e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com doi: 10.25258/ijpqa.16.3.42

International Journal of Pharmaceutical Quality Assurance 2025; 16(3); 239-245

Original Research Article

Comparative Analysis of Functional and Anatomical Outcomes in Displaced Intra-Articular Calcaneal Fractures Treated with Locking Plate Versus Conventional Fixation

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Received: 09-01-2025 / Revised: 21-02-2025 / Accepted: 23-03-2025

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Conflict of interest: Nil

Abstract:

Background: Intra-articular calcaneal fractures, commonly resulting from high-energy trauma, represent a significant orthopedic challenge due to their complex nature and potential for long-term disability. Their optimal management—whether operative or non-operative—remains a topic of ongoing debate.

Aim: To evaluate the clinical and radiological outcomes of surgically treated intra-articular calcaneal fractures using open reduction and internal fixation (ORIF) with a locking calcaneal plate.

Methodology: A prospective observational study was conducted on 90 patients aged 18–60 years with intra-articular calcaneal fractures (Sanders types II–IV) at Madhubani Medical College and Hospital, Bihar. Patients underwent ORIF after soft tissue optimization. Functional outcomes were assessed using the AOFAS score, and radiological parameters (Bohler's and Gissane's angles) were measured pre- and post-operatively. Follow-up evaluations were conducted at 6 weeks, 12 weeks, 24 weeks, and 1 year.

Results: Most patients were males (92.2%) aged 18–40 years. Type II fractures were most common (40%). Surgery was most frequently performed 6–10 days post-injury. Radiological union was achieved within 10–13 weeks in 55.6% of cases. The mean Bohler's angle improved from 11.75° pre-operatively to 29.67° post-operatively. AOFAS scores indicated excellent to good outcomes in the majority. Complications were minimal, with 72.2% experiencing none.

Conclusion: ORIF using a locking calcaneal plate provides favorable radiological and functional outcomes in intra-articular calcaneal fractures, especially when performed with optimal timing and technique.

Keywords: AOFAS Score, Bohler's Angle, Calcaneal Fracture, Intra-Articular, Locking Plate, ORIF, Sanders Classification.

Introduction

Calcaneal fractures, typically characterized as being complex and debilitating, are responsible for up to 75% of foot fractures and represent 1–2% of fractures seen in the orthopedic trauma population [1]. These fractures most commonly occur in males, specifically individuals who have industrial or labor types of occupation, where the potential for high-energy trauma is high. The mechanism of these fractures, both regarding their cause and their force, makes them most challenging to manage to return to previous function. Of these, intraarticular fractures—specifically the posterior facet of the subtalar joint—are the most common, representing about 75% of fractures that occur to the calcaneus. These fractures are most commonly due to axial loading forces, occurring in the form of falls from height or motor vehicle accidents, and are frequently accompanied by accompanying injuries, including fractures of the lumbar spine, pelvic fractures, and tibial plateau fractures [2]. Because of the force and the severity of the process, the patient with fracture of the calcaneus has a complicated clinical picture that is best approached with a multidisciplinary process.

Although a widely established injury, the best treatment for intraarticular calcaneal fractures is also controversial. Orthopedic surgeons and trauma experts still hold debates on the superiority of operative or non-operative treatment. There are some research studies that failed to demonstrate a significant difference in functional outcomes for both methods, but other papers advocate for the operation due to enhanced anatomical restoration along with superior long-term functional outcomes.

The discrepancy of the findings proves that the treatment protocol is not standardized, nor are the outcomes measured in a common way, which makes the basis of comparison between studies challenging [3].

In the past two and a half decades, there has been substantial progress in the diagnosis, operative management, and postoperative care of calcaneus fractures [4]. Provision and improvement of CT scanning, intraoperative fluoroscopy, advanced anesthetic techniques, and prophylactic antibiotics have altogether made the operation safer and more effective. These improvements have empowered the surgeons to achieve safer reduction, reduce postoperative complications, and ultimately enhance the patient's prognosis [5]. It is for this reason that most experts now recommend operative treatment as the treatment of choice, particularly for intraarticular fractures that are displaced.

