

Deformity Correction in Malunited Ankle Fracture the Clinical and Functional Outcomes

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Abstract

Background: Malunion of the ankle fractures is a frequent cause of morbidity. The normal ankle is essential for normal mobility. **Objective:** To evaluate the functional outcome of surgical correction of malunited ankle fractures. **Methods:** This was a retrospective, cross-sectional hospital-based study conducted at Bashaeir University Hospital between January 2019 and March 2023. The study sample was 40 patients fulfilled the inclusion criteria of the study. Patient timeline included initial fracture fixation, subsequent diagnosis of malunion during follow-up, and definitive corrective surgery. Surgical delay was defined as the interval between initial injury and primary fixation, and this definition was applied consistently across analyses. Functional outcome was measured using the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Score. **Results:** The mean age of the patients was 42.5 ± 12.3 years, with a male-to-female ratio of 1.5:1. The mean follow-up duration was 32.4 ± 10.1 months. The mean AOFAS Ankle-Hindfoot Score at final follow-up was 78.6 ± 16.2 . Good-to-excellent functional outcomes were achieved in 27 patients (67.5%), while 13 patients (32.5%) had fair-to-poor outcomes. Postoperative complications occurred in 8 patients (20.0%), most commonly symptomatic post-traumatic osteoarthritis (17.5%). One patient (2.5%) had a superficial surgical site infection. Good-to-excellent functional outcomes were significantly associated with Weber Type B fractures, shorter surgical delay (≤ 7 days), and absence of talar shift ($p < 0.05$). **Conclusion:** The study concluded that a good functional outcome with few postoperative complications after surgical correction of malunited ankle fractures at Bashaeir University Hospital during the study period was dominant and indicated that osteotomy, fusion, and open reduction and internal fixation in the surgical treatment of malunited ankle fractures are effective with few postoperative complications.

Keywords

Neglected Ankle Fracture, Ankle Fusion, Ankle deformity, Corrective Osteotomy

1. Introduction

Ankle fractures represent a significant clinical and economic challenge within the domain of orthopedic trauma, ranking among the most prevalent injuries of the lower extremities that necessitate surgical intervention [1]. The epidemiological pattern of these injuries exhibits a distinct bimodal distribution, primarily impacting younger males as a result of high-energy trauma, and older females due to low-energy, frailty-associated mechanisms [2]. Although a majority of ankle fractures are classified as stable, fracture-dislocations constitute a severe and intricate subgroup, arising from considerable disruptive forces that jeopardize both the skeletal framework and the adjacent soft-tissue envelope. The necessity for prompt management—encompassing immediate closed reduction and provisional stabilization—is well-documented, aimed at alleviating the risks of neurovascular compromise, skin necrosis, and additional articular damage [3]. Open reduction and internal fixation (ORIF) continues to serve as the foundational approach for the management of unstable fractures, with the objective of reinstating joint congruity, offering stable fixation conducive to early rehabilitation, and mitigating the long-term likelihood of post-traumatic osteoarthritis (PTOA) [4]. Notwithstanding advancements in surgical methodologies and implant technologies, a considerable percentage of patients encounter less than optimal outcomes. The determinants contributing to unsatisfactory results are complex and multifaceted, including considerable initial injury severity, patient comorbidities (such as diabetes and osteoporosis), inadequate surgical reduction, and the emergence of complications such as malunion or nonunion [5].

Accurate classification is essential for informing management strategies and predicting clinical outcomes. The Lauge-Hansen classification system, predicated upon the mechanistic position of the foot and the vector of the deforming force, yields critical insights into the concomitant ligamentous injuries and the sequence of fractures [6]. In contrast, the Danis-Weber classification, which delineates fractures based on the anatomical level of the fibular fracture in relation to the syndesmosis, provides a more direct framework for assessing instability and the potential necessity for syndesmotic fixation [7]. Unstable fracture patterns, notably those classified as Weber type C injuries, are inherently associated with syndesmotic disruption and present an elevated risk of complications, including chronic instability and articular degeneration, if not sufficiently managed [8].

