Functional outcomes of primary subtalar arthrodesis versus nonoperative treatment followed by late calcaneoplasty and subtalar arthrodesis in sanders type IV calcaneal fractures, a prospective cohort study

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Received: 17-Jun-2023
Revised: 02-Jul-2023
Accepted: 04-Jul-2023
Published: 08-Mar-2025

The Egyptian Orthopaedic Journal 2024, 59:605–611

Background
Primary subtalar arthrodesis (STA) or nonoperative treatment followed by late STA are both valid options in treating Sanders IV calcaneal fractures with no studies comparing them.
Methods
34 patients with Sanders IV calcaneal fractures were included. 17 patients were managed by open reduction and primary STA, while the others had late calcaneoplasty and STA. Outcomes were measured by American Orthopaedic Foot and Ankle Society's Ankle-Hindfoot scale (AOFAS-AHS) and Foot and Ankle Ability Measure - Activities of Daily Living (FAAM-ADL). We also documented time to return to work (RTW), union rate, wound complications and second surgeries.
Results
29 patients were followed for at least two years. At final follow-up, the mean American Orthopaedic Foot and Ankle Society's Ankle-Hindfoot scale and Foot and Ankle Ability Measure - Activities of Daily Living were slightly better in primary STA. The time to return to work was significantly shorter in primary STA with comparable union rate, wound complications and second surgeries.
Conclusion
Primary STA reduces the disability time of these severe fractures.
Level of evidence
Level II

Keywords:
calcaneus, late subtalar fusion, malunited calcaneus, primary subtalar arthrodesis, sanders type IV

Egypt Orthop J 2024, 59:605–611

1110-1148

Introduction

Displaced intraarticular calcaneal fractures are common and challenging [1]. There is no consensus about managing Sanders IV calcaneal fractures [2]. Some authors reported no difference between operative and nonoperative treatment [3,4]. Regardless the management, up to 72% of Sanders IV fractures led to posttraumatic subtalar arthritis. They were 5.5 times more likely to require subtalar arthrodesis than Sanders II fractures [2,5].

Meanwhile, other authors advocated that malunited calcaneus, after nonoperative management, compromised the outcomes of potential late subtalar fusion [6]; and surgical intervention (fixation or fusion) showed better outcomes in some patients [7]. Additionally, primary subtalar arthrodesis healed faster with no need for further surgeries [8].

We conducted this trial to help patients resume their former daily activities as soon as possible with the best available quality of life. We assumed that primary subtalar fusion is superior to nonoperative management followed by late subtalar fusion. Therefore, we compared patients who presented early and were managed by open reduction and primary subtalar fusion with those who presented late (within one year) and underwent late calcaneoplasty and fusion.

Methods

This is a prospective cohort study held in our hospital from September 2019 to October 2022.

Inclusion criteria

Adult patients (age from 16 to 60) with Sanders type IV displaced intraarticular calcaneal fractures confirmed by initial computed tomography (CT) scan [9].

Exclusion criteria

Patients with general contraindication to surgery, co-existent ipsilateral lower limb fracture, neurological injury or open calcaneal fractures. We excluded fractures older than one year and patients with no initial CT scan to classify the fracture.

Allocation

Patients presented with recent (within 30 days) fractures were included in group A (open reduction and primary subtalar arthrodesis). While patients referred to our clinic with old (more than three months and up to one year) fractures were included in group B (late calcaneoplasty and subtalar arthrodesis).

The decision of nonoperative treatment in group B was taken by other hospitals and patients were presented to our clinic with subtalar pain. Patients presented between one and three months after injury were excluded to decrease the selection bias. 'Calcaneoplasty' refers to restoration of calcaneal height and width plus realignment of hindfoot during subtalar fusion.

