ORIGINAL ARTICLE

Functional and Radiological Outcomes of Plate Osteosynthesis in Closed Displaced Intraarticular Calcaneal Fractures

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ABSTRACT

INTRODUCTION: Calcaneum fractures, particularly closed, displaced intraarticular fractures, are uncommon yet cause significant morbidity and impair quality of life (QOL). While open reduction and internal fixation a standard treatment, debate on optimal management continues. This study evaluated functional outcomes of plate osteosynthesis for these fractures, focusing on QOL and radiological measures. **MATERIALS AND METHODS:** This retrospective study reviewed records of patients with closed displaced intraarticular calcaneal fractures treated with plate osteosynthesis (January 2015-December 2020) at a single tertiary centre. Surgery involved open reduction and internal fixation using a locking calcaneal plate, performed on average 11 days post-trauma. Follow-up assessments were conducted for a minimum of one year, utilising the SF-36 for QOL and measuring Böhler's angle. **RESULTS:** Twenty-six patients (25 males, 1 female; mean age 42.8 years) were included. Fractures were primarily caused by motor vehicle accidents (65.4%). The mean QOL score was 55.9, and the mean post-operative Böhler's angle was 22°. Fracture type (Sanders' classification) was significantly associated with Böhler's angle. Correlation analysis revealed a weak, non-significant positive correlation between Böhler's angle and SF-36 scores ($r = 0.187$, $r^2 = 0.035$, $p = 0.360$). Superficial infections occurred in 7.6% of cases, all resolving without further surgery. **CONCLUSION:** Plate osteosynthesis for closed, displaced intraarticular calcaneum fractures provides favourable functional outcomes and restores anatomical alignment. The weak correlation between radiological restoration and patient-reported function suggests that additional factors may influence overall recovery.

Keywords
Böhler's angle, calcaneal fractures, plate fixation, quality of life, surgical outcomes.

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INTRODUCTION

Calcaneum fractures, particularly closed, displaced intraarticular fractures, represent a significant clinical challenge due to their relatively low incidence yet substantial impact on patients' quality of life.[1-3] These fractures, accounting for approximately 2% of all fractures,[4-6] primarily result from high-energy trauma, including motor vehicle accidents and falls from heights.[1,7] The calcaneus, the largest tarsal bone, is crucial in foot mechanics and overall mobility. Therefore, injuries to this bone can lead to long-term functional impairment and increased healthcare costs,[5,8] highlighting the need for effective treatment strategies.

Despite advancements in surgical techniques, the optimal management of displaced intraarticular calcaneal fractures remains contentious.[9-11] Open reduction and internal fixation (ORIF) has been established as a standard treatment;[1] however, the outcomes can vary significantly

among patients. Factors such as the fracture's complexity, the timing of surgical intervention, and the surgical approach can influence recovery and functional outcomes. Current literature indicates that while ORIF may improve anatomical alignment, the correlation between radiological outcomes and functional recovery is not well-defined, leaving a gap in understanding the overall effectiveness of these interventions.

Previous studies have emphasised restoring Böhler's angle, a radiological measurement that evaluates calcaneal alignment, to improve functional outcomes.[12-15] However, there is a lack of consensus on the relationship between radiological measures and patient-reported quality of life (QOL). Many existing studies focus on short-term outcomes, with limited follow-up periods, which may not capture the full spectrum of recovery and long-term implications of these fractures. This gap in the literature emphasises the need for comprehensive evaluations that assess both clinical and radiological outcomes over extended periods.

The primary objective of this study is to evaluate the functional outcomes and quality of life in patients with closed displaced intraarticular calcaneum fractures treated with plate fixation. By examining the correlation between post-operative Böhler's angle and quality of life scores, this research aims to provide insights into the effectiveness of surgical interventions and identify factors that contribute to optimal recovery. The findings of this study will contribute to the existing body of knowledge and inform clinical practice in the management of calcaneal fractures.

