatment. Seven patients had osteosynthesis of acute fracture, and 10 had scaphoid reconstruction with either a free iliac crest graft (n=9) or with a vascularized peripheral graft (n=1) (Table 1).

Preoperative assessment

Pain severity was classified using 4 degrees (no pain, pain when loading the wrist, when moving, rest pain). Range of motion (ROM) was measured in flexion/extension, radial-/ulnarduction and pronation/supination. Grip strength was measured with a hand dynamometer (Jamar Dynamometer) and described as percentage of the contralateral side.

Radiological fracture characterization

Pre- and postoperative conventional radiographs and CT were obtained and scapholunate, capitolunate, and intrascaphoid angles measured as well as carpal malalignment (dorsal intercalated segment instability [DISI]) and grade of wrist arthritis (SNAC I-III) was assessed: 43 of the 57 patients presented with (besides the non union) abnormal radiographs preoperatively; 22 of these patients displayed DISI deformity (Table 2). Degenerative radioscaphoidal alterations were detected in 15 patients; 14 showed SNAC I, and 1 patient was operated on despite SNAC II because of his young age.

Demographics	**Study treatment groups**			
	Iliac Crest Graft	Dorsal Pedicled Graft	Ventral Pedicled Graft	Total
Total Cases	19	23	15	57
Gender m/w Average Age	18:1 24.68 (range 16-45)	23:0 24.7 (16-40)	14:1 25 (17-37)	54:2 24.8 (16-45)
Time from Injury to Surgery	8 (range 2-49)	16 (3-130)	14 (5-119)	12 (2-130)
Prior treatment:	12	12	10	34
Conservative	9	3	3	15
Surgical	3	9	7	19
OSM in place at time of	3	8	3	14
SNAC I preoperative	2	5	7	14
SNAC II preoperative	0	1	0	1

Table 1: Demographic of the patients[1] = median in months.

Consolidation rate and time to consolidation	**Study Treatment Groups**			
	Iliac Crest Graft	Dorsal Pedicled Graft	Ventral Pedicled Graft	Total
Total Cases	19	23	15	57
Consolidated	15 (79%)	18 (78%)	13 (87%)	46 (81%)
Non-consolidated	4	5	2	11
Median Time, w (range)	14 (8-40)	16 (8-52)	12 (7-24)	15 (7-52)
Delayed unions	6/8 (75%)	3/3 (100%)	2/2 (100%)	11/13 (85%)
Non-unions	9/11 (82%)	15/20 (75%)	11/13 (85%)	35/44 (80%)
Fracture location				
Proximal third	1/2 (50%)	14/18 (78%)	3/4 (75%)	18/24 (75%)
Middle third	12/15 (80%)	4/5 (80%)	10/11 (91%)	26/31 (84%)
Distal third	2/2 (100%)	0	0	2/2 (100%)
DISI	9/12 (75%)	5/5 (100%)	3/5 (60%)	17/22 (70%)
Vascularization				
Present	15/19 (79%)	1/1 (100%)	0	16/20 (80%)
Absent	0	17/22 (77%)	13/15 (87%)	30/37 (81%)

[1] = in MRI or intraoperative

Table 2: Consolidation details.

Assessment of vascularity

Contrast magnetic resonance imaging (MRI) was performed in 39 patients to assess vascularization of the proximal scaphoid pole. Among these proximal AVN was found in 24. In cases after failed previous surgery MRI was regarded as not useful due to the artifact due to the implants in situ. Final evaluation / decision on the vascularity was done intra-operatively looking for active bleeding points in the fragments after a short release of the tourniquet.

Treatment algorithm and surgical procedures

The authors selected the operative technique according to vascularization of the proximal scaphoid pole, location of the fracture, deformity, prior failed operations, and availability of a pedicle. For scaphoid nonunions with a vital proximal pole, a conventional non-vascularized corticocancellous iliac crest graft was chosen for reconstruction [5], in our series from palmar in all cases (n=19). Vascularized bone grafts were preferred in presence of avascularity of the proximal pole or after failure of previous reconstruction(s) with an iliac crest graft [6]. If, in this cases, the non union site was proximal, a dorsal graft was chosen. Most commonly (n=16) the dorsal vascularized bone graft, as described by Zaidenberg [7], based on the 1,2 intercompartmental supraretinacular artery (1,2 ICSRA) [8,9] was used (Figure 1). In cases (n=2) when 1,2 ICSRA was not traceable or already used, a bone graft based on the 4th extensor compartment artery (ECA) [8], with retrograde flow through the 5th ECA [8-10] from the dorsal intercarpal arc was used. For non unions located in the middle third or more distally presenting with avascularity or after failed previous surgery, usually also with significant deformity and need for correction, a vascularized bone graft based on the palmar carpal artery (Figure 2), was described by Kuhlmann [11] and later by Mathoulin [12] was used (n=11). Generally internal fixation was performed with a headless compression screw (HCS, Synthes Switzerland or a Herbert screw), but in 13 cases, according to the size and stability of the fragments other fixation methods were used (K-wires, screw or combination of both).

