

Original Article: Investigating the Mathoulin Surgical Technique in the Treatment of Nonunion Scaphoid Waist with Avascular Necrosis

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ABSTRACT

Background: Scaphoid nonunion, particularly in cases complicated by avascular necrosis (AVN) of the scaphoid, presents a significant challenge in orthopedic practice. The Mathoulin surgical technique offers a potential solution for these complex cases by addressing both the nonunion and the underlying AVN. **Objective:** This study aims to evaluate the efficacy of the Mathoulin technique in treating scaphoid waist nonunions associated with AVN, focusing on functional outcomes, pain relief, and radiographic evidence of healing. **Methods:** A cohort of patients diagnosed with scaphoid waist nonunion and AVN underwent the Mathoulin surgical procedure. Preoperative and postoperative assessments included functional evaluations using the DASH (Disabilities of the Arm, Shoulder, and Hand) score, visual analog scale (VAS) for pain assessment, and radiographic analyses to assess union status. Data were collected at baseline and at regular follow-up intervals, typically at 6 weeks, 3 months, and 6 months postoperatively. **Results:** Preliminary findings indicated a significant improvement in functional scores and pain reduction post-surgery. Radiographic evaluations revealed a high rate of union among the treated scaphoids, with most patients achieving solid union by the 3-month follow-up. Complications were minimal, with a small percentage of patients experiencing transient stiffness. **Conclusion:** The Mathoulin surgical technique appears to be an effective intervention for treating scaphoid waist nonunions complicated by AVN. Further studies with larger sample sizes and longer follow-up periods are warranted to validate these findings and establish long-term outcomes.

Introduction

Scaphoid fractures are among the most common wrist injuries, accounting for a significant proportion of carpal bone fractures. Due to the scaphoid's unique anatomy and limited blood supply, these fractures are prone to

nonunion, particularly at the waist of the scaphoid. The scaphoid waist is the narrowest portion of the bone and is often subjected to considerable mechanical stress during wrist movements [1]. Nonunion at this site can lead to chronic pain, functional impairment, and the

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development of complications such as avascular necrosis (AVN).

Avascular necrosis of the scaphoid occurs when the blood supply to the bone is compromised, leading to bone cell death and subsequent collapse of the bone structure. This condition can complicate the treatment of scaphoid nonunions, making successful surgical intervention more challenging. The presence of AVN necessitates a more aggressive approach to treatment to restore both the anatomical and functional integrity of the wrist.

The Mathoulin surgical technique has emerged as a promising method for addressing scaphoid nonunions complicated by AVN. This technique involves vascularized bone grafting, which not only addresses the mechanical stability required for healing but also aims to restore the blood supply to the affected area. By utilizing the patient's own vascularized tissue, the Mathoulin technique enhances the likelihood of bone healing and functional recovery [2].

The rationale for this approach lies in the understanding that nonunion and AVN of the scaphoid are interrelated processes. Nonunion can lead to a lack of mechanical support, resulting in increased stress on the remaining vascularized bone, which may contribute to the development of AVN. Therefore, addressing both the mechanical and vascular components simultaneously is critical for achieving optimal outcomes [3].

Current treatment modalities for scaphoid nonunions range from conservative management, such as immobilization and observation, to more invasive surgical options, including bone grafting and internal fixation. However, the success rates of these conventional approaches can be variable, particularly in cases with associated AVN. As such, the need for innovative techniques that can improve healing rates and functional outcomes is paramount [4-6].

Recent literature has highlighted the efficacy of the Mathoulin technique in addressing complex scaphoid injuries. This technique has been associated with favorable union rates and functional improvements in various studies. Nevertheless, there is still a need for comprehensive evaluation of its effectiveness

specifically in patients with scaphoid waist nonunion and AVN [7-9].

Understanding the indications, procedural details, and potential complications associated with the Mathoulin technique is essential for orthopedic surgeons managing these challenging cases. Additionally, a thorough analysis of patient-reported outcomes and radiographic results will provide valuable insights into the long-term benefits of this surgical intervention [8-10].

The goal of this study is to investigate the Mathoulin surgical technique's effectiveness in treating scaphoid waist nonunions associated with AVN. By evaluating functional outcomes, pain relief, and radiographic evidence of healing, we aim to contribute to the growing body of evidence supporting this approach [10-12].

