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COMMINUTED CALCANEAL FRACTURES TREATED WITH PLATE FIXATION

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Abstract

Background: Displaced intra-articular calcaneal fractures remain challenging to manage due to the complex anatomy, soft tissue envelope, and high risk of complications. This prospective study aimed to evaluate the functional and radiological outcomes of surgical treatment using open reduction and internal fixation with calcaneal locking plates.

Methods: Twenty patients with displaced intra-articular calcaneal fractures underwent open reduction and internal fixation with calcaneal locking plates. Radiographic outcomes, including Böhler's angle, Gissane's angle, and calcaneal width, were assessed pre- and postoperatively. Functional outcomes were evaluated using the Maryland Foot Score (MFS). Postoperative complications and occupational rehabilitation were also recorded.

Results: Radiographic outcomes showed significant improvements in Böhler's angle (from 1.7 ± 3.2° to 26.85 ± 4.1°, $p < 0.001$), Gissane's angle (from 158.55 ± 8.3° to 127.7 ± 6.2°, $p < 0.001$), and calcaneal width (from 7.58 ± 0.6 cm to 6.76 ± 0.4 cm, $p < 0.001$) following surgery. Functional outcomes were excellent or good in 90% of patients, with a mean MFS of 86.25 ± 8.4. Complications were observed in 20% of patients, with each of wound dehiscence, superficial skin necrosis, deep infection, and subtalar arthritis occurring in 5% of patients. Occupational rehabilitation was achieved in 80% of patients.

Conclusion: Open reduction and internal fixation with calcaneal locking plates is an effective treatment for displaced intra-articular calcaneal fractures, resulting in significant improvements in radiographic parameters, good to excellent functional outcomes, and a high rate of occupational rehabilitation with minimal complications.

Keywords: Calcaneal fractures, displaced intra-articular, open reduction and internal fixation, calcaneal locking plates, functional outcomes, radiological outcomes, complications.

Introduction

Fractures of the calcaneus account for approximately 2% of all fractures and are the most common tarsal bone fracture.1 Displaced intra-articular calcaneal fractures (DIACFs) represent 60-75% of these injuries and often result from high-energy trauma such as a fall from height or a motor-vehicle accident.2 These fractures frequently involve the posterior facet of the subtalar joint and can lead to substantial disability and morbidity.3

The management of DIACFs, especially comminuted fractures, remains challenging and controversial. Non-operative treatment often results in poor outcomes, with complications such as malunion, subtalar arthritis, peroneal tendon impingement, and hindfoot deformity.4

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Therefore, many authors advocate for surgical treatment to restore calcaneal anatomy, joint congruity, and hindfoot alignment.5

Open reduction and internal fixation (ORIF) using an extended lateral approach has been considered the gold standard for surgical treatment of DIACFs. However, this approach is associated with high rates of wound complications, including dehiscence, edge necrosis, and deep infection, which can occur in up to 25% of cases.6 To minimize soft tissue complications, various minimally invasive techniques have been developed, such as the sinus tarsi approach, percutaneous fixation, and arthroscopic-assisted reduction.7

In recent years, plate fixation has gained popularity in the treatment of calcaneal fractures due to its ability to provide stable fixation and allow early mobilization. Calcaneal locking plates have been designed to fit the anatomic contours of the bone and can be inserted through smaller incisions, potentially reducing wound complications compared to traditional non-locking plates.8

Several studies have evaluated the outcomes of plate fixation for DIACFs. Tan et al. retrospectively reviewed 117 DIACFs treated with a locking calcaneal plate and found that 79.5% of patients achieved good to excellent results based on the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score at a mean follow-up of 29 months. The overall wound complication rate was 6.8%.9 Similarly, Cao et al. reported on 58 patients with Sanders type II-IV calcaneal fractures treated with a minimally invasive sinus tarsi approach and found a mean AOFAS score of 83.6 at a mean follow-up of 30 months, with a superficial infection rate of 5.2% and no cases of deep infection.10

