Original Article

The Impact of De-Roofing of Lateral Calcaneal wall in Open Reduction and Internal Fixation of Intra-Articular Fractures: Clinico-Radiological Outcomes of a Novel Technique and Review of Literature

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Abstract

Background: Most displaced intra-articular calcaneus fractures need to be treated surgically but postoperative soft tissue complications limit to achieve of optimal functional outcomes. Certain mini-invasive techniques lead to better soft tissue healing but anatomical reduction gets compromised. **Objectives:** We aim to evaluate the results of lateral wall de-roofing of the calcaneum to achieve good anatomical reduction as well as to minimise soft tissue complications in the internal fixation of calcaneal fractures. **Materials and Methods:** Thirty-two patients (40 ft) with displaced intra-articular calcaneus fractures (10 were of Sanders type II, 16 were of type III, and 14 were of type IV) were treated between January 2018 and September 2021. All patients were managed surgically with open reduction and internal fixation using lateral extensile approach combined with de-roofing of the lateral wall. All patients were followed up for ≥1 year using functional parameters American Orthopaedic Foot and Ankle Score (AOFAS), visual analogue scale (VAS) and radiological parameters (Bohler angle, Gissane angle, height of the calcaneus, width of the calcaneus and pitch of calcaneus). **Results:** Out of 32 patients, one patient lost to follow-up. At 1 year follow-up, mean AOFAS hindfoot score was 86.2 ± 5 (Sanders type II: 91.2, Sanders type III: 87.6, and Sanders type III: 81.4), mean VAS score was 91.3 ± 2.1, mean Bohler angle (°) was 27.2 ± 4.7, mean Gissane angle (°) was 136.4 ± 5.2, mean calcaneus height was 46.2 ± 2.1 mm and mean calcaneus width was 45.1 ± 3.2 mm. Patients with decreased Bohler angle between postoperative images and follow-up had lower AOFAS hindfoot scores. Complications included persistent swelling (64.10%), stiffness (33.33%), superficial infections (5.12%), and wound dehiscence (10.25%). **Conclusion:** Lateral wall de-roofing is a useful technique which allows the lateral wall to get flattened reducing soft tissue complications and providing bone graft as well. This approach also adequately exposes fracture fragments, subtalar and calcaneocuboid joints for good anatomical reduction. Hence, it can act as a useful adjunct in the internal fixation of intra-articular calcaneus fractures. **Level of Evidence:** III

Keywords: *AOFAS, Bohler angle, calcaneus fracture, lateral wall de-roofing, Sanders classification*

Introduction

Calcaneus fractures display a wide range of injury patterns with about 80% being intra-articular. Most displaced, intra-articular calcaneus fractures need anatomical reduction and internal fixation, approaches to which have been included in advanced traumatology owing to the complexity of the fracture morphology. A major proportion of calcaneus fractures result from axial impact inflicting a substantial number of young male industrial workers thus having a considerable socio-economic impact.[1]

Earlier, calcaneus fractures were being managed conservatively because of a lack of internal fixation techniques, meagre understanding of complex three-dimensional anatomy of bone, hind foot kinematics, and soft tissue handling.[2,3] However, the sequelae of non-operatively treated depressed calcaneus fractures were well-known and include mal-union, subtalar arthritis, tibiotalar impingement, non-union, and sub-fibular impingement.[4,5]

Computed axial tomography (CT) has played a vital role in to preferred surgical interventions to avoid these complications.[6] Sanders classification system was used for the classification of calcaneus fractures which was based on the CT scan findings.[7,8] This classification system had four types of

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fracture patterns which depend on the fracture line passing through the posterior facet.[9]

Currently, open reduction and internal fixation (ORIF) is considered the standard treatment of displaced intra-articular fractures of the calcaneus for restoration of calcaneus morphology and anatomic reduction of the articular surface as it improves pain, function, satisfaction, and decreases the radiographic evidence of sub-talar arthritis.[10,11] But calcaneus fractures require high skills for surgical intervention and it has a steep learning curve.[12,13]

There are various surgical approaches for ORIF but postoperative complications like wound infections, skin flap necrosis and wound dehiscence are common with these procedures.

This study aimed to evaluate the functional and radiological outcomes of calcaneus fractures after ORIF combined with de-roofing of the lateral wall as bulging of the lateral wall has a role in certain complications (like soft tissue impingement, wound complications, and sub-fibular impingement) and this approach allows excellent visualisation of the fracture and direct articular reduction.