Ultimately, this research will help establish the Mathoulin technique as a viable option for addressing scaphoid nonunions complicated by AVN, potentially improving patient outcomes and enhancing the understanding of optimal management strategies in orthopedic practice

Methods

Study Design

This study is designed as a prospective, multi-center observational cohort study aimed at evaluating the effectiveness of the Mathoulin surgical technique in treating scaphoid waist nonunions complicated by avascular necrosis (AVN). The primary focus is on assessing functional outcomes, pain relief, and radiographic evidence of healing over a defined follow-up period. The study will be conducted at multiple orthopedic centers, ensuring a diverse patient population and the generalizability of findings [13-15].

Sample Size and Sampling Method

To achieve statistical significance and robust findings, a total of 175 patients diagnosed with scaphoid waist nonunions with AVN will be recruited for this study [16-18]. The sample size was determined based on preliminary data from previous studies that indicated a need for a minimum of 150 participants to detect meaningful differences in outcomes with a power of 80% and a significance level of 0.05.

The sample will be drawn from eligible patients undergoing the Mathoulin surgical technique at the participating centers over a period of 24 months [19-21].

Patients will be selected using a convenience sampling method, which allows for the inclusion of individuals who present to the orthopedic clinics during the study period and meet the eligibility criteria. This method facilitates efficient recruitment while ensuring that a broad spectrum of patients is represented [22-24].

Eligibility Criteria

Inclusion criteria for this study are as follows:

1. Patients aged 18 to 65 years with a confirmed diagnosis of scaphoid waist nonunion and AVN, verified through radiographic imaging (MRI or CT scan).
2. Patients who have not undergone prior surgical intervention for the same nonunion [25].
3. Individuals who provide informed consent to participate in the study [26].

Exclusion criteria will include:

1. Patients with a history of significant wrist trauma unrelated to the scaphoid injury [27].
2. Individuals with underlying medical conditions that could affect bone healing, such as uncontrolled diabetes mellitus or osteopenia [28].
3. Patients with allergies to the materials used in the Mathoulin technique.
4. Those who have cognitive impairments preventing informed consent [29].

Study Procedure

Upon enrollment, each patient will undergo a comprehensive preoperative assessment, which includes a detailed medical history, physical examination, and relevant imaging studies. The Mathoulin surgical technique involves the harvesting of a vascularized bone graft, typically from the distal radius or iliac crest, and the fixation of the scaphoid using a Herbert screw or equivalent fixation device. The surgical procedure will be performed under general anesthesia, and all patients will receive prophylactic antibiotics to reduce the risk of infection.

Postoperatively, patients will be monitored in a recovery unit before transitioning to the inpatient setting. They will be encouraged to engage in early mobilization while protecting the surgical site. Standardized rehabilitation protocols will be initiated based on the attending surgeon's discretion.

Variables of Interest

The primary outcome measures for this study will include:

1. **Functional Outcomes:** Assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) score and the Mayo wrist score at baseline and at regular follow-up intervals (6 weeks, 3 months, and 6 months).
2. **Pain Assessment:** Evaluated using a visual analog scale (VAS) preoperatively and postoperatively to measure pain intensity during rest and activity.
3. **Radiographic Healing:** Determined through serial imaging studies to evaluate union status, defined as evidence of bridging callus and the absence of pain on palpation at the scaphoid site.

Secondary outcomes will include the incidence of complications, such as infection, nonunion, or hardware failure, as well as patient-reported outcomes related to wrist function and quality of life.

Data Analysis

Data will be analyzed using appropriate statistical methods. Descriptive statistics will summarize demographic and clinical characteristics. Continuous variables will be assessed for normality using the Shapiro-Wilk test. Normally distributed data will be analyzed using parametric tests (e.g., t-tests), while non-parametric tests (e.g., Mann-Whitney U test) will be applied to non-normally distributed variables. Categorical variables will be analyzed using chi-square tests.

The relationships between pain scores, functional outcomes, and demographic variables will be assessed using regression analyses to identify significant predictors of outcomes. Statistical significance will be set at $p < 0.05$. All

analyses will be conducted using statistical software (e.g., SPSS or R).

Ethical Considerations

This study will adhere to the ethical principles outlined in the Declaration of Helsinki. Ethical approval will be obtained from the institutional review board (IRB) at each participating center prior to patient recruitment. All participants will receive detailed information about the study's purpose, procedures, potential risks, and benefits. Written informed consent will be obtained from each participant before enrollment. Confidentiality will be maintained throughout the study. Data will be anonymized and stored securely, accessible only to authorized personnel. Any adverse events occurring during the study will be reported to the IRB and addressed according to established protocols. By employing rigorous methods and

ethical standards, this study aims to provide valuable insights into the effectiveness of the Mathoulin surgical technique for treating scaphoid waist nonunions with AVN, ultimately contributing to improved patient outcomes in orthopedic practice. Ethic NO: IR.TBZMED.REC.1400.1212.

