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Case Series

Progressive radiological and clinical outcomes of minimally invasive cannulated cancellous screw fixation in intra-articular calcaneal fractures: a case series

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ABSTRACT

Displaced intra-articular calcaneal fractures (DIACFs) pose a significant reconstructive challenge. Minimally invasive cannulated cancellous (CC) screw fixation has emerged as an optimal alternative to extensile lateral plating. This case series analyzes the progressive radiological and clinical outcomes over a 6-month follow-up, evaluating the impact of preoperative deformity severity while highlighting the operational and rehabilitative benefits of the percutaneous approach. A retrospective review was conducted on 16 DIACF cases. Standardized operative maneuvers utilizing Steinmann pin manipulation and CC screw fixation were employed. Serial assessments of Böhler's angle, Gissane's angle, Varus angle, and visual analog scale (VAS) pain scores were recorded preoperatively, immediately postoperatively, and at 1, 3, and 6 months. Progressive trends were analyzed using Friedman tests, and patients were stratified by the severity of their preoperative articular depression. Significant progressive corrections were observed across all parameters ($p<0.001$). Preoperative Böhler's angle (5.88°±5.30°) improved immediately (26.38°±3.50°) and was sustained at 6 months (26.62°±3.54°). VAS scores plummeted from 8.50±0.73 preoperatively to 0.38±0.50 at 6 months. Subgroup analysis revealed that patients with severe preoperative Böhler's depression (≤ 0°) achieved massive corrective improvements (mean 24.50°), reaching final outcomes parallel to those with mild initial deformity. CC screw fixation provides robust, sustained restoration of calcaneal anatomy regardless of initial deformity severity. Furthermore, it affords the added benefits of dramatically reduced wound complications, shorter operative times, lower operative morbidity, early rehabilitation, and superior cost-effectiveness compared to traditional open procedures.

Keywords: Böhler's angle, Gissane's angle, Heel varus, Essex-Lopresti, Intra-articular calcaneum fractures

INTRODUCTION

Displaced intra-articular calcaneal fractures (DIACFs) present significant reconstructive challenges due to the complex biomechanics of the hindfoot and the high risk of soft tissue envelope compromise. While open reduction and internal fixation (ORIF) via an extensile lateral approach have historically served as the gold standard, the associated complication profile—specifically wound dehiscence, flap necrosis, and deep-seated infections—has catalyzed a paradigm shift towards minimally invasive techniques. Several studies have established that extensive open exposures often exacerbate localized soft-tissue distress, necessitating less traumatic interventions.[1,2] Clinically reported studies indicate that percutaneous fixation styles successfully balance mechanical stability with biologic preservation.[3,4]

Percutaneous fixation using cannulated cancellous (CC) screws achieves rigid fixation while preserving the fragile extraosseous blood supply. Beyond the mechanical stability, percutaneous CC screw fixation carries the pronounced added benefit of significantly fewer wound complications. It is a strictly minimally invasive procedure

that routinely results in a shorter operative time and less operative morbidity. Consequently, this translates into a highly cost-effective surgical pathway that facilitates an early, predictable rehabilitation profile for the patient. A few studies have pointed out that minimizing the formal open approach substantially limits secondary post-operative stiffness and institutional stays.[5,6]

While previous literature affirms the general efficacy of percutaneous techniques, there remains a paucity of high-resolution data tracking the progressive temporal outcomes of these fixations throughout the rehabilitative timeline.[1,7] Furthermore, the correlation between the severity of the initial preoperative deformity and the ultimate radiological outcome remains debated. This case series aims to provide an extensive temporal analysis of clinical and radiological progressions up to 6 months postoperatively, stratify outcomes based on preoperative articular depression severity, and detail the clinical efficacy of a standardized percutaneous operative method.