Patients and Methods

This study is a prospective observational type of study conducted between January 2018 and September 2021 in a tertiary care trauma and Orthopaedic centre. Thirty-two patients were included in this study of which 28 were males and 4 were females.

Inclusion criteria

Patients aged more than 18 years including males or females (non-pregnant) with calcaneus fractures which include displaced intra-articular calcaneus fractures (articular facet step-off of >2 mm) managed with ORIF between January 2018 and September 2021.

Exclusion criteria

Un-displaced (articular facet step-off of <2 mm) or extra-articular calcaneus fractures.

Open and Pathological calcaneus fractures.

Patients who have diabetes, bleeding disorder or peripheral vascular disease.

Pre-operative planning

Appropriate informed and written consent was taken before enrolment within the study. Patients were evaluated for associated injuries and lateral and axial radiographic views of the calcaneus were obtained [Figure 1]. CT scan with three-dimensional reconstruction were also performed to assess the small print of articular depression [Figure 2]. After the injury, below knee slab was applied and the limb was kept elevated using pillows. The decision to the surgery (ORIF) was made once the swelling had subsided and the wrinkling of the skin (wrinkle sign) was observed by the senior most surgeon.[14]

Surgical technique

Skin incision and exposure

All procedures were performed by the same surgical unit. The patient's position was lateral decubitus with a flexed knee and pillow between two knees on OT table after spinal anaesthesia. Following the exsanguination of the limb, an inflatable tourniquet was used keeping the pressure around 100 mm Hg above the systolic blood pressure of the patient. The skin incision was made in an L-shape manner in which a vertical incision was made at the posterior one-third distance between the posterior aspect of the fibula and the anterior margin of the Achilles tendon. Then, a curved angle, about 90–100, was used to avoid potential flap necrosis as a sharp angle would increase the ischaemia risk of lateral flap edge at the corner, resulting in flap necrosis. The horizontal limb was placed in line of the fifth metatarsal and both limbs meet just under lateral malleoli at the junction of skin and heel [Figure 3a]. And sural nerve was dissected along the vertical limb to prevent its injury. Then sub-periosteal full-thickness skip flap was lifted and it's an important step to avoid flap necrosis [Figure 3b]. Then two to four 2 mm Kirschner wires were placed into the fibula,

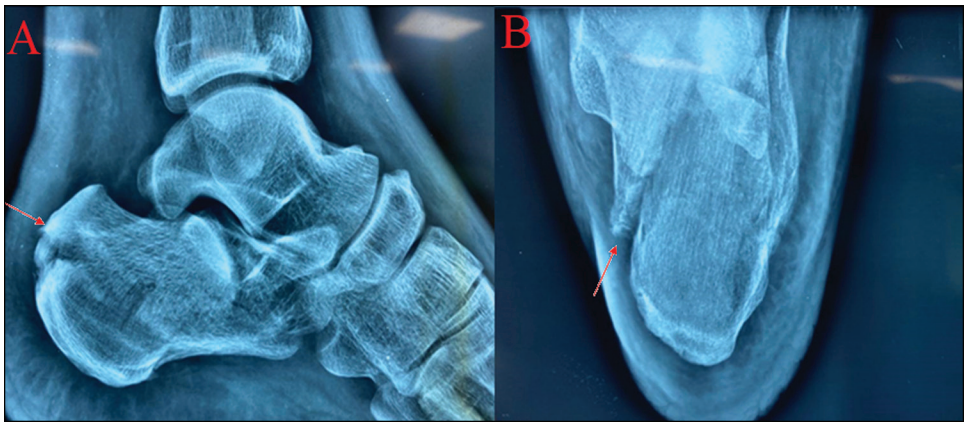

Figure 1: Lateral and axial radiographic views of heel depicting calacaneal fracture

