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FUNCTIONAL AND RADIOLOGICAL OUTCOMES OF DISPLACED INTRA-ARTICULAR CALCANEAL FRACTURES MANAGED WITH LOCKING CALCANEAL PLATING WITH VERSUS WITHOUT BONE GRAFT: A PROSPECTIVE COMPARATIVE STUDY

Dr Nimish Manoj Mehta[1*], Dr Venkata Kiran Pillella[2], Dr Hemanth Raj D[3], Dr Madhukar[4], Dr Abraham M. Antony[5]

[1*]MS Orthopaedics, Junior Resident, Final Year, Department of Orthopaedics, Bharath University, Sree Balaji Medical College and Hospital, Chromepet, Chennai – 600044, Tamil Nadu, India. Department of Orthopaedics, Sree Balaji Medical College and Hospital 7, Works Road, Chromepet, Chennai – 600044, Tamil Nadu, India. Orcid Id : 0009-0002-2943-1974Email: mehtanimish15@gmail.com
[2]Associate professor, MS Orthopaedics, Department of Orthopaedics, Bharath University, Sree Balaji Medical College and Hospital, Chromepet,Chennai–600044, TamilNadu,India. OrcidId:0000-0003-0642-4990. Email: Vk0772145@gmail.com
[3]Assistant Professor, MS Orthopaedics, DNB Orthopaedics, Department of Orthopaedics, Bharath University, Sree Balaji Medical College and Hospital, Chromepet, Chennai – 600044, Tamil Nadu, India. Email: hemanthrajcmc86@gmail.com
[4]DNB Ortho, Professor & Unit Chief, Guide. Department of Orthopaedics, Bharath University, Sree Balaji Medical College and Hospital, Chromepet, Chennai – 600044, Tamil Nadu, India. Orcid Id : 0000-0002-0719-9679. Email: drmadhukarca@gmail.com
[5]MS Ortho, Senior Resident. Department of Orthopaedics, Bharath University , Sree Balaji Medical College and Hospital, Chromepet, Chennai 600044, Tamil Nadu, India. Orcid Id :0000-0001-9107-0538. Email: drabrahammantony@gmail.com
Corresponding Author: Dr Nimish Manoj Mehta[1]

ABSTRACT
Background: The role of bone grafting in conjunction with locking calcaneal plating for displaced intra-articular calcaneal fractures (DIACFs) remains contested. Modern locked implants provide improved angular stability, raising the question of whether routine bone grafting confers additional functional or radiological benefit. This study prospectively compared outcomes of calcaneal plating with versus without bone graft in Sanders Type II and III fractures.
Materials and Methods: Thirty patients with DIACFs managed operatively at a tertiary care teaching hospital between March 2024 and September 2025 were enrolled in this prospective comparative study. Group A (n = 15) underwent open reduction and internal fixation (ORIF) with locking calcaneal plating and iliac crest autograft bone graft; Group B (n = 15) underwent ORIF without bone graft. Functional outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score at 2 weeks, 2 months, and 6 months. Radiological parameters evaluated included Böhler's angle and Gissane's angle at each follow-up interval. Complications were documented throughout.
Results: Both groups demonstrated significant postoperative improvement in Böhler's angle (Group A: 7.8°4.2° to 30.6°3.8°; Group B: 8.1°3.9° to 29.8°4.1°) and correction of Gissane's angle, with no significant intergroup difference at immediate postoperative assessment ($p = 0.52$ and $p = 0.41$, respectively). At final follow-up, Böhler's angle maintenance was marginally superior in Group A (29.2°3.5° vs 27.4°4.3°; $p = 0.04$). Mean AOFAS scores at 6 months were 91.4 in Group A and 88.6 in Group B ($p > 0.05$). Mean operative time was longer in Group A (88.2 ± 4.2 min vs 84.6 ± 3.8 min; $p = 0.09$). Complication rates were comparable between groups.
Conclusion: Locking calcaneal plating yields satisfactory functional and radiological outcomes in DIACFs with or without bone grafting. Bone graft offers a marginal advantage in maintaining Böhler's angle in comminuted Sanders Type III fractures but does not confer a significant functional benefit overall. A selective, fracture-severity-guided approach to bone grafting is recommended over routine use.