MATERIALS AND METHODS

Inclusion and Exclusion Criteria

The inclusion criteria for this study included patients aged 18 to 75 years who presented with either open or closed displaced intra-articular fractures involving the posterior facet of the calcaneus, including fracture dislocations. All included patients underwent fixation with a locking calcaneal plate and had a minimum follow-up of one-year post-operatively. Patients with open fractures were included only if the degree of contamination, as documented by the attending surgeon based on intraoperative clinical judgment, was deemed suitable for immediate internal fixation, similar to closed fractures. Conversely, patients were excluded if they had grossly contaminated open fractures requiring initial debridement and infection control with delayed fixation, nondisplaced or minimally displaced extra-articular fractures, peripheral vascular disease, neuropathic foot conditions, pathological fractures, or if they declined participation in the study.

Patient Recruitment and Data Collection

Eligible patients were identified through the elective surgery list and subsequently approached for participation in the study. Informed consent was obtained from all participants, and data collection was conducted during follow-up visits at the Orthopaedic Clinic. Each patient was administered the SF-36 health survey questionnaire to assess their functional outcomes and quality of life. Additionally, radiological imaging of the ankle in lateral view was performed to measure the Böhler's angle, which serves as a key indicator of anatomical restoration.

Fracture Types According to Sanders' Classification

Sanders' classification is a widely used system for categorizing calcaneum fractures in clinical practice.[6,16] It is based on coronal and axial computed tomography (CT) cross-sections, using the widest undersurface of the posterior facet of the talus as a reference. The CT scans are organized in two planes: the semi-coronal or oblique coronal plane, which is perpendicular to the normal position of the posterior facet, and the axial plane, which runs parallel to the sole. This classification divides the articular surface of the talus into three equal columns and further segments the posterior facet of the calcaneus into four possible fracture fragments: lateral, central, medial, and sustentaculum.[17] Table I summarises the description for the classification. Sanders' classification not only aids in treatment planning but also provides prognostic insights regarding fracture healing.

Surgical Technique

All surgical procedures were performed by foot and ankle-trained surgeons using an open reduction and internal fixation approach via the extended lateral approach (Seattle approach). The patient was positioned laterally on a radiolucent operative table, and a full-thickness skin flap was created through an L-shaped incision over the lateral aspect of the heel. After achieving adequate exposure of the calcaneus and subtalar joint, anatomical reduction was performed, followed by applying a locking calcaneal plate to stabilize the fracture. Post-operatively, patients received third-generation cephalosporin for five days, and daily wound inspections were performed to monitor for complications.

Table I: Sanders' classification for calcaneum fractures.

Classification type	Description
Type I	Nondisplaced fractures; no significant separation of the fracture fragments.
Type II	Two articular pieces involving the posterior facet, further divided into: Type IIA: Lateral fragment displaced Type IIB: Medial fragment displaced Type IIC: Central fragment displaced
Type III	Three articular pieces, including an additional depressed middle fragment, are further divided into: Type IIIA: Lateral and central fragments displaced Type IIIB: Medial and central fragments displaced Type IIIC: Lateral and medial fragments displaced
Type IV	Highly comminuted fractures with four or more fragments, making anatomical restoration complex.

Post-operative Care and Follow-Up

Following surgery, patients were initially immobilised in a below-knee back slab positioned neutrally for two weeks, until suture removal at week two. During this period, elevation of the lower limb combined with ice pack therapy was employed to facilitate soft tissue recovery. After removal of the back slab, active and passive range of motion exercises were encouraged to prevent ankle stiffness. Non-weight-bearing ambulation using crutches or a wheelchair was permitted for the first six weeks. Partial weight-bearing was then gradually introduced, based on fracture healing progress and patient compliance, with full weight-bearing typically allowed after twelve weeks. Patients were scheduled for regular clinical and radiological follow-up appointments at the Orthopaedic Clinic, ensuring a minimum follow-up duration of one year.

Assessment Tools

The SF-36 questionnaire was utilized to assess the functional outcomes and quality of life of patients in this study. Developed for use in clinical practice, research, and health policy evaluation, the SF-36 is designed to be completed in approximately 10 minutes while effectively measuring a wide range of health concepts.[1,18] It includes eight multi-item scales that evaluate: limitations in physical activities due to health problems, limitations in social activities due to physical or emotional issues, role limitations due to physical health, bodily pain, general mental health, role limitations due to emotional problems, vitality (energy and fatigue), and general health perceptions. Each component is scored from 0 to 100, with higher scores indicating better functional status.