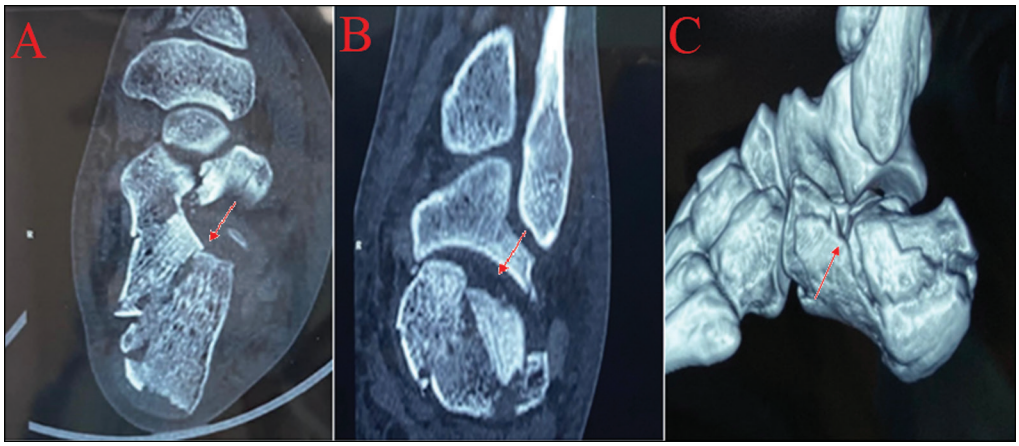

Figure 2: CT-Scans of heel with three-dimension reconstruction depicting detailed fracture morphology

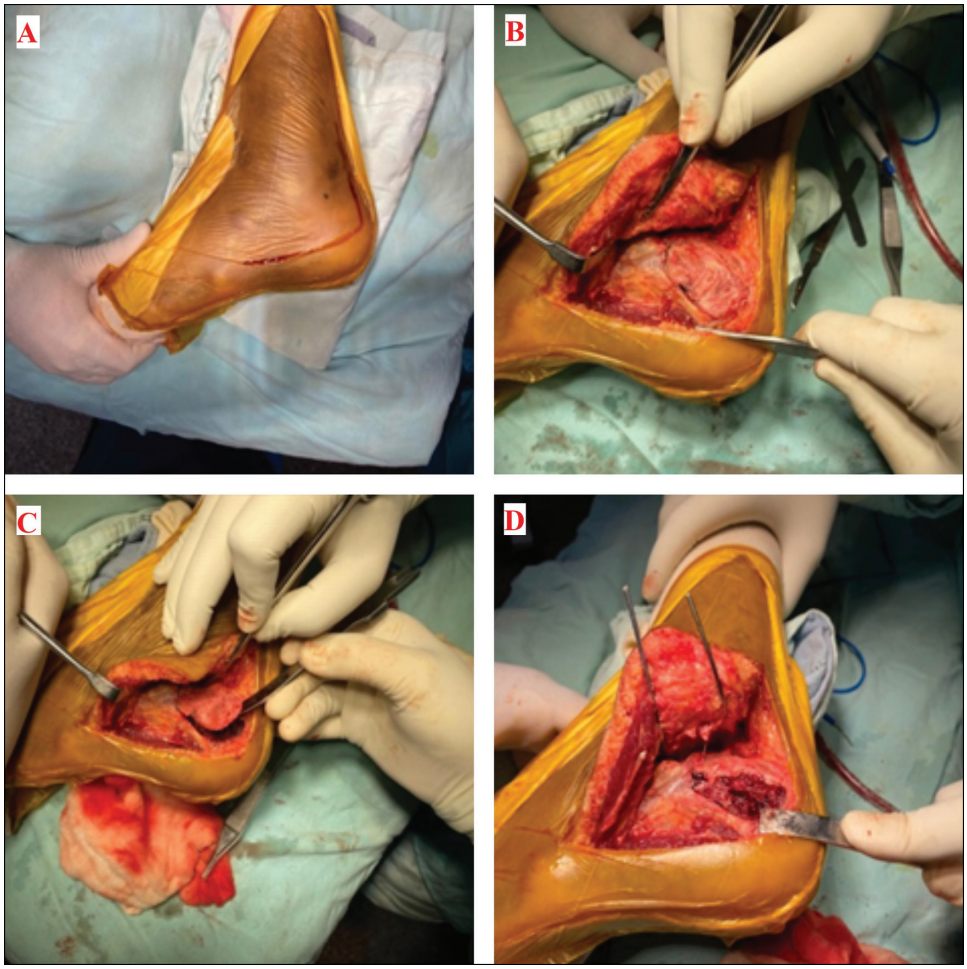

Figure 3: Surgical exposure showing: (a) extensile lateral incision, (b) raising the full-thickness flap, (c) elevation of the lateral wall, (d) de-roofing of the wall with periosteal elevator

neck of the talus, and cuboid to reveal the lateral wall of the calcaneus and full exposure of the talo-calcaneus joint.

