Non-Vascularized Bone Grafting in the Surgical Treatment of Scaphoid Nonunion with Avascular Necrosis in Children and Adolescents

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Introduction

While scaphoid fractures are uncommon in pediatric patients, they are the most common carpal bone fracture in children.[1–3] In children and adolescents, the majority of nondisplaced or minimally displaced scaphoid fractures resolve with immobilization, but in rare cases, nonunion and avascular necrosis (AVN) of the proximal pole may occur.[2–4] In adults, there is increasing preference for vascularized bone grafting (VBG) over non-vascularized bone grafting (NVBG) for scaphoid nonunion with AVN due to its higher reported union rate.[5] However, vascularized bone graft has a greater risk of complications, including deformity of the donor site and lateral femoral cutaneous nerve damage in the case of VBG from the iliac crest.[5] In addition, a 2023 meta-analysis comparing union rates between VBG and NVBG found conflicting results and suggested VBG may not be superior to NVBG, potentially negating the benefits of a more technically demanding and higher morbidity surgical procedure.[5–7] The efficacy of NVBG for treatment of pediatric patients with scaphoid nonunion and AVN is not well-reported. A study of VBG in adolescent (ages 14-18) patients with scaphoid nonunion identified an 85% union rate (22 of 26 patients) after treatment with VBG; however, specific outcomes for patients with evidence of AVN were not reported.[4] We hypothesized that NVBG would yield excellent union rates and reliably restore carpal alignment in children and adolescents with scaphoid fracture nonunion and AVN.

Methods

This was a multi-center, retrospective cohort study of all patients <21 years old with scaphoid fracture nonunion and evidence of AVN managed operatively with non-vascularized autograft from either the distal radius (DR) or iliac crest (IC). Pre- and postoperative scapholunate (SL) and radiolunate (RL) angles, pre- and postoperative wrist range of motion (ROM), and evidence of radiographic union (defined as bridging cortex visible on three of four cortices on radiographs) at final follow-up were recorded. Patients with nonunion but no evidence of AVN on radiographs or advanced imaging were excluded. Descriptive statistics were tabulated, and Mann-Whitney U tests were utilized to compare pre- and postoperative differences in carpal alignment and range of motion. Statistical analysis was performed in IBM SPSS Statistics v29.

Results

In total, 24 wrists with scaphoid nonunion and documented AVN across 24 patients (2 [8%] female) with a mean age of 14.9 ± 2.5 years at injury (range: 11.0-20.6 years) were included for analysis. Of these, 11 were managed with non-vascularized iliac crest (six corticocancellous, five cancellous) and 13 with non-vascularized distal radius (one corticocancellous, 10 cancellous). Nearly all (23/24) cases were managed with concomitant fixation utilizing headless compression screws. Radiographic union was achieved in 23 cases (96%). One patient managed with cancellous NVBG from the iliac crest and headless compression screw fixation developed a nonunion six months postoperatively due to hardware failure. Despite adequate postoperative immobilization and adherence to activity restrictions, this case required revision fixation with repeat NVBG from the distal radius. After repeat surgery, the patient achieved radiographic union with no further complications. Operative management with NVBG improved carpal alignment, though this difference was only significant for SL angle (mean preoperative SL angle 71.1° ± 9.5° versus 60.9 ± 11.3 postoperatively, $p = 0.002$). Mean final wrist range of motion was excellent, including flexion of 66.2° ± 12.1° and extension of 63.1° ± 11.4° postoperatively; however, the improvement in wrist range of motion after surgery was not statistically significant (Table 1, Figure 1).

Discussion

NVBG yields excellent union rates in children and adolescents and should generally be the preferred initial approach

Table 1. Preoperative Versus Postoperative Radiographic and Clinical Data

	Preoperative	Postoperative	P-value
Carpal Alignment (Degrees)			
Scapholunate angle	71.1 ± 9.5	60.9 ± 11.3	**0.002**[1]
Radiolunate angle	25.8 ± 14.2	20.6 ± 17.0	0.09[1]
ROM (Degrees)			
Wrist Flexion	63.9 ± 12.1	66.2 ± 12.1	0.55[1]
Wrist Extension	54.4 ± 21.1	63.1 ± 11.4	0.42[1]

Figure 1. (A) Preoperative radiographs demonstrating dorsal intercalated segment instability (DISI) deformity and computed tomography scan demonstrating sclerosis of proximal pole of scaphoid; **(B)** Postoperative radiographs demonstrating healing scaphoid fracture and improved carpal alignment.

given the morbidity associated with vascularized bone grafting, particularly free vascularized bone grafting. This is consistent with existing literature suggesting good outcomes from NVBG; however, most reports are based on skeletally mature patients, and are not restricted to scaphoid nonunion with evidence of AVN.[6] To our knowledge, this is the first study describing outcomes following NVBG in pediatric and adolescent patients with scaphoid nonunion and AVN.

The observed residual carpal malalignment in our cohort suggests that greater use of structural (corticocancellous) bone grafting could be beneficial. Further research should compare the restoration of carpal alignment following NVBG from the iliac crest versus the distal radius in pediatric patients with scaphoid nonunion, given known differences in structural properties between the two bone graft sources.[8]

These findings must be interpreted in the context of the following limitations. Our study is limited by nature of being a retrospective review. Additionally, given the rarity of scaphoid AVN in pediatric and adolescent patients, small sample size limited the power of our statistical tests. Future research including patients from additional large-volume pediatric institutions would allow for more robust analyses.

Conclusion

Non-vascularized bone grafting yields excellent outcomes in children and adolescents presenting with scaphoid nonunion and avascular necrosis and should be the preferred approach in management due to lower associated morbidity compared to vascularized bone grafting. Future research should compare restoration of carpal alignment in pediatric scaphoid nonunion managed with distal radius versus iliac crest non-vascularized bone grafting.

References

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