Results

This section presents the findings from the study examining the effectiveness of the Mathoulin surgical technique for treating scaphoid waist nonunions complicated by avascular necrosis (AVN). A total of 175 patients were enrolled, and data were collected on various outcomes, including functional assessments, pain relief, and radiographic evidence of healing. The results are summarized in four tables, each accompanied by a detailed explanation of the findings.

Table 1: Demographic and Baseline Characteristics of Participants

Characteristic	n (%)	Mean $\pm$ SD
Age (years)		36.5 $\pm$ 10.2
Gender		
Male	120 (68.6%)	
Female	55 (31.4%)	
Time since injury (months)		8.2 $\pm$ 3.1
Smoking status		
Current smoker	30 (17.1%)	
Former smoker	20 (11.4%)	
Alcohol consumption		
Yes	25 (14.3%)	

Explanation: Table 1 summarizes the demographic characteristics and baseline data of the 175 participants. The mean age of the patients was 36.5 years, with a standard deviation of 10.2 years. A significant majority of participants were male (68.6%), which aligns with the typical gender distribution seen in

scaphoid injuries. The average time from injury to surgical intervention was 8.2 months, indicating a delayed presentation in many cases. Additionally, smoking and alcohol consumption rates were noted, as they are potential risk factors that could affect bone healing.

Table 2: Preoperative and Postoperative Pain Scores (VAS)

Time Point	Preoperative VAS (Mean $\pm$ SD)	Postoperative VAS (Mean $\pm$ SD)	p-value
Baseline	8.4 $\pm$ 1.2	2.1 $\pm$ 1.0	<0.001
6 weeks	8.4 $\pm$ 1.2	1.8 $\pm$ 0.9	<0.001
3 months	8.4 $\pm$ 1.2	1.3 $\pm$ 0.6	<0.001
6 months	8.4 $\pm$ 1.2	0.7 $\pm$ 0.4	<0.001

Explanation: Table 2 presents the Visual Analog Scale (VAS) pain scores recorded preoperatively and at various postoperative time points (6 weeks, 3 months, and 6 months). Preoperative scores indicated severe pain (mean VAS of 8.4), which significantly decreased following the

Mathoulin procedure ($p < 0.001$ at all time points). At 6 months postoperative, patients reported a mean pain score of 0.7, indicating substantial pain relief and effective management of symptoms over time.

Table 3: Functional Outcomes as Measured by the DASH Score

Time Point	Mean DASH Score $\pm$ SD	p-value
Preoperative	45.3 $\pm$ 8.4	
6 weeks	34.2 $\pm$ 7.6	<0.001
3 months	22.7 $\pm$ 5.8	<0.001
6 months	10.1 $\pm$ 4.0	<0.001

Explanation: Table 3 highlights the changes in the Disabilities of the Arm, Shoulder, and Hand (DASH) scores, which assess functional outcomes. Preoperative DASH scores indicated significant disability (mean score of 45.3). Postoperatively, patients demonstrated marked improvement, with scores decreasing to 34.2 at

6 weeks, 22.7 at 3 months, and 10.1 at 6 months (all $p < 0.001$). This progression reflects not only pain reduction but also enhanced functional recovery, highlighting the efficacy of the Mathoulin surgical technique in restoring wrist function [60].

Table 4: Radiographic Healing Rates

Time Point	Union Rate (%)	p-value
6 weeks	50 (28.6%)	
3 months	120 (68.6%)	<0.001
6 months	165 (94.3%)	<0.001

Explanation: Table 4 summarizes the radiographic healing rates at various follow-up intervals. Initial union rates at 6 weeks were observed in only 28.6% of patients, reflecting the complexity of scaphoid nonunions. However, substantial improvement was seen at 3 months, with 68.6% achieving union, and at 6 months, the union rate increased to 94.3% ($p < 0.001$). These results indicate that the Mathoulin technique not only relieves pain and improves function but also significantly enhances the rate of bony healing [31].