Lateral wall de-roofing and fixation

After adequate exposure to fracture, the lateral wall of the calcaneus was lifted [Figure 3c and d]. De-roofing of the lateral wall was done using a small bone nibbler and the curved osteotome and the cancellous part of the lateral wall were preserved for bone grafting [Figure 4a]. Schanz pin was used for correction of varus and lateral translation. The articular surface and sub-talar joint were fully visualised by inverting the foot in traction and a lamina spreader was used for elevation of the thalamic fragment to reduce the fracture. Then reduced fracture was held by multiple K-wires through

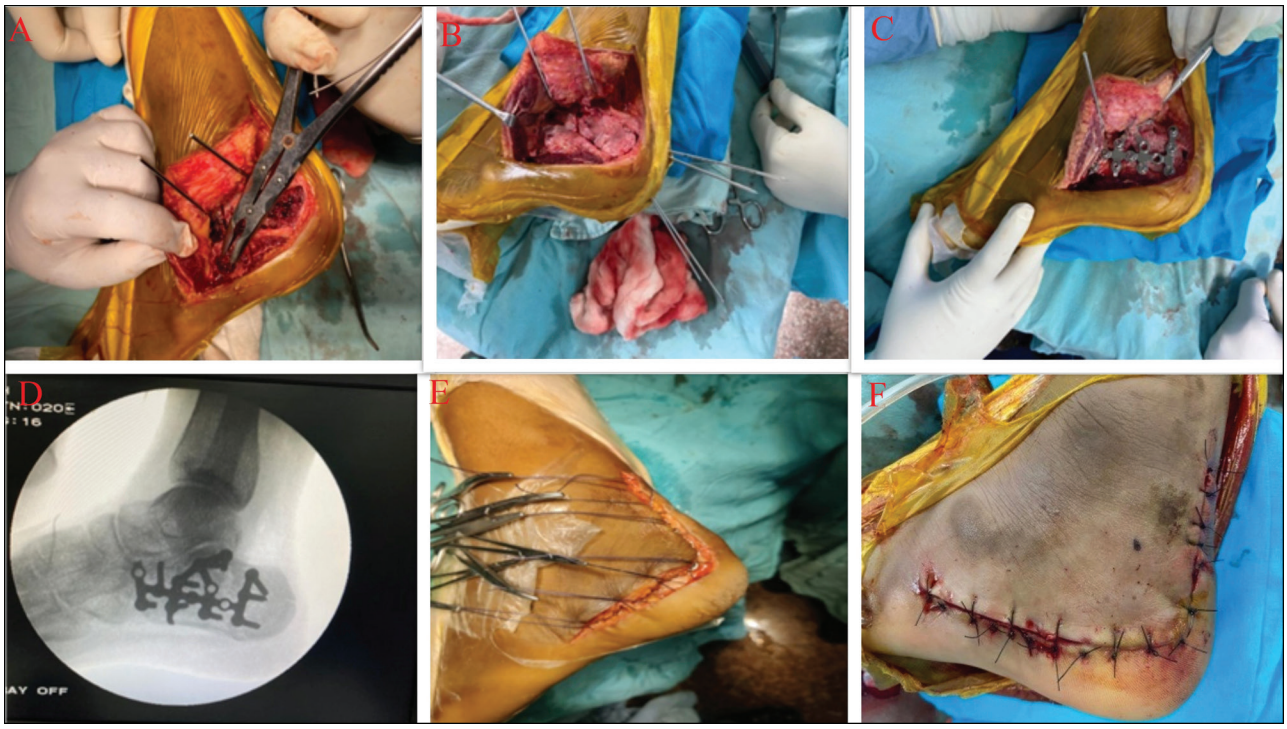

Figure 4: Reduction and internal fixation of the calacaneal fracture. (a) de-roofing of lateral wall completed with bone nibbler, (b) provisional internal fixation with K-wires after confirmation of reduction, (c) definitive fixation with locking plate, (d) intraoperative radiograph showing satisfactory fracture reduction with restoration of radiographic parameters, (e and f) closure with Allgower–Donati sutures