Malunion, characterized as the non-anatomical union of fracture segments, represents a significant and potentially preventable contributor to surgical failure in the context of ankle open reduction and internal fixation (ORIF). This condi-

tion may present as rotational malalignment of the fibula, lateral talar displacement, or articular step-off, each of which compromises the normal biomechanical function of the tibiotalar joint. Such alterations in load distribution can lead to abnormal cartilage contact stress, subsequently resulting in accelerated joint degeneration and the premature manifestation of incapacitating post-traumatic osteoarthritis (PTOA) [9]. Although the tenets of anatomical reduction are widely recognized, the precise incidence, underlying factors, and definitive clinical ramifications of malunion in both the medium and long term have yet to be thoroughly elucidated in extant scholarly work.

Study Rationale and Aim:

In light of the substantial repercussions of malunion on patient functionality and joint longevity, a comprehensive investigation into its outcomes is imperative for the enhancement of surgical methodologies and the improvement of prognostic precision. This study was designed to systematically assess the clinical outcomes of patients identified with malunited ankle fractures subsequent to surgical intervention. We aimed to delineate the predominant patterns of malunion, examine potential predisposing factors associated with initial injury characteristics and surgical techniques, and establish correlations between these findings and functional and clinical scoring as well as indicators of progressive osteoarthritis.

2. Patients and Methods

This retrospective, cross-sectional analytical study was conducted at the Orthopedic Department of Bashaeir University Hospital, a tertiary referral center. All patients who underwent surgical fixation for ankle fractures between January 1, 2019, and March 31, 2023, were identified through the hospital surgical registry.

Eligible patients were aged 18 years or older, had sustained a closed ankle fracture, underwent primary surgical management (corrective osteotomy, arthrodesis, or open reduction and internal fixation (ORIF)), and were subsequently diagnosed with malunion during follow-up. Exclusion criteria included open fractures, pilon fractures, associated ipsilateral lower-limb fractures, neurovascular injuries at presentation, incomplete medical records, or inadequate follow-up. A total of 40 patients met the inclusion criteria and were included in the final analysis.

Diagnostic Criteria and Radiographic Definitions. Malunion was defined as non-anatomical healing associated with one or more of the following radiographic parameters: fibular shortening > 2 mm, talar shift ≥ 2 mm, rotational malalignment, or articular incongruity on standard ankle radiographs. Measurements were obtained from weight-bearing anteroposterior and mortise measurements by the treating orthopedic surgeons. Reported radiographic findings primarily reflected residual deformity at final follow-up, while pre-correction deformity patterns were documented qualitatively in the operative record.

Corrective procedures included realignment osteotomy, ankle arthrodesis, or revision open reduction and internal fixation (ORIF). Joint-preserving osteotomy or ORIF was selected for patients with reconstructible joint surfaces and minimal

degenerative change, whereas arthrodesis was reserved for advanced post-traumatic arthritis, severe deformity, or poor cartilage quality. Procedure selection was based on radiographic deformity, joint congruity, patient symptoms, and surgeon judgment.

The primary outcome was functional outcome at final follow-up, assessed using the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Score. Outcomes were dichotomized into Good-to-Excellent (AOFAS ≥ 75) and Fair-to-Poor (AOFAS ≤ 74). Secondary outcomes included factors associated with functional outcome (e.g., fracture type and surgical delay) and postoperative complications.

Data were extracted from medical records, operative notes, discharge summaries, and follow-up radiographs. Functional outcome data were supplemented by direct patient interviews using a standardized questionnaire.

Statistical Analysis

Study were conducted utilizing SPSS version 26.0 (IBM Corp.). Descriptive statistics are shown in terms of frequencies, percentages, means, and standard deviations. The chi-squared test was employed to examine the relationship between categorical independent variables (such as fracture type and sex) and categorized functional outcomes (good-to-excellent versus fair-to-poor). A statistical significance level was established at $p < 0.05$.

Ethical Approval

This study was approved by the Institutional Review Board of Bashaeir University Hospital. Due to the retrospective design, consent for record review was waived; however, verbal informed consent was obtained from patients contacted for direct functional assessment interviews. All procedures complied with institutional ethical standards and the Declaration of Helsinki.

