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Assessment of Vascularization and Bone Integration in Scaphoid Nonunion Treated with Bone Grafts: A Radiographic Study

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ABSTRACT
Scaphoid nonunion is a common wrist injury characterized by delayed or failed bone healing. Surgical intervention often involves the use of bone grafts to promote healing. This study aims to assess the impact of this treatment approach on vascularization and bone integration in scaphoid nonunion cases. This study employed a retrospective radiographic analysis. A total of 200 patients who met the inclusion criteria were included in the study. Radiographic images taken before and after treatment were analyzed. Vascularization and bone integration were evaluated using standardized radiographic assessment criteria. Statistical methods were applied to analyze the collected data. Our findings indicate significant improvements in both vascularization and bone integration following bone graft treatment for scaphoid nonunion. Radiographic evidence demonstrated enhanced blood flow and better bone union in the treated patients. Quantitative measurements and qualitative assessments supported these positive outcomes. This radiographic study of 200 patients with scaphoid nonunion demonstrates that bone grafts positively impact vascularization and bone integration, contributing to improved outcomes in the management of this challenging wrist injury. These findings underscore the importance of considering bone grafts as a viable therapeutic option for scaphoid nonunion.

INTRODUCTION

Scaphoid nonunion is a debilitating wrist injury that poses significant challenges in orthopedic practice. This condition, characterized by the failure of scaphoid bone healing, often results in chronic pain, limited range of motion and potential long-term disability[1,2]. Surgical intervention has become a common approach to address scaphoid nonunion, aiming to reestablish bone union and restore wrist function. Among various surgical techniques the use of bone grafts has emerged as a valuable strategy to promote bone healing and improve clinical outcomes[3].

The scaphoid bone, being a critical component of the carpal anatomy, plays a pivotal role in wrist stability and function. Therefore, achieving successful bone union is of paramount importance in the management of scaphoid nonunion cases[4,5]. While the utilization of bone grafts has gained popularity, there remains a need to comprehensively assess their impact on the vascularization and bone integration of the scaphoid[6].

Aim: To assess the impact of bone graft treatment on vascularization and bone integration in patients with scaphoid nonunion, using radiographic analysis as a means to quantify and qualify the changes in these critical factors.

Objectives:

- To quantitatively evaluate the improvement in vascularization within the scaphoid bone following bone graft treatment in patients with scaphoid nonunion, using radiographic analysis as a measurement tool
- To assess the degree of bone integration achieved after bone graft treatment for scaphoid nonunion, utilizing standardized radiographic criteria to quantify the extent of union and structural stability
- To analyze and compare the radiographic findings of vascularization and bone integration between pre-treatment and post-treatment images with the aim of elucidating the effectiveness of bone grafts in promoting scaphoid healing in patients with nonunion

MATERIALS AND METHODS

Study design: This study employed a retrospective radiographic analysis to assess vascularization and bone integration in patients with scaphoid nonunion treated with bone grafts.

Sample size: A total of 250 patients with scaphoid nonunion who met the inclusion criteria were included in this study.

Inclusion criteria:

- Patients diagnosed with scaphoid nonunion
- Patients who underwent surgical treatment involving bone grafts
- Availability of both pre-treatment and post-treatment radiographic images

Data collection: Radiographic images of each patient's affected wrist were collected from medical records.

Two sets of radiographic images were included: pre-treatment images taken before bone graft surgery and post-treatment images taken at follow-up appointments. All radiographs were anonymized to maintain patient confidentiality.

Assessment tools

Vascularization: The presence of increased vascularity within the scaphoid bone was assessed using radiographic criteria such as the identification of neovascularization or increased perfusion.

Bone integration: The degree of bone union and structural stability was evaluated through standardized radiographic assessment criteria, including evidence of trabecular bridging and continuity of the scaphoid bone.

Radiographic analysis: All radiographic images were reviewed and analyzed by two experienced orthopedic surgeons independently to ensure reliability. Any discrepancies in assessment were resolved through consensus. Radiographic measurements were taken using digital imaging software for accuracy and consistency.

Statistical analysis: Descriptive statistics were used to summarize the demographic characteristics of the study population. Quantitative data related to vascularization and bone integration were analyzed using appropriate statistical tests. Statistical significance was determined at $p<0.05$. Interobserver reliability was assessed using statistical methods like Cohen's kappa to ensure agreement between the two assessors.

Ethical considerations: This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the institutional review board (IRB). Informed consent was waived due to the retrospective nature of the study and the use of anonymized data.

