Minimally invasive open reduction and percutaneous fixation of intra-articular calcaneal fractures

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Background
Calcaneal fracture is a topic in orthopedic fracture care that has been heavily debated over the past decades. The aim of the current study was to assess the results of minimally invasive open reduction and percutaneous fixation of intra-articular calcaneal fractures.
Patients and methods
Twenty-four calcaneal fractures in 21 patients were prospectively included in the current study. There were 15 males and six females, with a mean age of 34.8 years. A limited sinus tarsi approach was used in elevation of the depressed posterior facet, followed by fixation with one or two 4 mm cancellous screws. Fixation was completed by using one or two cannulated 4 mm partially threaded screws. Then two or more fully threaded cancellous screws were inserted percutaneously from the tuberosity along the calcaneus.
Results
The average duration of follow-up was 39 months (range: 24–41 months). According to the American orthopaedic foot and ankle score at final follow-up, 20.8% of all cases had excellent results, 66.7% had good results, 12.5% had fair results, and there were no poor results. The satisfactory results (excellent and good) were 87%, with the mean American orthopaedic foot and ankle score for hind foot being 84.95 points. The average postoperative visual analog scale for pain is 1.55 in Sanders type II group, 2.55 in Sanders type III group, and 3.75 in Sanders type IV group, with a significant statistical correlation between fracture type and postoperative pain ($P<0.00001$). The average satisfaction score for Sanders type II group was 7.44, 7 in Sanders type III group, and 6.75 in type IV.
Conclusion
Limited open reduction and percutaneous screw fixation yielded good results as the classic extended approach, with the advantage of far less soft tissue complications, less operative time, and less hospital stay.

Keywords:
calcaneal fractures, minimally invasive, sinus tarsi, type IV therapeutic case series

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Introduction

Calcaneal fracture is a topic in orthopedic fracture care that has been heavily debated over the past decades. Until the 1950s, either nonoperative treatment or late treatment with subtalar arthrodesis was advocated, and open surgical reduction of calcaneal fractures was thought to be contraindicated [1,2].

Essex-Lopresti [3] was the first to distinguish intra-articular fractures of the calcaneus from extra-articular fractures in his classification system. He demonstrated the poor long-term outcome of the intra-articular fracture types. Sanders classification system based on computed tomography appears to provide a more reliable indicator of prognosis and planning for surgical treatment [4]. Although nonoperative treatment remains a reasonable option for certain displaced intra-articular calcaneus fractures in patients older than 60 years, smokers, sedentary workers, or with simple fracture patterns [5], operative treatment significantly reduces the risk for future subtalar arthrodesis compared with nonoperative treatment [5].

The main goal of surgical treatment is to restore joint congruity through anatomic reduction of the joint surface [6]. The operative options are not without limitations, as it has its own risks. Wide surgical exposure carries the risks of high incidence of wound dehiscence, and deep infection may occur in up to 30% of patients [7]. Plate fixation increases the risk of peroneal impingement [7].

Limited surgical exposure and screw fixation of intra-articular calcaneal fracture achieve the goals of surgical management and avoid the complications of the classic extensile open reduction. The aim of the current study is to evaluate clinical and radiological results of limited surgical approach and screw fixation of intra-articular calcaneal fractures.

Patients and methods

Between May 2012, and May 2015, 24 calcaneal fractures in 21 patients were prospectively recruited in the current study at the Benha University Hospital. Inclusion criteria included displaced intra-articular calcaneal fractures. Exclusion criteria were age more than 60 years, open fractures, and associated foot or ankle fractures.

Fifteen patients were males (three of them had bilateral calcaneal fractures) and six were females, with a mean age of 34.8 years (range: 22–48 years). The mechanism of injury was a fall from height in 18 feet and motor-vehicle accidents in 6 feet. The study was approved by Institutional Ethical Board of Benha University, and all patients signed an informative consent.

Patients were evaluated clinically and radiologically using at least anteroposterior, lateral, and axial views. Calcaneal height, width, Bohler angle, and Gissane angle were measured preoperatively. Computed tomography scans were done for all patients to classify the fracture using Sanders classification [4].