tuberosity, thalamic fragment and talus [Figure 4b]. Bohler angle, Gissane angle, and physiological valgus were assessed under image intensifier using lateral view and axial view. After reduction, the cancellous part of the lateral wall was used as a bone graft and then lateral wall was placed over its previous site. Then appropriate size of the calcaneus plate was chosen and applied on flattened lateral calcaneus from anterior process to tuberosity of the calcaneus and held with screws maintaining in physiological valgus during implant fixation [Figure 4c]. K-wires were removed. Intra-operative radiographs were taken after the fixation of the calcaneus plate to assess the anatomical restoration of radiological parameters [Figure 4d]. Haemostasis was achieved and a small size drain was placed *in situ*. The wound was closed in layers with inner absorbable and outer non-absorbable Allgower–Donati sutures [Figure 4e and f]. Below knee posterior slab was applied and the limb was kept elevated over pillows.

Postoperative management

In the postoperative follow-up drain was removed on 3rd day of operation, and stitch removal was on the third week of the operation. On the fourth week of surgery, patients were allowed for a limited range of motion (mobilisation of ankle and sub-talar joint) without weight bearing. Partial weight bearing was started after 6 weeks and full weight bearing (as tolerated) after the 12th week of operation if the fracture remains reduced and stable radio-logically without any complaints of pain, swelling or tenderness at the fracture site.

Outcome measurement

Clinical and radiologic assessments were performed immediately after surgery, at 3 and 6 months postoperatively, and at regular follow-up visits every 6 months using functional parameters consisting American Orthopaedic Foot and Ankle Score (AOFAS) and visual analogue scale (VAS) and radiological parameters (Bohler angle, Gissane angle, height of the calcaneus and width of the calcaneus). These scores range is 0–100 and 100 is the best score.

Results

As depicted in Table 1, out of a total of 32 patients, 31 patients (39 ft) were available for final follow-up and analysis. The majority of the patients (23 cases, 75%) presented with unilateral involvement and eight patients were with bilateral calcaneus fractures. Out of 23, the right foot was involved in 17 patients and the left was in six patients and 27 were males while four were females. Out of a total of 39 fractures, nine were Sanders type II, 16 were Sanders type III, and 14 belonged to Sanders type IV.

The predominant mode of injury was fall from height (in 25 patients) while road traffic accident was the cause in the rest six cases. Six patients had associated injuries other than calcaneus fractures-three had spine injuries, two had tibial plafond injuries and one had tibial plateau injuries

Table 1: Patient's Demographics

Total 39 feet (31 patients)	23 Unilateral (17 Right/ 6 Left)	8 Bilateral
Gender	27 males	4 females
Sander's Type	Type II- 9, Type III-16, Type III- 14	
Mode of Injury	Fall from Height-25	Road traffic accident-6
Associated Injuries (n=6)	SpineFracture-3, Tibial Plafond-2, Tibial Plateau-1	

Table 2: Correlation of Boehler angle (pre-operative, immediate post-op and at one year follow-up) and AOFAS score

No. of patients	Pre-op Boehler's angle	Immediate post-op Boehler's angle	one year follow-up Boehler's angle	AOFAS score at one year follow up
1	18.4	35.7	34.2	93
2	0.6	24.2	20.4	83
3	10.2	31.4	30.4	92
4	9.6	29.4	29.4	88
5	13.4	36.2	35.2	95
6	1.2	26.7	21.6	81
7	0.3	25.8	20.6	83
8	11.5	36.8	35.8	94
9	5.7	28.2	24.6	81
10	2.0	26.9	22.2	82
11	15.4	32.4	30.4	87
12	12.8	28.6	27.4	84
13	0.7	26.4	22.6	85
14	1.1	25.2	20.4	83
15	10.6	32.6	30.6	90
16	1.2	25.4	21.4	88
17	1.0	27.4	22.2	83
18	8.2	31.6	30.2	92
19	1.3	28.2	23.9	85
20	0.6	26.8	21.6	82
21	9.5	31.1	28.9	86
22	1.7	29.6	27.2	84
23	14.7	34.6	30.6	91

[Table 1]. These patients underwent additional surgery for their respective injuries. All patients were operated within 2 weeks of injury once a positive wrinkle sign appeared and the average operating time was 82 min. All patients were followed for 1 year and the functional and radiological outcomes were recorded.

The postoperative Bohler angle improved in all subgroups, as shown in Table 2. The subgroups of Sanders type IV fractures showed a tendency to decrease in Bohler angle between the immediate postoperative and the follow-up radiographs. Patients with worse Bohler angles had inferior AOFAS hindfoot scores [Table 2].

