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Clinical and radiological outcomes of displaced intra-articular calcaneal fractures treated through the sinus tarsi approach: a prospective study

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ABSTRACT

Background: Displaced intra-articular calcaneal fractures (DIACFs) remain technically demanding because satisfactory articular reduction must be achieved without adding further injury to an already vulnerable soft-tissue envelope. The sinus tarsi approach (STA) offers a limited route to the posterior facet. This prospective study evaluated clinical and radiological outcomes after fixation of DIACFs through the STA.

Methods: Twenty adults with closed Sanders type II-IV DIACFs were enrolled prospectively at a Kasturba Medical College, Mangalore, Karnataka, tertiary care teaching hospital between January 2023 and December 2024. All fractures were treated through the STA, with the definitive fixation construct chosen according to fracture morphology and intraoperative stability. Radiological assessment included preoperative-to-postoperative change in Böhler's and Gissane's angles and time to union. Functional recovery was assessed with the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score at 6, 12, and 24 weeks and at 1 year. Complications were recorded throughout follow-up.

Results: All 20 patients completed 1-year follow-up. Mean age was 34.80±10.68 years, and 16 injuries (80.0%) followed a fall from height. Sanders type III fractures were most frequent (10/20, 50.0%), followed by type IV (7/20, 35.0%) and type II (3/20, 15.0%). Mean change in Böhler's angle was 15.30±5.67° and mean change in Gissane's angle was 20.15±9.56°. Radiological union occurred at a mean of 10.75±1.45 weeks. Mean AOFAS score was 53.30±12.16 at 6 weeks and 86.35±5.87 at 1 year. At final follow-up, 19 patients (95.0%) had a good or excellent AOFAS outcome. Four patients (20.0%) experienced postoperative complications: superficial wound infection in two patients (10.0%), ankle fibrosis in one patient (5.0%), and ankle fibrosis with varus deformity in one patient (5.0%). No deep infection or non-union was documented.

Conclusions: Fixation of DIACFs through the STA was associated with radiographic correction, progressive postoperative functional recovery, and fracture union in this prospective series. These findings support the STA as a practical operative corridor for appropriately selected DIACFs, while the inclusion of Sanders type IV fractures warrants cautious interpretation and longer-term evaluation.

Keywords: Calcaneal fracture, Displaced intra-articular calcaneal fracture, Sinus tarsi approach, Böhler's angle, Gissane's angle, AOFAS, Minimally invasive fixation

INTRODUCTION

Displaced intra-articular calcaneal fractures represent a difficult balance between bony reconstruction and soft-tissue preservation. Injury to the posterior facet may be accompanied by loss of calcaneal height, widening of the heel, varus malalignment, and distortion of the subtalar joint. Persistent deformity can compromise hindfoot mechanics and contribute to pain, stiffness, and post-traumatic subtalar degeneration.[1,2] Computed tomography is therefore central to operative planning, and the Sanders classification remains a widely used method for describing posterior-facet comminution.[3]

The extensile lateral approach provides broad exposure of the calcaneus, but the soft-tissue dissection required for that exposure has driven interest in less invasive alternatives. The STA reaches the posterior facet through a shorter lateral incision and preserves a larger proportion of the lateral soft-tissue envelope. Contemporary evidence suggests that this reduction in exposure can be achieved without a consistent penalty in final radiographic alignment, while wound complications are generally less frequent than with extensile lateral exposure.[4-6] Earlier JOSR meta-analyses reached broadly similar conclusions regarding wound morbidity and radiographic or functional outcomes.[7,8]

The clinical literature nevertheless remains heterogeneous. Fracture severity, reduction technique, implant selection, rehabilitation, and outcome definitions vary across series, and many comparative studies are dominated by Sanders type II and III injuries.[9] More recent work has extended interest in STA fixation to Sanders type IV fractures and to differing screw and plate-based constructs.[10-13] Prospective series that report serial functional recovery together with radiographic correction, union, and complications therefore remain relevant. The present study evaluated clinical and radiological outcomes of DIACFs treated through the STA in a prospectively followed cohort with 1-year assessment.