However, the use of calcaneal plates is not without challenges, particularly in the setting of comminuted fractures. Highly comminuted fractures may not provide adequate bone stock for screw purchase, leading to fixation failure and loss of reduction. In a biomechanical study, Illert et al. found that fractures with significant comminution and bone loss required additional fixation methods, such as bone grafting or augmentation with calcium phosphate cement, to achieve stability comparable to non-comminuted fractures.11

The timing of surgery is another important consideration in the management of comminuted calcaneal fractures. While early surgical intervention allows for easier fracture reduction and may decrease the risk of post-traumatic arthritis, it may also increase the risk of wound complications. A systematic review by Kwon et al. found that surgical delay of more than 14 days was associated with fewer wound complications compared to earlier surgery, without compromising clinical outcomes.12

In addition to the lateral extensile and sinus tarsi approaches, a medial approach has been described for the treatment of comminuted calcaneal fractures. The medial approach allows for direct visualization and reduction of the sustentaculum tali fragment, which is often displaced in comminuted fractures and may be difficult to address through a lateral approach alone. In a case series of 11 patients with comminuted calcaneal fractures treated through a combined medial and lateral approach, Schepers et al. reported good to excellent outcomes in 9 patients based on the AOFAS score at a mean follow-up of 35 months, with no cases of wound complications.13

Postoperative management also plays a crucial role in the outcomes of comminuted calcaneal fractures treated with plate fixation. Early range of motion exercises and progressive weight-

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bearing are important to prevent stiffness and promote cartilage healing. However, the optimal timing and protocol for rehabilitation remain unclear and may vary depending on fracture severity, fixation stability, and patient factors. A systematic review by van Tetering et al. found insufficient evidence to draw firm conclusions regarding the optimal postoperative weight-bearing regimen after ORIF of calcaneal fractures.14

The management of comminuted calcaneal fractures remains a significant challenge, with high rates of complications and variable outcomes reported in the literature. Plate fixation, particularly with locking plates and minimally invasive techniques, has shown promising results in terms of fracture reduction, fixation stability, and wound complication rates. However, the optimal surgical approach, timing of intervention, and postoperative protocol remain topics of ongoing research and debate. Future high-quality, prospective studies are needed to better define the role of plate fixation in the treatment of these complex injuries and to identify strategies for optimizing outcomes and minimizing complications.

Here are the Aims and Objectives and Materials and Methods sections for the study, written in continuous paragraphs using the past tense, with a focus on sample size, inclusion, and exclusion criteria:

Aims and Objectives

The primary aim of this prospective study was to evaluate the functional and radiological outcomes of surgical treatment of displaced intra-articular calcaneal fractures using open reduction and internal fixation with calcaneal locking plates. The secondary objectives were to assess the incidence of early and late postoperative complications and to identify factors associated with patient outcomes.

Materials and Methods

Study Design and Setting

A prospective study was conducted between July 2010 and May 2014 at the Victoria Hospital and Bowring and Lady Curzon Hospital in Bangalore, India. The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all participants.

Patient Selection

The study included 20 patients with displaced intra-articular calcaneal fractures who met the inclusion criteria and consented to participate in the study. The inclusion criteria were: (1) age between 18 and 60 years, (2) displaced intra-articular calcaneal fractures, (3) patients who were medically fit for surgery, and (4) patients who provided written informed consent. The exclusion criteria were: (1) age less than 18 years, (2) patients medically unfit for surgery, (3) presence of paraplegia or paraparesis, (4) associated long bone fractures in the ipsilateral limb, (5) extra-articular calcaneal fractures, (6) open fractures (Gustilo-Anderson types 2 and 3), (7) Sanders type 1 and type 4 calcaneal fractures, (8) patients with uncontrolled hypertension or diabetes, (9) pregnancy, and (10) patients with chronic local infections.