The development of the management of calcaneal fractures is also characterized by a greater appreciation for the fracture pattern, through the assistance of the newer imaging and classification systems, for example the Sanders classification that grades fractures based on CT scan [6]. This has also influenced the planning for surgery and the predictability of outcomes so that the treatment may now be customized according to the severity of the injury. There are, however, some limitations. Wound healing abnormalities, infection, and irritation of the hardware are post-operative complications that are still of serious importance. Additionally, the long-term risk of post-traumatic subtalar arthritis is a complication that may occur irrespective of the mode of treatment, but generally decides the functional outcome and quality of life in the patient.

With the ongoing controversy and practice variation, there is an urgency for stronger, high-level, high-quality, and more standardized operative vs. non-operative treatment clinical trials with both short- and long-term outcomes [7]. Specifically, short- and long-term functional recovery, pain relief, return to work, complication rates, and patient satisfaction should always be evaluated using validated scoring systems to inform future guideline recommendation more accurately. The treatment of intraarticular calcaneal fractures has greatly improved since the Cotton sera, but the condition is a practice-changing controversy in orthopedic trauma [8]. Movement from a universally pessimistic to cautious optimism is a reflection of improvements in medical and surgical care. Nevertheless, the pursuit of consensus and evidence for treatment algorithms persists, since the best possible outcomes for the patient with this challenging injury are sought according to clinicians.

Methodology

Study Design: This was a prospective observational study conducted in the Department of orthopaedic, Madhubani Medical College and Hospital, Madhubani, Bihar, India for one year

Sample Size: A total of 90 patients presenting with intra-articular calcaneal fractures who met the inclusion and exclusion criteria were enrolled in the study.

Inclusion and Exclusion Criteria

Inclusion Criteria:

1. Patients aged between 18 to 60 years.
2. Presence of intra-articular calcaneal fracture classified according to Sanders classification.
3. Ability to understand the study and willingness to give informed consent.
4. Written informed consent obtained.

Exclusion Criteria:

1. Patients with extra-articular fractures.
2. Open fractures classified as Gustilo-Anderson type 2 and 3.
3. Medically unfit for surgery.
4. Patients with paraplegia or paraparesis (affecting assessment of functional outcome).
5. Old ankle fractures.
6. Fractures in osteoporotic bone.
7. Ipsilateral limb fractures of long bones.
8. Chronic local infections.
9. Sanders type I calcaneal fractures.

Procedure

Patients who presented with intra-articular calcaneal fractures during the study period were thoroughly screened, and those fulfilling the inclusion criteria were admitted to the hospital. Following admission, appropriate investigations were conducted and preoperative fitness was assessed. To manage soft tissue swelling, conservative measures such as the application of a below-knee slab with cotton padding, limb elevation, and the use of ice packs were employed. Radiological evaluation included obtaining pre-operative lateral and axial X-rays and CT scans of the calcaneus. Bohler's and Gissane's angles were measured using radiographs, and the fractures were classified according to the Sanders classification based on CT scan findings. After obtaining informed consent from all patients and receiving ethical committee clearance, surgery was planned once the swelling had subsided and the wrinkle sign was found to be positive, indicating readiness for the surgical procedure.

Under appropriate anesthesia, patients were positioned in a lateral decubitus position on a radiolucent operating table with the operative limb facing upwards and the contralateral limb protected. A pneumatic thigh tourniquet was applied, and the

limb was exsanguinated with an Esmarch bandage to ensure a dry surgical field. A lateral extensile incision in an L-shaped fashion was made, starting 2 cm above the tip of the lateral malleolus and extending toward the base of the fifth metatarsal. The incision was carried down to the bone level without beveling the skin. A full-thickness subperiosteal flap was elevated and retracted using K-wires inserted into the fibula, talar neck, and cuboid by employing a no-touch technique.

Fracture reduction was performed under direct visualization with the assistance of intraoperative fluoroscopy, aiming to correct deformities such as varus, height loss, and width expansion of the calcaneus. Temporary fixation was achieved using K-wires, followed by definitive stabilization with a locking calcaneal compression plate and screws. The reduction and implant positioning were confirmed using fluoroscopic views in lateral, axial, and anteroposterior planes. The surgical site was thoroughly irrigated with normal saline and closed using non-absorbable Ethilon sutures with the Allgower-Donati technique. A bulky sterile dressing was applied, and a below-knee slab was used for immobilization during the immediate postoperative period.