METHODS

Study design and participants

This prospective case series was conducted at a Kasturba Medical College, Mangalore, Karnataka between January 2023 and December 2024 following approval by the Institutional Ethics Committee. Consecutive eligible patients with DIACFs selected for operative fixation through the STA were enrolled and followed for 1 year. All participants provided written informed consent, and the study was conducted in accordance with the Declaration of Helsinki.

Eligible patients were 18-65 years of age and had a closed intra-articular calcaneal fracture with an articular step-off greater than 2 mm and Sanders type II, III, or IV morphology on computed tomography. Surgery was undertaken within 3 weeks of injury after the soft-tissue condition was considered suitable.

Exclusion criteria were medical unfitness for surgery, refusal of operative treatment, open fracture, significant local soft-tissue compromise, congenital hindfoot deformity, ipsilateral refracture, previous hindfoot surgery, associated fracture of adjacent tarsal bones, neurovascular injury, surgery later than 3 weeks after injury, or a neurological deficit that prevented reliable functional assessment.

Preoperative assessment

Initial management consisted of below-knee slab immobilization, limb elevation, ice application, and compression as required for swelling. Standard radiographs included anteroposterior, lateral, axial, and Broden views. Computed tomography was obtained for fracture characterization and Sanders classification.[3]

Surgical technique

Procedures were performed with the patient in the lateral decubitus position under tourniquet control. Lateral, axial, and Broden fluoroscopic views were confirmed before incision. The sinus tarsi were approached through an oblique incision (Figure 1) from the lateral malleolar region toward the base of the fourth metatarsal. The extensor digitorum brevis was mobilized superiorly to expose the sinus tarsi and allow visualization of the posterior facet (Figure 2).



Figure 1: Incision for sinus tarsi approach



Figure 2: Visualization of the posterior facet.

Distraction and correction were assisted by a Schanz screw or 2.0 mm Kirschner wire placed in the posteroinferior calcaneal tuberosity. Reduction was provisionally maintained with Kirschner wires directed toward the sustentaculum tali. Definitive fixation was then chosen according to fracture morphology, the requirements of reduction, and intraoperative stability. Constructs included cannulated cancellous screws, calcaneal plates, sinus tarsi plates, and combined plate-and-screw fixation. Wounds were closed with interrupted non-absorbable sutures and protected in a below-knee posterior slab.

Postoperatively, the limb was elevated and antibiotics were administered according to the study protocol. Immobilization in a below-knee slab was maintained for 3-6 weeks. Sutures were removed at approximately 2 weeks when wound healing permitted. Active ankle motion was introduced at about 3 weeks together with gentle passive subtalar mobilization. Weight-bearing was advanced between 8 and 12 weeks according to clinical progress and radiographic evidence of consolidation.

Outcome measures and radiological assessment

Follow-up assessments were scheduled at 6 weeks, 12 weeks, 24 weeks, and 1 year. Radiological outcomes were the preoperative-to-postoperative change in Böhler's angle, change in Gissane's angle, and time to radiological union. Two observers performed the radiographic assessment. Union was defined by trabecular continuity or bridging together with disappearance of the fracture line.

Functional recovery was recorded using the AOFAS hindfoot score at each scheduled visit. Final scores were categorized as excellent (90-100), good (75-89), fair (50-74) or poor (<50). Postoperative complications were documented throughout follow-up.

Statistical analysis

Data were summarized descriptively. Continuous variables are reported as mean±standard deviation (SD), and categorical variables as number and percentage. Serial AOFAS scores are presented at each predefined follow-up point without inferential testing of within-patient change. No statistical comparison was performed between fixation constructs.

