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Review Article

Open Reduction and Percutaneous Screws Fixation of Displaced Calcaneal Fractures. A Review of 60 Fractures

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Abstract

Introduction

Treatment of displaced intra-articular calcaneal fractures remains controversial. The unsatisfying clinical results after conservative treatment of displaced intra-articular calcaneal fractures resulted in a reappraisal of the surgical approach. Although the literature generally supports operative treatment of these injuries, there are still certain disorders that may impede wound or bone-healing.

Aim of the Work

The aim of this work was to evaluate the clinical and radiographic results of minimally invasive osteosynthesis technique for treatment of displaced intra-articular fractures of the calcaneus.

Patients and Methods

The study included 60 patients with displaced closed intra-articular calcaneal fractures treated during the period from December 2015 to March 2018. These were treated by minimally invasive osteosynthesis technique. The mean age of patients was 35.3 years, (range 18.0-55.0 years). Fifty four patients were males and 6 were females. Patients were assessed radiologically and clinically according to modified Mc Master scoring system.

Results

At the end of follow up (mean 29.7 months) (range 12 - 36 months), it was found that the mean final score was 82.0 ± 12.29 with a range (52.0 - 95.0). According to the scoring system, fifteen patients (25.0%) had excellent results, 33 (55.0%) good, 6 (10.0%) fair and 6 (10.0%) had poor results.

Conclusion

Treatment of displaced intra-articular calcaneal fractures by minimally invasive osteosynthesis technique is a reliable method for obtaining satisfactory reconstitution of the fracture fragments and avoids the common wound related complications of the conventional open reduction approach. The fixation with percutaneous screws entails delayed weight bearing to avoid failure of fixation.

Introduction

Calcaneal fractures account for 60% of tarsal bone injuries and 2% of all fractures. They usually occur as the result of a fall from a height and typically occur in men more than women [1-3]. Many patients are debilitated for several years and others never return to their preinjury occupations and activity [4,5].

Treatment of displaced intra-articular calcaneal fractures remains controversial [6,7]. The first accurate description of treatment for such fractures occurred in 1720 by Petit and DeSault in France. They recommended "rest until the fragments consolidate" [8]. Conservative management by rest and elevation remained the mainstay of treatment until the 1900s [9]. In 1902, Morestin was the first to advocate open reduction [10]. In 1908, Cotton and Wilson described their closed reduction technique in an attempt to restore normal anatomy and reduce the disabilities previously associated with calcaneus fractures. They proposed closed manual molding of the fracture fragments after disimpaction with a small hammer followed by casting [10]. In 1913, Leriche was the first to use plates and screws for osteosynthesis [11]. In 1931, Böhler modified this closed technique using pin and clamps in an attempt to restore normal anatomy [12]. In 1948, Palmer popularized his method of open reduction using a lateral approach with bone grafting [13]. However, the unacceptably high infection rates and inadequate fixation devices have led to a decline of calcaneus surgery in the mid-20th century with many surgeons advocating primary or secondary subtalar arthrodesis [13,14].

Recently, the unsatisfying clinical results after conservative treatment of displaced intra-articular calcaneal fractures and the routine availability of CT scanning for diagnosis resulted in a reappraisal of the surgical approach in the 1980s [15-19]. The focus of current treatment is on operative methods, with the goal of restoring not only articular congruency but also the shape and alignment of the calcaneus. Several studies revealed that operative management yields superior results when compared with conservative treatment [20].

Although the recent literature generally supports operative treatment of these injuries, there are still certain contraindications, including neuropathies, insulin-dependent diabetes mellitus, peripheral vascular disease, venous stasis, lymphedema, immunocompromise, heavy smoking, or other disorders that may impede wound or bone-healing [17,19,21]. Considering that the wound complication rates range from 2% to 27% in the series fixed with the popular posterolateral extensile approach, alternative approaches or less invasive techniques with potentially reduced associated complication rates have been advocated [22-24].

The long period of recovery in calcaneal fractures and the frequent marked permanent loss of function following these fractures are due to its extension to the talar facets, in addition to disturbance of the kinematics of the subtalar joint and the altered physiological angles following incongruity of the displaced articular facets. This may end in a painful joint ankylosis which affects significantly the adaptability of the foot during walking on a sloping or uneven ground [25]. Perfect reduction of the displaced articular facets and preservation of normal values of calcaneal angles enable the foot to adapt the variations in walking surfaces, body posture and to absorb shock. The morphology of the calcaneal facets plays an important role in the static and dynamics of the foot. Accordingly, the subtalar varus or valgus are harmful for the whole lower limb mechanics [26]. This clarifies the great importance of reconstruction and maintenance of subtalar joint normality. The calcaneal angles are good indices for normal mechanics of the reduced subtalar collapse following calcaneal fractures [27].

Aim of the Work

The aim of this work was to evaluate the clinical and radiographic results of minimally invasive osteosynthesis technique for treatment of displaced intra-articular fractures of the calcaneus.

Patients and Methods

The study included 60 patients with displaced closed intra-articular calcaneal fractures treated at El-Hadra University Hospital, Alexandria, Egypt, during the period from December 2015 to March 2018. These were treated by minimally invasive osteosynthesis technique. All patients signed written informed consents, and university hospitals ethics committee approval had been obtained.

