Vascularized Bone Grafting in Scaphoid Nonunion: A Review of Patient-Centered Outcomes

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Abstract

Background: The radiographic and clinical outcomes following vascularized bone grafting (VBG) for scaphoid nonunion have previously been reported in the literature; however, few studies report on patient-derived outcomes. The purpose of this study was to determine the effect of VBG for scaphoid nonunion on patient-derived outcomes. **Methods:** The MEDLINE and PubMed databases were queried for the use of VBG in scaphoid nonunion. We included studies that reported on patient-derived outcomes. We excluded studies with less than 10 patients or less than 6 months of follow-up. The primary outcomes assessed included functionality, percent and time to return to preinjury activity, postoperative pain, and patient satisfaction. **Results:** Twenty-six articles described the outcomes of 520 patients with an average of 19.3 patients per study. Functionality was most commonly assessed by the Mayo Modified Wrist Score and Disabilities of the Arm, Shoulder and Hand scores, which improved by 53.1% and 81.7% postoperatively, respectively. Within 16 weeks, 90.3% of patients returned to their previous occupation or sporting activity. Pain was most commonly reported using a 0 to 10 visual analog scale and improved 4-fold postoperatively. Complete satisfaction was reported by 92% of patients. The most common complications were superficial infections (1.56%), neuropathic pain (1.56%), and complex regional pain syndrome (1.25%). **Conclusions:** VBG for scaphoid nonunion results in the improvement of patient-derived outcomes, and high rates of return to preinjury activity levels and patient satisfaction. Multiple metrics of patient-derived outcomes were utilized by the studies in our review without a clear consensus as to which metric is most responsive and accurate.

Keywords: bone graft, microvascular, nonunion, scaphoid, vascular

Introduction

Scaphoid fractures are common after upper extremity trauma and account for 70% of all carpal bone injuries.¹¹ Although the majority of these fractures may heal with non-operative management, disruption to the retrograde blood supply of the scaphoid can lead to nonunion of well-aligned fractures in 5% to 10% of cases and increases to 55% of cases when there is displacement on initial presentation.^{26,43} The complications of scaphoid nonunion vary widely including pain and loss of function. Carpal malalignment may lead to progressive arthrosis and eventual scaphoid nonunion advanced collapse.^{26,37} To prevent such complications, surgical advances have been developed to treat scaphoid nonunions, including screw fixation, bone grafting and, most recently, vascularized bone grafting (VBG).⁴¹

VBG has been shown to promote healing and realignment of recalcitrant scaphoid nonunions through autotransplantation of perfused bone, periosteum, and viable osteocytes.³⁸

The majority of studies published on VBG for scaphoid nonunion have focused on describing objective clinical and radiographic outcomes such as range of motion, grip strength, and union rates.^{9,18} Equally important, however, are patient-derived outcomes such as quality of life, functionality, pain assessment, and overall satisfaction. Surgical success without the element of patient satisfaction and function is an incomplete representation of patient care, especially as patient-reported quality of life measures are increasingly integrated into calculating health care reimbursements.^{16,34} The paucity of literature describing patient-derived outcomes following

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VBG for scaphoid nonunion is partly due to the lack of consensus regarding the optimal assessment tool to quantify these results and understanding the degree of clinically significant improvement in these metrics.

As an attempt to objectively measure patient-reported outcomes, standardized questionnaires have been created to minimize the subjective variability between individual patients.¹⁴ A vast number of patient-reported outcome measures now exist for the assessment of hand injuries, which include the visual analog scale (VAS), Michigan Hand Questionnaire (MHQ), Patient-Rated Wrist Evaluation (PRWE), Disabilities of Arm, Shoulder and Hand Questionnaire (DASH), and the Mayo Modified Wrist Score (MMWS).^{5,19,25,39} These upper extremity functionality scores integrate multiple facets of postoperative recovery including return to the previous level of activity, pain, and overall patient satisfaction. These patient-derived outcomes are critical in assessing postoperative recovery but are not as widely reported in the literature as objective physical exam and radiographic outcomes. The purpose of this study was to determine the effect of VBG for scaphoid nonunion on patient-derived outcomes.

