Surgical Treatment of Scaphoid Fractures: Recommendations for Management

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Abstract

Background: Several operative treatments exist for scaphoid fractures, varying by approach (e.g., ercutaneous, volar, or dorsal), implant type (e.g., screw or Kirschner wire), and bone raft choice (e.g., none, nonvascularized, or vascularized). Many previous systematic eviews and meta-analyses have investigated outcomes following different surgicalÚpproaches, the use of vascularized versus nonvascularized bone graft for scaphoidßracture nonunions, and treatment for specific fracture patterns. However, given the advancements n scaphoid fracture treatment in recent years, there is a need for updated treatment recommendations hat would be beneficial to hand surgeons.

Purpose: We present a comprehensive review of the operative treatment of scaphoid fractures based on recent literature and propose a unified treatment algorithm for managing these fractures.

Methods: The English-language literature was searched from 2002 to 2023 for high evidence level (e.g., randomized trials), review, and meta-analysis articles with the following search terms: “scaphoid, ”u8220“scaphoid” AND “nonunion, ” and “scaphoid” AND “malunion. ” Each article was creened by the authors to determine the scaphoid fracture scenario addressed and ubsequent treatment recommendations. The findings from article reviews were then rganized by scaphoid fracture types in this manuscript.

Results: A total of 95 pertinent articles were ultimately selected and used as the basis for reviewing different scaphoid fracture scenarios. A treatment algorithm was then proposed based on literature review.

Conclusion: This summary of the recent literature can guide hand surgeons in addressing scaphoidßractures. Future research in scaphoid fracture treatment, particularly for nonunions, would be most beneficial n the form of systematic review, meta-analysis, or multicenter prospective randomized clinical trials.

Level of Evidence: IV

Keywords
- avascular necrosis
- bone graft
- humpback deformity
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The retrograde blood supply to the scaphoid from the dorsal radial artery places proximal scaphoid fractures at a high risk of nonunion.[1] Specific patient risk factors have been implicated in fracture nonunion, such as delay in appropriate treatment[2] and current smoking status.[3,4] Fracture characteristics such as comminution at the fracture site and volar flexion (humpback) deformity can also heighten the risk of nonunion.[5] A large payer database study including data on 7,149 scaphoid fractures estimated an overall nonunion rate of 15.5%.[6] Left untreated, a persistent ununited scaphoid fracture progresses to scaphoid nonunion advanced collapse (SNAC) and arthrosis in 56% of patients after a mean follow-up of 36 years after injury.[7] Although surgical treatments for specific scaphoid fracture scenarios exist in the literature, an updated treatment algorithm, to our knowledge, has not been proposed.

We present a concise update of the treatment of various scaphoid fracture scenarios synthesized from a literature review, incorporating key findings from high-quality studies, systematic reviews, and meta-analyses. Our subsequent goal is to propose an algorithm for scaphoid fracture management, incorporating knowledge obtained from the literature review.

Materials and Methods

The authors searched the PubMed database (https://pubmed.ncbi.nlm.nih.gov/) for articles relevant to the surgical treatment of scaphoid fractures. Search terms used in the literature review included "scaphoid," "scaphoid AND nonunion," and "scaphoid AND malunion."

After this was performed, the titles and abstracts of retrieved articles were first assessed in order to ensure they were recent and pertinent. Thus, the following criteria for article inclusion in our literature view were applied: (1) articles must be in the English language; (2) publication dates were in the years 2002 to 2023; (3) full-text versions of the articles needed to be available for review; and (4) articles were high-evidence level (e.g., prospective randomized clinical trials [RCTs] representing level 1 evidence) or pertinent to a very specific scaphoid fracture scenario, meta-analysis, or review articles. If there was uncertainty regarding the suitability of an article after reviewing the title and abstract, the authors obtained and reviewed the full-text version of the article. A total of 95 articles were ultimately selected and used as the basis of the literature review in the following sections.