Surgical technique

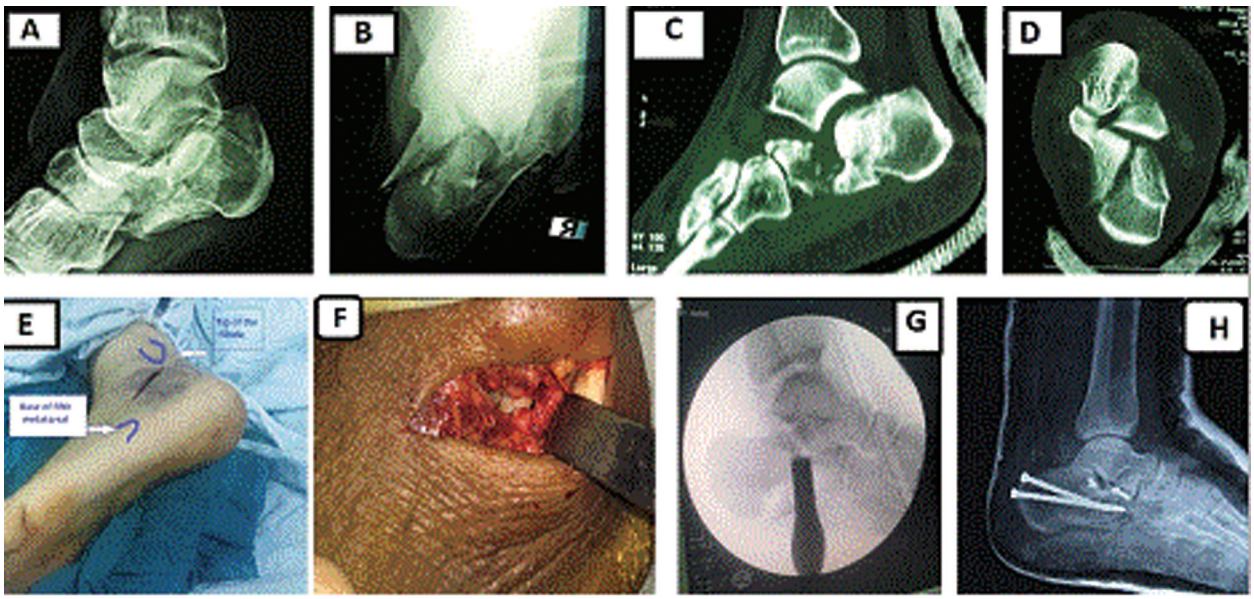
Patients were positioned in the lateral decubitus position with the affected side uppermost, on an orthopedic radiolucent table, with access for intraoperative radiography. Pneumatic tourniquet was used and set at 400 mmHg.

The first step was inserting a 4.5 mm Steinmann pin in the tuberosity from lateral to medical. It is used to disimpact the fracture by traction and correcting varus deformity. This gives space for reduction of depressed intra-articular fragments.

The second step was elevation of the depressed posterior facet through a limited sinus tarsi approach as described by Carr [8]. Longitudinal skin incision began from below the tip of lateral malleolus toward the base of the fourth metatarsal (Fig. 1). The peroneal tendons were retracted, and the sinus tarsi fat was dissected. The depressed posterior facet was elevated by a small osteotome, and temporary k-wires were used to fix it until reduction was checked using axial view. Definitive fixation was done using one or two cannulated 4 mm partially threaded screws.

Under fluoroscopic guide showing lateral view, two fully threaded cancellous screws were then inserted from the tuberosity toward the calcaneocuboid joint. Additional screws could be used according to the fracture configuration.

Figure 1



(a) Preoperative lateral view, (b) preoperative axial view, (c and d) computed tomography scan of the same case, (e) sinus tarsi incision, (f) exposure of posterior facet, (g) elevation of depressed posterior facet, and (h) postoperative radiograph.

Postoperative care

A well-padded below-knee cast was used for 2 weeks, then it was removed, and full range of ankle and subtalar movement was allowed. Partial weight bearing was allowed after 6 weeks and full weight bearing after 3 months. Radiological assessments were done immediately after surgery, at 6 weeks, and every 2 weeks till union.

At final follow-up, Bohler and Gissane angles together with calcaneal width and height were measured. Clinical assessment was done using the American orthopaedic foot and ankle score (AOFAS) for hindfoot, visual analog scale for pain (composed of 10 points where zero is no pain at all and 10 is maximum unbearable pain), and a satisfaction scale composed of 10 points, where 10 is completely satisfied and zero is not satisfied at all.