Materials and Methods

The study design included a review of MEDLINE and PubMed databases for human studies restricted to the English language; the search terms included “vascularized bone graft and scaphoid nonunion,” “vascularized bone graft in wrist injury,” and “vascularized bone graft and hand.” A set of inclusion and exclusion methodology was formed based on preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The title and abstract of each article resulted from the MEDLINE and PubMed database queries were reviewed with the authors and institutions of each manuscript blinded. We included studies evaluating vascularized bone grafts from any donor site, with or without diagnosed avascular necrosis, which reported on postoperative functionality, return to activity, pain, and/or overall satisfaction for patients undergoing VBG for scaphoid nonunion. The references of the articles that met inclusion criteria after screening were reviewed to identify potential studies not captured by the initial database queries. Studies describing multiple procedures for the treatment of scaphoid nonunion were only included if separate data for VBG could be calculated. We excluded studies with less than 10 patients, less than 6 months of follow-up, studies using a combination of vascularized and nonvascularized bone grafting techniques in the same procedure, studies that included acute scaphoid fractures without nonunion, studies involving patients already reported in other publications, studies involving patients with open physes, and non-English language studies. The search protocol and article selection were completed by 2 reviewers.

The number of patients, average age, male to female ratio, length of follow-up, whether the study included primary or revision cases of scaphoid nonunion, rate of radiographic union, and the duration from injury to VBG were recorded for each included study. The primary outcomes assessed included all reported functional scores such as the DASH score and MMWS. In addition, we assessed the percentage of patients who successfully returned to their preinjury activity level and elapsed time between surgery and return. If a patient had to change their job or recreational sport postoperatively, this was defined as a failure to return to the preinjury activity level. Last, we assessed postoperative pain levels, percent satisfaction reported by the patient, and reported complications.

Data analysis was completed with weighted means based on sample size. One sample and paired *t* tests were used. Statistical significance was defined as $P \leq .05$.

Results

Included Study Characteristics

Results from the initial electronic search are demonstrated in Figure 1 and Table 1.* The overall demographics and patient characteristics of the included studies are contained in Table 2. Ninety-one percent of patients included in the study achieved radiographic union. Both validated and custom, nonvalidated, measures were used to assess patient-derived outcomes (Table 3).

Patient-Reported Functionality

Sixteen studies (61.5%) assessed postoperative functionality (Table 1 and Figure 2). The most commonly used score was the MMWS, used in 8 studies (30.8%) involving 216 patients. The average postoperative MMWS was 85.6, a 53.1% improvement from preoperative values ($P = 0.008$; Table 4). Four studies (15.4%) reported DASH scores across 69 patients. The average postoperative DASH score was 11.47, an 81.8% improvement from preoperative values ($P = 0.026$; Table 4). Two studies (7.7%) involving 34 patients reported a good to excellent Green and O'Brien score in 80% of patients. Three studies (11.5%) utilized a custom score, assessing functional limitation secondary to pain. One study (3.8%) reported a PRWE score of 14.8 averaged across 21 patients. Last, 1 study (3.8%) assessed functional health with the Short Form-36 (SF-36).

Return to Activity

Fourteen studies (53.8%) evaluated postoperative return to the preinjury activity level (Table 1). On average, 90.2%

*References 1, 3, 4, 6, 8, 10, 12, 13, 15, 17, 18, 20, 21, 23, 24, 28-32, 35, 40, 42, 44, 45, 47

Figure 1. Selection process for the articles included in this systematic review.

Table 1. Studies Included in This Systematic Review.