3. Results

Patient Demographics

Forty patients who underwent surgical correction for malunited ankle fractures were included. All procedures were performed by one of eight orthopedic consultants. The cohort consisted of 24 males (60%) and 16 females (40%), with a mean age of 42.5 ± 12.3 years (range: 19 - 72 years). The mean follow-up duration was 32.4 ± 10.1 months.

Fracture Characteristics

Low-energy trauma (simple falls) accounted for 28 cases (70%), while high-energy trauma accounted for 12 cases (30%). According to the Danis-Weber classification, fractures were Type A in 5 patients (12.5%), Type B in 22 patients (55.0%), and Type C in 13 patients (32.5%). The mean time from injury to initial surgical fixation was 5.2 ± 3.1 days. Nine patients (22.5%) had comorbidities, most commonly diabetes mellitus ($n = 6$, 15.0%).

Procedure Distribution

Out of the 40 patients, 6 had a corrective osteotomy, 25 underwent primary or

revision ORIF, and 9 received a primary ankle arthrodesis. Usually, osteotomy or revision fixation as most frequently used in patients whose joint surfaces were still relatively intact. On the other hand, ankle fusion was more common in patients who had developed significant post-traumatic osteoarthritis. Functional Outcomes.

The mean AOFAS Ankle-Hindfoot Score at final follow-up was 78.6 ± 16.2 . Outcomes were graded as Excellent in 12 patients (30.0%), Good in 15 patients (37.5%), Fair in 9 patients (22.5%), and Poor in 4 patients (10.0%). Overall, 27 patients (67.5%) achieved Good-to-Excellent outcomes, while 13 patients (32.5%) had Fair-to-Poor outcomes.

Factors Associated with Functional Outcome

Fracture type was significantly associated with functional outcome ($p = 0.02$). Good-to-excellent outcomes were most frequent in Weber Type B fractures (81.8%), followed by Type A (60.0%) and Type C fractures (46.2%). A surgical delay of more than 7 days was significantly associated with fair-to-poor outcomes ($p = 0.04$). No significant associations were found between functional outcome and age ($p = 0.31$), sex ($p = 0.45$), or presence of comorbidities ($p = 0.28$) (see **Figure 1**).

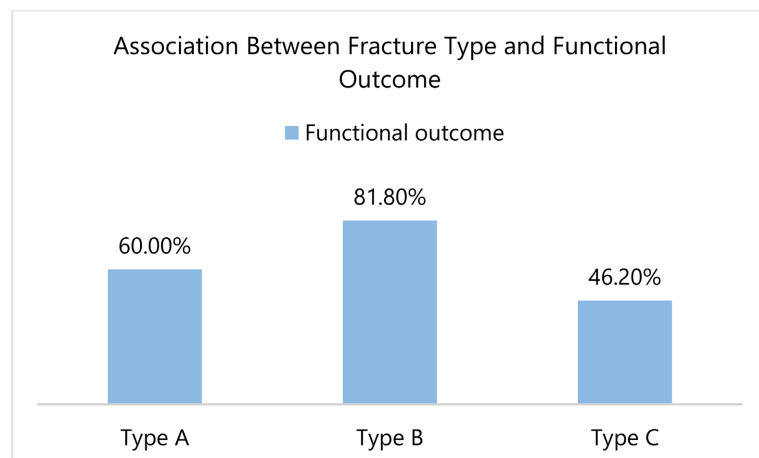


Figure 1. Functional outcome according to weber fracture classification.

Complications and Reoperations

Postoperative complications were defined prospectively before analysis. Symptomatic post-traumatic osteoarthritis was defined as persistent ankle pain with radiographic degenerative changes requiring ongoing treatment or surgical intervention. Complications were identified through clinical visits, radiographic review, and patient interviews. All patients completed a minimum follow-up of 12 months, with a mean follow-up duration of 32.4 ± 10.1 months. Reoperations and timing of secondary procedures were recorded.

Radiographic Findings

At final follow-up, fibular shortening greater than 2 mm was observed in 14 patients (35.0%), and talar shift of 2 mm or more was noted in 11 patients (27.5%).

Six patients (15.0%) demonstrated combined deformities. Talar shift was significantly associated with fair-to-poor functional outcomes ($p = 0.01$).

