A new minimally invasive technique for the treatment of intra-articular fractures of the calcaneus preliminary results

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Received 02 July 2014
Accepted 05 August 2014

Egyptian Orthopedic Journal 2014, 49:225–230

Background
The goal of therapy for calcaneal fractures is elimination of pain and restoration of normal foot shape and walking ability. The occurrence of wound complications is a serious concern in treating calcaneal fractures. The aim of this study was to evaluate the results of our modified minimally invasive surgical technique for the treatment of intra-articular fractures of the calcaneus.

Patients and methods
Twenty-one patients with 26 closed, intra-articular fractures of the calcaneus were treated by a minimally invasive technique that we developed by modifying the procedure of Forgon.

Results
Combining the anatomical and functional results, an overall rating of good, fair, and poor was assigned to each fracture. The results were good in 17 (81%) patients, fair in two (9.5%) patients, and poor in two (9.5%) patients.

Conclusion
Our results were comparable with the results obtained using other minimally invasive techniques while avoiding the serious soft-tissue complications encountered with open surgery. Thus, we believe that the new technique is an effective and safe alternative for intra-articular calcaneal fracture fixation.

Keywords:
intra-articular calcaneus fractures management, minimally invasive treatment for fracture calcaneus, percutaneous fixation of fracture calcaneus

Egypt Orthop J 49:225–230

1110-1148

Introduction

Calcaneal fractures comprise 1–2% of all fractures. A fracture of the calcaneus allowed to heal in improper anatomical position leads to static and dynamic malfunctions of the whole foot, with consequent limited load-bearing capacity and walking ability. The goal of therapy for calcaneal fractures is elimination of pain and restoration of normal foot shape, biomechanics, and walking ability [1].

The development of major wound complications is a serious concern in the treatment of calcaneal fractures. The soft-tissue envelope around the calcaneus is particularly thin and vulnerable over the lateral wall, which is exposed for surgery in most cases. After open reduction and internal plate fixation of displaced calcaneal fractures, wound edge necrosis is observed in 0.4–14% with the extended lateral approach [2–5]. With combined medial and lateral approaches, the rate of wound edge necroses reaches 27% [6]. Folk *et al*. [7] reported on 25% of wound complications in a cohort of 190 patients with fracture calcaneus treated with open reduction and internal fixation using a standard, L-shaped lateral approach, with 21% requiring further surgery. Diabetes, open fractures, and smoking were identified as risk factors. Infection rates with the use of the extended lateral approach vary between 1.3 and 7% [8]. The frequency of soft-tissue complications with open surgery called for minimally invasive techniques to achieve adequate reduction of intra-articular fractures with the least possible surgical trauma.

The aim of this study is to evaluate the clinical and radiographic results of our minimally invasive surgical treatment of intra-articular fractures of the calcaneus.

Patients and methods

Patients

Between 2007 and 2011, a total of 21 patients with 26 closed, intra-articular fractures of the calcaneus were consecutively treated with a minimally invasive technique that we developed by modifying the procedure of Forgon [9].

Seven patients were operated upon in Erfan Hospital in Jeddah, Kingdom of Saudi Arabia. The rest of the patients underwent their surgeries in Kasr El-Aini Cairo University Hospital, Egypt.

The average age of the patients at the time of injury was 33.3 years (range: 18–53). There were 19 (90.4%) men

and two women. Fifteen (57.6%) fractures occurred in the right foot. Five (23.8%) patients had bilateral fractures. One (4.7%) patient had an ipsilateral open fracture of the femur and one patient had an ipsilateral medial malleolus fracture. The cause of fracture was falling from varying heights in all cases. Surgery was performed within an average of 6 days (range: 1–15). The average follow-up period was 18 months (range: 6–30).

Diagnosis

Each patient was initially evaluated with standard lateral and axial radiographs of the calcaneus. Computed tomography (CT) with transverse and coronal views was performed in all patients. The fractures were classified according to Sanders *et al.* [10]. There were seven (27%) Sanders' type II fractures, 11 (42.3%) type III fractures, and eight (30.7%) type IV fractures.