Radiological outcomes were assessed by measuring Böhler's angle, which is defined by two intersecting lines: one drawn from the anterior process of the calcaneus to the highest point of the posterior articular surface, and the other from that point to the most superior point of the tuberosity (Figure 1). In our population, a normal Böhler's angle ranges from 20 to 40 degrees.[19] This angle is a critical prognostic factor in determining treatment outcomes, as its restoration is associated with improved recovery.[13,20,21] To ensure the accuracy of measurements, all requests for post-operative radiographs for calcaneal fractures included the specific purpose of measuring Böhler's angle, adhering to the standards set by our radiological colleagues. Measurements were taken three times by experienced foot and ankle surgeons, and the mean of these measurements was used as the final value.

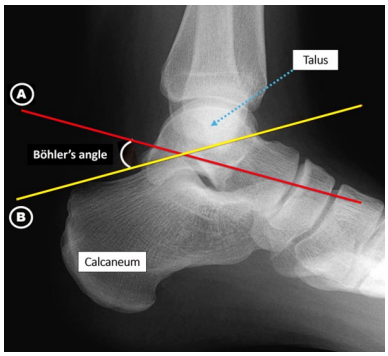

Figure 1: Measurement of the Böhler's angle. The angle is defined by the intersection of two lines: Line A (red), which extends from the anterior process of the calcaneus to the highest point of the posterior articular surface, and Line B (yellow), which runs from the posterior articular surface to the most superior point of the calcaneal tuberosity.

Sample Size Calculation

To assess the adequacy of our sample size, we conducted a post-hoc power analysis using G*Power software. For

this analysis, we utilised a Pearson correlation coefficient to evaluate the relationship between post-operative Böhler's angle and SF-36 scores. Based on preliminary data and similar studies in the literature,[4] we estimated a small to medium effect size (Cohen's r = 0.2). With an alpha level set at 0.05 and a desired power level of 0.80, the G*Power analysis indicated that a minimum sample size of 30 participants would be required to achieve adequate power for detecting a significant correlation. This calculation accounted for an anticipated dropout rate of approximately 15-20%, which is commonly accepted in clinical studies.

Data Analysis

Data collected from the SF-36 questionnaire and radiological measurements were analysed using SPSS version 27. Descriptive statistics were employed to summarize demographic data, functional outcomes, and radiological results. Pearson correlation coefficients were utilized to assess the relationship between post-operative Böhler's angle and SF-36 scores. Additionally, chi-square tests (with Yates' continuity correction applied for 2x2 comparisons) were conducted to evaluate the association between fracture type and radiological outcomes. Statistical significance was set at a p-value of less than 0.05.

RESULTS

A total of 30 patients with closed displaced intra-articular fractures of the calcaneus were identified; however, only 26 patients were included in the final analysis. Of the four patients excluded after recruitment, all declined to proceed with participation in the study. This rate of declined participation falls within the expected attrition range considered during sample size calculation. The demographic characteristics of the study population are summarised in Table II.

The majority of patients were male (96.2%), with a mean age of 42.8 years (± 13.97). Most patients in this cohort had type III fractures (69.2%), whereas type IV fractures were the least common, represented by a single patient. The mechanism of injury was predominantly due to motor vehicle accidents (65.4%), while falls accounted for 34.6% of cases. The average time from injury to surgery was 11.12 days (± 1.75). Two patients (7.6%) experienced superficial infections at the incision site, both of which healed with extended intravenous antibiotics and did not require further surgery. There were no cases of deep infection, compartment syndrome, peroneal tendinitis, reflex sympathetic disorder, or implant failure. Fracture union was achieved in all cases, and none of the patients required bone grafting.

Table II: Demographic distribution of study participants (n = 26).