At 1-year postoperative follow-up, mean AOFAS hindfoot score was 86.2 ± 5 and mean VAS score was 91.3 ± 2.1. And mean Bohler angle (°) was 27.2 ± 4.7, mean Gissane angle (°) was 136.4 ± 5.2, mean calcaneus height (mm) was 46.2 ± 2.1 and mean calcaneus width (mm) was 45.1 ± 3.2. All types II and III were anatomically reduced and 10 out of 14 in type IV (71.42%) were anatomically reduced. Type IV had the worst AOFAS score [Table 3].

The mean time to return to work was 5.6 months (range 2–18 months). Five patients changed their former occupations and two were unable to return to any occupation for 1 year. Table 4 depicts the time to return to work depending on the pre-accident degree of manual labour.

Superficial infection was seen in two patients (5.12%), which was managed by regular dressings and did not require additional surgical procedures or prolonged antibiotic administration. No patient was reported with deep infection, sural nerve symptoms or any impingement symptoms. No patient had required implant removal, flap reconstruction or sub-talar arthrodesis in this follow-up period. Patients had complaints of persistent swelling (25/39 ft, 64.10%), stiffness (13/39 ft, 33.33%), and wound dehiscence (4/39 ft, 10.25%).

All feet were examined for tenderness, and 24 patients (77.4%) were painless. Heel width was also examined and

compared with normal limb and there were differences of less than 0.5 cm difference in 29 patients and more than 0.5 cm in two patients. These two patients were of Sanders type IV and had to change their shoe sizes.

Discussion

Intra-articular calcaneus fractures are serious injuries which cause disabilities and deformities if not addressed precisely. Surgical management of these fractures requires meticulous surgical planning and technique. Not infrequently, postoperative soft tissue complications were seen with surgical management. Different types of techniques have been described to reduce these complications.

Yeo *et al.*[15] Showed in a study with 60 patients of intra-articular calcaneus fractures operated with lateral extensile approach had good functional and radiological outcomes as AOFAS ranges from 76 to 94 and VAS ranges from 1 to 5. But out of them, 8 patients (13.3%) had wound healing complications, 4 (6.6%) patients had complained of sural nerve symptoms and one case of peroneal tendinitis was observed. Five patients had complained of subtalar stiffness. Because of the said complications, many surgeons have tried alternative techniques to minimise these complications.

Table 3: AOFAS hind foot score

Sander's classification	No. of Feet	Mean AOFAS Score
I	0	0
II	9	91.2
III	16	87.6
IV	14	81.4

Schindler *et al.*[16] did a retrospective study in 2021 where 114 patients with intra-articular calcaneus fractures were operated on with different surgical techniques, the majority of these (102 patients) by ORIF via extensile lateral approach and others by percutaneous K-wires, External fixators, screw fixation and primary subtalar fusion. The overall complication rate was 29% (37/129 ft). Troubled wound healing (11%) and infection (5%) were among the most frequent complications. Non-union (4%) was seen in smokers. Mean AOFAS-hind score was 74 (Sanders type I: 99, Sanders type II: 74, Sanders type III: 77, and Sanders type IV: 70). Patients with a decreased Bohler angle between postoperative images and follow-up had lower AOFAS hindfoot scores.

Another technique was the sinus tarsi approach, used by Meng *et al.*[17] for intra-articular fractures which uses a small incision compared to the lateral extensile approach. The authors concluded that there were fewer complications but the anatomical reduction was compromised in Sanders type III and IV fractures. Hence, the Sinus Tarsi approach may be more appropriate for Sanders type IIA and IIB fractures.