Results of Literature Review and Fracture Scenarios

Acute Nondisplaced Scaphoid Waist Fractures

When treated nonoperatively with casting less than 3 weeks after injury, acute nondisplaced scaphoid waist fractures exhibited union rates of 88 to 95%.[8] Siotos et al found no difference in nonunion rates between long and short arm casts and casts with and without thumb immobilization.[9] Grewal et al studied 172 patients treated with casting, showing a 99.4% union rate and a mean time to union (MTU) of 53 ± 37 days.[10]

Several investigations have compared casting to operative management of scaphoid waist fractures, such as a randomized comparison by Bond et al demonstrating an average time to union of 7 ± 0.5 weeks (following percutaneous screw fixation in 11 patients) versus 12 ± 0.7 weeks (after cast immobilization in 14 patients) for screw and cast treatments, respectively.[11] In the same study, time to return to work was 7 ± 0.7 versus 15 ± 0.7 weeks following screw fixation and casting, respectively.[11] Dias et al described a randomized comparison of casting (44 patients) and open reduction and internal fixation (ORIF) via a volar approach with screw fixation (44 patients) and found similar clinical outcomes.[12] Union was achieved in all 39 ORIF-treated patients followed to study completion and in 34 of the 44 cast-treated patients.[12] McQueen et al conducted a later randomized comparison of 30 patients treated with casting and 30 patients treated with percutaneous screw fixation and found no difference in union rate (97 vs. 87% for screw and cast treatment, respectively), grip, pinch, or range of motion (ROM) at 1 year.[13] However, the MTU was lower (9.2 vs. 13.9 weeks) and the mean time to return to full employment was also less (3.8 vs. 11.4 weeks) in those treated with screw fixation.[13] In the Scaphoid Waist Internal Fixation for Fractures Trial (SWIFFT) RCT studies, 219 patients with nondisplaced or minimally displaced (i.e., <2 mm) waist fractures were randomized to surgery and 220 to cast immobilization: by 12 weeks, 47% of those treated with surgery fully united in imaging compared to 22% treated with casting, but no difference in functional outcomes at 1 year was noted.[14–16] Other structured analyses of the literature have confirmed no clear difference in functional outcomes between surgical and nonsurgical treatment of these scaphoid fracture types.[17–20]

Displaced Scaphoid Waist Fractures (Aside from Nonunions)

Displacement of scaphoid waist fractures, by greater than 1 mm, has been associated with high rates of nonunion (55%) and avascular necrosis (AVN; 50%).[21] Thus, operative intervention is advised for displaced scaphoid waist fractures, which is supported by a meta-analysis reporting an odds ratio of 16.8 for nonunion following casting versus surgery.[22] Scaphoid fractures in these situations require attention to reduction and maintenance of fragments during fixation, which was accomplished with ORIF (using a volar approach and cannulated screw fixation) in a series of 35 patients and produced a 100% union rate within 4.0 ± 1.2 months.[23] Another series of acute displaced waist fractures, in 14 patients using ORIF with a Herbert screw or Kirschner wires and distal radius nonvascularized bone graft (NVBG), reported a 93% union rate with an MTU of 11.5 weeks.[24] Closed reduction and percutaneous screw fixation has also been used as a treatment for displaced waist fractures, with a 93% union rate and an MTU of 2.8 months in 14 patients successfully treated with this method.[25]

Scaphoid Waist Fracture Nonunions

Ununited scaphoid waist fractures have been typically treated by ORIF with bone grafting, which attained a 95% union rate in 26 patients (in a median time of 4 months) by utilizing an iliac crest BG (ICBG) wedge technique.[26] A later study on 22 patients treated with a volar approach, cannulated 3.5-mm screws, and ICBG achieved 100% union treating delayed unions (with an MTU of 19 weeks) and a 91% union rate treating nonunions.[27] A prospective RCT by Hegazy et al comparing 49 patients treated with ICBG to 49 patients with cancellous BG only found similar union rates, pain, and functional outcomes between the two groups.[28] Recent orthobiologic therapies utilizing mesenchymal stem cells[29] and bone morphogen proteins[30] have shown promise in scenarios with scaphoid fracture nonunions or revision operations.

In the last decade, VBGs have become an attractive option for facilitating the healing of fracture nonunions, with VBG based on the palmar carpal artery (PCA) achieving 100% union.[31] A different VBG, based on the pronator quadratus pedicle, achieved 100% union in 27 waist fracture nonunions, with an MTU of 11.5 weeks.[32] Despite these results with VBG, 100% union rates have been reported in 12 nonunions with an MTU of 14 weeks utilizing only limited debridement and distal radius cancellous BG.[33] Although a comparison of several VBGs in the literature have demonstrated union rates from 86 to 94%,[34] other reviews of studies have cast doubt on clear superiority in union rates and functional outcomes of VBGs over NVBGs.[35–38]