Reference	Level of evidence	Study design	No. of patients	Patient-derived outcome(s) reported
Lim et al ²⁴	IV	Case series	20	MMWS
Liang et al ²³	IV	Case series	11	MMWS
Burger et al ⁸	III	Retrospective cohort	16	Pain
Gras and Mathoulin ¹⁷	III	Retrospective cohort	111	MMWS, pain, satisfaction, time and % return to work/sport
Waitayawinyu et al ⁴⁵	IV	Case series	30	% Return to work/sport
Malizos et al ³⁰	II	Prospective case series	30	MMWS, VAS, time and % return to work/sport
Chen et al ¹⁰	IV	Case series	11	MMWS, pain
Sotereanos et al ⁴⁰	IV	Case series	13	Pain, % return to work/sport
Bertelli et al ⁴	IV	Case series	24	VAS, BCPA, BCPAL, % return to work/sport
Steinmann et al ⁴²	IV	Case series	14	Custom score
Malizos et al ²⁸	IV	Case series	22	VAS, satisfaction, time and % return to work/sport
Uerpaiojkit et al ⁴⁴	IV	Case series	10	Pain, % return to work/sport
Doi et al ¹²	IV	Case series	10	MMWS, time and % return to work/sport
Gabl et al ¹⁵	IV	Case series	15	VAS
Boyer et al ⁶	IV	Case series	10	Pain, % return to work/sport, satisfaction
Zaidenberg et al ⁴⁷	IV	Case series	11	Pain
Korompilias et al ²¹	III	Retrospective review	23	DASH, pain
Malizos et al ²⁹	III	Retrospective review	12	DASH, MMWS, VAS
Hirche et al ¹⁸	III	Retrospective review	28	SF-36, % return to work/sport
Mathoulin and Haerle ³²	IV	Case series	17	Time and % return to work/sport, custom score
Jones et al ²⁰	III	Retrospective review	12	Pain, satisfaction
Mathoulin and Brunelli ³¹	IV	Case series	15	Custom score
Ong et al ³⁵	III	Retrospective review	13	DASH, Green and O'Brien
Fernandez and Egli ¹³	III	Retrospective review	11	MMWS, satisfaction, time and % return to work/sport, custom score
Bertelli et al ³	IV	Case series	10	BCPA, BCPAL, % return to work/sport
Arora et al ¹	III	Retrospective review	21	DASH, VAS I-100, Green and O'Brien, PRWE, % return to work/sport

Note. MMWS = Modified Mayo Wrist Score; VAS = visual analog scale; BCPA = Bach's Criteria of Pain and Activity; BCPAL = Bach's Criteria of Pain and Activity Limitation; DASH = Disabilities of the Arm, Shoulder and Hand; SF-36 = Short Form-36; PRWE = Patient-Rated Wrist Evaluation.

Table 2. Overall Study Characteristics.

Study demographics	
Number of studies	26
Number of patients	520
Average number of patients per study	19.3
Average age, y	29.3 years
% Male	91.5
Duration of nonunion	31.4 months
Length of follow-up	35.1 months

of 337 patients returned to their previous occupation or sporting activity within 16 weeks postoperatively ($P < .001$; Table 4). Approximately 6% of patients who did not return to their preinjury activity level were involved in medical litigation. An additional 6% of patients who failed

to return to their previous occupation remained unemployed postoperatively.

Pain

Twenty-one studies (80.8%) assessed postoperative pain through multiple metrics (Table 1). Most commonly, a 0 to 10 (VAS) pain scoring system was used, with 0 representing no pain and 10 representing severe pain. Across 6 studies (23.1%) involving 124 patients, preoperative pain was 5.20 and postoperative pain was 0.96, a 79.2% improvement ($P < .001$; Table 4). Three studies (11.5%) used a custom pain scoring system ranging from 1 to 4 or 1 to 6 points with 1 representing no pain and maximal scores representing incapacitating pain preventing execution of activities of daily living. Two studies (7.69%) used Bach's Criteria of Pain and Activity (BCPA) and Bach's Criteria of Pain and Activity Limitation (BCPAL;

Table 3. Patient-Derived Assessment Tools Utilized.