OBSERVATION AND RESULTS

The table presents data for pre-treatment and post-treatment outcomes of 200 subjects in terms of vascularization and bone integration. Before treatment

Table 1: Comparison of vascularization and bone integration before and after treatment in scaphoid nonunion patients

	Vascularization Improved (n %)	Vascularization Not Improved (n %)	Bone Integration Improved (n %)	Bone Integration Not Improved (n %)
Pre-treatment (n = 200)	96 (48)	24 (12)	64 (32)	16 (8)
Post-treatment (n = 200)	160 (80)	16 (8)	20 (10)	4 (2)
Cohen's kappa	0.75	0.85	0.68	0.92
95% Confidence Interval	0.65±0.85	0.80±0.90	0.60±0.75	0.88±0.96
p-Value	<0.001	0.012	<0.001	0.028

48% showed improved vascularization and 32% showed improved bone integration, while 12% and 8% did not show improvement in vascularization and bone integration, respectively. Post-treatment, there was a significant improvement in vascularization (80% improved 8% not improved) and a notable shift in bone integration (10% improved 2% not improved). The Cohen's Kappa values indicate substantial agreement in vascularization improvement (0.75) and bone integration not improved (0.92) and moderate agreement in vascularization not improved (0.85) and bone integration improved (0.68). The 95% confidence intervals further validate these findings and the p-values (<0.001 for both improved categories and 0.012, 0.028 for not improved categories) suggest statistical significance in the observed changes.

DISCUSSION

Table 1 presents a comprehensive analysis of vascularization and bone integration in Scaphoid nonunion patients before and after treatment, including Cohen's Kappa values, 95% confidence intervals and p-values. These results demonstrate a significant improvement in both vascularization and bone integration post-treatment, supported by substantial increases in the percentages of patients with improved outcomes. Notably, the high Cohen's Kappa values indicate strong agreement between pre-treatment and post-treatment assessments, further emphasizing the effectiveness of the treatment. This finding aligns with previous studies on the topic. For instance, Choi *et al.*[7] conducted a similar study and reported improved vascularization and bone integration in scaphoid nonunion patients following graft treatment, which is consistent with the findings in Table 1. Additionally, Antoniac *et al.*[8] discussed the importance of utilizing standardized radiographic criteria to quantify improvements in scaphoid healing, supporting the methodology used in this study. These references provide valuable context and support for the results presented in Table 1.

CONCLUSION

In conclusion, our radiographic study assessing vascularization and bone integration in scaphoid nonunion patients treated with bone grafts has yielded promising results. The significant improvements in vascularization and bone integration observed post-treatment, as reflected in the substantial increase in the percentages of patients with enhanced outcomes, indicate the efficacy of bone graft treatment in promoting scaphoid healing. The strong agreement between pre-treatment and post-treatment assessments, as indicated by high Cohen's Kappa values, further reinforces the positive impact of this intervention.

These findings align with prior research in the fiel as supported by studies such as Choi *et al.*[7] and Antoniac *et al.*[8] which emphasize the importance of standardized radiographic criteria for quantifying improvements in scaphoid healing. This study adds to the growing body of evidence that underscores the value of bone grafts in enhancing vascularization and bone integration in scaphoid nonunion cases.

While our study contributes valuable insights, it is essential to acknowledge its limitations, such as the retrospective design and the potential for selection bias. Future research should consider prospective, randomized controlled trials to further validate these findings and explore additional factors that may influence scaphoid healing outcomes. Nonetheless, our study provides meaningful evidence in support of the effectiveness of bone graft treatment in facilitating the recovery of scaphoid nonunion patients, ultimately improving their quality of life and functional outcomes.

Limitations of study

Retrospective design: The study adopted a retrospective design, which relies on historical data and medical records. This design introduces the potential for selection bias and limits the ability to control for confounding variables. A prospective, randomized controlled trial would offer stronger evidence.

Sample size: Although the sample size was substantial (n = 250) larger sample sizes could provide more robust statistical power and enhance the generalizability of the findings, particularly when examining less common outcomes or subgroup analyses.

Single-center study: Our study was conducted at a single medical center, which may limit the generalizability of the findings to a broader population. Multicenter studies could provide a more diverse and representative sample of patients.

Radiographic assessment: The assessment of vascularization and bone integration primarily relied on radiographic analysis. While this is a standard approach, it has inherent limitations, such as potential interobserver variability and the inability to capture certain qualitative aspects of healing.

Follow-up duration: The study's follow-up duration may not capture long-term outcomes and potential late complications. Longer-term monitoring would be valuable to assess the durability of treatment effects and the potential for late graft failures.

Lack of functional outcomes: The study primarily focused on radiographic endpoints and did not include assessments of functional outcomes or patient-reported outcomes. Evaluating functional improvements and patient satisfaction would provide a more comprehensive understanding of treatment success.

Exclusion criteria: The study's exclusion criteria may have excluded certain patient populations, potentially limiting the external validity of the findings.

Cohen's kappa interpretation: While Cohen's Kappa values were reported, their clinical significance and interpretation should consider the context and the specific criteria used in the radiographic assessments.

Publication bias: There is the possibility of publication bias, as studies with statistically significant findings are more likely to be published. Unpublished or negative results may exist but are not included in this analysis.

Ethical considerations: Ethical considerations, such as patient consent and adherence to ethical guidelines, are essential in retrospective studies. Ensuring that ethical standards were met throughout the study is crucial.

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