Volar flexion (humpback) deformity is usually associated with significant bone loss and malalignment leading to dorsal intercalated segment instability (DISI), which requires correction to decrease pain, increase wrist mobility, facilitate union, and arrest progression to arthritis.[39] Furthermore, the presence of DISI can pose a risk of failure to VBGs.[40] Volar plate fixation has been used to stabilize these humpback deformity fractures: in 20 patients treated with plating and volar distal radius VBG, a 90% union rate was achieved with an MTU of 4.7 ± 4.5 months.[41] In contrast, screw fixation with cancellous distal radius BG achieved 100% union in 12 patients.[42] Despite these encouraging results with NVBG methods, a meta-analysis of 5,246 cases of nonunions demonstrated an 80% union rate with NVBG alone, 84% union rate with NVBG and fixation, and 91% with VBG.[43] Moreover, VBG has been demonstrated as a successful primary procedure (98.2% union rates with waist nonunions with an MTU of 9.2 weeks).[44]

Despite the aforementioned success rates of most VBGs, the often-utilized distal radius VBGs experience a 50% failure rate in situations where waist nonunion, proximal AVN, and humpback deformity are present together.[45] In these scenarios, a meta-analysis of 48 articles by Pinder et al showed that medial femoral condyle (MFC) VBG could achieve 100% union rates,[46] with a later systematic review demonstrating 93% united at a mean time of 15.6 weeks.[47] A similar union rate (94%) is seen in the recently described medial femoral trochlear graft.[48]

Proximal Pole Scaphoid Fractures

Operative treatment has typically been advised for proximal pole scaphoid fractures due to the decreased vascularity of the proximal portion.[49] In 17 patients with an acute proximal scaphoid fracture (with 4 being displaced), Rettig and Raskin performed ORIF with a single screw (using distal radius BG in 14 cases) and achieved 100% union with an MTU of 10 weeks.[50] Displacement of proximal pole fractures can significantly delay healing, with Brogan et al showing 70% union for nondisplaced fractures and only 23% union for displaced fractures (at 14 weeks postoperatively).[51] As suggested by Chong et al, inconsistencies in studies describing the location of the fracture may underlie many of these heterogenous outcomes with union.[52]

Before treating a scaphoid fracture proximal pole nonunion (PPNU), it is important to determine if AVN is present. Lim et al evaluated distal radius VBG for small proximal pole fragments (mean size 21% of the scaphoid) with AVN and achieved an 86% union rate with an MTU of 14 weeks.[53] With these findings, dorsal ORIF with VBG (based on the 1,2-intercompartmental supraretinacular artery) has been advocated as a treatment for PPNU with AVN,[54] although cancellous BG has been examined as well.[55]

When AVN is not present, PPNUs have been treated successfully with NVBG, with a study by Luchetti et al highlighting a 90% union rate in 20 PPNUs using distal radius BG and screw fixation.[56] Using a capsular-based VBG, in contrast to NVBG, has been found to achieve an 85% union rate (with an MTU of 12.3 weeks) in an 89-patient series of PPNUs.[57]

Salvage Options

When persistent scaphoid fractures with nonunion and findings of SNAC are present, several salvage options are available and guided by the degree of bone loss and arthritis.[58] For SNAC affecting the radioscaphoid joint alone, radial styloidectomy with scaphocapitolunate arthrodesis is one option, shown to decrease pain and Disabilities of the Arm, Shoulder, and Hand (DASH) scores (without progressive arthrosis), in 20 patients.[59] Distal scaphoid resection is another option: 19 patients treated with this option exhibited a mean visual analog scale (VAS) score for pain of 0.9, grip strength of 83% of the contralateral wrist, wrist ROM of 79% of the contralateral wrist, and no development of radiolunate arthritis,[60] with a meta-analysis demonstrating 93% of patients returning to work in a mean time of 6.9 weeks.[61]

Once SNAC progresses beyond the radioscaphoid joint, other treatment options, such as proximal row carpectomy (PRC) and four-corner arthrodesis (4CF), should be considered. Mulford et al reviewed 52 articles, finding that both PRC and 4CF improve pain.[62] However, greater postoperative ROM, fewer complications, and less risk of subsequent arthritis were found following PRC compared to 4CF.[62]

