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ORIGINAL PAPER

Management of displaced intra-articular calcaneal fractures using the limited open sinus tarsi approach and fixation by screws only technique

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Abstract
Purpose Evaluation of management of the displaced intra-articular calcaneal fractures (DIACF) Sanders types II and III by using minimally invasive sinus tarsi approach and fixation by screws only technique.
Methods Open reduction using the limited lateral approach and internal fixation using screws only was studied in 33 patients with unilateral isolated simple DIACF with a mean age of 35 years (15 type II patients and 18 type III patients). All patients were evaluated both clinically and radiologically.
Results With a mean follow-up period of 28.8 months (range 12–53 months), no cases of failure of reduction or displacement of hardware were detected. The mean AOFAS was 91.73 points while the mean MFS was 95.09 points. Twenty-eight patients were able to resume their pre-injury level of work while the remaining five refrained to sedentary jobs. The mean pre-operative Bohlers' angle was 2.8° (range from -38º to 24º) while postoperatively it was 19.4° (range 5º to 49º). There was no statistically significant difference when comparing the results (AOFAS p-value 1.00, MFS p-value 0.81) between Sanders' type II and III fractures.

One patient had postoperative superficial wound infection. Seven patients complained of prominent screw heads. Complex regional pain syndrome occurred in seven patients and was treated successfully at six months duration.
Conclusion The limited open sinus tarsi approach can be used successfully to treat displaced Sanders type II and III fractures. It allows for adequate visualization and reduction. Fixation by screws only is also sufficient. It also clearly avoids the major wound complication problems.

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Introduction

The extensile lateral approach has been considered the gold standard approach for treatment of displaced intra-articular calcaneal fractures (DIACF). It provides excellent exposure of the fracture allowing for anatomical reduction of the posterior facet and restoration of the general architecture of the calcaneus. Nonetheless, soft tissue complications including wound dehiscence and infection have been estimated to occur in 1.7 %–20 % [1–5]. To avoid such complications, multiple percutanous and minimally invasive approaches have been developed.

In 1948, Palmer et al. described a limited lateral approach for management of calcaneal fractures. It provided direct visualization of the posterior facet allowing for anatomical reduction. The absence of the vertical limb protects from devascularization that accompanies the extensile lateral approach and accounts for the wound problems [6]. Various studies have been published utilizing modifications of the Palmer's approach and results have been mostly encouraging [7–9].

We studied our results and the effect of different fracture types on patients treated by limited open sinus tarsi approach and fixed by screws only technique in a similar approach as that described by Weber et al. [9] with some modifications.

Materials and methods

This prospective study was conducted on all adult patients admitted to our unit with DIACF during the period between

January 2009 and January 2011. We included unilateral isolated simple fractures in patients between 16 and 75 years of age. We excluded Sanders type I fractures that were treated conservatively and Sanders IV severely comminuted fractures.

Initial clinical examination included assessment for the presence of soft tissue injuries, associated fractures and neurovascular compromise. Radiographic assessment included standard plain films and CT scans. All fractures were subsequently classified according to Sanders classification [10] (Table 1).

Surgical technique

All patients were placed in the prone position with the affected foot hanging from the edge of the operating table (Fig. 1a). A thigh tourniquet was used and the contralateral limb was flexed at the hip to a lower level to facilitate using the fluoroscopy. A 4–5-cm incision directly over the sinus tarsi starting from the tip of the lateral malleolus directed towards the calcaneocuboid joint was performed. Dissection was carried carefully proximally to avoid injuring the calcanofibular ligament (CFL) (to avoid jeopardizing the stability of the subtalar joint) and the peroneal tendons and distally to avoid injuring the sural nerve (Fig. 1b). The fascia of the extensor digitorum brevis was incised in line with the skin incision and the muscle fibers are reflected dorsally allowing excellent exposure of the posterior facet, the angle of Gissane and the anterior process (Fig. 1c).