Variables	n (%)
Age (years)	42.81 + 13.97*
Gender	
Male	25 (96.2)
Female	1 (3.8)
Mechanism of injury	
Motor-vehicle accident	17 (65.4)
Fall	9 (34.6)
Sanders' Classification	
II	7 (26.9)
III	18 (69.2)
IV	1 (3.8)
Days to surgical intervention	11.12 + 1.75*
Post-operative Böhler's angle	
Normal (20°-40°)	24 (92.3)
Abnormal (<20°)	2 (7.7)
Mean + SD	22.69° + 3.39*
Duration of follow-up (months)	
12	9 (34.6)
18	2 (7.7)
24	14 (53.8)
36	1 (3.8)
Mean + SD	24.31 + 3.59*
Complication	
Superficial infection	2 (7.6)

*Data presented in mean ± SD

Table III: Assessment of functional outcome and QOL by using SF-36 (n=26).

Domain/ Scale	Mean + SD
Overall SF-36 score	55.9 + 14.27
Physical functionality	60.8 + 16.11
Role limit due to physical health	51.9 + 28.22
Role limit due to emotional problems	57.7 + 33.42
Energy fatigue	51.9 + 11.58
Emotional well-being	63.2 + 11.32
Social functionality	74.0 + 20.29
Physical pain	67.4 + 15.34
General health	38.1 + 11.50
Health change	38.5 + 12.71

Functional Outcome and QOL Assessment

The functional outcomes were evaluated using the SF-36 questionnaire, with the results presented in Table III. The overall mean SF-36 score was 55.9 (± 14.27). The highest scores were recorded for social functionality (74.0 ± 20.29) and physical pain (67.4 ± 15.34), while general health had the lowest score (38.1 ± 11.50). Other dimensions of the SF-36, including physical functionality (60.8 ± 16.11) and emotional well-being (63.2 ± 11.32), also indicated moderate functional recovery among patients.

Radiological Outcomes

Post-operative measurements of the Böhler's angle were performed, with the mean angle recorded at 22.69 degrees (± 3.39). As shown in Table II, 24 out of 26 patients (92.3%) achieved a normal Böhler's angle (20°-40°), while 2 patients (7.7%) had an abnormal Böhler's angle (<20°). The correlation between the post-operative Böhler's angle and SF-36 scores was assessed, revealing a weak positive correlation of 18.7%, indicating that while anatomical restoration was achieved, it did not strongly correlate with functional outcomes.

Correlation Between Post-operative Böhler's Angle and SF-36 Score

Figure 2 presents the scatter plot illustrating the relationship between post-operative Böhler's angle and SF-36 scores. The correlation analysis using Pearson's correlation coefficient revealed a weak positive correlation (r=0.187, r^2=0.035), which was not statistically significant (p=0.360).

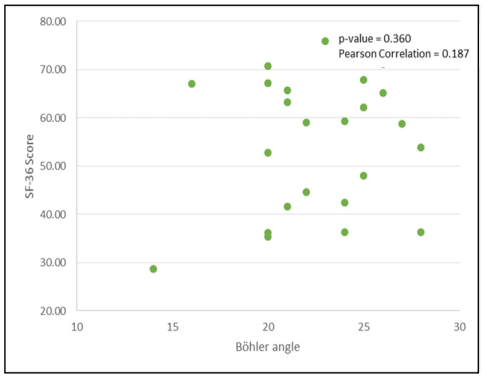

Figure 2: Scatter plot showing the correlation between post-operative Böhler's angle and SF-36 scores.

Association Between Fracture Type and Böhler's Angle

The association between fracture type (according to Sanders' classification) and post-operative Böhler's angle was statistically significant (p=0.002), as shown in Table IV. Among patients with type 2 fractures, all (100%) maintained a normal Böhler's angle, while 94.4% of type 3 fractures were within the normal range. Conversely, the patient with a type 4 fracture exhibited an abnormal Böhler's angle, highlighting the complexity associated with more severe fracture patterns.

Table IV: Association between post-operative Böhler's angle and types of fracture (according to the Sanders' Classification).