RESULTS

Patient and fracture characteristics

Twenty patients were included in the final analysis, and all completed 1-year follow-up. The mean age was 34.80±10.68 years. Sixteen patients (80.0%) were injured in a fall from height and 4 (20.0%) in a road traffic accident. Sanders type III was the most common fracture pattern (10/20, 50.0%); type IV was present in 7 patients (35.0%) and type II in 3 (15.0%) (Table 1).

Fixation constructs

Cannulated cancellous screws were used in 9 patients (45.0%), a calcaneal plate in 6 (30.0%), a sinus tarsi plate in 4 (20.0%), and combined calcaneal plate plus cannulated cancellous screw fixation in 1 patient (5.0%). Implant choice followed fracture morphology and intraoperative stability rather than a uniform implant protocol (Table 1).

Radiological outcomes

The mean preoperative-to-postoperative change in Böhler's angle was 15.30±5.67°. The corresponding mean change in Gissane's angle was 20.15±9.56°. Mean time to radiological union was 10.75±1.45 weeks (Table 2). The radiographs of one of our patients showing pre-operative fracture pattern, immediate post-operative status and one-year follow-up status have been depicted in Figures 3-5 respectively.



Figure 3 (A and B): Pre-operative radiograph showing calcaneal fracture.

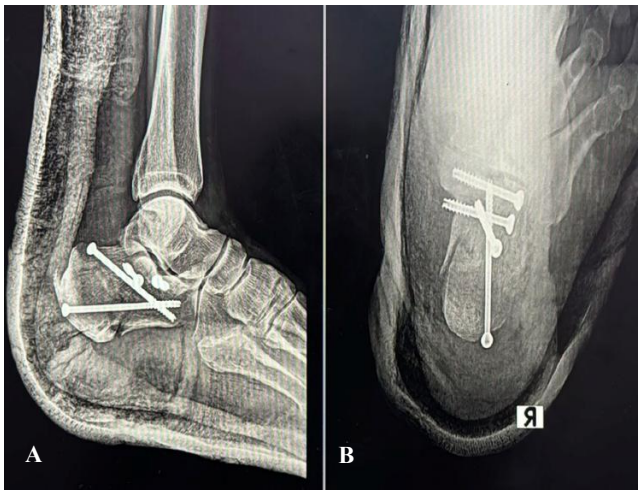


Figure 4 (A and B): Immediate post-operative radiograph showing fracture fixation with cannulated cancellous screws.



Figure 5 (A and B): One year follow-up radiograph.

Table 1: Patient, fracture and treatment characteristics.

Characteristics	Value
Number of patients	20
Age (years)	34.80±10.68
Mechanism of injury	
Fall from height	16 (80.0%)
Road traffic accident	4 (20.0%)
Sanders classification	
Type II	3 (15.0%)
Type III	10 (50.0%)
Type IV	7 (35.0%)
Definitive fixation construct	
Cannulated cancellous screws	9 (45.0%)
Calcaneal plate	6 (30.0%)
Sinus tarsi plate	4 (20.0%)
Calcaneal plate + cannulated cancellous screws	1 (5.0%)

Values are mean ± SD or n (%), as appropriate.

Table 2: Radiological and functional outcomes after sinus tarsi fixation.

Outcomes	Value
Radiological outcomes	
Change in Böhler's angle,°	15.30±5.67
Change in Gissane's angle,°	20.15±9.56
Time to radiological union, weeks	10.75±1.45
AOFAS hindfoot score	
6 weeks	53.30±12.16
12 weeks	69.85±8.17
24 weeks	81.70±7.04
1 year	86.35±5.87
AOFAS category at 1 year	
Excellent	7 (35.0%)
Good	12 (60.0%)
Fair	1 (5.0%)
Poor	0 (0%)

Continuous variables are mean±SD and categorical variables are N (%). AOFAS, American Orthopaedic Foot and Ankle Society.