Intervention

Patients in group A were initially treated with below knee slab, limb elevation and analgesics. We scheduled surgery after resolution of the edema and appearance of wrinkle sign. Surgery was done under tourniquet in lateral position. Lateral extensile approach was used. A full flap was developed by subperiosteal dissection with protection of sural nerve and peroneal tendons. Three k-wires were inserted in fibula, lateral surface of talus and cuboid bone as retractors. The lateral wall of the calcaneus was retracted. Articular cartilage of inferior surface of the talus and posterior facet of the calcaneus were debrided thoroughly and drilled by 2 mm k-wire. A 4 mm Schanz was inserted in the calcaneal tuberosity to restore calcaneal height and hindfoot alignment. A lateral nonlocked plate was applied to reduce the lateral wall blow out and calcaneal broadening. A tricortical iliac bone autograft was harvested and inserted in the subtalar joint. Two guide wires were introduced, under fluoroscopic guidance, from the calcaneal tuberosity to the talus then two cannulated partially threaded 7.3 mm screws. The wound was closed in two layers (subcutaneous and skin) after homeostasis. Below knee slab was applied and patients were kept nonweightbearing for 6 weeks.

Patients in group B were encouraged to increase weightbearing. A new preoperative ankle CT scan was done to assess the calcaneal deformity. The same position and approach were used. Lateral wall exostosis was resected to deal with subfibular impingement. We resected plantar exostosis to relief plantar pain. Hindfoot malalignment (mostly varus) was corrected through the subtalar joint. Loss of calcaneal height was corrected by tricortical iliac bone autograft to distract the subtalar joint. Fixation by two cannulated screws and closure as mentioned above. Also, patients were instructed to be non-weightbearing for six weeks in below knee slab.

Patients were followed after intervention every 2 weeks for 6 weeks then every 3 months for 1 year then at 2 years. Follow-up radiograhpy were done the next day after surgery, 6 weeks later and every 3 months till radiological union. CT scans were done at 1 year to confirm union.

Outcomes

Two scores were used to assess the functional outcomes; (1) the American Orthopaedic Foot and Ankle Society's Ankle-Hindfoot scale (AOFAS-AHS) [10] and (2) Foot and Ankle Ability Measure - Activities of Daily Living sub scale (FAAM-ADL) [11]. We calculated the functional scores using questionnaires at 6, 12, and 24 months. Data was collected by the authors in the clinic.

We asked the patients to describe the physical demand of their previous jobs to categorize themselves into heavy or light manual jobs. We documented if they returned to work after injury (same or new job) and the time to return to it. We also evaluated wound complications, second surgeries and union at 1 year.

Sample size calculation

After reviewing the literature about the mean AOFAS score after primary [12] and late [13] subtalar arthrodesis, we performed an a priori power calculation assuming that to find a difference of 10 points±10 using a two tailed hypothesis considering type I and type II errors. Significance level (alpha) and power (probability of detecting significant results) were 0.05 and 80%, respectively. We considered a 5% anticipated drop out. So, we aimed to enroll 34 patients, 17 in each group.

Statistical analysis

We used statistical package for social science (SPSS 15.0.1 for windows; SPSS Inc, Chicago, 2001). For normally distributed continuous variables, data was presented as Mean and Standard deviation and differences between groups were analysed using Student t test. We used paired-samples t test and Repeated Measure ANOVA test to measure change in different quantitative variants. Categorical data was presented as frequency and percentage and groups were compared using χ^2 test (Fisher Exact). P value less than 0.05 was considered significant.

All participants provided a written informed consent by themselves.

The protocol was registered in ClinicalTrials.gov on 1/8/2022.

Results

From September 2019 to October 2022, 34 patients were recruited and followed for at least 2 years. Patients' enrolment is illustrated in (Fig. 1). 17 patients were managed by open reduction and primary subtalar arthrodesis. The average time interval between trauma and surgery was 18 (range, 9–25) days. 17 patients underwent late calcaneoplasty and subtalar arthrodesis. The average time interval between trauma and surgery was 9 (range, 5–12) months. Figures 2 and 3 demonstrate the radiology of a patient from group A and a patient from group B, respectively.