4. Discussion

This study evaluated the functional outcomes of surgical correction for malunited ankle fractures in a cohort of 40 patients treated at Bashaeir University Hospital between January 2019 and March 2023. The mean patient age was 42.5 ± 12.3 years, with a male-to-female ratio of 1.5:1, which is comparable to previously published studies. Mohapatra and Raj reported a similar mean age of 43.8 ± 5.46 years in their cohort, while Guo *et al.* reported a slightly younger population with a mean age of 37.1 years at the time of realignment surgery [10] [11].

The principal finding of this study was a mean postoperative AOFAS Ankle-Hindfoot Score of 78.6 ± 16.2 , with approximately two-thirds of patients achieving good-to-excellent functional outcomes. These results support the effectiveness of corrective osteotomy, arthrodesis, and open reduction and internal fixation (ORIF) in the management of malunited ankle fractures, consistent with outcomes reported in the literature. The overall complication rate was 20.0%, with symptomatic post-traumatic osteoarthritis being the most frequent complication (17.5%) and only one case of superficial surgical-site infection (2.5%). (see **Table 1**)

Table 1. Postoperative complications and reoperations.

Complication/Reoperation	Number of Patients (n)	Percentage (%)
Post-traumatic osteoarthritis (symptomatic)	7	17.5
Superficial surgical site infection	1	2.5
Deep infection	0	0.0
Nonunion	0	0.0
Neurovascular injury	0	0.0
Total complications	8	20.0
Reoperations		
Ankle arthrodesis (for osteoarthritis)	3	7.5

In this study, surgical delay specifically referred to time from injury to initial fixation rather than time to deformity correction, which may partly explain its association with later functional outcome.

Fracture pattern and timing of surgical intervention were significant determinants of functional outcome. Weber Type B fractures demonstrated the most favorable results, while Type C fractures were associated with poorer outcomes (**Figure 1**). Additionally, a surgical delay of more than seven days from injury to fixation was significantly associated with fair-to-poor outcomes, highlighting the importance of timely surgical management. In contrast, patient age, sex, and the presence of comorbidities were not found to have a statistically significant impact on functional outcome in this cohort.

Post-traumatic osteoarthritis was the primary indication for reoperation (7.5%), with ankle arthrodesis serving as an effective salvage procedure in these cases. Although arthrodesis results in loss of ankle motion, it provides reliable pain relief and functional stability in patients with advanced degenerative changes, as also reported by Kouamé *et al.* [12].

Overall, the findings of this study reinforce the role of accurate fracture reduction, appropriate surgical technique, and early intervention in optimizing functional outcomes following malunited ankle fractures.

Preoperative AOFAS scores were not consistently available due to the retrospective design; therefore, functional results are presented as final-status outcomes rather than change scores. Pain level and functional limitation were documented qualitatively in clinical records prior to corrective surgery.

5. Study Limitations

The conclusions of this study must be interpreted within the context of its limitations. Although informative, the retrospective analysis is subject to inherent selection and information biases. Although the sample size was adequate for identifying strong associations, it may have been underpowered for a multifactorial analysis of all potential outcome predictors, such as specific osteotomy techniques or graft types. The primary use of the AOFAS score, a clinician-reported outcome measure, is another limitation. The incorporation of validated patient-reported outcome measures (PROMs) would provide a more comprehensive assessment of success from the patient's perspective. Finally, the mid-term follow-up duration, while sufficient for evaluating union and early functional recovery, is insufficient for assessing the long-term durability of joint-preserving corrections or the inevitable progression of adjacent joint arthritis after arthrodesis.

6. Conclusion and Clinical Implications

In conclusion, this series confirms that surgical reconstruction of malunited ankle fractures can successfully improve pain and function. Outcomes are optimized by intervention within several months of injury in younger, healthier patients with constructible joint surfaces. The surgical strategy must be individualized, with joint preservation pursued when feasible, and arthrodesis reserved for the definitive management of arthrosis. These results underscore that symptomatic malunion is a mechanical problem that is often amenable to surgical treatment. Future prospective studies with longer follow-up, advanced gait analysis, and patient-centered outcome metrics.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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