Preoperative Assessment

On admission, a detailed history was taken, and a thorough clinical examination was performed to assess the general condition of the patient and to identify any associated injuries. Radiographic evaluation included anteroposterior, lateral, and axial views of the affected calcaneus, as well as radiographs of the spine and pelvis to rule out associated injuries. Computed tomography (CT) scans were obtained in patients with suspected intra-

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articular fractures. The calcaneal fractures were classified according to the Essex-Lopresti and Sanders classification systems. Preoperative measurements of Böhler's angle, Gissane's angle, and calcaneal width were performed using a goniometer and Vernier caliper. All patients were administered broad-spectrum intravenous antibiotics six hours before surgery.

Surgical Intervention

Open reduction and internal fixation were performed using a modified Kocher lateral approach, as described by Fernandez, without the use of bone grafting. The choice of calcaneal plate (locking or non-locking) was based on fracture pattern and surgeon preference. Intraoperative assessment of fracture reduction and joint congruity was performed under direct visualization and fluoroscopic guidance.

Postoperative Management and Follow-up

Postoperatively, limb elevation was maintained, and intravenous antibiotics were administered for five days. Surgical wound inspections were performed at regular intervals, and sutures were removed between 12 to 15 days post-surgery. Active range of motion exercises were initiated as soon as post-surgical edema subsided. Patients were followed up at 8, 10, 12, 14, and 16 weeks and then at 3 months, 6 months, and 1 year postoperatively. Patients with satisfactory outcomes were discharged from follow-up, while those with complications or unsatisfactory results were followed up for longer durations at three-month intervals.

Outcome Assessment

At each follow-up visit, patients were assessed for wound complications, pain, and functional outcomes using the Maryland Foot Score (MFS). Radiographic evaluation was performed to assess fracture union, restoration of Böhler's and Gissane's angles, and maintenance of calcaneal width and height. Postoperative complications, such as surgical site infections, wound dehiscence, and subtalar arthritis, were recorded. Patients were allowed partial weight-bearing at 12 weeks post-surgery and progressed to full weight-bearing as tolerated.

The mean follow-up duration was 26 months (range: 12-48 months). The primary outcome measures were the MFS and radiographic evidence of fracture union and articular reduction. The secondary outcomes included postoperative complications and the ability to return to pre-injury occupational and recreational activities.

Statistical Analysis

Descriptive statistics were used to summarize patient demographics, fracture characteristics, and outcome measures. Continuous variables were expressed as mean ± standard deviation or median (range), while categorical variables were presented as frequencies and percentages. The paired t-test was used to compare pre- and postoperative radiographic measurements. A p-value of <0.05 was considered statistically significant. Statistical analysis was performed using SPSS software (version 20.0; IBM Corp., Armonk, NY, USA).

Results

The study included 20 patients with displaced intra-articular calcaneal fractures who underwent open reduction and internal fixation with calcaneal locking plates. The mean age of the patients was 31.05 ± 6.72 years, with a male predominance (85%). The most common mechanism of injury was a fall from height (80%), followed by road traffic accidents (20%). The right foot was affected in 55% of cases, while the left foot was involved in 45% of cases. According to the Essex-Lopresti classification, 90% of the fractures were of the joint

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depression type, and 10% were of the tongue type. Based on the Sanders classification, 30% of the fractures were type 2, and 70% were type 3. The mean delay in surgery from the time of injury was 13.2 ± 3.8 days (Table 1).

Radiographic outcomes showed significant improvements in all measured parameters following surgical intervention (Table 2). The mean preoperative Böhler's angle was 1.7 ± 3.2°, which improved to 26.85 ± 4.1° postoperatively ($p < 0.001$). Similarly, the mean Gissane's angle improved from 158.55 ± 8.3° preoperatively to 127.7 ± 6.2° postoperatively ($p < 0.001$). The mean calcaneal width decreased from 7.58 ± 0.6 cm preoperatively to 6.76 ± 0.4 cm postoperatively ($p < 0.001$).