The data of 29 patients were collected for analysis, while 5 patients were lost during follow-up. Patients were assessed regarding age, gender, smoking, co-morbidities and associated fractures. Their demographics are summarized in (Table 1). Both groups were similar.

The time to return to work was significantly shorter in group A. All patients who had primary subtalar fusion -except one- returned to work after the mean time of 7.46 ± 1.85 months. In group B, 12 patients (80%) returned to work after the mean time of 15.33 ± 2.57 months from initial injury. They could not resume their jobs between injury and surgery. preinjury occupation and the time to return to work are summarized in (Table 2).

At 1-year follow-up, the mean AOFAS score for group A and group B were 72.86 ± 3.13 and 70.80 ± 3.63, respectively, while the mean FAAM score for group A and B were, respectively, 57.29 ± 2.27 and 55.27 ± 2.74. At 2-year follow-up, the mean AOFAS score for group A and group B were 74.42 ± 1.95 and 73.80 ± 1.9, respectively, while the mean FAAM score for group A and B were, respectively, 59.21 ± 1.6 and 58.73 ± 1.7. The two scores are reported in (Table 3).

In group A, we had one (7.14%) patient with delayed wound healing (more than 3 weeks) and one (7.14%)

Figure 1

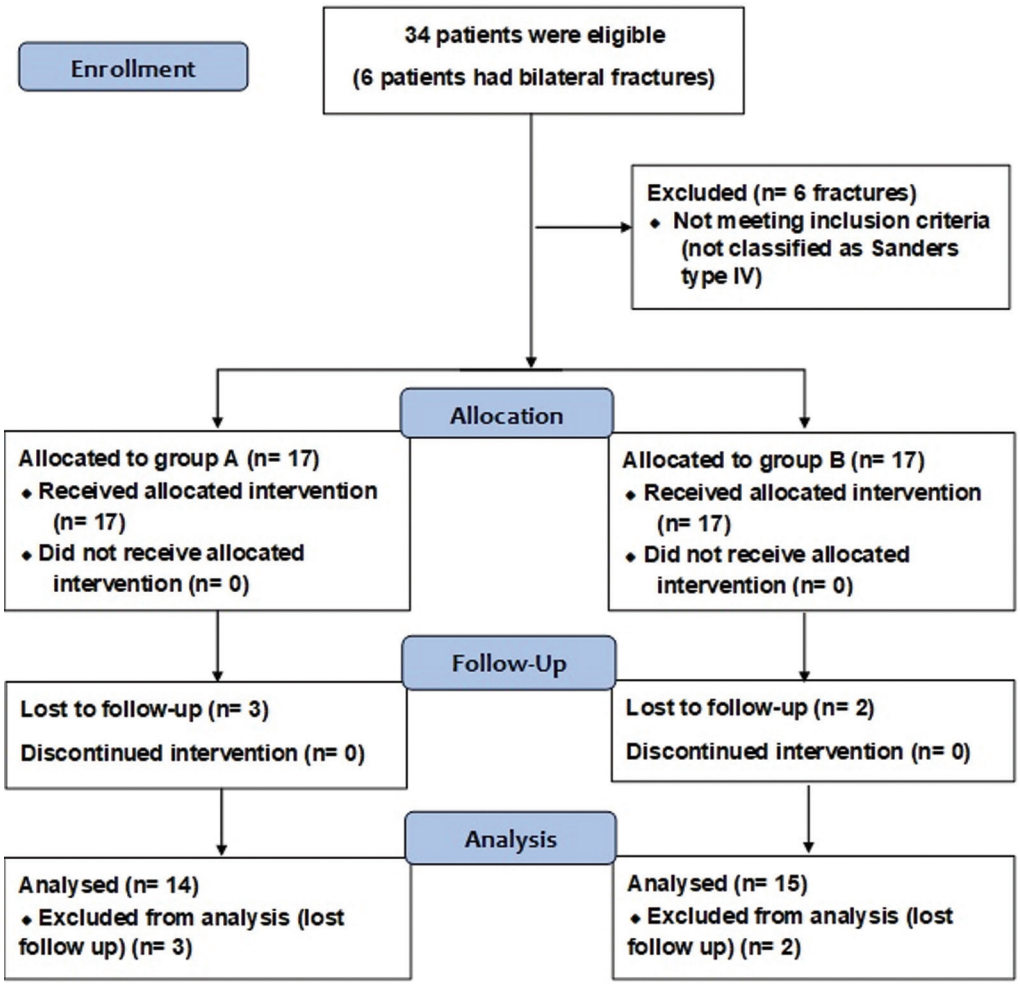
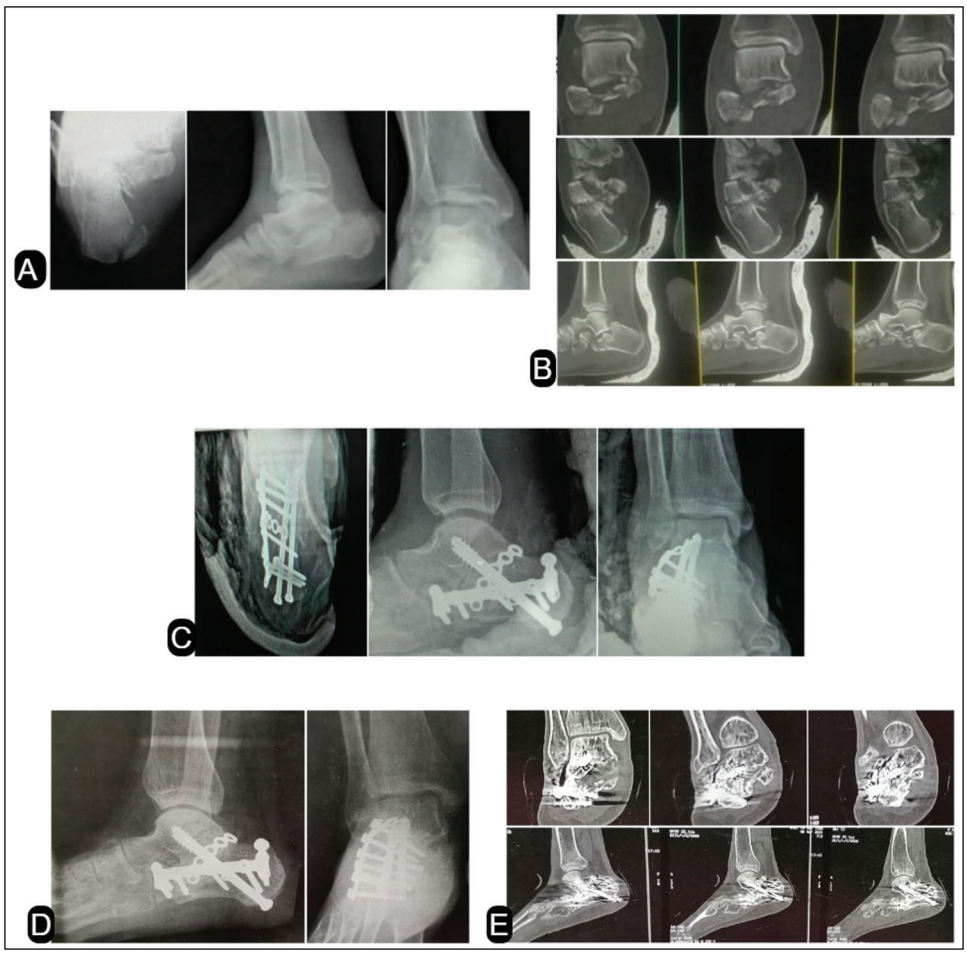


Diagram for patients' enrollment in our study.