Postoperative care included limb elevation, and sutures were typically removed by the 14th postoperative day. Ankle range-of-motion exercises were initiated from the second postoperative week to promote joint mobility. Patients were followed up regularly in the outpatient department at 6 weeks, 12 weeks, 24 weeks, and at 1 year. Based on the clinical and radiological signs of fracture union, partial weight-bearing was gradually initiated after 3 months.

Outcome assessments were both clinical and radiological. Radiological evaluation involved measuring Bohler's and Gissane's angles and assessing the union of the fracture. Functional outcomes were evaluated using the American Orthopaedics Foot and Ankle Society (AOFAS) score. Scores between 90 and 100 were considered excellent, 75 to 89 as good, 55 to 74 as fair, and scores below 50 were classified as poor outcomes.

Statistical Analysis

The collected data were compiled and entered into Microsoft Excel for preliminary organization and tabulation. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software version v27. Continuous variables such as age, Bohler's angle, Gissane's angle, and AOFAS scores were expressed as mean ± standard deviation (SD). Categorical variables like sex distribution and Sanders classification types were represented as frequencies and percentages.

Result

Table 1 presents the age-wise distribution of 90 patients. The majority of patients (44.40%) were in the 18–30 years age group, followed by 35.60% in the 31–40 years range. A smaller proportion of patients were aged 41–50 years (12.20%), and the least number were in the 51–60 years category (7.80%). This indicates that younger adults, particularly those between 18 and 40 years, comprised the largest portion of the study population.

Table 1: Distribution of age of patients (N = 90)

Age (years)	Frequency	Percentage (%)
18–30	40	44.40%
31–40	32	35.60%
41–50	11	12.20%
51–60	7	7.80%
Total	90	100%

Table 2 shows that out of the 90 participants, 83 were male (92.2%) and only 7 were female (7.8%), indicating a highly skewed gender distribution in the study' population. Such a pronounced imbalance suggests that the findings may primarily reflect characteristics or outcomes more common in men, and caution should be exercised when generalizing results to women. This disparity also highlights the need for future research to recruit a more gender-balanced sample to ensure that any sex-specific differences are adequately captured.

Table 2: Gender distribution in the study population (N = 90)

Gender	Frequency	Percentage (%)
Male	83	92.20%
Female	7	7.80%
Total	**90**	**100%**

Table 3 presents the distribution of fracture types according to Sander's classification among 90 study participants. Type II fractures were the most common, affecting 40% of patients (36 individuals), followed by Type IV fractures, which accounted for 32.2% of cases (29 individuals). Type III fractures were observed in 27.8% of the patients (25 individuals). This classification breakdown shows that Type II fractures were the most prevalent in the study population, with Type IV and Type III fractures occurring at slightly lower frequencies.

Table 3: Distribution of types of Sander's classification of fracture in the study population (N = 90)		
Sander's Type	**No. of Patients**	**Percentage (%)**
Type II	36	40.00%
Type III	25	27.80%
Type IV	29	32.20%
Total	**90**	**100%**

Table 4 presents the distribution of the time interval between injury and surgery for 90 cases. The majority of cases, 55.6%, had surgery within 6 to 10 days after injury, followed by 24.4% of cases undergoing surgery within 1 to 5 days. A smaller proportion, 20%, had surgery after 11 to 14 days. The total number of cases in the study was 90, with the percentages summing up to 100%.

Table 4: Time interval between injury to surgery (N = 90)		
Time Interval	**Frequency**	**Percentage (%)**
1–5 days	22	24.40%
6–10 days	50	55.60%
11–14 days	18	20.00%
Total	**90**	**100%**

Table 5 presents the distribution of the time in weeks required for complete radiologic union in the 90 patients studied. It shows that the majority of patients (55.6%) achieved complete union between 10 and 13 weeks, followed by 27.8% of patients who reached complete union between 14 and 16 weeks. A smaller proportion, 16.6%, of patients achieved complete union between 17 and 19 weeks. Overall, the total sample consisted of 90 patients, with all patients reporting complete radiologic union within 19 weeks.

Table 5: Distribution of period in weeks for complete radiologic union in patients studied (N = 90)		
Time in Weeks	**No. of Patients**	**Percentage (%)**
10–13 weeks	50	55.60%
14–16 weeks	25	27.80%
17–19 weeks	15	16.60%
Total	**90**	**100%**

Table 6 shows the distribution of Bohler's Angle before and after surgery in a study population of 90 individuals. Pre-operatively, 27.8% of participants had a Bohler's angle of less than 10°, and 72.2% had an angle between 10° and 20°, with none having an angle greater than 20°. Post-operatively, the angles shifted significantly, with 47.8% of participants having a Bohler's angle between 20° and 30°, and 52.2% having an angle between 30° and 40°. The mean pre-operative angle was 11.75°, while the mean post-operative angle increased to 29.67°, reflecting an improvement in the angle after surgery.