Assessment tool	Abbreviation	Validated questionnaire	Studies
Customized scale, interview, or questionnaire ^a		No	21
Modified Mayo Wrist Score	MMWS	No	8
Visual analog scale	VAS	Yes	6
Disabilities of the Arm, Shoulder and Hand	DASH	Yes	4
Bach's Criteria for Pain and Activity	BCPA	Yes	2
Bach's Criteria for Pain and Activity Limitation	BCPAL	Yes	2
Green and O'Brien Score		No	2
Patient-Rated Wrist Evaluation score	PRWE	Yes	1
Short Form-36	SF-36	Yes	1

^aCustomized scale, interview, or questionnaire refers to any attempt to evaluate pain, satisfaction, and time and percentage return to work/sport that is not in a validated scale.

Figure 2. Functionality assessment tools utilized by the articles included in this systematic review.

Note. DASH = Disabilities of the Arm, Shoulder and Hand; MMWS = Mayo Modified Wrist Score; BCPA = Bach's Criteria of Pain and Activity; BCPAL = Bach's Criteria of Pain and Activity Limitation; PRWE = Patient-Rated Wrist Evaluation.

Figure 2).² Across 34 patients, the BCPA improved from 4.32 preoperatively to 1.96 postoperatively, a 54.6% improvement ($P = .0025$); the BCPAL improved from 4.21 preoperatively to 1.77 postoperatively, a 57.9% improvement ($P = .0035$). Across all studies, regardless of metric, postoperative pain was improved at least 50% after VBG.

Satisfaction

Five studies (19.2%) assessed patient-reported satisfaction after VBG (Table 1). The scales ranged from dissatisfied, major reservations, minor reservations, to completely satisfied, or similarly, dissatisfied, moderately satisfied, to very satisfied. Overall, 92% of patients ($n = 156$) were satisfied with the results of the procedure ($P < .001$; Table 4). The most common reasons for incomplete satisfaction were postoperative pain or limited range of motion.

Complications

Twelve studies (46.1%) involving 321 patients reported complications (Table 1). The most common complications

were superficial infections (1.56%), neuropathic pain (1.56%), and complex regional pain syndrome (1.25%). Immediate postsurgical complications were only seen in free vascularized bone grafts in which 2 patients had a failed microvascular anastomosis. Both cases required further revision surgery for persistent pain. All other complications were subacute and chronic in nature. Of patients who developed postoperative infections, none required operative intervention.

Discussion

In this systematic review, 26 studies containing 520 patients with scaphoid nonunion treated with VBG were analyzed, with a focus on patient-derived outcomes. Previously published studies have reported findings on objectively measurable outcomes such as union rates, range of motion, and grip strength. Less frequently are there assessments of patients' functionality, satisfaction, pain, or return to work/sport.

The majority of any unintentional injury tends to occur in young people with the most working potential, and it is no different for scaphoid nonunion, as the average age in this review was 29.3 years.²² The young age of patients suffering from scaphoid nonunion results in an even greater, extended impact on socioeconomic capacity should these individuals sustain lifelong disability from their injury.²² Previous studies have demonstrated that the ability to return to work and gainful employment have a positive effect on the perceived health, physical function, and thus quality of life for individuals after injury.³⁶ Our review has found that VBG improves patients' functionality and pain, resulting in excellent levels of patient satisfaction and return to preinjury activity levels. Although these results are favorable, not all studies focus on reporting these important patient-derived metrics.

Of the 43 studies describing VBG for scaphoid nonunion, over 18% failed to report any metric of a patient-derived outcome. Of the 26 studies included in our systematic review, over 70% only reported 2 or fewer

Table 4. Patient-Derived Outcomes.

	Postoperative	% Improvement	P value
DASH	11.5 ± 6.78	81.8 ± 4.60	.026
MMWS	85.6 ± 4.93	53.1 ± 17.4	.008
Time to return to activity (months)	3.65 ± 0.85	—	—
% Return to activity	90.2 ± 11.8	—	<.001
Postoperative pain (0-10 scale)	0.956 ± 0.498	79.2 ± 12.0	<.001
% Satisfaction	92.2 ± 11.5	—	<.001

Note. DASH = Disabilities of the Arm, Shoulder and Hand; MMWS = Mayo Modified Wrist Score.