Figure 2



Radiology of a patient in group A; (A) Trauma radiography, (B) Trauma CT scan, (C) Postoperative radiography, (D) Radiography one year after surgery, (E) CT scan one year after surgery.

patient with superficial wound infection. On the other hand, one (6.7%) patient had delayed wound healing and two (13.3%) patient had superficial wound infection in group B. No deep infection was encountered, and the five patients were managed by dressings without any further interventions.

Two patients in group A had a second surgery. The first one complained of excessive heel valgus. After 6 months, we removed the implants and performed a medial displacement calcaneal osteotomy which was fixed by one cannulated screw. The second patient complained of pain because of prominent cannulated screws from posterior and they were removed. In group B one patient had a symptomatic nonunion which required revision surgery one year after initial surgery.

Both wound Complications and the need for further surgeries are mentioned in (Table 4). CT scan at 1 year showed 100% union rate in group A and 93.3% in group B. With the numbers available, no significant difference could be detected between the two groups.

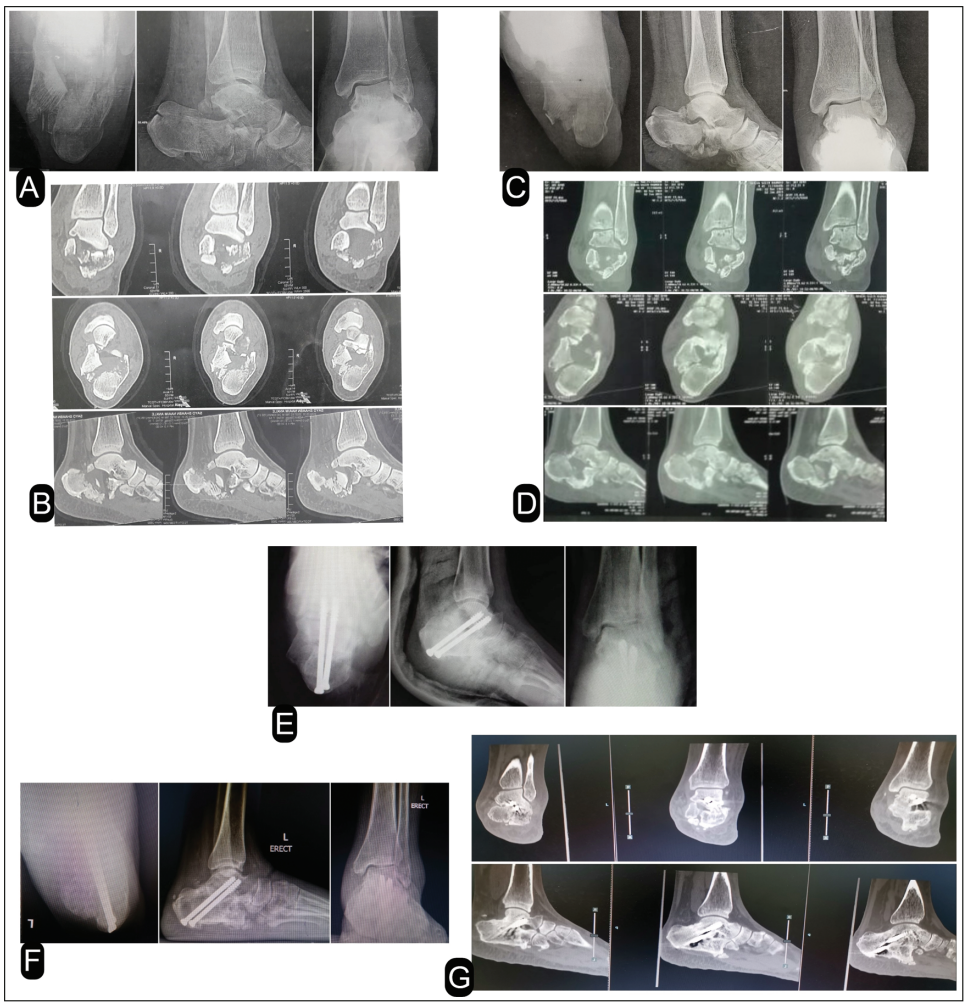
Discussion

Despite the similar functional outcomes, group A had a short period of work abstinence. Driessen and colleagues [14], reported that 68% of patients after surgical management of calcaneal fracture were able to return to work after a median time 6 months (Interquartile range, 3-7).

