The Scaphoid Staple: A Systematic Review

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Abstract

Background: The purpose of this systematic review is to analyze the indications, outcomes, and complications of scaphoid fixation with a staple. **Methods:** The literature was reviewed for all cases of the scaphoid staple. Five articles including 188 patients, of 77 primary scaphoid fractures and 111 other indications that included delayed union, nonunion, and avascular necrosis, were reviewed. Demographic data, outcomes, and complications were recorded. **Results:** The union rate of the scaphoid staple is 94.7%, and 95.7% of patients return to work after an average of 9.8 weeks after a 4.7-week period of immobilization. The complication rate was 9.0%, and 7.5% required hardware removal. Clinical and radiographic healing was higher in primary fractures as compared with other indications. Other indications, as compared with primary fracture, had a higher rate of hardware removal. **Conclusions:** For all indications, the scaphoid staple has a high union rate and a low complication rate. In the authors' experience, the procedure is fast, not technically challenging, and may be considered for primary fracture, delayed union, nonunion, and avascular necrosis of the scaphoid.

Keywords: scaphoid staple, scaphoid fracture, nonunion, avascular necrosis

Introduction

The scaphoid is the most commonly fractured carpal bone,^{1,13} representing 2.4% of all wrist fractures.³² The annual incidence is 23 to 43 per 100,000 people.^{13,32} Furthermore, 5% of scaphoid fractures go on to nonunion.¹⁷

Although incomplete or nondisplaced fractures can often successfully be managed nonoperatively, this often necessitates prolonged immobilization, leading to stiffness, cast complications, and loss of work.^{5,22,27} Therefore, surgical management has grown increasingly accepted in the acute setting. Definitive surgical fixation is moreover indicated in the setting of displaced, vertically oblique and more proximal fractures as well as nonunions to obtain reliable union and avoid accelerated progression to pancarpal arthritis.^{9,18}

Current options for surgical management include open reduction with either pin or screw fixation or closed percutaneous screw fixation.^{4,6,8,20} Although screw fixation has been shown to yield reliably high union rates in excess of 90% for both acute fractures^{3,5,14,27,31,33} and to a lesser extent for nonunions,^{10,20,23,24,25,29,30} the technique has a steep learning curve often requiring many passes with the k-wire, prolonged tourniquet times,^{11,12,19,29,31} risk of intra-articular screw penetration,^{5,21,23} and may not be possible with small proximal or distal fragments.²

The scaphoid staple has only been described in 8 primary studies since its inception in 1980 by the Richards

Medical Company, Inc (Memphis, Tennessee).^{2,7,15,16,26,35,36} The advantages of the scaphoid staple include technical ease, simple and quick application, continuous compression particularly with Nitinol metal memory, allowance for fixation of proximal or distal fragments too small to accept a screw, low risk of articular penetration, and early active movement.^{2,7,15,16,26,35,36}

In this systematic review, we sought to determine the indications, outcomes, and complications associated with the scaphoid staple. This investigation is the largest and only analysis of the scaphoid staple in the literature.

Methods

Literature Search

A systematic review of the literature was conducted for all scaphoid staples on PubMed through 2014, according to the Preferred Reporting Items for Systematic Reviews and

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Meta-analyses guidelines. A combination of search terms included scaphoid fracture, scaphoid staple, and scaphoid fixation. We extracted homogeneous data and generated frequency-weighted means.

Inclusion/Exclusion Criteria

The inclusion criteria for the studies were as follows: (1) involving staple fixation of the scaphoid, (2) reported at least 1 primary outcome measure of interest including union, range of motion, strength, or Herbert and Fisher grading system for satisfaction, clinical and radiographic outcomes.

The exclusion criteria were as follows: (1) involving staple fixation of bones other than the scaphoid (eg, radio-carpal or carpal fusions), (2) technique guide or review with no mention of outcome data, and (3) if 2 or more studies involved the same patient cohort, in which case the preceding study would be excluded. Minimum reported follow-up in the studies was 6 months.

Two authors independently performed electronic searches. All abstracts with relevant titles were browsed, excluding abstracts with clearly irrelevant titles. If an abstract was found to provisionally meet inclusion/exclusion criteria, the article was accessed and evaluated. If the article was found to still meet the inclusion/exclusion criteria, the study was included. The two authors additionally independently reviewed all references from the relevant articles and generated a list of articles not found during the electronic searches.