KEYWORDS: Calcaneal fracture; intra-articular; locking plate; bone graft; AOFAS score; Böhler's angle; Sanders classification; ORIF

INTRODUCTION
Calcaneal fractures constitute approximately 1–2% of all skeletal fractures and nearly 60–75% of tarsal bone injuries, making them the most frequent fractures of the hindfoot [1,2]. They disproportionately affect young, economically productive males following high-energy axial loading — predominantly falls from height and road traffic accidents — and carry a substantial socioeconomic burden, particularly in developing nations where manual labour constitutes a major occupational category [3,4]. Intra-articular involvement, present in 70–75% of cases, disrupts the subtalar joint, predisposes to post-traumatic arthritis, and imposes significant long-term functional disability [5,6].
Open reduction and internal fixation (ORIF) using locking calcaneal plates via the extensile lateral approach has gained widespread acceptance, with evidence from landmark randomised trials demonstrating its superiority over conservative management in selected patient populations [7]. Restoration of Böhler's angle, Gissane's angle, and posterior facet congruity are the primary radiological objectives [8,9].

The adjunctive role of bone grafting during calcaneal plating, however, remains a subject of active debate. Historically, autologous bone graft was used to fill metaphyseal voids created after elevation of the depressed posterior facet, with the theoretical aim of preventing late articular collapse [10]. Advocates demonstrated improved maintenance of calcaneal height and Böhler's angle in grafted series [11,12]. Against this, proponents of graft-free fixation cite the mechanical sufficiency of modern locked implants, elimination of donor-site morbidity, reduced operative time, and the absence of a consistent functional advantage in graft-bearing groups [13,14]. Despite multiple comparative studies, no definitive consensus has emerged regarding the necessity of routine bone grafting in the era of locking plate technology.

This prospective comparative study was designed to evaluate and compare the functional and radiological outcomes of displaced intra-articular calcaneal fractures managed with locking calcaneal plating with versus without iliac crest autograft bone graft, to provide contemporary evidence to guide surgical decision-making.

MATERIALS AND METHODS

Study Design and Setting

This prospective, controlled, comparative study was conducted in the Department of Orthopaedics at a tertiary care teaching hospital. Institutional Ethics Committee approval was obtained prior to commencement of the study (IEC reference available on request), and all procedures conformed to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants in their preferred language.

Patients

Patients presenting with displaced intra-articular calcaneal fractures between March 2024 and September 2025 were screened for eligibility. Thirty patients meeting the inclusion criteria were enrolled and allocated into two groups of 15 each.

Inclusion criteria: Age ≥18 years; Sanders Type II or Type III closed calcaneal fractures on CT assessment; ambulatory prior to injury; medically fit for surgery; willing and able to comply with follow-up.

Exclusion criteria: Sanders Type I and Type IV fractures; extra-articular calcaneal fractures; open fractures (Gustilo–Anderson Type II and III); pathological fractures; associated ipsilateral long-bone fractures; chronic or active local infection; neurological deficit; patients medically unfit for general or spinal anaesthesia; loss to follow-up.

Group Allocation

Allocation to Group A (ORIF with iliac crest autograft bone graft, n = 15) or Group B (ORIF without bone graft, n = 15) was based on intraoperative assessment of the cancellous bone void following posterior facet elevation and reduction, in conjunction with fracture severity. All patients in Group A demonstrated a substantial residual void judged by the operating surgeon to require structural support; Group B fractures were assessed as adequately stabilised by the locking plate construct alone. No randomisation was performed.

Surgical Technique

All procedures were performed under spinal or general anaesthesia with the patient in the lateral decubitus position, operated limb uppermost, with a pneumatic tourniquet applied. The extensile lateral (L-shaped, hockey-stick) approach was employed uniformly. Following full-thickness fasciocutaneous flap elevation, the lateral wall, sinus tarsi, and posterior facet were exposed. Reduction was performed in a sequential manner: calcaneal height and length were restored first, followed by anatomical reduction of the posterior facet using the sustentaculum tali as a stable reference. Temporary Kirschner wire fixation was followed by definitive fixation with a locking calcaneal plate (AO-type locking calcaneal plate). In Group A, a cancellous autograft harvested from the ipsilateral iliac crest was packed into the residual metaphyseal void following articular reduction. Wound closure was performed in layers, and a below-knee backslab was applied.