Role of Arthroscopic Techniques in Treating Scaphoid Fractures

In the 1990s, Dr. Terry Whipple reviewed the use of arthroscopy to guide the placement of a cannulated Herbert screw to

fixate scaphoid fractures and allow contact athletes to return to sport 1 week postoperatively.[63,64] Taras et al also described arthroscopic-assisted fixation as an option in athletes, but cautioned that the technique be employed only in select cases[65] Gupta et al recommended percutaneous fixation with arthroscopic-assisted reduction for minimally displaced scaphoid fractures,[66] with all 15 acute fractures having healed in a study by Shih et al.[67] Slade et al proposed a dorsal approach for percutaneous screw fixation, achieving 100% union in 27 cases at an average of 12 weeks.[68] Further details of the Slade technique and a comparison to the other techniques were provided by Geissler and Hammit,[69] Geissler,[70] and Monaghan.[71] This dorsal approach was used in more challenging injury patterns, such as scaphoid fractures associated with perilunate injuries, with encouraging results.[72–75] Only one randomized trial comparing nondisplaced scaphoid waist fractures treated with either casting or arthroscopic-assisted fixation was done (with a minimum follow-up of 4 years); it demonstrated potential improved function in the short term, but with a risk of radioscaphoid arthritis, with surgery.[76,77] Arthroscopy has also been described in assisting fixation of scaphoid fracture nonunions, described by Ruch et al in a case series for proximal pole fractures[78] and then explicated in more detail.[79] Scaphoid fracture nonunion treatment was further explored by Slade et al using a dorsal approach.[80] Arthroscopy with different grafts have achieved high union rates: using BG substitute (93%),[81] distal radius autograft (94%),[82] iliac crest autograft (96%),[83] and olecranon autograft (100%).[84] Numerous review articles are available for further review dedicated to arthroscopic scaphoid fracture treatment along with other wrist pathologies[85–88] and toward scaphoid fractures specifically[89] with discussions of treating nonunion scenarios.[90–92] A recent detailed review of the history and technique of arthroscopic-assisted scaphoid nonunion repair was outlined by Nakamura et al.[93]

Proposed Treatment Algorithm and Discussion

By synthesizing the aforementioned data from the literature and case series, we propose an algorithm for managing scaphoid fractures, as depicted in ►**Fig. 1**. The preceding diagnostic workup could utilize the algorithm detailed by Kawamura and Chung.[8] Initially, radiographs would be screened for signs of SNAC: if an advanced stage of SNAC is present, one should consider salvage procedures such as PRC and 4CF.

For acute nondisplaced waist fractures, information on the patient's activities of daily living and occupational needs (such as the need to facilitate return to sport[94]) should be gathered, and the surgeon should thoroughly review the risks and benefits of cast immobilization versus percutaneous screw fixation with the patient. Arthroscopy or three-dimensional printed guides[95,96] may be useful fixation adjuncts, per surgeon familiarity and preference. Nondisplaced waist