Types of Fracture	Post-operative Böhler's angle		Total	p-value*
	Normal (20°-40°)	Abnormal (<20°)		
II	7 (100%)	0 (0%)	7	0.002
III	17 (94.4%)	1 (5.6%)	18	
IV	0 (0%)	1 (100%)	1	
Total	24	2	26	

*Chi-square test with Yates' correction

Of the three fracture types classified according to Sanders', the majority were type III fractures (69.2%, or 18 patients). Among these, 94.4% maintained a normal Böhler's angle (20-40°), with only one patient unable to achieve this range (<20°). Type II fractures had the second highest representation, with all seven patients maintaining a normal Böhler's angle. Conversely, only one patient with a type IV fracture, characterised by a highly comminuted pattern, exhibited an abnormal post-operative Böhler's angle. The statistical analysis confirms a significant association between fracture type and post-operative Böhler's angle (p = 0.002). Figure 3 presents a histogram comparing Böhler's angles across different fracture types according to Sanders' classification.

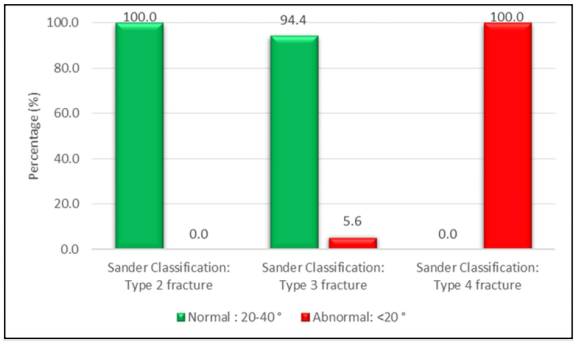

Figure 3: Association between post-operative Böhler's angle and types of fracture (according to the Sanders' Classification) (n = 26).

DISCUSSION

This study provides valuable insights into patients' functional and radiological outcomes with closed displaced intraarticular calcaneum fractures treated with plate fixation. The demographic data indicate a predominance of male patients, with a mean age of 42.8 years, consistent with literature showing that calcaneal fractures often occur in younger, active males engaged in high-risk activities.[10,18,22] Motor vehicle accidents were the leading cause, accounting for 65.4% of cases, highlighting the need for improved road safety measures.

Functional outcomes, measured by the SF-36 questionnaire, revealed a mean score of 55.9, indicating

moderate quality of life post-surgery. The highest scores were in social functionality and physical pain, suggesting that while physical limitations exist, social interactions remain relatively intact. This aligns with previous studies that have reported varying degrees of recovery in different dimensions of QOL following calcaneal fractures.[18,23] However, the lowest score was in general health, reflecting the significant impact of injury on overall well-being due to psychological and physical challenges.

Radiologically, the mean post-operative Böhler's angle was 22.69 degrees, with most patients maintaining a normal range. This restoration of anatomical alignment is crucial,[12,13,15] as deviations can lead to poor functional recovery and increased complications. Our findings underscore the importance of meticulous surgical techniques and careful patient selection, particularly in complex fractures. Restoring the post-operative Böhler's angle to a normal value is one of the most important prognostic factors for obtaining satisfactory results,[13,14] with our study showing a significant association between post-operative Böhler's angle and Sanders' classification.

In addition to Böhler's angle, maintaining the height, length, and width of the calcaneus is equally important.[12,15] In our series, all patients except two with highly comminuted fractures maintained a normal Böhler's angle (20 to 40 degrees). A previous study reported a strong association between Böhler's angle and Sanders' classification based on an analysis of 80 patients.[7] Similarly, our study identified a significant association between post-operative Böhler's angle and Sanders' classification among the 26 patients analysed. Technically, restoring Böhler's angle to the normal range is more challenging in cases of multifragmentary fractures compared to less severe injuries, suggesting that those with severe comminution are more likely to experience poor outcomes.[13] The results of our study align with previously reported outcomes for ORIF with plate osteosynthesis, demonstrating superiority over conservative treatment methods.[6,24]

Despite successfully restoring the Böhler's angle in most patients, the weak correlation with SF-36 scores (18.7%) indicates that anatomical alignment alone may not ensure optimal functional recovery. Previous studies suggest that post-treatment outcomes for calcaneus fractures are worse than those for knee and hip arthroplasties, likely due to the acute nature of the injury, which leaves little time for adaptation compared to chronic conditions.[18] Patients with displaced intraarticular calcaneus fractures often experience greater impairment and pain compared to those recovering from total knee or hip arthroplasties. Factors such as pre-existing health conditions, psychological well-being, and rehabilitation protocols are crucial in influencing functional outcomes, necessitating a comprehensive approach to recovery.