Postoperative Protocol

Non-weight-bearing mobilisation was commenced at 48 hours postoperatively. Suture removal was performed at 2 weeks, and radiographic assessment was repeated. Partial weight-bearing was initiated at 8–10 weeks following evidence of radiological union. Full weight-bearing and structured physiotherapy, including active and active-assisted range-of-motion exercises for the wrist, ankle, and subtalar joints, were commenced at 10–12 weeks. Formal follow-up evaluations were conducted at 6 weeks, 3 months, and 6 months.

Outcome Measures

The primary functional outcome was the AOFAS hindfoot score (0–100), assessed at 2 weeks, 2 months, and 6 months postoperatively. Results were graded as excellent (90–100), good (75–89), fair (55–74), or poor (<55). Primary radiological outcomes were Böhler's angle and Gissane's angle, measured on standardised lateral radiographs preoperatively, immediately postoperatively, and at final follow-up. Secondary outcomes included time to radiological union, complication rates (wound dehiscence, superficial and deep infection, implant failure, malunion), and operative duration.

Statistical Analysis

Continuous variables are reported as mean ± standard deviation (SD). Intergroup comparisons for continuous variables were performed using the independent samples t-test. Categorical variables were analysed using the chi-squared test or

Fisher's exact test as appropriate. A p-value <0.05 was considered statistically significant. Analysis was performed using SPSS version 25.0.

RESULTS

Demographic Profile

The mean age of patients was 38.6 ± 8.4 years in Group A and 37.9 ± 7.9 years in Group B (p = 0.79). The age range was 22–55 years. Male predominance was noted in both groups (86.7% in each). Falls from height accounted for 80.0% of injuries in Group A and 73.3% in Group B, with road traffic accidents constituting the remainder. Right-sided fractures were slightly more common overall (56.7%). Groups were comparable with respect to Sanders classification distribution, comorbidities, nutritional status, and time to surgery (Table 1).

Table 1: Baseline demographic and operative characteristics of study groups. SD = standard deviation.

Parameter	Group A (n=15)	Group B (n=15)	p-value
Mean age (years)	38.6 ± 8.4	37.9 ± 7.9	0.79
Male sex	13 (86.7%)	13 (86.7%)	1.00
Fall from height	12 (80.0%)	11 (73.3%)	0.67
Right limb	9 (60.0%)	8 (53.3%)	0.72
Sanders Type II	9 (60.0%)	10 (66.7%)	0.71
Sanders Type III	6 (40.0%)	5 (33.3%)	0.71
Diabetes mellitus	3 (20.0%)	4 (26.7%)	0.67
Mean operative time (min)	88.2 ± 4.2	84.6 ± 3.8	0.09

Radiological Outcomes

Preoperative Böhler's angles were comparable between groups (Group A: 7.8 ± 4.2°; Group B: 8.1 ± 3.9°; p = 0.81). Both groups demonstrated significant postoperative restoration of Böhler's angle (Group A: 30.6 ± 3.8°; Group B: 29.8 ± 4.1°; p = 0.52). At final six-month follow-up, Group A maintained a marginally higher Böhler's angle than Group B (29.2 ± 3.5° vs 27.4 ± 4.3°; p = 0.04). Gissane's angle correction was comparable between groups at all time points, with no statistically significant intergroup difference (Table 2).

Table 2: Radiological outcomes. *Statistically significant (p < 0.05). SD = standard deviation.

Parameter	Group A (mean ±SD)	Group B (mean ±SD)	p-value
Böhler's angle — preoperative	7.8 ± 4.2°	8.1 ± 3.9°	0.81
Böhler's angle — immediate postoperative	30.6 ± 3.8°	29.8 ± 4.1°	0.52
Böhler's angle — 6 months	29.2 ± 3.5°	27.4 ± 4.3°	0.04*
Gissane's angle — preoperative	156 ± 10°	154 ± 9°	0.63
Gissane's angle — postoperative	132 ± 6°	134 ± 7°	0.41

Functional Outcomes

Mean AOFAS hindfoot scores improved progressively in both groups across all follow-up intervals. At 2 weeks, mean scores were 46.9 in Group A and 45.8 in Group B. At 2 months, mean scores were 84.3 and 82.7 respectively. At final 6-month follow-up, mean AOFAS scores were 91.4 in Group A and 88.6 in Group B; this difference was not statistically significant (p > 0.05). Excellent or good outcomes were recorded in 14 of 15 patients in Group A (93.3%) and 13 of 15 patients in Group B (86.7%) at 6 months (Table 3). Subgroup analysis demonstrated marginally superior AOFAS scores in Group A for Sanders Type III fractures (89.8 vs 86.2), while scores for Sanders Type II fractures were comparable between groups (92.1 vs 90.3).