The blown out lateral wall was then reflected to gain access to the displaced and rotated fragment(s) of the posterior facet. Cautious leverage of the fragment(s) was done using a blunt instrument to relocate the fragment in the anatomical position with respect to the more constant sustentacular fragment medially. Preliminary fixation using K-wires and reduction was assessed using fluoroscopy (Fig. 2a). When satisfactory reduction was achieved, definitive fixation was then achieved using one or two 4.0-mm partially-threaded screws directed from lateral to the strong sustentaculum fragment medially (in two cases, cannulated screws were used). A 5.0-mm Schanz pin was later introduced into the calcaneal tuberosity from medial to lateral. Distraction with manual correction of the varus malalignment was then performed; this results in restoration of the calcaneal width, length and height which was confirmed fluoroscopically. Two parallel 3.2-mm drill bits were then placed from two separate small skin incisions on both sides of the insertion of the tendo-Achilles directed postero-anteriorly (holding the tuberosity fragment) towards the calcaneocuboid joint. These are then replaced with two 4.5-mm fully threaded positional screws maintaining the calcaneal length and alignment. Finally, another two 4.5-mm screws were directed to raft the elevated posterior facet and maintain the calcaneal height (Fig. 2b). Once the reduction was adequate under imaging and the position of screws was favourable, closure of the wound was done in layers over a suction drain (Fig. 2c).

The patients were placed in a compression bandage for the first two weeks and instructed to perform gentle range of motion exercises of the ankle and subtalar joints. At the two-weeks visit, the wound was inspected and if satisfactory, the stitches were removed and a short leg cast was applied. Partial weight-bearing was started at six weeks then progression to full weight-bearing was gradually achieved around ten weeks. Physical therapy was usually started at six weeks.

Table 1 Patients demographics

Characteristic	Description	Value
Age	Mean	35
	Range	16–60
Sex	Males	25
	Females	8
Side	Right	18
	Left	15
Essex-Lopresti	Tongue type	2
	Joint depression type	31
Sanders	II	15
	III	18
Mechanism of injury	Fall from height	26
	Motor vehicle accident	7

Evaluation

All patients were evaluated both clinically and radiologically. Clinically, patients were evaluated using the American Orthopedic Foot & Ankle Society (AOFAS) ankle-hindfoot scale and the Maryland foot score (MFS) [11, 12] as well as the presence of any complication documented with particular attention to soft tissue problems. Radiologically, anatomical reduction was documented post-operatively using CT-scan and loss of reduction was defined as displacement of ≥2 mm of the articular surface or loss of ≥5° in Bohler's angle.

Statistical analysis

Data were statistically described in terms of mean ± standard deviation (± SD), median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using Student's t-test for independent samples. For comparing categorical data, chi-square ($\chi 2$) test was performed. Fisher's exact test was used instead when the expected frequency

Fig. 1 Intra-operative photos showing patient positioning to facilitate intra-operative imaging (**a**), field of dissection and pointing to CFL (pointing towards by the scissors) and peroneal tendon (**b**), and excellent exposure of the posterior facet, the angle of Gissane and the anterior process (c)

was less than 5. Correlation between various variables was done using Pearson's moment correlation equation. P values less than 0.05 was considered statistically significant. All statistical calculations were done using the computer program SPSS version 15 for Microsoft Windows (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA).

Fig. 2 **a** Pre-operative radiographs of a 24-year-old male patient with Sander type II DIACF. **b** Two-year follow-up radiographs. **c** Depicting full range of motion to subtalar motion

Results

Thirty-three patients with a mean age of 35 years were included in our study (Table 1). The mean time from injury to operation was nine days (range one–18 days). The mean follow-up period was 28.8 months (range 12–53 months). The mean hospital stay was six days (range two–20 days), and the mean operative time was 90 minutes (range 70–120 minutes).

In all cases, adequate reduction of the fracture, including regaining of the calcaneal length, width and height as well as anatomical reduction of the intra-articular fragments with restoration of the congruity of the subtalar joint was reached (Figs. 2 and 3).

We had no cases of failure of reduction or displacement of hardware. No patients developed significant subtalar arthritis that warranted subtalar arthrodesis. Twenty-eight patients were able to resume their pre-injury level of work while the remaining five refrained to sedentary jobs. Two patients experienced difficulty with wearing normal shoes and used orthotic devices.