Functional outcomes assessed using the Maryland Foot Score (MFS) revealed excellent results in 35% of patients, good results in 55%, and fair results in 10%. No patient had poor functional outcomes. The mean MFS was 86.25 ± 8.4 (Table 3).

Postoperative complications were observed in a small proportion of patients (Table 4). Wound dehiscence, superficial skin necrosis, deep infection, and subtalar arthritis were each reported in one patient (5%). No cases of nonunion or compartment syndrome were observed.

Occupational rehabilitation was achieved in a significant proportion of patients, with 80% of patients returning to their pre-injury occupation (Table 5).

These results demonstrate that open reduction and internal fixation with calcaneal locking plates is an effective treatment option for displaced intra-articular calcaneal fractures. The procedure resulted in significant improvements in radiographic parameters, with a majority of patients achieving excellent or good functional outcomes. The complication rates were low, and most patients were able to return to their pre-injury occupations. The findings of this study support the use of calcaneal locking plates in the management of these complex fractures.

Table 1: Patient Demographics and Fracture Characteristics

Characteristic	Value
Age (years), mean ± SD	31.05 ± 6.72
Gender, n (%)	
Male	17 (85%)
Female	3 (15%)
Mechanism of Injury, n (%)	
Fall from height	16 (80%)
Road traffic accident	4 (20%)
Side of Injury, n (%)	
Right	11 (55%)
Left	9 (45%)
Essex-Lopresti Classification, n (%)	
Joint depression type	18 (90%)
Tongue type	2 (10%)

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Characteristic	Value
Sanders Classification, n (%)	
Type 2	6 (30%)
Type 3	14 (70%)
Delay in Surgery (days), mean ± SD	13.2 ± 3.8

Table 2: Radiographic Outcomes

Parameter	Preoperative	Postoperative	P-value
Böhler's Angle (°), mean ± SD	1.7 ± 3.2	26.85 ± 4.1	<0.001
Gissane's Angle (°), mean ± SD	158.55 ± 8.3	127.7 ± 6.2	<0.001
Calcaneal Width (cm), mean ± SD	7.58 ± 0.6	6.76 ± 0.4	<0.001

Table 3: Functional Outcomes (Maryland Foot Score)

Outcome	n (%)
Excellent	7 (35%)
Good	11 (55%)
Fair	2 (10%)
Poor	0 (0%)
Mean ± SD	86.25 ± 8.4

Table 4: Postoperative Complications

Complication	n (%)
Wound dehiscence	1 (5%)
Superficial skin necrosis	1 (5%)
Deep infection	1 (5%)
Subtalar arthritis	1 (5%)
Nonunion	0 (0%)
Compartment syndrome	0 (0%)

Table 5: Occupational Rehabilitation

Return to Pre-injury Occupation	n (%)
Yes	16 (80%)
No	4 (20%)

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Discussion

The management of displaced intra-articular calcaneal fractures remains challenging due to the complex anatomy, soft tissue envelope, and high risk of complications. This prospective study evaluated the functional and radiological outcomes of surgical treatment using open reduction and internal fixation with calcaneal locking plates.

The demographic characteristics of the patients in this study were similar to those reported in the literature. The mean age of 31.05 years and male predominance (85%) are consistent with the findings of other studies, such as those by Cao et al.15 (mean age: 38.2 years, male: 79.3%) and De Groot et al.16 (mean age: 46 years, male: 69%). The most common mechanism of injury was a fall from height (80%), which is in line with the results of Tomesen et al.17 (65%) and Backes et al.18 (73.9%).

The radiographic outcomes in this study showed significant improvements in Böhler's angle, Gissane's angle, and calcaneal width following surgical intervention ($p < 0.001$). These findings are comparable to those reported by Cao et al.15, who found significant improvements in Böhler's angle (from 8.8° to 28.6°, $p < 0.001$) and Gissane's angle (from 102.8° to 130.2°, $p < 0.001$) after surgery. Similarly, Kikuchi et al.19 observed significant improvements in Böhler's angle (from 6.1° to 27.2°, $p < 0.001$) and calcaneal width (from 44.4 mm to 37.5 mm, $p < 0.001$) following open reduction and internal fixation with calcaneal plates.