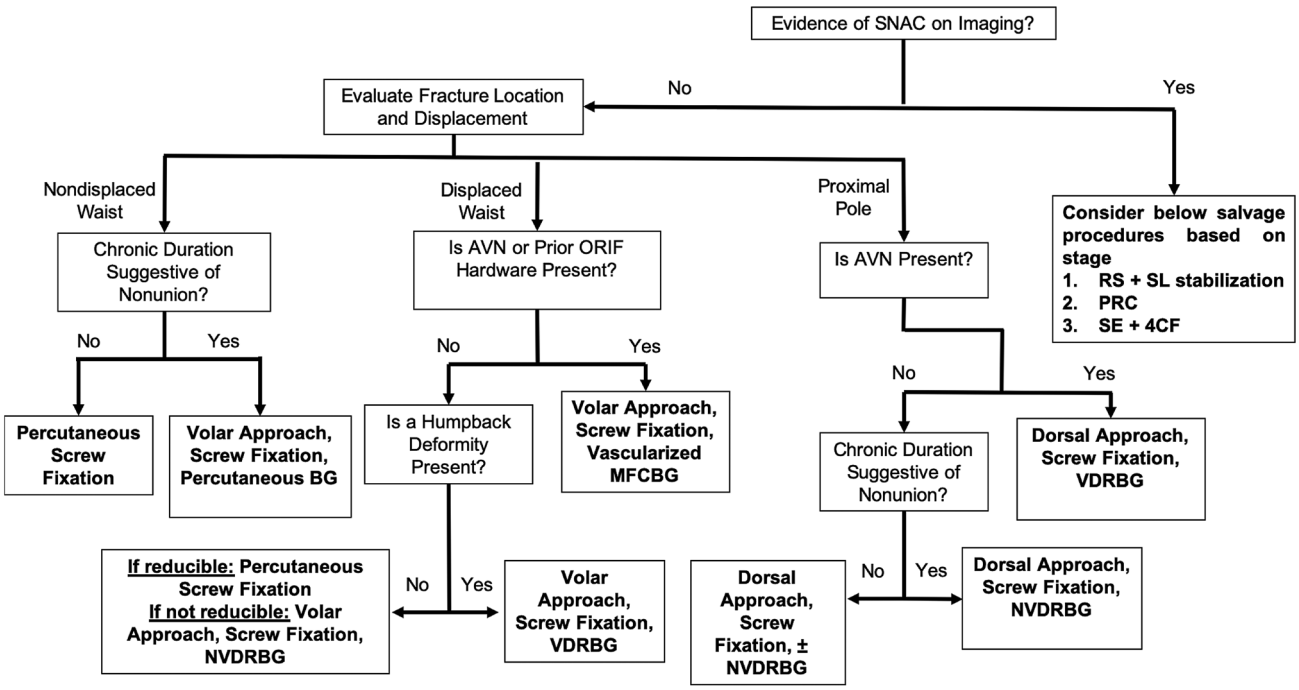

Fig. 1 Treatment algorithm summarizing recommendations based on data from our literature review. Course of treatment is dependent on the presence of scaphoid nonunion advanced collapse, fracture location, fracture displacement, injury chronicity suggestive of nonunion or delayed union, presence of avascular necrosis, and presence of volar flexion (humpback) deformity. AVN, avascular necrosis; MFCBG, medial femoral condyle bone graft; NVDRBG, nonvascularized distal radius bone graft; ORIF, open reduction and internal fixation; RS + SL stabilization, radial styloidectomy + scapholunate stabilization; PRC, proximal row carpectomy; SE + 4CF, scaphoid excision and four-corner arthrodesis; SNAC, scaphoid nonunion advanced collapse; VDRBG, vascularized distal radius bone graft.

nonunions would undergo a limited volar approach to visualize the fracture site, debrided as appropriate, and fixation with a single screw with ipsilateral distal radius NVBG applied if there is concern about stability.[97] Other possible fixation constructs in this scenario include bioabsorbable screws,[98] multiple Kirshner wires,[99] and plate–screw combinations.[100]

An MFC VBG with screw fixation would be advantageous for displaced waist fractures with AVN (diagnosed on radiographs or magnetic resonance imaging [MRI]), via a volar approach, to visualize and correct any humpback deformity that is present as well as revascularize the proximal pole. If AVN is not present, but humpback deformity is, then a volar approach with distal radius VBG or NVBG (based on surgeon preference) and screw fixation would be used. Acute and chronic (i.e., nonunion) displaced waist fractures without AVN or humpback deformity could be adequately treated with either closed reduction and percutaneous screw fixation (if reducible under fluoroscopy) or a volar approach with screw fixation and NVBG from the distal radius (if it is irreducible under fluoroscopy).

Proximal pole fractures with AVN would benefit from a VBG and screw fixation, but a dorsal approach could provide adequate visualization and distal radius VBG should provide a high rate of successful union while preserving MFC VBG if subsequent nonunion occurs. For PPNU, ipsilateral distal radius NVBG should be strongly considered, but acute cases could utilize NVBG if significant comminution is noted intraoperatively.

Ideally, a future set of multicenter randomized clinical trials assessing the efficacy of different approaches, fixation methods, BGs, and postoperative protocols would inform a future and comprehensive treatment algorithm with high-level evidence. Certainly, the aforementioned recommendations reflect a compilation of findings reported on the treatment of scaphoid fractures in a methodical review of the literature. Furthermore, it is supplemented by the cumulative experience of the co-authors, who are fellowship-trained hand and upper extremity surgeons. A systematic reappraisal of the evidence summarized in this article by convened expert panels of hand surgeons could be a logical next step toward adopting clinical practice guidelines, similar to what was done for distal radius fractures.[101] We concur with Pinder et al[46] that it would be difficult to obtain the large patient numbers necessary for these trials. In lieu of this route, we recommend continued high-quality surgical technique descriptions and cohort studies (ideally prospective) of novel scaphoid fracture treatments, with detailed data collection of patient demographics, fracture characteristics, and fixation and bone grafting used as proposed by Ferguson et al.[102] Subsequent meta-analyses and systematic reviews of those enhanced primary studies can then provide further guidance on optimal scaphoid fracture treatments.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was not required for this study.

Ethical Committee Statement

This manuscript did not require the approval of the Biomedical Institutional Review Board of The Ohio State University.

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Conflict of Interest

None declared.

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