We used AOFAS score to compare our results to the literature but recently there is emphasis on patient-reported outcome measures without interpretation by healthcare providers Kitaoko and colleagues [15]. So, we used FAAM score to assess the function.

Both groups had low FAAM scores, and this reflects the severity of the injury. In spite of the statistically significant better mean FAAM score in group A at one-year follow-up, 2 points may not be of clinical importance. The Minimum Clinically Important Difference (MCID) in FAAM scores is not reported in trauma but in some elective surgeries it is 11.1 to 22.7 points Sutton and colleagues [16]. Eventually after

Figure 3



Radiology of a patient in group B; (A) Initial radiography, (B) initial CT scan, (C) Preoperative radiography, (D) Preoperative CT scan, (E) Postoperative radiography, (F) Radiography one year after surgery, (G) CT scan one year after surgery.

Table 1 Baseline demographics and clinical characteristics of enrolled patients

	Age		Gender		Smokers No. (%)	Co-morbidities No. (%)	Associated fractures* No. (%)
	Mean	SD	Male No. (%)	Female No. (%)			
Group A (*N*=14)	37.64	10.16	12 (85.7)	2 (14.3)	3 (21.4)	1 (7.1)	6 (42.9)
Group B (N=15)	35.20	10.35	10 (66.7)	5 (33.3)	2 (13.3)	1 (6.67)	4 (26.7)
P value	0.53		0.39		0.65	0.96	0.36

* Ipsilateral lower limb fractures are not included from the start.
No, (Number); SD, (standard deviation).

Table 2 Preinjury occupation and return to work

	Pre injury occupation	Return to work		New job No. (%)	unemployed No. (%)	Time from injury to return to work (months)	
		Yes	No				
	Heavy manual No. (%)	Light manual No. (%)	Same job No. (%)			Mean	SD
Group A (N=14)	8 (57.1)	6 (42.9)	10 (71.43)	3 (21.43)	1 (7.14)	7.46	1.85
Group B (N=15)	7 (46.7)	8 (53.3)	5 (33.3)	7 (46.7)	3 (20)	15.33	2.57
P value	0.57			0.12		0.00001	

Table 3 Functional scores at one year and two years after surgery

	American Orthopaedic Foot and Ankle Society's Ankle-Hindfoot scale (AOFAS-AHS)				Foot and Ankle Ability Measure (FAAM)			
	One-year		Two-year		One-year		Two-year	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group A (*N*=14)	72.86	3.13	74.42	1.95	57.29/84 (68.20%)	2.27	59.21/84 (70.49%)	1.6
Group B (*N*=15)	70.80	3.63	73.80	1.9	55.27/84 (65.80%)	2.74	58.73/84 (69.92%)	1.7
P value	0.12		0.88		0.04		0.44	

Table 4 The rate of wound complications and need for further surgeries

	Wound complications			The need for further surgeries	
	Superficial infection Number (%)	Delayed healing Number (%)	No wound complications Number (%)	Yes Number (%)	No Number (%)
Group A (*N*=14)	1 (7.14)	1 (7.14)	12 (85.7)	2 (14.3)	12 (85.7)
Group B(N=15)	2 (13.3)	1 (6.7)	12 (80)	1 (6.7)	14 (93.3)
P value		1.00		0.44	