Functional outcomes

AOFAS hindfoot scores rose across successive postoperative assessments. The mean score was 53.30±12.16 at 6 weeks, 69.85±8.17 at 12 weeks, 81.70±7.04 at 24 weeks, and 86.35±5.87 at 1 year. At final follow-up, 7 patients (35.0%) were classified as excellent, 12 (60.0%) as good, and 1 (5.0%) as fair; no poor outcome was recorded. Accordingly, 19 of 20 patients (95.0%) had a good or excellent final AOFAS category.

Postoperative complications

Four patients (20.0%) experienced postoperative complications. Superficial wound infection occurred in two patients (10.0%), ankle fibrosis in one patient (5.0%), and ankle fibrosis with varus deformity in one patient (5.0%). No deep infection or non-union was documented during follow-up (Table 3).

Table 3: Postoperative complications.

Complications	N (%)
Any documented postoperative complication	4 (20.0)
Superficial wound infection	2 (10.0)
Ankle fibrosis	1 (5.0)
Ankle fibrosis with varus deformity	1 (5.0)
Deep infection	0 (0.0)
Non-union	0 (0.0)

Values are presented as N (%). The four documented complications occurred in four different patients.

DISCUSSION

Principal findings

This prospective series showed three consistent features after STA fixation of DIACFs: measurable correction of calcaneal angular parameters, a progressive rise in postoperative AOFAS scores through 1 year, and radiological union at a mean of approximately 11 weeks. Nineteen of 20 patients reached a good or excellent AOFAS category at final review. Four patients had documented complications, but no deep infection or non-union was observed. These findings were observed in a cohort in which 17 of 20 fractures were Sanders type III or IV, indicating that the series was not confined to relatively simple intra-articular patterns.

Radiological outcomes

Anatomical reconstruction of the calcaneus aims to recover hindfoot alignment and posterior-facet relationships while avoiding additional damage to the soft-tissue envelope.[1,2] In the present study, Böhler's angle changed by a mean of 15.30° and Gissane's angle by 20.15° after reduction. The available dataset supports interpretation of these values as cohort-level radiographic

correction; it does not provide separate individual preoperative and postoperative values from which the proportion of fractures restored to a predefined normal range could be calculated.

That distinction is relevant when comparing the present findings with the literature. A 2024 meta-analysis of 21 comparative studies involving 2,086 patients found no meaningful difference between STA and extensile lateral exposure in final Böhler's angle, Gissane's angle, calcaneal height, length, or width, while wound complications favored STA.[4] A recent randomized JOSR trial and a 2025 meta-analysis restricted to randomized studies likewise support the ability of minimally invasive approaches to achieve radiographic results comparable with extensile exposure.[5,6] Earlier pooled analyses reached similar conclusions.[7-9] The current findings are therefore consistent with the broader observation that limiting the lateral exposure does not necessarily compromise correction of overall calcaneal geometry.

Böhler's and Gissane's angles remain indirect measures. They describe global calcaneal morphology but cannot by themselves establish posterior-facet congruity or subtalar surface restoration. For this reason, the present study avoids equating angular change with complete anatomical reconstruction.

Functional recovery

Postoperative function improved numerically across the scheduled assessments, with the mean AOFAS score increasing from 53.30 at 6 weeks to 86.35 at 1 year. The study was designed to describe this postoperative trajectory; inferential repeated-measures testing was not undertaken. The serial values should therefore be read as descriptive evidence of recovery rather than as a statistically tested longitudinal effect. The final score lies within the range reported in contemporary STA series. Randomized and pooled comparative evidence generally shows functional results with STA that are at least comparable with extensile lateral fixation, with some recent studies reporting an advantage for minimally invasive treatment.[5-8] Differences between published cohorts in fracture complexity, fixation construct, rehabilitation, and follow-up make direct numerical comparison of mean AOFAS values less informative than the overall consistency of favorable functional recovery.