Operative technique

All patients were consented before surgery. The principle introduced by Forgon [9] in 1992 was closed reduction and fixation of the articular surface with a cannulated short threaded screw, and then maintenance of the height and the width of calcaneus using two positional screws. He used cannulated fully threaded 7.3 mm screws as positional screws. We modified that technique using a small lateral incision to reduce and fix the articular surface under direct vision.

All the operations were performed under regional anesthesia and tourniquet, which was released before wound closure for hemostasis.

The foot part of the operative table was removed. The patient was placed and supported in the lateral position with the affected limb up. The affected limb was projecting outside the table and was flexed 90° at the hip and the knee with a support placed under the leg, loosely bound to it, and a broad upright standing support holding the back of the thigh to perform counter traction during pulling on the calcaneus. The foot was left hanging free at the end of the leg support. The other limb was pulled backwards away from the field and fixed with adhesive plaster (Figs. 1 and 2).

The image intensifier was placed at the side of the affected limb with enough space to allow it to move freely to take lateral, dorsoplantar, and half-axial views. The half-axial view was used to visualize the subtalar joint and the sustentaculum tali, together with assessment of calcaneal width.

A 5 mm Steinmann pin was inserted from lateral to medial in the calcaneal tuberosity taking care not to interfere with the insertion of later screws. Then, a traction stirrup was mounted on the pin. A strong traction was then applied on the stirrup in an attempt to loosen the impaction of the fracture by moving the calcaneal tuberosity downwards.

Traction was maintained until Böhler's angle and calcaneal length were restored. Special attention was paid to correct any varus deformity and prevent it throughout the procedure (Fig. 3).

A small incision was made, under image control, parallel to the peroneal tendons above the posterior facet (Fig. 4). The Peroneal tendons were retracted cranially. Under image intensifier control, a small strong elevator was pushed under the posterior facet and used to lift the impacted fragments. Often, we had to use considerable force, but carefully, to avoid breaking through into the subtalar joint. The articular surface was visualized and the reduction was checked in lateral and half-axial views. Then, the articular surface was fixed primarily with Kirschner-wires. Pressure was applied medially and laterally below the sustentaculum to reduce the width of calcaneus.

Under the image intensifier control, a 4.5 mm cannulated, short threaded screw was used as a transverse compression screw directly below the posterior facet. The guide wire was drilled only a short distance into the bone while obtaining the lateral view, aiming medially and distally toward the sustentaculum tali. The half-axial view was then obtained to visualize the posterior facet in the transverse plain and the Kirschner-wire was then advanced into the sustentaculum tali (Fig. 5).

After measuring the screw length and drilling in the routine manner, the cannulated screw was inserted and tightened on a washer.

Figure 1

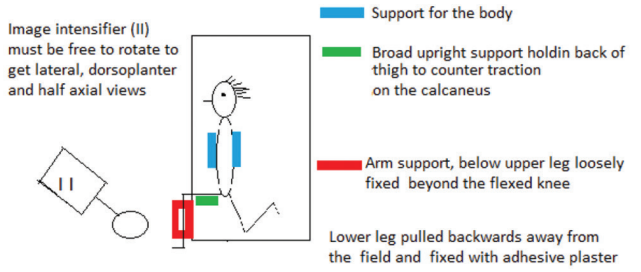
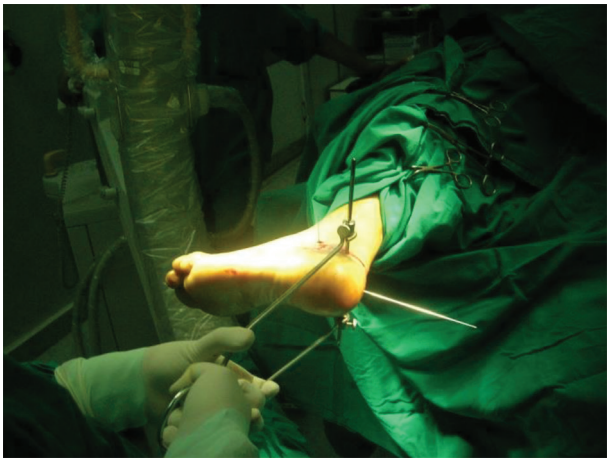


Diagram showing patient position during the surgical procedure.