CASE SERIES

Study design and demographics

A retrospective review was conducted on 16 consecutive patients treated for DIACFs with minimally invasive CC screw fixation. The cohort consisted of 13 males (81.3%) and 3 females (18.7%), with a mean age of 37.31±11.47 years. Fractures were classified utilizing the Sanders classification (type II: n=6; type III: n=8; type IV: n=2).

Operative technique

Patients were positioned in the lateral decubitus position with the affected limb supported over a bolster. Under fluoroscopic guidance, standard lateral, axial, and Broden views were obtained to assess the fracture morphometry. Reduction was systematically achieved using the modified Essex-Lopresti maneuver combined with percutaneous Steinmann pin manipulation to elevate the depressed fragments, restoring calcaneal height and posterior facet alignment. Following the restoration of height, residual varus deformity and heel widening were corrected using large reduction clamps applied percutaneously. Once anatomical reduction was achieved, definitive fixation was performed using 4 mm or 6.5 mm cannulated cancellous screws. The trajectory of the screws was individualized according to the specific fracture morphology to maximize purchase in the intact bone. Final reduction, joint congruity, and hardware placement were meticulously confirmed fluoroscopically prior to closure. The percutaneous intraoperative setup and reduction maneuvers are detailed sequentially in Figure 1.

Postoperative protocol and rehabilitation

Patients were clinically and radiologically reassessed immediately postoperatively, and subsequently at 1 month, 3 months, and 6 months postoperatively. In the immediate postoperative phase, the affected limb was immobilized in a plaster slab.

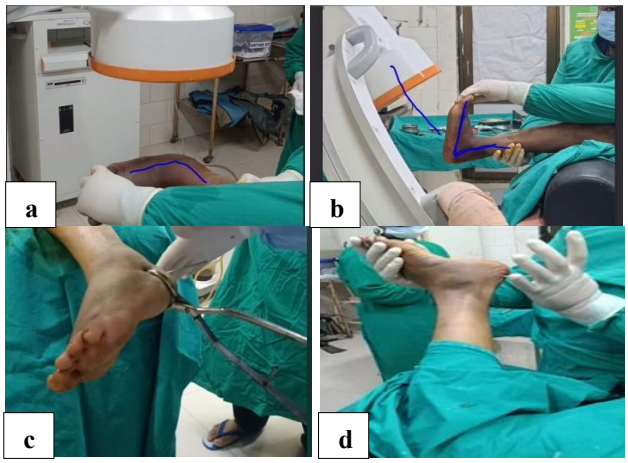

Figure 1: Intraoperative positioning and percutaneous reduction maneuvers for intra-articular calcaneal fractures (a) patient placement in the lateral decubitus position for standard fluoroscopic lateral view assessment, (b) positioning and path under C-arm fluoroscopy for the axial view, (c) percutaneous application of a large reduction clamp across the calcaneus to correct lateral heel widening and residual varus deformity, and (d) execution of the percutaneous Modified Essex-Lopresti maneuver using a Steinmann pin inserted posteriorly into the tuberosity to elevate the depressed articular posterior facet fragment.

Rehabilitation was strictly phased. At 1.5 months postoperatively, the slab was removed, and active/active-assisted ankle range of motion (ROM) exercises were initiated to prevent stiffness and optimize joint nutrition. Strict non-weight-bearing was enforced until the 3-month mark to protect the cancellous fixation. Weight-bearing was commenced at 3 months and progressed gradually based on clinical tolerance and radiographic signs of union.

Outcome parameters and statistical analysis

Radiological parameters (Böhler's angle, Gissane's angle, and Varus angle) and clinical pain (Visual Analog Scale, VAS) were tracked across the five timepoints. Longitudinal progressive data were analyzed using the non-parametric Friedman test. Patients were further stratified into subgroups based on preoperative Böhler's severity (severe≤0°; moderate 1°–10°; mild>10°) and Gissane's severity (mild-moderate≤150°; severe>150°). Significance was set at $p<0.05$.

Results

The longitudinal application of CC screw fixation resulted in highly significant anatomical maintenance across the 6-month period, resisting late-stage collapse.