Table 3: AOFAS hindfoot score outcomes at each follow-up interval. E/G = excellent or good result (≥75 points).

Follow-up	Group A mean	Group A (E/G)	Group B mean	Group B (E/G)
2 weeks	46.9	—	45.8	—
2 months	84.3	10/15 (67%)	82.7	8/15 (53%)
6 months	91.4	14/15 (93%)	88.6	13/15 (87%)

Time to Union and Complications

Mean time to radiological union was 13.4 ± 1.8 weeks in Group A and 14.6 ± 2.2 weeks in Group B; this difference was not statistically significant ($p = 0.09$). Complication profiles are detailed in Table 4. Wound-related complications occurred in 2 patients (13.3%) in Group A and 4 patients (26.7%) in Group B; this difference did not reach statistical significance. Deep infection occurred in one Group B patient, managed successfully with debridement and antibiotic therapy. One Group B patient developed implant failure requiring revision. No non-unions were recorded in either group. Donor-site morbidity in Group A was minimal and transient, comprising pain at the iliac crest harvest site resolving within 4–6 weeks in all patients.

Table 4: Complication profile by group. No statistically significant intergroup differences were identified.

Complication	Group A (n)	Group A (%)	Group B (n)	Group B (%)
Superficial wound infection	1	6.7%	2	13.3%
Deep infection	0	0%	1	6.7%
Wound dehiscence	1	6.7%	2	13.3%
Implant failure	0	0%	1	6.7%
Malunion	1	6.7%	2	13.3%
No complication	12	80.0%	7	46.7%

DISCUSSION

This prospective comparative study evaluated 30 patients with displaced intra-articular calcaneal fractures managed by ORIF with locking calcaneal plating, comparing outcomes between those receiving adjunctive iliac crest autograft bone graft and those treated without graft. The central finding is that both techniques yield satisfactory functional and radiological outcomes at six months. Bone grafting conferred a statistically significant but clinically modest advantage in Böhler's angle maintenance at final follow-up ($p = 0.04$), an advantage that was most apparent in Sanders Type III fractures, yet did not translate into a significant difference in AOFAS scores or time to union overall.

The demographic profile of our cohort reflects established epidemiological patterns. Calcaneal fractures disproportionately affect young males engaged in manual labour, with falls from height constituting the predominant mechanism [1,7]. Male predominance of 86.7% in our series aligns with published rates of 75–90% in large institutional series [3,15]. The bilateral comparability of our groups with respect to fracture severity, Sanders classification distribution, and comorbidity profile strengthens confidence in attributing observed differences to the intervention rather than baseline heterogeneity.

The finding that bone grafting preserves Böhler's angle more effectively at six-month follow-up is consistent with the mechanistic rationale for graft use. Following elevation of a depressed posterior facet, a cancellous void persists beneath the reduced articular surface; without structural support, this void is susceptible to late collapse under physiological loading. Poeze et al. demonstrated improved calcaneal height maintenance in grafted cases and linked this to better functional scores at medium-term follow-up [12]. Stephenson similarly reported structural benefits of autograft in comminuted fractures [11]. Our finding of a statistically significant Böhler's angle difference at six months but not at the immediate postoperative interval suggests that graft primarily prevents late subsidence rather than facilitating initial reduction — a distinction with practical surgical relevance.

Against this, Schepers et al. reported no significant functional difference between grafted and non-grafted locking-plate cohorts, a finding replicated in recent meta-analyses that collectively found no consistent functional advantage of routine bone grafting in the era of angular-stable fixation [13,14]. Our AOFAS score data corroborate this: the between-group difference at six months (91.4 vs 88.6) did not reach statistical significance, and excellent or good outcomes were achieved in the large majority of both groups. This raises the clinically important question of whether Böhler's angle maintenance, while radiologically measurable, is the primary determinant of patient-reported function in this context.