Figure 2

Patient position during the surgical procedure.

Figure 3

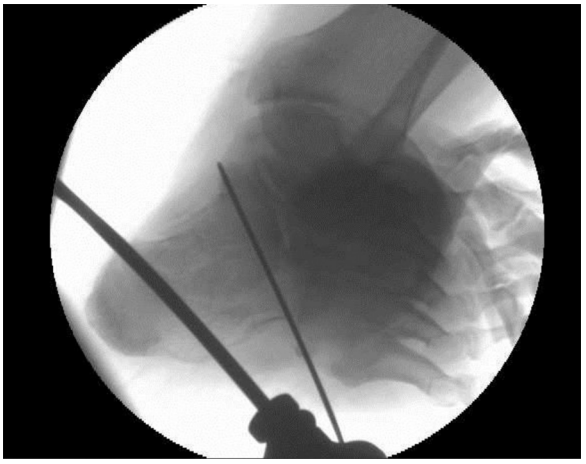


Position of the Steinmann pin. Traction is applied to the stirrup by the assistant.

Figure 4

Small lateral incision parallel to the peroneal tendons.

Figure 5



Position of the guide wire for the transverse cannulated compression screw on the half-axial view.

While performing the procedure for the transverse screw, the assistant held the stirrup all the time in traction, maintaining normal calcaneal length and Böhler's angle and preventing varus deformity. On the half-axial view, the calcaneal width should be restored to normal by side-to-side pressure.

The guide wire for the first positional screw was then applied from the upper medial part of the calcaneal tuberosity, directly below the compression screw into the anterior process of the calcaneus, stopping a few millimeters proximal to the calcaneocuboid joint. Targeting toward the base of the fourth metatarsal bone together with image intensifier guidance helped get this screw into the correct position. Lateral view was obtained initially to position the guide wire below the transverse screw, and then a half-axial view was obtained to correct any residual varus. Finally, a dorsoplantar view was obtained to position the wire in the middle of the anterior process or the region of best bone quality in the anterior process observed on preoperative CT (Fig. 6).

The guide wire for the second positional screw was started at the plantar lateral aspect of the tuberosity and directed superiorly and medially, passing below the transverse screw, and ending below the sustentacular fragment, supporting it and preventing it from tilting downward. This trajectory was guided initially on the lateral view and after a few millimeters of drilling, checked on the half-axial view to control the position of the wire in the mediolateral distance (Fig. 7). No bone graft was used.

Postoperatively, no cast was applied and early physiotherapy was started on the first postoperative day for ankle and subtalar joints. Early mobilization of the subtalar joint was important to correct any residual

minor incongruities. The patients were kept nonweight bearing on the affected limb for 6 weeks.

Results

The results were evaluated in view of restoration of anatomy, the functional outcome, and the complications that occurred.

Restoration of anatomy was evaluated radiographically by measuring the tuber joint angle of Böhler and assessing reduction of the posterior articular facet fragment to restore congruity of the subtalar joint (Fig. 8). The mean preoperative Böhler's angle was 14 (range: 2–20) and was restored to 29 (range: 20–40) at the last follow-up. A congruent reduction of the posterior facet was achieved in 24 (92.3%) fractures as seen on Broden's view and CT scan (Fig. 8).