Table 5 Our results compared with literature

	Primary subtalar arthrodesis		Late subtalar arthrodesis	
	Almeida *et al*. [17]	Our study	Fletcher *et al*. [22]	Our study
Number of patients	41 patients in 4 studies	14 patients	467 patients in 25 studies	15 patients
Male	52% - 92%	85.7%	68%	66.7%
Age (years)	40 to 53.8	37.64 ± 10.16	45 (28 to 60)	35.20 ± 10.35
Follow-up (years)	2 to 4.9	2	4 (0.6 to 6)	2
Time from injury to surgery	6 to 42 days	18 (9 to 25) days	25 (16 to 74) months	9 (5 to 12) months
Return to work	Not reported	92.86%	64% to 100%	80%
Time to return to work (months)	Not reported	7.14 ± 1.85	Not reported	15.33 ± 2.57
AOFAS-AHS	65.5 to 86.8	74.42 ± 1.95	74 (64 to 85)	73.80 ± 1.9
FAAM-ADL	Not reported	59.21 ± 1.6	Not reported	58.73 ± 1.7
Wound complications	Not clarified in 2 studies 0% in 2 studies	14.3%	6.4%	20%
Second surgeries	1 patient (hematoma revision)	2 patients (calcaneal osteotomy and implant removal)	12% (implant removal)	6.7% (1 patient had revision after nonunion)
Union rate	Not reported	100%	93.9%	93.3%

2 years, both AOFAS and FAAM scores were slightly better in group A but with no statistical difference.

Almeida and colleagues [17] reviewed the previous clinical trials of the primary subtalar fusion from 2005 to 2020. Four studies Buckley and colleagues, Holm and colleagues [18–21] used the AOFAS score and the mean scores ranged from 65.8 to 86.8 points at the last follow-up (2 to 5 years). The trials did not report the wound complications or the union rate. The need for second surgery in primary subtalar arthrodesis ranged from 16.6 to 66.6%. It was mostly implant removal due to skin irritation by hardware Almeida and colleagues [17].

Fletcher and colleagues [22]. included 25 studies reporting 492 feet in 467 patients who had late subtalar fusion. It is not specific for sanders type IV calcaneal fractures. The mean postoperative AOFAS score was 74 (range, 64-85) points. The wound complications rate was 6.4%. It included delayed wound healing (4%) and superficial wound infection (2.4%). The higher incidence in our study (20%) may be attributed to severity of the deformity that may attenuate the skin after restoring the heel alignment and calcaneal height. Nonunion was 6.1% in late subtalar arthrodesis which is comparable to our results 6.7%. The most common cause of second surgeries was implant removal (12% of patients required implant removal for prominent hardware) Fletcher and colleagues [22]. Our results compared with literature are summarized in (Table 5).

Regarding **s**trengths, it is a prospective single-center study. We stratified only Sanders type IV calcaneal

fractures to recruit. Surgeries were done by experienced foot and ankle surgeons. It is the first clinical trial to compare primary with late subtalar arthrodesis and the second prospective comparative study after Buckley and colleagues [18]. to compare two different techniques. Our study is the first to report the time to return to work and union rate after primary subtalar arthrodesis. We achieved two years of follow-up although the difficulties imposed by the corona pandemic.

Our weaknesses include the small number of patients. Our study was not randomized so, we could not estimate the total number of patients with sanders type IV calcaneal fractures who were originally treated conservatively and their functional outcomes. We did not use a validated method to categorize the pre injury occupation. Also, there is no third arm for open reduction and internal fixation as a treatment option for these fractures.

In summary, Primary and late subtalar arthrodesis have similar functional outcomes with comparable complications. However, Primary subtalar arthrodesis offers a fast track to recovery. It can spare the patient the suffering during the nonoperative period and shorten the disability time. More research is needed to establish the best management for these challenging debilitating fractures.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Financial support and sponsorship
Nil.

Conflicts of interest
No conflict of interest

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