Osteosynthesis with locking plates provides superior outcomes in maintaining Böhler's angle and accommodating the calcaneus's complex shape. A biomechanical study demonstrated that locking plates offer greater stability during cyclic loading than non-locking plates.[25] They effectively manage multifragmentary fractures, preventing unstable displacement, especially in osteoporotic bones. Postoperative splinting is unnecessary, enabling early range of motion exercises that reduce stiffness and improve mobility.[26,27] Additionally, the use of locking plates reduces the need for bone grafting, as they do not yield superior results compared to fixation alone,[13,28-31] thereby minimising patient morbidity.

While ORIF is effective for anatomic reduction, it can lead to complications.[32-34] Our study reported a low complication rate, with only 7.6% of patients experiencing superficial infections, all resolving without further surgery. This suggests that locking calcaneal plates and the extended lateral approach may effectively manage soft tissue integrity. However, vigilance for complications is essential, as infection rates can vary based on surgical technique and patient factors. Continuous monitoring and early intervention are critical for minimising complications and improving recovery. Similar findings

were found in a survey of German orthopaedic surgeons.[35] Other studies have reported that the infection rate for ORIF ranges from 5% to 31%, with a reoperation rate due to infection at approximately 5%.[1,36-39]

Moreover, developing standardised rehabilitation protocols could enhance patient outcomes in this challenging area of orthopaedic practice.[1] The post-operative care protocol used in this study emphasised early mobilisation and gradual weight-bearing, which likely contributed to the positive functional outcomes observed. Early range of motion exercises are crucial for preventing stiffness and improving joint mobility, significantly impacting recovery.[40]

Study Limitations and Future Recommendations

Several limitations of this study must be acknowledged. The relatively small sample size may impact statistical power and introduce biases in data collection and patient selection. Additionally, the mean follow-up period of only two years restricts our ability to assess long-term degenerative changes in the subtalar joint. While the gender distribution reflects the demographic characteristics of patients presenting with calcaneal fractures in our clinical setting, it may raise concerns regarding potential bias. Although a more balanced gender distribution could enhance the generalizability of our findings, we believe our sample adequately represents the population we serve (4). Furthermore, our focus on Bohler's angle, while a well-established measure, limits the comprehensiveness of our analysis, as the exclusion of Gissen's angle restricts insights into subtalar joint integrity. We also could not assess post-fixation varus/valgus alignment due to the lack of weight-bearing radiographs, which were not part of our study protocol.

Future research should focus on larger cohorts and longer follow-up periods to better understand the long-term implications of treatment strategies for calcaneal fractures. Incorporating both Bohler's and Gissen's angles, as well as varus/valgus assessments, would provide a more comprehensive evaluation of alignment post-fixation. Additionally, exploring psychosocial factors, rehabilitation, and comorbidities, along with comparing complication rates with other studies, could enhance our understanding of recovery outcomes. These considerations may lead toward prospective or randomized controlled studies and the adoption of advanced imaging modalities, contributing to improved treatment strategies for calcaneal fractures.

CONCLUSION

Plate osteosynthesis for closed, displaced intraarticular calcaneum fractures results in favourable functional and radiological outcomes, with a significant restoration of anatomical alignment as evidenced by the restoration of Böhler's angle in the majority of patients. While a moderate quality of life was reported post-surgery, the weak correlation between anatomical alignment restoration and functional recovery suggests that additional factors, including psychosocial aspects and rehabilitation protocols, play a critical role in patient outcomes. These findings emphasise the importance of careful surgical technique and comprehensive post-operative care to minimise complications and optimise recovery.

INSTITUTIONAL REVIEW BOARD (ETHICS COMMITTEE)

This study employs a retrospective descriptive design to evaluate the functional and radiological outcomes of patients with closed displaced intraarticular calcaneum fractures treated with plate fixation at a single tertiary referral centre from January 2015 to December 2020. The institutional ethical committee approved the study (Ref. No.: IIUM/215/14/11/3/IREC435).

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