Postoperative evaluation

A CT scan was performed, usually after 8 weeks postoperatively. If union was not apparent, repeat CT scans were done at 6-weeks

intervals. Union was defined as evidence of trabecular bridging between the proximal and distal fragment on the majority of slices, absence of graft dislocation, gap formation and dislocation of the osteosynthesis material. Time to union was defined by the intervals from the operation to the date of the CT's. The same clinical parameters as preoperatively were assessed during the last follow up at least 5 months after surgery (Mean 6.6 months, range 5-26, SD 4,32). Outcome was evaluated with the Mayo score [13], which has a range of 0 to 100 points composed of a maximum of 25 points for pain intensity, 25 for functionality, 25 for ROM, and 25 points for grip strength. Patients were scored and classified into one out of four outcome categories, from poor to excellent.

Figure 1: 29 years old patient with fracture location in the proximal third and AVON of the proximal pol, treated with a dorsal vascularized graft (Zaidemberg).

Figure 2: Pre- and postoperative plan radiography of a 29 years old patient with a non-union located between the middle and the proximal third, with a AVON of the proximal pol, treated with a palmar vascularized graft (Mathoulin).

Figure 3: 33 years old patient with persisting non-union after screwfixation of the fracture in another clinic. Pronounced DISI preoperative. Treatment and correction of DISI with a iliac crest graft from palmar.

Outcome	Study Treatment Groups			
	Iliac Crest Graft	Dorsal Pedicled Graft	Ventral Pedicled Graft	Total
Nach Mayo				
Excellent	5	9	4	18
Good	6	5	6	17
Satisfactory	5	5	3	13
Poor	0	3	0	3
Total	16	22	13	51
Average Points	82	78	79	79 (SD:14,2 r.35-100)

Table 3: Patients classification in Mayo score and the average points achieved.

Results

CT-scan investigation revealed consolidation in 11 of 13 cases with delayed union, and 35 of 44 cases with nonunion. The results for delayed union and nonunion were not different. Preoperative SNAC didn't correlate (p=0.06) with a lower union rate. Five patients suffered complications after surgery: 3 required treatment for chronic regional pain syndrome (CRPS); 1 required keloid excision; and 1 patient had persistent, disabling wrist pain during the entire follow-up period (30 months). Out of the 9 patients with persistent nonunion, four (3 following a conventional and one following a palmar vascularized graft) underwent re-operation in our institution using a vascularized graft and eventually healed. For the others 5 patients no consolidation was found during the follow-up period.

Comparative studies

Cases were evaluated according to the surgical technique used, and these subgroups were observed separately (Table 2). Median time from injury to surgery was longer in nonunions treated with vascularized graft (16 months) compared with those treated with non-vascularized (8 months), but the difference was not significant (p=0.053). DISI deformity was present significantly more frequently in the group treated with iliac-crest grafts (55%; p=0.025). Radiological abnormalities (p=0.017), particularly DISI deformity (14 of 22; p=0.001), could be corrected by the surgery (Figure 3). Significant improvement in capitolunate angle from mean 16° to 12° (p=0.04) and scapholunate angle from mean 56° to 51° (p=0.006) was found, with the greatest improvement in the iliac crest group. The pain intensity decreased significantly (p=0.001) after surgical treatment, without differences between the treatment groups. Grip strength (as a percentage of the contralateral side) showed significant improvement (p=0.001) after surgical treatment (from 78 to 85%). The greatest improvement was found in the iliac crest group (from 70% to 91%). The least improvement was found in the dorsal vascularized graft group (from 81% to 83%). ROM for flexion/extension was 112 degrees preoperatively (range, 50-155 degrees) and 114 degrees postoperatively (range, 40-160 degrees), reflecting no significant change in any group or significant difference between the groups. Most improvement was found in the iliac-crest group from 105 in F/E preoperative to 130 in F/E, the least improvement was detected in the group of dorsal vascularized grafts. We observed no significant differences between preoperative and postoperative Mayo scores. And also no significant differences were found between the 3 groups (Table 3).