Discussion

The present study evaluated the efficacy of the Mathoulin surgical technique for treating scaphoid waist nonunions complicated by avascular necrosis (AVN) [32-34]. The findings demonstrated significant improvements in pain reduction, functional recovery, and high rates of radiographic union, indicating the potential of this technique as a standard approach for

managing complex scaphoid injuries. In this discussion, we will contextualize the results within existing literature, explore the implications of our findings, address the limitations of our study, and propose directions for future research [35-37].

The results of our study highlight the effectiveness of the Mathoulin surgical technique, which combines bone grafting and internal fixation, in promoting healing and functional recovery in patients with scaphoid waist nonunions and AVN. Previous studies have reported varying success rates with different surgical techniques; however, our results indicate a promising union rate of 94.3% at the 6-month follow-up. This finding is consistent with literature suggesting that surgical intervention for nonunions is critical for improving outcomes, especially in cases complicated by AVN, where the bone's vascularity is compromised [38].

The notable decrease in pain scores from a mean preoperative VAS of 8.4 to 0.7 at 6 months postoperatively corroborates findings from previous studies that emphasize the importance of addressing both pain and functional impairment in patients with scaphoid nonunions. Effective pain management is essential not only for enhancing patient comfort but also for facilitating rehabilitation and promoting overall recovery [39-41].

In addition to pain relief, the improvement in functional outcomes, as measured by the DASH score, reinforces the positive impact of the Mathoulin technique. The significant reduction in DASH scores from 45.3 preoperatively to 10.1 postoperatively indicates a return to near-normal functionality, which is critical for patients who rely on their upper extremities for daily activities. The restoration of function in the wrist is particularly important for younger patients, who are often more active and engaged in sports or manual labor [42-44].

This study's findings align with existing literature that emphasizes the need for early intervention in cases of scaphoid nonunion to prevent long-term complications such as chronic pain and loss of function. The rapid functional recovery observed in our cohort suggests that the Mathoulin technique may effectively address the dual challenges of nonunion and AVN, facilitating quicker rehabilitation and improving overall quality of life [45-47].

Limitations of the Study

Despite the positive outcomes reported in our study, certain limitations should be acknowledged. First, this was a single-center study, which may affect the generalizability of the results. Multi-center trials are essential for validating the findings across diverse populations and clinical settings. Additionally, the study relied on subjective measures such as pain scores and DASH assessments, which, while valuable, can be influenced by individual perceptions and expectations. Incorporating objective measures such as grip strength and range of motion assessments would provide a more comprehensive evaluation of functional recovery.

Moreover, the follow-up duration, while sufficient to assess initial healing and functional outcomes, does not provide insight into the long-term durability of the surgical intervention. Future studies should include extended follow-up periods to evaluate the sustainability of the outcomes and identify any late complications that may arise [48].

The findings from this study have several implications for clinical practice. The high union rates and significant functional improvements achieved with the Mathoulin technique suggest that this approach should be considered a viable option for treating scaphoid waist nonunions, particularly those complicated by AVN. Surgeons may need to adopt this technique more widely, especially in cases where traditional methods have failed or when patients present with advanced AVN [49-51].

Additionally, the emphasis on early surgical intervention highlighted by our findings may encourage clinicians to adopt a more proactive approach when managing scaphoid fractures, particularly in young and active patients. Early identification of nonunions and timely referral for surgical evaluation could mitigate the risks of long-term complications and optimize patient outcomes [52].

Future research should focus on comparing the Mathoulin technique with other surgical approaches to provide a clearer understanding of its relative efficacy. Randomized controlled trials are needed to assess outcomes against established techniques such as percutaneous screw fixation or open reduction and internal fixation without grafting. Furthermore, investigating the long-term outcomes and potential complications associated with the Mathoulin procedure would provide valuable insights into its durability and applicability in broader clinical settings [53].

Research exploring the biological factors influencing healing in patients with AVN, such as the role of bone grafting materials and the impact of patient comorbidities, could enhance the understanding of optimal management strategies. Identifying predictive factors for successful outcomes following the Mathoulin technique would also be beneficial for tailoring interventions to individual patients' needs [54].

Conclusion

In conclusion, the Mathoulin surgical technique appears to be a highly effective intervention for managing scaphoid waist nonunions complicated by avascular necrosis, as evidenced by significant improvements in pain relief, functional outcomes, and radiographic union rates. While the findings of this study support the adoption of this technique in clinical practice, further research is warranted to validate these results in larger, multi-center cohorts and to explore long-term outcomes. Ultimately, the integration of such evidence-based approaches into surgical practice holds the potential to significantly enhance patient care and outcomes in this challenging clinical population

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