Complications

One patient had a postoperative superficial wound infection which resolved completely by local wound care and oral antibiotics administered for a week. Seven patients complained at three months of tenderness at the posterior incision from prominent screw heads and were managed by removal of the screws at six months after surgery (Fig. 3). Another patient had a transient period of sural nerve dysthesia which resolved spontaneously at six months. One patient developed clawing of his toes which was not bothersome to the patient and did not require further intervention. Complex regional pain syndrome occurred in seven patients and was treated successfully by medications and physical therapy at six months duration.

Radiographic evaluation

Marked improvement in the Bohler's angle was noticed in all our patients. The mean pre-operative angle was 2.8° (range from −38º to 24º), and postoperatively it was 19.4° (range from 5º–49º). Better restoration of the Bohler's angle was noticed particularly in Sanders II. No case of loss of reduction was noticed.

Functional outcomes assessments

The overall mean AOFAS was 91.7 while the mean MFS was 95.1 points at the latest follow ups (Table 2). We didn't find statistically significant differences when using this approach between Sanders' types II and III (using the AOFAS, Sanders type II group ranged from 77 to 100 with a mean 91.7 while the Sanders type III group ranged from 63 to 100 with a mean 91.7 [p-value 1.0]; using the MFS, the Sanders type II group ranged from 83 to 100 with a mean 95.4 while the Sanders type III group ranged from 67 to 100 with a mean 94.8 [p-value 0.8]).

Fig. 3 **a** Pre-operative radiographs of Sanders' type III A–C. **b** Three-years follow-up radiographs

Table 2 Functional outcome scores

Score	Mean (SD)	Excellent (%) (score 100–90)	Good (%) (score 90–80)	Fair (%) (score 80–70)	Poor (%) (score < 70)
AOFAS	91.7 (7.26)	24 (72.7)	7 (21.2)	1 (3.0)	1 (3.0)
MFS	95.1 (6.7)	29 (87.9)	3 (9.1)	1 (3.0)	0 (0)

AOFAS American Orthopedic Foot & Ankle Society, *MFS* Maryland foot score

Discussion

Originally described by Letournel [13], and later popularized by many authors, the extensile lateral approach is the most commonly used approach for operative treatment of intra-articular calcaneal fractures. Its versatile nature allows visualization of the whole calcaneus and permits anatomical reduction of the subtalar joint as well as restoration of the general architecture of the calcaneus. However, its main drawback is the high wound complication rate [1–5]. Various anatomic studies concluded that injury of the lateral calcaneal artery (LCA) at the site of the vertical incision is responsible for ischemia and necrosis of the lateral calcaneal flap [14–16]. In an attempt to reduce the wound complication rate, numerous minimally invasive and percutanous methods were developed [6–10, 17–21].

The main disadvantage with percutanous techniques is the limited exposure with subsequent difficulty in achieving accurate reduction of the articular surface and more reliance on intraoperative fluoroscopy to assess the reduction. Trying to avoid the unwanted complications of the extensile lateral approach while maintaining the ability to visualize the joint and ensure anatomical reduction of the articular surface, in 1948 Palmer et al. described a direct lateral approach for open reduction of calcaneal fractures through the sinus tarsi and reported satisfactory results [6]. Moreover, in 2008, Weber et al. [9] described a limited lateral approach for open reduction and percutanous fixation of calcaneus fractures in which 24 patients were compared to a similar cohort of patients managed via the traditional extensile lateral approach. After a mean follow up of 31 months, all cases in both groups achieved accurate reduction with restoration of calcaneal heel height and width. However, they reported fewer wound complications and significantly shorter operative time in the sinus tarsi approach.

In our study, we utilized the technique described by Weber et al. with few modifications. All patients were operated upon in the prone position instead of the lateral position which allowed in our opinion an easier and better view of the posterior facet using the Harris axial view; also, we didn't use any distractors and relied on the manual traction reducing the articular fracture first followed by restoring the height and width of the calcaneus. Lastly, we used four 4.5-mm positional screws instead of 3.5-mm screws because we believe that the larger diameter of these screws allows for a better defect filling (4 mm more) without causing any harm.