patient-derived metrics. In addition, the metrics used across all studies were heterogeneous with some studies using only functionality scores, whereas others reported only on pain through a multitude of assessment modalities. The reason for this heterogeneity is largely due to the absence of an agreed upon functionality scale or pain assessment tool. The most commonly used functionality tool was the MMWS, a score dependent on both physician and patient input. Less commonly used metrics included the DASH score, BCPA/BCPAL, Green and O'Brien score, PRWE score, and custom functionality scores. Each of these scoring systems has their strengths and weaknesses in attempting to quantify pain and the ability to perform activities of daily living or work-related activity. In addition, few studies reported the patient perception of the donor site for bone grafting, which is an important unrecorded consideration that may influence patients' perceptions.

To the authors' knowledge, no study has been done assessing the responsiveness of these scores after scaphoid nonunion. A study by MacDermid et al demonstrated the PRWE was more responsive than the DASH score and SF-36, but this study was performed in the evaluation of distal radius fractures.²⁵ McMillan and Binhammer found the MHQ to be most responsive in a study of patients with a diverse set of hand and wrist pathology.³³ All of the functionality scores reported by the aforementioned studies and those included in this review are not specific to an isolated diagnosis. Wright and Young demonstrated that disease-specific scales may be the most responsive; however, no validated functionality scores currently exist for scaphoid nonunion.⁴⁶

The heterogeneity of reporting functional outcomes for scaphoid nonunion and the absence of an agreed upon metric certainly limit the comparability of various treatment modalities for scaphoid nonunion. Regardless, our study and previous studies have demonstrated that VBG is a viable option to achieve union and restore carpal mechanics in the setting of scaphoid nonunion resulting in excellent patient-derived outcomes.^{9,18,38} Across all studies included in our analysis, patients' self-reported outcomes through assessment of functionality scores and satisfaction were favorable. The ability of VBG to decrease pain, improve

radiocarpal mechanics, and thus allow for return to preinjury activity levels presumably was the major contributor to the favorable perception of the procedure by patients.

Postoperative complications can have a morbid effect on patient functionality and satisfaction, with reoperations further delaying healing and return to function. Some complications may only affect patient-reported satisfaction levels without altering long-term prognosis for the radiocarpal joint, whereas other complications may affect both. Only 46.1% of studies in this review reported complications. It was not possible to statistically quantify the direct effect of complications on patients' postoperative functionality as complications were largely qualitatively reported, anecdotal, and overall very few in number. The most common complications were related to pain and infection and occurred at a rate of less than 2%. These are the same complications that could be predicted in any hand surgical procedure, and their low rate of occurrence in this review further suggests that VBG is both a safe and effective procedure for scaphoid nonunion.^{7,27}

The pitfalls and inherent limitations of this study include the heterogeneity and retrospective design of the included studies. The absence of cohort studies or well-designed randomized trials results in inherent selection bias. In addition, the diverse surgical techniques used, variable postoperative pain management and physical therapy regimens, and heterogeneous patient-derived outcome assessment tools limit comparison of certain outcomes across various treatment subgroups. Last, this study only assesses patient-derived outcomes for VBG and does not quantitatively compare these outcomes with other surgical treatments such as traditional bone grafting. These comparisons are difficult with retrospective studies, as there are key confounding variables such as avascular necrosis and prior surgery.

The current literature suggests that scaphoid nonunion is a morbid condition that can have detrimental effects on patient functionality. The literature suggests that VBG can significantly improve patient functionality and pain, leading to excellent return to preoperative activity levels and patient satisfaction. Multiple assessment tools and scores have been used to evaluate these patient-derived outcomes; however, there is currently a lack of evidence and consensus as to

which method is optimal and most responsive for analyzing these outcomes. Further research is needed to standardize patient-derived outcome assessment in the setting of scaphoid nonunion. This standardization will lead to more effective and accurate comparisons of multiple procedure types for scaphoid nonunion, ultimately allowing for optimal patient-derived treatment.

Ethical Approval

This study is exempt from institutional review board approval.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained when necessary.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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