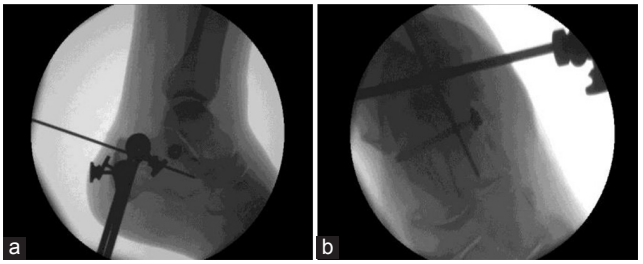
Functional outcome assessment was based on return to work status, the subtalar motion (10° eversion and 20° inversion from a neutral position), and the residual postoperative pain. Pain intensity was assessed using the Visual Analogue Scale (VAS).

All patients returned to their previous occupation within 6 months of surgery. Twenty-four (92.3%) feet had regained 75% (range: 50–100%) of range of motion of the subtalar joint; the remaining two feet had less than 50% of range in the subtalar joint. There was no pain with walking, except in four patients, in whom pain was experienced after 1 h of walking with an average intensity of 2.5 on VAS (range: 1–4).

No wound infection or skin sloughing occurred. However, soft-tissue swelling of the heel persisted with variable degrees in 20 (77%) feet 1 year after surgery.

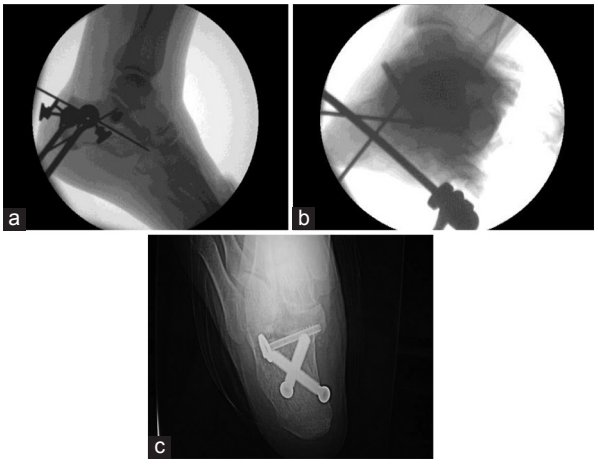
Combining the anatomical and functional results, an overall rating of good, fair, and poor was assigned to each fracture. The patient who had a good overall result had a congruent reduction of the posterior facet, subtalar motion that ranged from 50 to 100% of normal, and no pain. The one fair result was observed in a patient with anatomic reduction, subtalar range of motion 50–75% of normal, and experienced mild pain (VAS: 1–2). Poor results were found in patients with abnormal anatomy; subtalar range of motion ranged from 30 to 69% of normal and moderate pain (VAS: 3–4). The results were good in 17 (81%) patients, fair in two (9.5%) patients, and poor in two (9.5%) patients.

Figure 6



Position of the guide wire for the first positional screw in lateral (a) and dorsoplantar (b) views and its relation to the transverse compression screw.

Figure 7



Position of the transverse compression screw and the guide wires for both positional screws in lateral (a) and half-axial (b) views. Final position of the three screws as seen on half-axial view (c).

Figure 8

Case presentation: (a) preoperative radiograph lateral view showing depression of the posterior calcaneal facet, a displaced tongue fragment, and significantly reduced Böhler's angle. (b) Postoperative lateral view showing the position of the main three screws in addition to a fourth screw used to fix the tongue fragment. Normal Böhler's angle is restored. (c) Postoperative Broden's views at 10, 20, 30, and 40° of cephalic tilt, showing congruent reduction of the subtalar joint. (d) Postoperative computed tomographic scan showing anatomical reduction of the calcaneal posterior articular facet fragment.

Discussion

Approximately 75% of calcaneal fractures are intra-articular. Intra-articular fractures require anatomic reduction and stable fixation to improve the chances of a good outcome [3]. The management of intra-articular calcaneal fractures remains controversial. Controversy exists on the best treatment method. Different options include conservative treatment, minimally invasive treatment, open reduction with internal fixation (ORIF), and primary subtalar arthrodesis.

Conservative treatment of the displaced intra-articular fractures is unlikely to result in normal function because of secondary arthritis and malunion of the calcaneus.