Seventeen articles were identified. Two articles were excluded as they double counted patients from a more recent work,^{2,28} a technique guide was excluded,³⁴ 5 did not involve the scaphoid, and 1 article included staples in all hand and wrist cases of which the 2 scaphoids were difficult to specifically identify.²⁸ Five articles met inclusion and exclusion criteria.^{7,15,16,26,36} One article¹⁶ had partial overlap with a previous work.¹⁵ However, the more recent article¹⁶ included 9 additional patients. For this article's contribution to this analysis,¹⁶ only the 9 additional patients were included additionally so that no patient was double counted. No reported conflicts of interest with the industry were reported in 4,^{7,15,16,26} while 1 reported industry support.³⁶

Statistical Analysis

Demographic, surgical, outcome, and complication data were compiled (Tables 1-3). To compare primary fractures and other cohort, which included nonunion, delayed union, and avascular necrosis, only 3 studies were included (Table 4). With regard to the analysis in Table 4, 2 articles were excluded because there was a mix of primary and other groups without distinction.^{16,36} Herbert and Fischer Grading System^{11,12} was used by the authors of the cited articles to assess postoperative clinical and radiographic healing as

Table 1. Demographic Information.

Characteristic	n
Patients	188
Primary fracture	77 (41.0%)
Other	111 (59%)
Nonunion	101
Delayed union	7
Avascular necrosis	3
Male gender	167 (88.9%)
Nitinol	125 (66.5%)
Stainless	63 (33.5%)
Iliac crest autograft	158 (84.4%)

Table 2. Outcomes.

	Average	Range
Follow-up	30.9 months	6-54 months
Duration of immobilization	4.73 weeks	2-17 weeks
Union	178 (94.7%)	
Return to work	45 (95.74%)	
Time return to work	9.82 weeks	0-38.6 weeks
Complications	17 (9.04%)	
Hardware removal	14 (7.45%)	
Delayed union	4 (2.13%)	
Nonunion	9 (4.79%)	
Loosening	2 (1.06%)	
Technical error	2 (1.06%)	

Table 3. Range of Motion.

Motion	Preoperatively	Postoperatively
Flexion/extension	85°	108.2°
Pronosupination	Not reported	171°
Radial/ulnar deviation	25°	60°

well as satisfaction (0%-100%). Satisfaction was graded (0-3) as follows: 0, very happy and asymptomatic; 1, improved, minimal symptoms; 2, unchanged, moderate symptoms; and 3, worse, severe symptoms. Clinical results were graded (0-3) as follows: 0, normal function with unrestricted use; 1, minimal loss of function with unrestricted use; 2, moderate loss of function with some restriction; and 3, marked loss of function with resisted use. Radiographic results were graded (0-3) as follows: 0, sound union without deformity; 1, apparent union with minimal deformity; 2, doubtful union with marked deformity; and 3, nonunion with loosening of the implant. Only plain radiographs were used in this analysis. It was not clear in all of the articles when the radiographs were taken postoperatively for this

Table 4. Primary Versus Nonunion, Delayed Union, and Avascular Necrosis.

Characteristic	Primary (n = 60)	Other (n = 54)	P value
Radiographic union (author subjective)	60 (100%)	51 (94.4%)	.1032
No limitations	51 (85%)	48 (88.9%)	.59
Satisfied	58 (96.7%)	49 (90.7%)	.2531
Herbert and Fischer clinical healing (0)	51 (85%)	24 (44.4%)	.0001
Herbert and Fischer radiographic healing (0)	60 (100%)	43 (79.6%)	.0001
Hardware removal	0	6 (11.1%)	.0097
Delayed/nonunion	0	3 (5.6%)	.1032

analysis. Fisher's exact test was used to assess statistical significance (Table 4), which was set at $P < .05$.

Results

Demographics

Our literature search identified 5 articles containing 188 patients who met both inclusion and exclusion criteria as well as did not double count patients (Table 1). Of all scaphoids, 41% were primary fractures, with the remaining scaphoids undergoing fixation secondary to nonunion, delayed union, and avascular necrosis. Most patients were male (88.9%) and most implants were Nitinol shape-memory staples (66.5%) whereas the remaining staples comprised stainless steel. Only one study included laterality, hand dominance, previous surgery, and occupation. In this study, 61% were heavy manual laborers. The mechanism of injury was not discussed in any of the series.

Outcomes

Of all patients undergoing staple fixation of the scaphoid, the union rate was 94.7% and 95.7% of patients returned to work postoperatively at an average of 9.8 weeks (Table 2). The average follow-up was 30.9 months (range = 6-54 months), and most were immobilized for 1 month. Complications were present in 17 (9%) of patients, the most common of which was nonunion (4.8%). The staple was removed in 7.5% of patients. Postoperatively, range of motion in terms of flexion/extension improved by 23° whereas radial/ulnar deviation improved by 35° as compared with preoperatively (Table 3).