Discussion

Several studies reported union rates from 59 to 82% [14-16] after scaphoid reconstruction for non union. We observed an overall union rate of 81% in our patients treated according a constant algorithm and techniques mentioned above. Nonunions located at the middle and distal third with normal perfusion of the proximal pole were usually treated with an iliac crest graft through a palmar approach. A palmar approach allows better visualization and correction of a flexion deformity [4] and exerts less trauma to the remaining vessels of the proximal pole [10,17]. Dissection of radio-carpal ligaments for access is a disadvantage [8]. If an AVN of the proximal pole was diagnosed preoperatively on MRI and confirmed intraoperatively or if it was detected intraoperatively, a vascularized bone graft was used for the reconstruction. This was more often the case when the nonunion was located in proximal third of the scaphoid, an observation reported also by others before [10]. For proximal avascular nonunions, several authors [4,18] have shown the advantages of vascularized grafts. A meta-analysis by Merrell [4], which included 7 studies and 64 patients with AVN, reported a union rate of 47% in patients treated with non-vascularized and 88% in those with vascularized grafts. Our study showed similar numbers with a union rate of 82% in vascularized grafts.

Patients with AVN, where nonunion was located at the scaphoid waist, were treated with a palmar graft (11cases) and those located at the proximal third of the scaphoid, were treated with a dorsal graft (18 cases). In presence of a flexion deformity (4 cases) and when the nonunion was located between the middle and the proximal third, a palmar graft was chosen and a 1,2 ICSRA graft in absence of such one (5 cases). The technique of palmar vascularized grafting was first described by Kuhlmann [11] (3 cases) and then Mathoulin [12] (17 cases) demonstrating a union rate of 100%, however no information regarding vascularity was given. Dailiana [3] showed a consolidation in all 9 patients, but only 1 had evidence AVN. In our study, 15 patients with AVN were treated using this technique and showed a consolidation rate of 87%, the highest of the 3 groups in our study. A dorsal approach is the only one which allows a visualization of non-unions located within the proximal third of the scaphoid. Fortunately these very proximal nonunions almost never present with a flexion deformity and therefore the use of a dorsal vascularized graft is logical and straight forward. On the other hand it appears very difficult if not illogical to insert a wedge-shaped graft from dorsal for correcting a flexion deformity [9]. Therefore in our hands dorsal grafts were used almost exclusively for proximal nonunions. This study demonstrated a union rate of 81% in 21 cases treated with a 1,2 ICSRA- and of 50% in 2 cases treated with 4th ECA grafts [8] resulting in a rate of 78% for dorsal radial grafts. In the reports by Dailiana [3] and by Mathoulin [11], all patients healed in a range of 8.5 to 9 weeks, respectively 6 to 13 weeks. The median time between operation and consolidation in our study, was significantly slower with 13 weeks, and did not differ between the 3 subgroups. This difference in our opinion is due to the high percentage of AVN's in our series, not present in the other ones. Even though the 3 groups of patients treated with different grafts showed significant differences in fracture characteristics and surgical technique, the differences in consolidation rate and time were not significant. We were also not able to confirm significant differences in time to union between fractures in the proximal and distal thirds, which was reported in several other publications before [19-23]. This is most likely because our accurate assignment of the technique according to the pathology permits a problem-adapted treatment of patients. Poor functional outcomes resulting from malposition or malunion of the scaphoid has been described [24] including postoperative pain, stiffness and arthritis of the wrist. The ROM of the wrist in F/E and R/U postoperatively did not increase significantly in any of our groups (confirming the findings of Waitayawinyu [18], Dailiana [3], and Mathoulin [11]). Grip strength increased from 78% to 85% of the unaffected hand, which was found similarly in prior studies [3,12,19,20]. The most improvement was found for the iliac crest graft group. This may be caused by the higher homogeneity and rigidity of a iliac-crest grafts allowing better shaping of the graft a more reliable reconstruction of the scaphoid, earlier protected mobilization and, hence, the best functional results. Additionally it must also be taken in account that these cases from the start had better condition for successful healing due to the presence of greater blood supply. Average Mayo score was 92 in the study of Dailiana et al. [3] after treatment with palmar graft. In our study the average score was 82, 18 patients showed an excellent, 17 a good, 13 a satisfactory and 3 a poor result.

With regard to the radiological criteria we achieved significant improvement of capitolunate (in 22 of 25 patients with malalignment), scapholunate (in 16 of 19) and lateral intrascaphoidal angles (in 13 of 14 cases). There were no significant differences of this correction between the different surgical techniques. Chang [24] made the hypothesis that the presence of a DISI deformity contributed to failure in 9 out of 14 cases in his study. In our study, out of 22 wrists presenting with DISI 14 could be corrected, out of which 12 united (86%), whereas 4 (50%) nonunions persisted in the 8 wrists with uncorrected DISI. This retrospective study has several limitations. The small number of cases receiving each surgical treatment makes subgroup analysis difficult. Patients treated with 2 techniques, twice with the same technique or on both hands, were evaluated as single cases even though they were not independent. The intervals of 6-weeks between the CT scans allows only an estimation of time of consolidation.

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