In this study, we noticed that the postoperative Bohler angle was a strong independent predictor for the AOFAS hindfoot score at the time of follow-up. additionally, we could validate that a decrease in the Bohler angle between the postoperative and follow-up X-rays, indicating a loss of reduction, is associated with worse outcomes which was also seen in several studies.[18-20]

This study aimed to minimise soft tissue complications and achieve good anatomical reduction. The lateral calcaneus artery has an important role to supply skin flaps around

Table 4: Return to work depending on pre-injury degree of manual labour and Sander's classification

Degree of physical work	Sander's type	No. of patients	Return to previous job	Job changed	Mean time for return to job (months)	Return to any job
Light	I	0	0	0		
	II	2	2	0	2.5 (2 to 3)	2
	III	4	4	0	3.7 (2 to 5)	4
	IV	2	2	0	4.5 (4 to 5)	2
	Total	8	8	0		8
Moderate	I	0	0	0		
	II	1	1	0	3.5	1
	III	5	5	0	6.1 (3 to 15)	5
	IV	3	2	1	5.6 (4 to 7)	3
	Total	9	8	1		9
Heavy	I	0	0	0		
	II	1	1	0	3	1
	III	1	0	1	9	1
	IV	4	2	1	6	3
	Total	6	3	2		5
Bilateral involved patients						
Light activity		1	1	0	3.5	1
Moderate activity		4	3	1	6.8 (4 to 10)	4
Heavy activity		3	1	1	11.5 (5 to 18)	2
	Total	8	5	2		7

the surgical site area.[21] Hence, a vertical incision was taken at the posterior one-third distance between the posterior border of the lateral malleolus and the lateral border of the Achilles tendon to avoid damage to the lateral calcaneus artery.[22,23] The sural nerve is dissected along the vertical limb of the L-shape incision to avoid sural nerve injury.

This technique provides adequate exposure of fracture fragments for reduction as all Sanders type II and type III were anatomically reduced and 10 out of 14 in Sanders type IV were completely reduced. Type IV fractures occur due to high-energy trauma which was most difficult to handle and these types of fractures had the worst outcome as compared to type II and type III in this study, Sanders type IV had the least mean AOFAS score and mean time for return to their job was also more in Sanders type IV. Two patients who had type IV fractures had to change their shoe size as well.

After 1 year of follow-up, outcomes were good in term of radiological and clinical parameters (AOFAS and VAS score) and less complications as compared to previous studies.[15,16] Lateral wall of calcaneus has an important role in fixation as plate is applied on this surface. Lateral wall bulged out after injury and it causes stretching of soft tissue and tension on suture line even after fixation. In this study, we did relative flattening of lateral wall by de-roofing of cancellous part of lateral wall that may facilitate locking plate to contour accurately, reduces tension on suture line, prevents peroneal tendon and fibular impingement, wound dehiscence and flap necrosis complications.

In addition, the cancellous bone of lateral wall was used as a bone graft to fill small voids which enhances bony union and reduces the donor site morbidity which occurs iliac crest or any other site is used as donor. Henceforth, we could conclude that the lateral wall de-roofing is a useful, safe and effective adjunct to the lateral extensile approach which aids in anatomical reduction, minimises soft tissue complications and provides a potential bone graft without increasing other complications in internal fixation of intra-articular fractures of the calcaneum.

The advantage of this study is adequate exposure of fractured fragments, sub-talar joint and calcaneocuboid joint, primary wound healing tendency and reduced morbidity.

This study's limitation was the small sample size and short-term follow-up. Therefore, the study findings need to be validated using a large sample size and long-term follow-up.

Declaration of patient Consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Availability of data and material

The authors declare no conflict regarding the data transparency.

Authors' contributions

Mohit Bansal and Kishore Raichandani conceptualised and designed the study; Amit Singh, Nirottam Singh, Mukesh Kumar Saini and Nirottam Singh participated in the acquisition, analysis, and interpretation of the data, and drafted the initial manuscript; Mukesh Kumar Saini and Mohit Bansal revised the article critically for important intellectual content.

Ethics approval

Ethical approval was obtained from Institutional review board for this study.

Consent to participate

Written informed consent was signed by all participants in this study.

Consent for publication

Relevant written informed consent was signed by all participants for publication.