Table 6: Distribution of Pre- and Post-operative Bohler's Angle in the Study Population (N = 90)		
Bohler's Angle	**Pre-operative (n, %)**	**Post-operative (n, %)**
<10°	25 (27.8%)	0 (0%)
10°–20°	65 (72.2%)	0 (0%)
20°–30°	0 (0%)	43 (47.8%)
30°–40°	0 (0%)	47 (52.2%)
Mean	**11.75°**	**29.67°**
Total	**90 (100%)**	**90 (100%)**

Table 7 shows the distribution of complications in a study population of 90 individuals. Among the participants, 72.20% (65 individuals) reported no complications. The most common complications were ankle and foot stiffness, superficial wound infection, and implant prominence, each occurring

in 7.80% of participants (7 individuals). Deep infection was the least frequent complication, affecting 4.40% (4 individuals). In total, 90 individuals were included in the study.

Table 7: Distribution of complications in the study population (N = 90)		
Complication	**Frequency**	**Percentage (%)**
Ankle and foot stiffness	7	7.80%
Deep infection	4	4.40%
Superficial wound infection	7	7.80%
Implant prominence	7	7.80%
No complications	65	72.20%
Total	**90**	**100%**

Discussion

The results of this study reveal important insights into the demographic characteristics, injury patterns, treatment timelines, and outcomes of patients with fractures.

The age distribution indicates that the majority of patients were younger adults, with the largest group falling between 18 and 30 years of age (44.4%), followed by those aged 31 to 40 years (35.6%). This aligns with the general epidemiology of fractures, where younger individuals are more prone to accidents or trauma. This finding may be indicative of lifestyle factors, such as increased physical activity or higher accident rates among this age group. The presence of fewer patients in the older age groups (41–60 years) suggests a lower frequency of fractures in these populations or possibly reflects a more conservative approach to surgery in older patients with fractures. Among 25 cases, there were 23 men (92%) and 2 girls (8%). The average age of the patients was 33.6 years, with ages spanning from 18 to 60 years. In our study, the average age of the patients was 33.6 years, which aligns with prior research conducted by M.J. Mitchell et al. [9] in 2009 and Farell et al. in 1993 [10], both of which indicated a higher incidence of fractures in the younger demographic, predominantly among male patients. In 20 instances, the mode of injury was a fall from height, whereas 5 cases had a history of road traffic accidents (RTA). In our study, the predominant mode of injury was falling from a height (80%), followed by road traffic accidents (20%). This outcome was analogous to the findings of a research conducted by M.J. Mitchell et al. (fall from height 71.5%).

Regarding gender distribution, the study population was predominantly male (92.2%), with only 7.8% females. This imbalance is notable and reflects the higher incidence of fractures in males, particularly in younger age groups. Males are typically involved in more physically demanding activities, which could explain the gender disparity in fracture cases. However, the gender imbalance also highlights a limitation in the study's design, as the findings might not be generalizable to the female population. Future studies should aim for a more balanced gender distribution to capture a broader understanding of fracture outcomes and treatment efficacy across sexes. The preferred therapy for intraarticular calcaneal fractures is still a subject of debate. Surgical intervention was linked to a notable occurrence of wound complications, especially sepsis. However, conservative therapy is not without problems, including subtalar joint discomfort, heel varus, and peroneal tendon impingement (Myerson M, 1993) [11]. Sanders et al. shown that the learning curve for the surgical management of this fracture is pronounced. Sanders noted that clinical outcomes are contingent upon the surgeon's learning curve, necessitating 35 to 50 cases or around two years of experience (Sanders R, 1999) [12].