Results

Clinical results

The average duration of follow-up was 39 months (range: 24–41 months). According to the AOFAS at final follow-up, 20.8% of all cases had excellent results, 66.7% had good results, 12.5% had fair results, and there were no poor results. The overall satisfactory results (excellent and good) were 87%, with the mean AOFAS for hindfoot being 84.95 points.

There was a statistically significant correlation between complexity of fracture (according to Sanders classification), and postoperative AOFAS score ($P<0.0001$) (Table 1).

The average postoperative visual analog scale for pain was 1.55 in Sanders type II group, 2.55 in Sanders type III group, and 3.75 in Sanders type IV group. There was a statistically significant correlation between fracture type and postoperative pain ($P<0.001$). The average satisfaction score for Sanders type II group was 7.44, 7 in Sanders type III group, and 6.75 in type IV.

Table 1 Functional outcome score in relation to fracture type

Sanders type II	9	89.11	1.56	7.44
Sanders type III	11	84.36	2.54	7
Sanders type IV	4	77.25	3.75	6.75

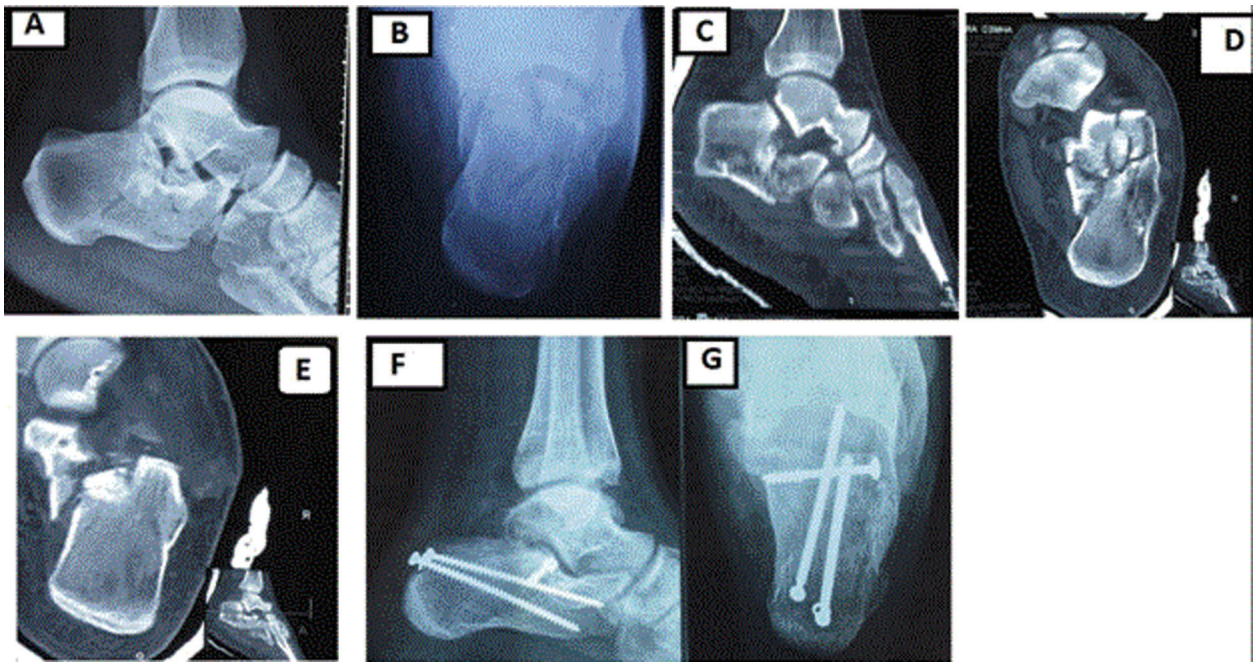
Radiological results

The average postoperative Bohler's angle, Gissane's angle, and calcaneal height significantly increased (Table 2), whereas calcaneal width significantly

Table 2 Summary of postoperative and preoperative radiological measures

	Preoperative average (range)	Postoperative average (range)	*P* value
Width	38 mm (30–44)	32.5 mm (30–38)	<0.001
Height	29.8 mm (22–35)	36.8 mm (33–42)	<0.0001
Bohler	9.33 (0–20)	26.5 (18–34)	<0.0001
Gissane	100 (90–115)	113 (110–120)	<0.001

Figure 2



(a) Preoperative lateral radiograph, (b) preoperative axial radiograph, (c) preoperative Sagittal computed tomography, (d and e) preoperative coronal computed tomography, (f) postoperative radiograph after union with prominent screw, and (g) postoperative axial view.

decreased, as compared with average preoperative values.