Fracture complexity

A notable feature of the cohort was the high proportion of more comminuted fractures: 50% were Sanders type III and 35% were type IV. Many earlier comparative datasets are dominated by type II and III injuries.[9] More recent evidence specifically addressing Sanders type IV fractures has shown that STA can be used in selected highly comminuted patterns, although those studies also emphasize the technical demands of achieving and maintaining reduction.[10] In the present series, type IV fractures contributed to the overall cohort result, but the available data do not support a fracture-grade-specific efficacy claim.

Complications and soft-tissue considerations

The rationale for STA is closely tied to preservation of the lateral soft tissues. Two patients in this series developed a superficial wound infection; no deep infection was documented. The observed 10% superficial infection rate should be presented as a cohort finding rather than labelled intrinsically low. Comparative evidence provides the more appropriate context: the updated 2024 meta-analysis reported a substantially higher risk of wound-related complications with extensile lateral exposure than with STA, and recent randomized evidence also favored STA for skin and wound complications.[4,5] Earlier JOSR meta-analyses reached the same general conclusion.[7,8]

Mean radiological union occurred at 10.75 weeks, with no recorded non-union. Cross-study comparison of union time is inherently imprecise because definitions of union, imaging schedules, fracture severity, and weight-bearing protocols differ. The present estimate is therefore best treated as a descriptive healing endpoint defined by trabecular continuity or bridging together with loss of the visible fracture line.

Fixation strategy and clinical implications

The STA in this study functioned as an operative corridor rather than as a protocol tied to one implant. Screw-only, plate-based, and combined constructs were selected according to fracture morphology and intraoperative stability. This reflects contemporary practice, in which the fixation strategy is tailored to the reduction problem rather than dictated by the incision itself.

Recent evidence supports the feasibility of both screw- and plate-based constructs through STA. A systematic review and meta-analysis of 728 patients found broadly similar AOFAS and several radiographic outcomes between screw and plate fixation, although plate fixation showed advantages in selected measures related to maintenance of reduction and fixation failure.[11] A subsequent comparative study reported lower pain scores and better results on selected functional scales with screw-only fixation, while radiographic correction was similar between screw-only and screw-plus-mini-plate groups; the difference in implant removal was not statistically significant.[12] Long-term comparative data have also shown durable outcomes after percutaneous reduction with screw fixation and after plate fixation performed through the STA, although these are distinct operative strategies.[13] Earlier clinical series established the technical feasibility of limited sinus tarsi exposure and contributed to its wider adoption.[14,15]

Taken together, the present findings support the STA as an adaptable option when the posterior facet can be visualized adequately and stable fixation can be obtained. The choice

of approach and construct should remain driven by fracture morphology, soft-tissue status, the feasibility of correcting heel alignment, and surgeon experience.

Strengths and limitations

The prospective design, consecutive recruitment, CT-based fracture classification, predefined follow-up schedule, serial functional assessment, and use of both radiological and clinical endpoints strengthen the internal coherence of the study. Radiographs were assessed by two observers, and the cohort included a substantial proportion of Sanders type III and IV fractures.

The single-centre cohort of 20 patients limits the precision and generalizability of the estimates. Radiographic measurements were obtained by two observers, but interobserver reliability was not quantified in the available summarized dataset. Follow-up was limited to 1 year; this interval captures fracture union and early functional recovery but is insufficient for robust assessment of late post-traumatic subtalar osteoarthritis or delayed implant-related problems. Larger multicentre cohorts with longer surveillance and formal assessment of measurement reliability would help define the durability and reproducibility of these findings.

CONCLUSION

Operative fixation of DIACFs through the sinus tarsi approach was associated with radiographic correction, progressive postoperative functional recovery, and fracture union in this prospective cohort. At 1 year, 95% of patients had good or excellent AOFAS outcomes, and no deep infection or non-union was documented. Screw-, plate-, and combined fixation were used according to fracture morphology in a cohort predominantly comprising Sanders type III and IV injuries. These findings support STA as a viable operative strategy for appropriately selected DIACFs. Longer-term multicentre evaluation is warranted to define the durability of functional and subtalar outcomes.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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