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

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Abstract
Background: Calcaneal fractures is a topic in orthopedic fracture care, that has been heavily debated over the last 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 6 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 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 to 41). 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 satisfactory results (excellent and good) were 87% with the mean AOFAS for hind foot was 84.95 points. The average postoperative VAS 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 significant statistical correlation between fracture type and postoperative pain (p<0.0001). 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 hospital stay.

Key words: Calcaneal fractures, minimally invasive, sinus tarsi

Level of evidence: type IV therapeutic case series

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

Essex-Lopresti, was 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[3]. Sanders classification systems based on CT, appears to provide a more reliable indicators of
prognosis and planning for surgical treatment[4]. Although non-operative treatment remains a reasonable option for certain displaced intra-articular calcaneus fractures in patients older than 60, smokers, sedentary workers, or with simple fracture patterns[5], however, operative treatment significantly reduces the risk for future subtalar arthrodesis compared to non-operative treatment[6].

The main goal of surgical treatment, is to restore joint congruity through anatomic reduction of the joint surface[7]. The operative options are not without limitations, 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[8]. Plate fixation increases the risk of peroneal impingement[8].

Limited surgical exposure and screw fixation of intraarticular 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 intraarticular 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 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 were males (3 of them had bilateral calcaneal fractures) and 6 were females with a mean age of 34.8 years (range, 22 to 48). 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 have signed an informative consent.

Patients were evaluated clinically and radiologically using at least anteroposterior (AP), lateral, and axial views. Calcaneal height, width, Bohler angle, and Guissan angle were measured preoperatively. Ct 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 400mmhg.

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 intraarticular fragments.

The second step was elevation of the depressed posterior facet, through a limited sinus tarsi approach as described by Carr[9]. 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 & D CT scan of the same case, E sinus tarsi incision, F exposure of posterior facet, G elevation of depressed posterior facet, H postoperative radiograph.

Post-operative 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 guissan 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 (VAS) 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 to 41). 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 was 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).

Table 1: Functional outcome score in relation to fracture type

<table>
<thead>
<tr>
<th>Sanders type II</th>
<th>AOFAS</th>
<th>VAS</th>
<th>HSS</th>
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<tr>
<td>9</td>
<td>89.11</td>
<td>1.56</td>
<td>7.44</td>
</tr>
<tr>
<td>Sanders type III</td>
<td>11</td>
<td>84.36</td>
<td>2.54</td>
</tr>
<tr>
<td>Sanders type IV</td>
<td>4</td>
<td>77.25</td>
<td>3.75</td>
</tr>
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</table>

The average postoperative VAS 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 significant statistical 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.

**Radiological results**

The average postoperative Bohler’s angle, Gissane’s angle and calcaneal height significantly increased (table2), while calcaneal width significantly decreased, as compared to average preoperative values.

Table 2: summary of postoperative and preoperative radiological measures

<table>
<thead>
<tr>
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<th>Preoperative Average (range)</th>
<th>Postoperative Average (range)</th>
<th>P value</th>
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<tbody>
<tr>
<td>Width</td>
<td>38 mm (30–44)</td>
<td>32.5 mm (30–38)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Height</td>
<td>29.8 mm (22–35)</td>
<td>36.8 mm (33–42)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Bohler</td>
<td>9.33 (0–20)</td>
<td>26.5 (18–34)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Guissan</td>
<td>100 (90–115)</td>
<td>113 (110–120)</td>
<td>&lt; 0.001</td>
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</table>

**Complications**

5 cases complained of posterior ankle pain due to screw head prominence (fig 2), and treated by removal of the screws after union.

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

**Discussion**

Many randomized controlled trials comparing operative versus non-operative treatment concluded that patients with simple fracture patterns might benefit from non-operative management. Others, would uncommonly have serious foot deformities, malunions, or peroneal impingement in the
In a recent level II randomized, controlled multicenter trial comparing operative with nonoperative treatment of 60 displaced intra-articular calcaneal fractures, Agren et al. found that, at 8 to 12 years follow-up, operative treatment was associated with reduced prevalence of posttraumatic arthritis[11].

The gold standard method in management of intraarticular fractures of the calcaneus (as any intraarticular fracture), remain anatomical reduction of the intraarticular fracture and stable fixation by plate. The classic wide exposure through lateral approach has shown good results in term of functional outcome and minimizing rate of subtalar arthritis as compared to conservative treatment[11, 12]. However, the surgeon has to expect high rates of wound problems and infection in a high percent of up to 30% of patients [8]. In order to reduce wound complications, many mini-invasive techniques have been used; including different external and ring fixators[13], and limited approaches with fixation by wires, screws or plates[14].

In the current study, we combined open reduction through a limited incision to assure anatomical reduction of the intraarticular 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, 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. treated 50 calcaneal fractures with calcaneal plates. The rate of excellent and good results was 80%, with the mean AOFAS scale system was 86.8 points[15]. Also, the results are matched with those achieved by Makki et al.[16]. 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 patients 77.7%[16].

Comparing our results with other types of mini-invasive techniques in calcaneal fractures management, the satisfactory results in this study are higher than those achieved by Schepers et al.[13]. In their series of 59 patients managed by skeletal triangular distraction and intraarticular fracture percutaneous fixation. AOFAS Hindfoot scores were good to excellent in 72% (compared to 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.[17] 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 weber results as shown in table 3.

Table 3: comparison of current series and Weber et al series (17)

<table>
<thead>
<tr>
<th>Age</th>
<th>Classification</th>
<th>Average follow-up</th>
<th>Average AOFAS</th>
<th>Duration of operation</th>
<th>Hospital stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.6 years</td>
<td>20 II e 4 III</td>
<td>31.2 months</td>
<td>87.2 (84% good or excellent)</td>
<td>108 min</td>
<td>4.5 days</td>
</tr>
<tr>
<td>34.8 years</td>
<td>9 II, 11 III, 4 IV</td>
<td>24 months</td>
<td>84.9 (87.5 good or excellent)</td>
<td>84 minute</td>
<td>2.1 days</td>
</tr>
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</table>
Our average operative time was 84.3 minutes which is near the time of weber et al. series which reported 52 minutes less than the time of extended open group. Average hospital stay in our series was 2.1 days. This match with Abdelmagid [18] series (2.3 days), while in weber limited approach group it was 4.5 days. The average hospital stay time of the classic open calcaneoplasty range from 5.8 days[17] to 18 days[19].

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. Reported cases in similar studies[20] could be due to early weight bearing or use of less rigid fixation as k-wires in Stulik study which reported 4.5% collapse[21].

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.

**References**