References

1. Sanders, R., Rammelt, S. Fractures of the calcaneus. In: M. j. Coughlin, C. R. Saltzman, j. B. Anderson, editors. Mann's Surgery of the Foot & Ankle, 9th ed. St. Louis: Elsevier, 2013. p. 2041–2100.
2. Crosby LA, Fitzgibbons T. Intraarticular calcaneus fractures, results of closed treatment. Clin Orthop Relat Res 1993;290:47-54.
3. Kitaoka HB, Schaap EJ, Chao E, An KN. Displaced intra-articular fractures of the calcaneus treated non-operatively clinical results and analysis of motion and ground-reaction and temporal forces. J Bone Joint Surg Am 1994;76:1531-40.
4. Banerjee R, Saltzman C, Anderson RB, Nickisch F. Management of calcaneus malunion. J Am Acad Orthop Surg 2011;19:27-36.
5. Clare MP, Lee WE, Sanders RW. Intermediate to long-term results of a treatment protocol for calcaneus fracture mal-unions. J Bone Joint Surg Am 2005;87:963-73.
6. Matherne TH, Tivorsak T, Monu JU. calcaneus fractures: What the surgeon needs to know. Curr Probl Diagn Radiol 2007;36:1-10.
7. Badillo K, Pacheco JA, Padua SO, Gomez AA, Colon E, Vidal JA. Multidetector CT evaluation of calcaneus fractures. Radiographics 2011;31:81-92.
8. Piovesana LG, Lopes HC, Pacca DM, Ninomiya AF, Dinato MC, Pagnano RG. Assessment of reproducibility of sanders

classification for calcaneus fractures. Acta Ortop Bras 2016;24: 90-3.
9. Ohashi K, Sanghvi T, El-Khoury GY, Ahn JM, Bennett DL, Geijer M, *et al*. Diagnostic accuracy of 3D color volume-rendered CT images for peroneal tendon dislocation in patients with acute calcaneus fractures. Acta Radiol 2015;56:190-5.
10. Agren PH, Wretenberg P, Sayed-Noor AS. Operative versus nonoperative treatment of displaced intra-articular calcaneus fractures: A prospective, randomized, controlled multicentre trial. J Bone Joint Surg Am 2013;95:1351-7.
11. Buckley R, Tough S, McCormack R, Pate G, Leighton R, Petrie D, *et al*. Operative compared with nonoperative treatment of displaced intra-articular calcaneus fractures: A prospective, randomized, controlled multicenter trial. J Bone Joint Surg Am 2002;84:1733-44.
12. Poeze M, Verbruggen JP, Brink PR. The relationship between the outcome of operatively treated calcaneus fractures and institutional fracture load. A systematic review of the literature. J. Bon Joint Surg Am 2008;90:1013-21.
13. Sanders R, Fortin P, Dipasquale T, Walling A. Operative treatment in 120 displaced intraarticular calcaneus fractures results using a prognostic computed tomography scan classification. Clin Orthop Relat Res 1993;290:87-95.
14. Sanders R. Intra-articular fractures of the calcaneus: Present state of the art. J Orthop Trauma 1992;6:252-65.
15. Yeo JH, Cho HJ, Lee KB. Comparison of two surgical approaches for displaced intra-articular calcaneus fractures: Sinus tarsi versus extensile lateral approach. BMC Musculoskelet Disord 2015;16:63.
16. Schindler C, Schirm A, Zdravkovic V, Potocnik P, Jost B, Toepfer A. Outcome of intra-articular calcaneus fracture: Surgical treatment of 114 consecutive cases at a maximum care trauma center. BMC Musculoskelet Disord 2021;22: 234.
17. Meng Q, Wang Q, Wu X, Peng A, Yan J. Clinical application of the sinus tarsi approach in the treatment of intra-articular calcaneus fracture. Medicine (Baltimore) 2018;97:13.
18. Rammelt S, Zwipp H. Calcaneus fracture: Facts, controversies and recent developments. Injury 2004;35:443-61.
19. Su Y, Chen W, Zhang T, Wu X, Wu Z, Zhang Y. Boehler's angle's role in assessing the injury severity and functional outcome of internal fixation for displaced intra-articular fractures: A retrospective study. BMC Surg 2013;13:40.
20. Basile A. Operative versus non-operative treatment of displaced intra-articular calcaneus fractures in elderly patients. J Foot Ankle Surg 2010;49:25-32.
21. Kwon JY, Gonzalez T, Riedel MD, Nazarian A, Ghorbanhoseini M. Proximity of the lateral calcaneus artery with a modified extensile lateral approach compared to standard extensile approach. Foot Ankle Int 2017;38:318-23.
22. Geddes C, Tang M, Yang D, Morris S. Anatomy of integument of lower extremity. In: Blondeel PNMS, Hallock GG, Neligen PC, editors. Perforator Flaps. St. Louis: Quality medical publishing; 2013. p. 694-7.
23. Elsaidy MA, El-Shafey K. The lateral calcaneus artery: Anatomic basis for planning safe surgical approaches. Clin Anat 2009;22:834-9.