Böhler's angle

Improved from a preoperative mean of 5.88°±5.30° to 26.38°±3.50° immediately postoperatively. The restoration was rigidly maintained through 1 month (26.25°), 3 months (26.62°), and 6 months (26.62°) (Friedman p<0.0001).

Gissane's angle

An abnormal preoperative mean of 155.62°±7.04° was corrected to 126.00°±2.88° immediately. The reduction held flawlessly, settling at 124.12°±3.36° at 6 months (Friedman p<0.0001).

Varus angle

The preoperative varus deviation (12.62°±4.13°) was aggressively corrected to 4.62°±1.36° postoperatively, maintaining physiological alignment at 5.88°±1.59° by final follow-up (Friedman p<0.0001).

Progressive clinical outcomes (VAS)

Pain trajectories displayed a uniform regression. From a peak preoperative score of 8.50±0.73, subjective pain dropped after surgery (4.12±0.81). As early ROM commenced at 1.5 months and weight-bearing at 3 months, pain continued to resolve: 2.50 at 1 month, 1.50 at 3 months, resulting in practically pain-free mobilization at 6 months (0.38±0.50) (Friedman p<0.0001).

Subgroup analysis by preoperative severity (Böhler's angle)

The severe cohort (≤0°; n=4) showed a massive mean improvement of 24.50°, reaching a final 6-month mean of 24.50°. The moderate cohort (1°–10°; n=8) improved by 23.75°, achieving the highest final mean of 28.75°. The mild cohort (>10°; n=4) improved by 11.00°, terminating at 24.50°.

All three cohorts neutralized at near-identical terminal pain scores (VAS ~0.25 to 0.50), indicating that severe initial depression does not preclude an optimal clinical result if mechanically restored via percutaneous leverage.

Subgroup analysis by preoperative severity (Gissane's angle)

Patients presenting with a severe Gissane disruption (>150°) required a massive corrective maneuver (mean improvement of 35.17°) compared to the mild-moderate group.

Both groups stabilized at physiological final angles (~124°) and achieved identical terminal pain relief (VAS ~0.33 to 0.50). The post-reduction confirmation and final internal architecture are shown in Figure 2.

Figure 2: Radiographic tracking and hardware confirmation of cannulated cancellous screw fixation (a) intraoperative fluoroscopic screen captures demonstrating percutaneous reduction and optimal cross-screw alignment, (b) postoperative lateral radiograph at follow-up showing correction and maintenance of Böhler's and Gissane's angles, and (c) postoperative axial radiograph showing the hardware pathway and maintenance of horizontal heel width.

DISCUSSION

The fundamental objective of surgical intervention in DIACFs is the anatomical restoration of posterior facet congruity and the tridimensional morphology of the calcaneus. Historically, ORIF via an extensile lateral approach have been standard. However, modern comparisons of robot-assisted percutaneous cannulated screws versus open reduction continue to highlight the extensive soft-tissue morbidity and structural demands associated with wide open surgical approaches.[1] Our progressive temporal analysis confirms that minimally invasive CC screw fixation provides an immediate, highly stable construct that successfully resists late-stage subsidence, specifically during the critical rehabilitation transition to full weight-bearing at 3 months. This clinical progression aligns with the protocol validated by Long et al, who established that a systematic, closed reduction paired with percutaneous screw configurations yields predictable and highly reproducible structural alignment in managing these complex injuries.[3]

The rigid biomechanical integrity of our crossing CC screw configuration is objectively validated by the minor deviation in radiological parameters observed over time. In our cohort, Böhler's angle deviated by less than 0.4° between the immediate postoperative phase and the 6-month clearance. This flawless structural maintenance strongly corroborates the findings of Tomesen et al, who reported excellent long-term preservation of calcaneal geometry and high functional outcomes without significant secondary loss of reduction when closed

reduction and percutaneous screw fixation are utilized.[5] Furthermore, the classic cadaveric study by Smerek et al. comparing percutaneous screw configuration versus perimeter plating demonstrates that optimized percutaneous screw configurations provide structural stiffness and construct stability completely comparable to perimeter plates under physiological loads, effectively validating why our constructs successfully resisted late-stage collapse.[4] This mechanical stability is further reinforced by Zhang et al, whose biomechanical analysis of minimally invasive crossing screw fixation explicitly supports the implications of this stability for early weight-bearing rehabilitation timelines.[7] This precise alignment and final screw architecture are clearly visualized in our radiographic assessments (Figure 2).