Currently, the trend is toward ORIF to obtain accurate reduction and stable fixation. However, complications, particularly soft-tissue problems, are frequent with ORIF of calcaneal fractures [5,7,11]. Although wound complication rates vary, there is a consensus among experienced surgeons that this is one of the most devastating complications resulting from operative management of calcaneal fractures [12].

Benirschke *et al.* [3] reported two deep infections in 80 patients after ORIF through an extensile lateral approach (16% overall wound complication rate). The same group, more recently, reported better results after ORIF with one deep infection in a patient with neuropathy who ultimately required a below-knee amputation (11% overall complication rate in 218 fractures) [13]. The better outcomes were believed to be because of greater attention to soft-tissue handling, better techniques of fixation, and greater experience of surgeons. Despite the improved soft-tissue results, 95 additional procedures were performed, most for hardware removal. Nine patients, however, required additional calcaneal reconstructive procedures including four calcaneal osteotomies for varus malunions and five subtalar fusions. The average initial surgical time was 4.3 h.

Folk *et al.* [7] reviewed 190 calcaneal fractures and found a 25% wound complication rate, with 21% requiring reoperation. Abidi *et al.* [2] reviewed factors contributing toward the complication rates of surgical management of calcaneal fractures and discovered an overall 33% wound complication rate (14% superficial and 18% deep dehiscence).

To correct deformations of the calcaneus, spare the soft tissue, and lower the complication rate, indirect and less invasive reduction and fixation techniques for calcaneal fractures have been developed [14–17]. Successful use of 'minimal' fixation (generally pins, wires, and screws) has been reported by Fernandez and colleagues [18–24]. What remains an unresolved issue is the 'best' minimal fixation. A study by Carr *et al.* [25] investigating the effect of plate size on fixation strength observed that the reduction with bone contact was an important factor, not necessarily the plate size. It is for this reason that fluoroscopy and arthroscopy are used to assist in obtaining the best posterior facet reduction possible with these limited exposures.

In the current study, we have modified Forgon's [9] previously described closed reduction and internal fixation technique, developing a new minimally invasive technique.

Our technique depends on reduction and fixation of the articular surface under direct vision through a minimal lateral approach together with restoration and maintenance of the height and width of the calcaneus with two positional screws. It is not easy to believe that fixation with three screws alone can hold the fracture without redisplacement. However, this has become possible on the basis of Forgon's experience with 256 cases and on our preliminary experience with 26 cases. The screws act as pillars supporting the strong three cortical points of the calcaneus, namely, the calcaneal tuberosity, the sustentaculum tali, and the anterior process.

Our results were comparable with the results achieved using other minimally invasive techniques.

Forgon reported 89% good to excellent results in a series of 265 patients treated exclusively with this method [9].

Fernandez and Koella [18] treated 41 fractures in 38 patients with open reduction and screw fixation of the posterior facet, bone grafting, and percutaneous pinning of the body. They reported excellent results in 14 (37%) patients, good in 16 (42%) patients, fair in three (8%) patients, and poor in five (13%) patients.

Walde *et al.* [1] treated 92 fractures in 76 patients with closed reduction and percutaneous wire fixation. They reported that 41 (61.2%) patients had a very good or good result, 24 (35.8%) patients had a satisfactory result, and two (3%) patients had a poor result.

Conclusion

We presented a minimally invasive technique for the treatment of intra-articular calcaneus fractures and could obtain results comparable with those of other minimally invasive techniques, avoiding the serious soft-tissue complications encountered with ORIF. In the majority of cases, Böhler's angle

and geometry of the calcaneus were restored to the standard normal anatomical values. Moreover, like all other minimally invasive techniques, future removal of screws would be achieved easily through small stab incisions, with minimal soft-tissue injury and a short surgical procedure that could be performed under local anesthesia. Thus, we believe that our minimally invasive technique is a valuable alternative for the treatment of intra-articular calcaneal fractures.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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