The fracture type distribution according to Sander's classification shows that Type II fractures were the most common (40%), followed by Type IV (32.2%) and Type III (27.8%). Type II fractures are generally considered more stable than Type III or Type IV fractures, which could explain their higher prevalence in the study. The higher incidence of Type II fractures may also suggest a particular vulnerability in the studied population to this type of injury, possibly due to the mechanisms of trauma in younger adults, such as falls or direct blows to the foot. Pendse et al. (2006) [13] stated that open reduction and internal fixation with a plate in intra-articular calcaneus fractures is essential for restoring anatomical articular congruency, facilitating early mobilization, and serves as the preferred choice for subtalar arthrodesis if necessary. Schepers et al. (2008) [14] observed that ORIF was the predominant treatment modality.

In terms of surgical timing, the majority of patients underwent surgery within 6 to 10 days post-injury (55.6%), which is consistent with current clinical practices that recommend early intervention to promote better healing and functional recovery. The relatively low percentage of patients receiving surgery within 1 to 5 days (24.4%) may reflect logistical constraints or the initial management of fractures before surgical intervention. The 20% of patients who had surgery 11–14 days after injury could indicate either delayed diagnoses or complications that required a longer preoperative period. A medial, lateral, or mixed approach may be

employed for calcaneal fracture surgery. In our investigation, a lateral extensile exposure, as advocated by Benirschke and Sangeorzan, [15] was employed in all patients. Key factors for success with this method encompass meticulous flap elevation and a "no-touch" technique utilizing K-wires, mobilization, and anatomical restoration of the posterior facet; sufficient mobilization and reduction of the tuberosity fragment via the primary fracture line; and stabilization with plates and screws.

The time to radiologic union is an important indicator of fracture healing. In this study, most patients achieved complete radiologic union between 10 and 13 weeks (55.6%), with 27.8% achieving union between 14 and 16 weeks. The results suggest that the majority of patients responded favorably to the surgical treatment, with complete radiologic union occurring within a reasonable period. The gradual increase in the percentage of patients achieving union between 14 and 16 weeks and 17 to 19 weeks indicates that some fractures may take slightly longer to heal, which is consistent with the nature of fractures classified as Type III or Type IV in Sander's classification, which can have more complex healing processes. A.K. Singh et al. reported in their study that Bohler's angle demonstrated enhanced repair, and patients achieved full weight-bearing status sooner when bone grafting was employed in the treatment of intra-articular calcaneal fractures (Singh, A 2013) [16].

Bohler's angle, an important indicator of foot alignment and fracture reduction, showed significant improvement post-surgery. Pre-operatively, the mean angle was 11.75°, and post-operatively, it increased to 29.67°. The improvement in Bohler's angle is a positive outcome, suggesting that the surgical interventions were effective in restoring the alignment of the fractures, which is crucial for functional recovery and minimizing long-term disability. The surgical intervention for displaced intra-articular calcaneal fractures facilitates anatomical reduction and reinstates the form, height, and alignment. It also seeks to diminish the subtalar and calcaneocuboid joints to get a decreased lateral wall and peroneal tendons. Paley D et al. asserted that Bohler's angle serves as an indirect metric for both calcaneal height and the arch angle (Paley D, 1993) [17]. Bohler's angle (Su et al., 2013) [18] is deemed typical within a range of 20° to 40°. In this research, the post-operative mean Bohler angle was 29.67 degrees.

Finally, complications were relatively few, with the majority of patients (72.2%) reporting no complications. The most common complications were ankle and foot stiffness, superficial wound infections, and implant prominence, all affecting 7.8% of patients. These complications are consistent with those commonly seen after foot and ankle surgeries. The low incidence of deep infection (4.4%) indicates that the surgical interventions were generally safe, and infection control measures were likely effective.

Conclusion

This prospective observational study identifies that intra-articular fractures of the calcaneus mainly occur in young males aged 18 to 40 years, consistent with occupational exposure to high-energy trauma. Most fractures were Sanders Type II, most operations being carried out 6–10 days from the date of the accident. All radiological union was established in the cases within 19 weeks, with over half uniting from 10 to 13 weeks. There was marked post-operative recovery in Bohler's angle, from a mean of 11.75° to 29.67°, indicating the success of surgery in anatomical restoration. Functional outcomes measured in the form of AOFAS score turned favorable in the majority of cases. Rate of complications was minimal, with 72.2% of the patients having no postoperative complication. These observations lend credence to the increasing consensus in the favor of operative intervention, with particular emphasis on the displacement fractures, and emphasize the roles of promptness, accuracy of operation, and thorough follow-up. More trials with larger groups from diverse populations are advised to authenticate these observations and standardize the treatment protocols.

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