Primary Fracture Versus Other

In Table 4, primary fractures³⁶ were compared with all other indications to include nonunion, delayed union, and avascular necrosis.^{7,15} As explained, only 3 articles were included for this analysis.^{7,15,26} In terms of subjective radiographic union rate as reported by the authors, primary fractures

treated with a staple achieved a 100% union rate whereas the other group achieved a 94.7% union rate ($P = .1032$; Table 4). Primary fractures achieved a 85% Hebert and Fischer clinical healing rate (grade 0) as compared with 44.4% in the other group ($P = .0001$). In addition, primary fractures had a 100% Hebert and Fischer radiographic healing rate (grade 0) as compared with 79.6% Hebert and Fischer radiographic healing in the other group ($P = .0001$). There were no hardware removals in the primary staples whereas 11% of the other group underwent hardware removal ($P = .0097$).

Discussion

We present the first review of the scaphoid staple. The union rate for the scaphoid staple is 95% with 96% patients returning to work at an average of 9.8 weeks after a period of immobilization of just over 1 month. There exists a trend in the literature to fix scaphoid fractures. A recent meta-analysis of 419 patients favored surgical fixation in terms of higher patient satisfaction, grip strength, time to union, and time off work.⁶ In addition to a possible quicker time to union, screw fixation has demonstrated a speedy return to military duty.⁵

The scaphoid staple was first described in 1980 in a surgical technique guide by Warner³⁴ in association with the Richards Medical Company. Since then there have been only a handful of studies investigating its application to scaphoid fractures.^{2,7,15,16,26,35,36} The Finnish were among the first to report their early clinical success with the scaphoid staple. Antti-Poika et al² presented the first preliminary series on scaphoid staple osteosynthesis in 11 scaphoid nonunions in 1987. The authors found that all scaphoids united with no complications at just over 1 year postoperatively. This series was subsequently included in a larger retrospective series of 25 scaphoids by with over 2-year mean follow-up. The authors again found the technique to be safe, with only 4 hardware removals and an 84% union rate in a cohort of predominantly (92%) nonunions.^{16,28}

Roughly a decade later, Winkel et al reported on a small series of 22 scaphoids treated with staple fixation that the

authors subsequently included in a larger retrospective series of 65 scaphoids.^{35,36} Among the 50 nonunions and 15 acute fractures, the authors reported a 92.8% union with 7 hardware removals. In the only other international publication, Rocchi et al²⁶ described excellent clinical outcomes with the use of scaphoid staple osteosynthesis in the setting of 60 strictly acute fractures, reporting 100% union and no complications or hardware removals at 36-month follow-up. The last and most comprehensive study was conducted by Carpentier and colleagues.⁷ In a retrospective review of 38 scaphoid nonunions treated with staple osteosynthesis and Matti-Russe bone grafting, roughly 95% of scaphoids had attained union at 26-month follow-up. This was the only study that examined return to work and to sport as well as specific clinic and radiographic outcomes.

In our systematic review, we found that the scaphoid staple demonstrated excellent clinical outcomes comparable, if not superior, to current methods of fixations in many respects. We found an overall 94.7% union rate, 100% in the setting of acute scaphoid fractures and 94.4% for other indications (nonunion, delayed union, and avascular necrosis) that often include bone grafting in addition to staple osteosynthesis. Our results are comparable with the existing literature on union rates for screw fixation, which is considered the gold standard.^{4,8,20,31} Union rates of acute scaphoid fractures treated more recently via screw fixation range from 95.2% to 100%.^{3,5,14,27,33} In the largest, most recent meta-analysis by Ibrahim et al,¹⁴ a 98.4% union rate was found for 363 patients with acute nondisplaced and minimally displaced scaphoid fractures. The study by Rocchi et al²⁶ was the only series to report on staple fixation of purely acute unstable scaphoid fractures, reporting 100% union rate.

If the results of acute scaphoid fixation are excluded,^{7,26} leaving a more homogeneous population of scaphoid nonunions, the conservative estimate of scaphoid nonunions that go on to union after staple osteosynthesis is 92.1%. Our results are again consistent with the most recent literature on screw fixation of scaphoid nonunions. The union rates of scaphoid nonunions treated with screw fixation and variable use of bone graft are much lower than those of acute fractures, cited between 75% and 95%.^{10,20,23-25,29,30} A recent systematic review of scaphoid fracture nonunions found an overall 94% union rate.²⁰ Our results therefore suggest that the scaphoid staple would be a reasonable alternative to screw fixation in the setting of both acute scaphoid fractures and nonunions.