Sanders Type III fractures constitute the subgroup in which bone grafting appeared most advantageous in our series, corroborating the hypothesis that the benefit of graft is proportional to the degree of comminution and the size of the residual metaphyseal void. In Type II fractures, where the void after reduction is smaller and the locking plate construct achieves adequate biomechanical support, graft-free fixation produced outcomes indistinguishable from the graft group. This supports a selective approach: graft usage guided by intraoperative assessment of void size and fracture severity, rather than routine application to all DIACFs.

Wound complications represented the most clinically significant perioperative risk in both groups, consistent with the extensive literature documenting the vulnerability of the lateral calcaneal soft tissue envelope [16,17]. Our complication rates were comparable between groups, though numerically higher in Group B; this difference may reflect the greater proportion of wound-related complications when structural void support is absent and subtle late settling occurs. However, the absence of statistical significance limits firm conclusions. The single deep infection and implant failure, both in Group B, may suggest a relationship between void instability and hardware stress, but again our sample size precludes definitive inference.

Operative time was slightly longer in Group A by a mean of 3.6 minutes (88.2 vs 84.6 min; $p = 0.09$), a difference unlikely to carry clinical significance for otherwise healthy patients but potentially relevant in those with systemic comorbidities. Donor-site morbidity, a recognised concern with iliac crest harvest, was self-limiting in all Group A patients. These practical factors further support a selective rather than universal approach to bone grafting.

Limitations: This study is limited by its small sample size, single-centre design, non-randomised allocation, and relatively short follow-up of six months. A larger randomised trial with longer follow-up, incorporating patient-reported outcomes and assessment of subtalar arthritis on CT, would provide more definitive evidence. Generalisation to Sanders Type IV fractures, excluded from this study, should not be attempted.

CONCLUSION

Locking calcaneal plating with open reduction and internal fixation yields satisfactory functional and radiological outcomes in displaced intra-articular calcaneal fractures, with or without bone grafting. Bone grafting demonstrates a statistically significant but modest advantage in Böhler's angle maintenance at six months, most apparent in Sanders Type III fractures with substantial metaphyseal voids, without a corresponding significant difference in AOFAS functional scores. Routine bone grafting is not supported for all intra-articular calcaneal fractures managed with modern locking plate technology. A selective, intraoperative-assessment-driven approach — reserving graft use for comminuted fractures with large residual cancellous voids and compromised bone quality — is recommended to optimise outcomes while minimising operative time and donor-site morbidity.

Declarations

Ethics Approval: This study was approved by the Institutional Ethics Committee. All procedures were conducted in accordance with the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all patients prior to enrolment.

Conflict of Interest: The authors declare no conflict of interest.

Sources of Support: Nil. No external funding was received.

Figure Legends

Figure 1: Preoperative lateral radiograph demonstrating a displaced intra-articular calcaneal fracture with severely reduced Böhler's angle and posterior facet depression (Group A, representative case).

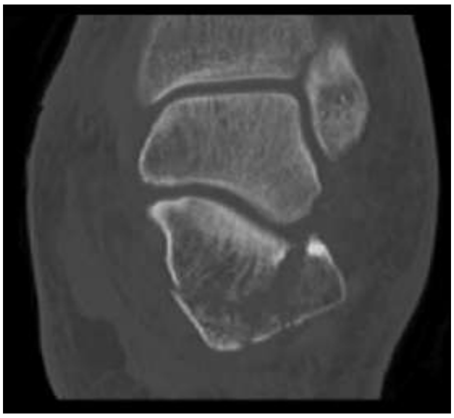

Figure 2: Coronal CT scan demonstrating Sanders Type III fracture with comminution of the posterior facet and associated lateral wall blowout.

Figure 3: Immediate postoperative lateral radiograph following ORIF with locking calcaneal plate and iliac crest bone graft (Group A), demonstrating restoration of Böhler's angle to 30° and anatomical reduction of the posterior facet.

Figure 4: Postoperative lateral radiograph following ORIF with locking calcaneal plate without bone graft (Group B), demonstrating comparable restoration of calcaneal morphology.

Figure 5: Six-month follow-up lateral radiographs comparing Böhler's angle maintenance in representative Group A (above) and Group B (below) cases, demonstrating marginal loss of correction in the non-graft group.

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