Beyond structural stability, the transition from extensile lateral approaches to percutaneous techniques yields undeniable perioperative and soft-tissue advantages. By positioning the patient in the lateral decubitus position and utilizing fluoroscopic lateral and axial views, a highly precise, low-impact surgical workspace is established (Figure 1). Utilizing the modified Essex-Lopresti maneuver alongside percutaneous Steinmann pin manipulation and large reduction clamps, the surgeon can entirely bypass extensive lateral soft-tissue stripping. This direct avoidance of soft-tissue disruption is the primary catalyst for avoiding devastating complications such as wound sloughing, flap necrosis, and deep-seated infections common to open plating. As rigorously documented by Schepers et al in their evaluation of percutaneous reduction and fixation, this technique drastically curtails overall wound complication rates.[2] Similarly, Shams et al concluded in their comparative work that percutaneous fixation using cannulated screws significantly reduces immediate perioperative morbidity, results in shorter operative times, and offers a superior alternative to open methods.[6]

From an institutional and patient-centric standpoint, this minimal baseline morbidity translates into shorter hospital stays, minimal complex wound care management, and an immensely cost-effective surgical pathway.[5,6] Crucially, the completely preserved extraosseous blood supply and uncompromised soft-tissue envelope enable an aggressive, highly structured rehabilitation protocol.[2,7] The ability to safely remove the immobilization slab and initiate active/active-assisted ankle range of motion (ROM) exercises as early as 1.5 months postoperatively prevents debilitating subtalar stiffness. While prolonged casting or extensive internal scarring from plating routinely results in permanent joint restrictions, our early mobilization protocol optimizes joint nutrition and accelerates functional recovery. When coupled with strict non-weight bearing until 3 months, this timeline provides an ideal mechanical environment for cancellous bone healing without compromising the achieved reduction.[3,4]

Finally, our subgroup analysis introduces a highly encouraging clinical directive: the severity of the initial preoperative structural collapse does not dictate a poorer postoperative prognosis or final clinical score. Patients presenting with severe articular depression (Böhler's angle ≤0° or Gissane's angle >150°) naturally required more strenuous, multi-planar percutaneous leverage and clamp compression maneuvers. However, these severely impacted subgroups ultimately arrived at 6-month structural and clinical endpoints indistinguishable from patients who initially presented with mild impaction. All cohorts neutralized at near-identical terminal pain scores (VAS ~0.25 to 0.50), confirming that percutaneous screw fixation can achieve robust, sustained restoration of complex calcaneal anatomy regardless of the initial fracture severity. These findings strongly reinforce the clinical protocols of Long et al, proving that a systematic, step-by-step percutaneous reduction is a highly reliable, reproducible, and definitive protocol for managing even the most severely displaced intra-articular calcaneal fractures.[3]

CONCLUSION

Minimally invasive CC screw fixation represents a formidable, reliable, and cost-effective option for the management of displaced intra-articular calcaneal fractures. Progressive longitudinal analysis proves that this method successfully withstands rehabilitative weight-bearing forces without late-stage structural collapse. By minimizing soft tissue disruption, the technique ensures fewer wound complications, shorter operative times, and facilitates early functional rehabilitation. Most importantly, severely impacted calcanei demonstrate exceptional responsiveness to percutaneous reduction, yielding final anatomical and clinical outcomes completely parallel to those of milder injuries.

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