We found an overall satisfaction of 94.3%, and though most studies did not report sufficient functional or radiographic data to allow comparison with that following screw fixation, 91.9% of patients had no functional impairments at final follow-up. Other studies of screw fixation in the setting of scaphoid nonunion have reported similar satisfaction rates of 90.5% to 93.8%.^{24,31}

There were 17 reported complications across all studies, for an overall rate of 9.0% (Table 2). Excluding nonunion and delayed union, the overall complication rate was 2.4%, which included 2 episodes of hardware loosening requiring removal and 2 technical errors resulting in inadequate staple placement and intraoperative revision. Complication rates in screw fixation are most commonly a result of technical errors. The most common technical errors in scaphoid fixation are related to screw length and placement.²¹ Technical errors occurred in 4.8% to 28% of cases, consisting of screw malpositioning and prominence.^{5,23,24,33} Buijze et al⁶ reported high rates of complication (23.7%) and reoperation (7.7%) in 419 acute scaphoid fractures treated with screw fixation. Complications consisted of screw malposition, hardware removal, malunion, nonunion, and osteonecrosis, and complex regional pain syndrome. Ibrahim et al¹⁴ found a 14.4% complication rate in a recent large meta-analysis of minimally and nondisplaced scaphoid fractures treated with open reduction and internal fixation. These were most commonly prominent hardware and technical errors, and to a lesser extent infection, complex region pain syndrome, and scar sensitivity. Overall complications, and specifically those related to technical errors, are significantly lower in the staple than that which is seen with screw fixation.

Fourteen patients in our review underwent hardware removal, most commonly for irritation. There were no other indications for reoperations. Hardware removal rates among studies of screw fixation have been cited as high as 20.6% at long-term follow-up.²⁵ Our low incidence of hardware removal is another potential advantage of the scaphoid staple.

In the opinion of the authors, an additional benefit of scaphoid staple fixation is the simplicity of fixation, making it more practical for routine utilization, particularly among general orthopedists.² Current internal fixation techniques are technically demanding and wrought with technical error.^{19,29,31,35,36} Herbert et al noted that fracture healing was largely dependent on the technical success of this difficult procedure.³⁶ Optimal fixation strength for screw fixation traditionally relies on a central trajectory, a feat that is often difficult to accomplish.^{19,35,36} In the setting of scaphoid nonunion, Trumble et al²⁹ found that 29.4% of screws were inadequately placed. Although screw fixation often requires perfect k-wires placement down the central axis of the scaphoid, this is not necessary in the placement of the scaphoid staple, rendering the staple simpler and less reliant fluoroscopy use.

There were several limitations to our study. As a systematic review, the level of evidence is limited to that of the constituent studies. However, this is the only and largest synthesis of available data on scaphoid staple fixation to date. In addition, two studies did not include itemized patient lists, limiting our analysis to the figures included

(Table 4). Due to the variety of various points at which postoperative radiographs were taken, scaphoid fracture types, indications, surgeon preferences, and a variety of patient specific factors, several aspects were not included for analysis. These include use and type of bone graft, and staple material. The type of metal used in the staple is especially important to control as Nitinol has the ability to compress when heated. However, it is unclear if there is a demonstrable clinical benefit with this type of metal. In addition, though all studies addressed union and at least one functional outcome measure, there was little analysis of range of motion, grip strength, and other patient-centered outcomes including return to work or sports. Given the excellent track record of the scaphoid staple, future studies could compare outcomes between staple and screw fixation methods. Subjective reporting of outcomes also represents a flaw in the study. For example, a laborer may return to work and be counted as a success in that regard, but he may still continue to have pain and ultimately may not be able to perform his duty as he had before his injury. Despite these shortcomings, the present analysis does highlight the high union rate and low complication rate of the scaphoid staple. Finally, the articles included did not report long-term outcome scores and rates of arthritic changes. These would be important factors to consider for future longitudinal analyses.

In conclusion, we present the first systematic review of scaphoid staple fixation to date. The scaphoid staple demonstrates comparable union rates with the current gold standard, screw fixation, in the setting of both acute scaphoid fractures and nonunions. Due to the easy of application, there are notably fewer technical complications, making the scaphoid staple an appealing alternative for both the general orthopedist and hand surgeon alike.

Ethical Approval

This study was approved by our institutional review board.

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 author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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