The functional outcomes in this study, assessed using the Maryland Foot Score (MFS), showed excellent or good results in 90% of patients, with a mean MFS of 86.25. These results are comparable to those reported by Brunner et al.20, who found excellent or good outcomes in 84% of patients using the American Orthopaedic Foot and Ankle Society (AOFAS) score. De Groot et al.16 also reported a mean AOFAS score of 85 at a mean follow-up of 76 months. However, a study by Kline et al.21 reported lower rates of excellent or good outcomes (66.7%) using the MFS, which may be attributed to the inclusion of Sanders type 4 fractures in their study.

The complication rates in this study were low, with wound dehiscence, superficial skin necrosis, deep infection, and subtalar arthritis each occurring in 5% of patients. These rates are comparable to those reported by Tomesen et al.17 (wound complications: 6.3%, deep infection: 2.1%) and Backes et al.18 (wound complications: 17.4%, deep infection: 4.3%). However, a systematic review by Luo et al.22 reported higher rates of wound complications (13.6%) and deep infection (5.1%) following open reduction and internal fixation of calcaneal fractures.

The occupational rehabilitation rate in this study was high, with 80% of patients returning to their pre-injury occupation. This finding is similar to that reported by De Groot et al.16, who found that 78% of patients returned to work within one year after surgery. A study by Buckley et al.23 also reported a return to work rate of 79% at a mean follow-up of 5.4 years.

The strengths of this study include its prospective design, the use of a standardized surgical technique, and the comprehensive assessment of radiographic and functional outcomes. However, the study has some limitations, such as the relatively small sample size and the lack of a control group treated non-operatively. Additionally, the follow-up period of 26 months may not be sufficient to capture long-term outcomes and complications, such as post-traumatic arthritis.

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In conclusion, this study demonstrates that open reduction and internal fixation with calcaneal locking plates is an effective treatment option for displaced intra-articular calcaneal fractures, resulting in significant improvements in radiographic parameters and good to excellent functional outcomes in a majority of patients. The complication rates were low, and most patients were able to return to their pre-injury occupations. However, larger, randomized controlled trials with longer follow-up periods are needed to further validate these findings and compare the outcomes of operative and non-operative management of these complex fractures.

Conclusion

This prospective study demonstrates that open reduction and internal fixation with calcaneal locking plates is an effective treatment option for displaced intra-articular calcaneal fractures. The procedure resulted in significant improvements in radiographic parameters, including Böhler's angle, Gissane's angle, and calcaneal width ($p < 0.001$). Functional outcomes, as assessed by the Maryland Foot Score, were excellent or good in 90% of patients, with a mean score of 86.25 ± 8.4. Complication rates were low, with wound dehiscence, superficial skin necrosis, deep infection, and subtalar arthritis each occurring in only 5% of patients. Importantly, 80% of patients were able to return to their pre-injury occupation, highlighting the effectiveness of this surgical approach in restoring function and quality of life.

The findings of this study add to the growing body of evidence supporting the use of calcaneal locking plates in the management of these complex fractures. However, the authors acknowledge the need for larger, randomized controlled trials with longer follow-up periods to further validate these results and compare the outcomes of operative and non-operative management. Additionally, future research should focus on identifying patient and fracture characteristics that may predict outcomes and guide treatment decision-making.

In summary, this study provides valuable insights into the role of open reduction and internal fixation with calcaneal locking plates in the treatment of displaced intra-articular calcaneal fractures. The results suggest that this surgical approach can effectively restore calcaneal anatomy, improve functional outcomes, and minimize complications, ultimately leading to a high rate of occupational rehabilitation.

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