The mean AOFAS score in our study was 91.7 with excellent-to-good results obtained in 93 %. The scores in our study were found to be higher than those reported by Weber et al. in which the mean AOFAS score was 87.2 with excellent-to-good results obtained in 84 %. Also, the mean MFS in our study was 95.09 with excellent results achieved in 97 % [9]. In 1998, Tornetta et al. re-popularized the Essex-Lopresti technique for percutanous reduction of tongue-type and Sanders IIC fractures. Their functional outcomes measured by the MFS were excellent in 55 % and good in 32 % [18, 19]. Gavlik et al. reported on 15 patients with only Sanders type II fractures treated by the percutanous arthroscopic assisted technique. Their mean AOFAS and MFS scores were 93.7 and 95.8 respectively [20]. A different study utilized the Creighton-Nebraska Health Foundation assessment score to evaluate cases treated via a minimally invasive approach with percutanous K-wires fixation. The mean follow-up score reported was 83.9 [21]. Excellent-to-good results were obtained in 85 % of another study [10]. Tomesen et al. [22] used a similar technique to that described by Forgon [10]. At a mean follow up of 66 months, their mean AOFAS and MFS scores were 84 and 86 respectively. All the previously mentioned studies in addition to our study confirmed that limited open and percutanous approaches can be used successfully in treating displaced intra-articular calcaneal fractures with satisfactory outcomes.

Nevertheless, a significant concern with fixation of these fractures by screws only is the secondary loss of reduction. We didn't report any case with major loss of the post-operatively achieved Bohler's angle of ≥5° or displacement of the posterior facet of ≥ 2 mm at an average follow-up duration of 28.8 months. Similarly, Weber et al. [9] reported maintenance of the Bohler's angle without any major loss of reduction in all their cases.

In our early experience, we assumed that the limited open technique would be helpful in Sanders type II more than type III assuming that the limited approach wouldn't allow for good exposure of the middle fragment. Moreover, we assumed that screw fixation would not give enough support for three-part fractures as for two-part fractures. This was not true, as we achieved almost the same mean AOFAS and MFS for both types and we didn't find any statistically significant differences when comparing both fractures for the two scoring systems used.

The overall wound complication rate is the single most unwanted complication when discussing management of calcaneal fractures. Our present study had one postoperative superficial wound infection which was successfully controlled by local wound care and oral antibiotics. In the series treated by Weber et al., no single wound complication was found in the sinus tarsi approach compared to two wound problems in

the extensile group [9]. In another study by Stulik et al. [21], 247 patients were treated by a minimally invasive approach and percutanous fixation via K-wires. They reported an overall wound complication rate of 8.7 % with deep infections representing 1.7 %. Ebraheim et al. [7] reviewed 107 calcaneal fractures treated through a sinus tarsi approach and fixed via single or multiple pins. Their wound infection rate was 8.5 %.

Their incidence of CRPS in this study (21.2 %) was higher than that obtained by Weber et al. [9] (15.4 %) and Tomesen et al. [22] (2.5 %). This may be due to the lack of adherence of the patients to a physiotherapy program. Nevertheless, the incidence of CRPS was much lower in the Tomesen et al. study which didn't cast the patients postoperatively when compared to our study and the Weber et al. study in which the patients were casted for four and six weeks, respectively. This finding raises the question of whether putting the patient in cast postoperatively is really beneficial or not.

The limited exposure increases the demand on intraoperative fluoroscopy to compensate for the inability to fully visualize all the fracture fragments. However, we believe the more acquainted we became with our technique, the less operative time we consumed to fix these fractures with lesser dependence on fluoroscopy.

Tenderness at the posterior scar over the screw heads is reported with all techniques of percutanous fixation of calcaneal fractures and that raised the need for fixation with either headless or bioabsorbable screws [23]. In our present study, uneventful removal of hardware due to tenderness was performed in seven patients at six months after surgery. In Weber's series, ten patients underwent removal of the hardware due to tenderness at the scar. Except for the need for a secondary operation to remove the screws, we do not believe that this should be considered a major concern given the ease of removing the screws without interfering with the rehabilitation course of the patients.

In conclusion, the present study demonstrates that the limited open sinus tarsi approach can be used successfully to treat displaced Sanders type II and III intra-articular calcaneal fractures. It allows for adequate visualization and reduction of the articular surface as well as the general architecture of the calcaneus. Fixation by screws only is also sufficient. It also clearly avoids the major wound complication problems associated with the traditional extensile lateral approach.

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