Complications

Overall, five cases complained of posterior ankle pain owing to screw head prominence (Fig. 2), and treated by removal of the screws after union.

No soft tissue complications were recorded, no wound dehiscence, and no infections.

Discussion

Many randomized controlled trials comparing operative versus nonoperative treatment concluded that patients with simple fracture patterns might benefit from nonoperative management. Others would uncommonly have serious foot deformities, malunions, or peroneal impingement in the long term [9]. In a recent level II randomized, controlled multicenter trial comparing operative with nonoperative treatment of 60 displaced intra-articular calcaneal fractures, Agren *et al.* [10] found that at 8–12 years of follow-up, operative treatment was associated with reduced prevalence of posttraumatic arthritis.

The gold standard method in the management of intra-articular fractures of the calcaneus (as any intra-articular fracture) remains anatomical reduction of the intra-articular fracture and stable fixation by plate. The classic wide exposure through lateral approach has shown good results in terms of functional outcome and minimizing rate of subtalar arthritis as compared with conservative treatment [10,11]. However, the surgeon has to expect high rates of wound problems and infection in a high percent of up to 30% of patients [7]. To reduce wound complications, many mini-invasive techniques have been used, including different external and ring fixators [12], and limited approaches with fixation by wires, screws, or plates [13].

In the current study, we combined open reduction through a limited incision to ensure anatomical reduction of the intra-articular fracture and percutaneous screws fixation of the tuberosity fragment, limiting extensive soft tissue dissection. The results obtained in the current study are like those achieved by many studies that used classic open reduction and plate fixation. We have treated 25 calcaneal fractures with satisfactory (excellent and good) results in 87.5% of cases, and no poor results, with a mean AOFAS score of 84.9 points.

Wang *et al.* [14] treated 50 calcaneal fractures with calcaneal plates. The rate of excellent and good results was 80%, with the mean AOFAS scale system being 86.8 points. Moreover, the results are matched with those achieved by Makki *et al.* [15]. In their series of 45 calcaneal fractures treated by open reduction and internal fixation using calcaneal plate, excellent and good results were achieved in 35 (77.7%) patients [15].

Comparing our results with other types of mini-invasive techniques in calcaneal fracture management, the satisfactory results in this study are higher than those achieved by Schepers *et al.* [12]. In their series of 59 patients managed by skeletal triangular distraction and intra-articular fracture percutaneous fixation, AOFAS hindfoot scores were good to excellent in 72% (compared with 87.5% in our study). However, 10 patients developed subtalar arthritis requiring fusion and 10 patients had infection from superficial pin tract to osteomyelitis.

One of the very few prospective controlled trials comparing classic lateral approach and calcaneal plate fixation with a limited approach and screw fixation was conducted by Weber *et al.* [16] including 26 and 24 patients in each group, respectively. Results show higher AOFAS score in limited approach group (87.2 vs 82.6) and less complication rate. The results of our study match those of Weber et al, as shown in Table 3.

Our average operative time was 84.3 min, which is near the time of Weber et al., which reported 52 min less than the time of extended open group. Average hospital stay in our series was 2.1 days. This matched with the series by Abdelmagid [17] (2.3 days); however, in the limited approach group by Weber *et al.*, it was 4.5 days. The average hospital stay time of the classic open calcaneoplasty range from 5.8 [16] to 18 days [18].

Table 3 Comparison of current series and the series by Weber *et al*. [16]

Age (years)	Classification	Average follow-up (months)	Average AOFAS	Duration of operation (min)	Hospital stay (days)
42.6	20 II e 4 III	31.2	87.2 (84% good or excellent)	108	4.5
34.8	9 II, 11 III, 4 IV	24	84.9 (87.5% good or excellent)	84	2.1

Screws fixation might provide a less rigid fixation of fracture fragments compared with plating. However, in our study, no collapse or loss of reduction in any of our cases was seen. Reported cases in similar studies [19] could be owing to early weight bearing or use of less rigid fixation as k-wires in Stulik study, which reported 4.5% collapse [20].

No cases of infection either superficial or deep or any other form of soft tissue complications were encountered in our series.

Conclusion

Limited open reduction and percutaneous screw fixation yielded good results as the classic extended approach, with the advantage of far less soft tissue complications, less operative time, and hospital stay.

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Conflicts of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

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