Inclusion Criteria

Closed displaced intra-articular fracture of calcaneus Sanders type II or III in patients age 18 years or older.

Exclusion Criteria

- A previous diagnosis of neurologic or vascular diseases affecting the lower extremities.
- Open fracture or skin necrosis or infection prior to surgery.
- Sander type IV.
- Bilateral calcaneal fractures or any associated lower limb fractures which will affect the final assessment.

The mean age of patients was 35.30±10.04 years, (range 18.0-55.0 years). Fifty four (90%) were males and 6 (10%) were females. There were fifty one (85%) heavy manual workers, 3 (5%) housewife, 3 (5%) office workers and 3 (5%) engineers. The right side was affected in forty two (70%) while the left was involved in 18 (30%). Falling from a height was the mechanism of injury in fifty four patients (90%) and RTA in 6 patients (10%). According to Sander's classification (17), 30 fractures (50%) were classified as type II fractures and 30 (50%) as type III fractures. The mean time lapse before surgery was 4.85 ± 3.25days (range 1-10 days).

Surgical Technique

The surgical principle used was introduced by Forgon [26] in 1992 in the form of 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. Gomaa MA *et al* [27] modified that technique using a small lateral incision to reduce and fix the articular surface under direct vision which was used in this study.

All the operations were performed under spinal anesthesia and tourniquet, which was released before wound closure for hemostasis. The patient was placed and supported in the lateral position with the affected limb up.

The technique entailed the exact reduction of subtalar joint surfaces and reduction of the main calcaneal fragments to realign medio-lateral alignment and reduction of broadening of the entire calcaneal substance. The image intensifier was placed at the side of the affected limb with enough space to allow it to move freely to take lateral and axial views. The axial view was used to visualize the subtalar joint and the sustentaculum tali, together with assessment of calcaneal width. A 5mm Steinmann pin was inserted from lateral to medial in the calcaneal tuberosity taking care not to interfere with the insertion of the 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 Bohler's angle and calcaneal length were restored with special attention paid to correct any varus deformity and prevent it throughout the procedure. A small incision was made, under image control, parallel to the peroneal tendons above the posterior facet. 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 carefully, to avoid breaking through into the subtalar joint. The articular surface was visualized and the reduction was checked in lateral and axial views with the articular surface fixed primarily with Kirschner wires (Fig. 1).

Figure 1: *The reduction was checked in lateral and the articular surface was fixed primarily with Kirschner wires*

Under the image intensifier control, a 4.5mm cannulated, short threaded screw was used as a transverse compression screw directly below the posterior facet after pressure was applied medially and laterally below the sustentaculum to reduce the width of calcaneus. 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 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. 2).

Figure 2: *Short threaded screw was used as a transverse compression screw directly below the posterior facet*

After measuring the screw length and drilling in the routine manner, the cannulated screw was inserted while the assistant holding the stirrup all the time in traction, maintaining normal calcaneal length and Bohler's angle and preventing varus deformity.

The guide wire for the first 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 axial view to control the position of the wire in the mediolateral distance (Fig. 3).

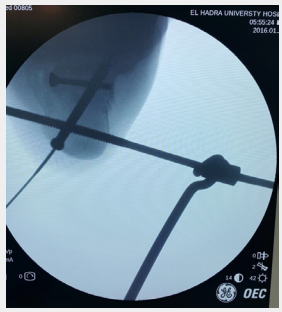

Figure 3: *First positional screw was started at the plantar lateral aspect of the tuberosity and directed superiorly and medially, passing below the transverse screw, and ending below the sustentacular fragment*

The guide wire for the second 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. No bone graft was used.

Postoperative Care

- Examination of the vascular and neurological status.
- Post-operative check X-rays for reduction and position of screws.
- Below knee plaster cast was done for six weeks.
- After six weeks, removal of the cast was done and partial weight bearing in another walking cast was allowed for another two weeks, then after 8 weeks removal of cast and partial weight bearing for another four weeks without cast.
- Full weight bearing started after the confirmation of union.
- Check X-rays were obtained 6 weeks post-operative and then every month till the end of follow up period.

Method of Assessment

At the end of follow up period (range 12 -36 months), patients were assessed according to the modified Mc Master scoring system (the modification was done on Mc Master score was accurate assessment of ankle and subtalar range of motion, change of shoe size, hind foot alignment and limping) [28] . A score of 90 to 100 points is an excellent result, 80 to 89 points is a good result; 65 to 79 points is a fair result and 64 points or less is a poor result.

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp).Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean and standard deviation. The significance of the obtained results was judged at the 5% level.

Results

At the end of follow up (mean 29 ± 7 months) (range 12 - 36 months), it was found that the mean final score was 82.0 ± 12.29 with a range (52.0 - 95.0). According to the scoring system, fifteen patients (25.0%) had excellent results, 33 (55.0%) good (Figure 4), 6 (10.0%) fair and 6 (10.0%) had poor results. (Table 1).

Table 1: *Distribution of the end results*

McMaster scoring	No.	%
Satisfactory	**48**	**80.0**
Good	33	55.0
Excellent	15	25.0
Unsatisfactory	**12**	**20.0**
Poor	6	10.0
Fair	6	10.0
Min. - Max.	52.0 - 95.0	
Mean ± SD.	82.0 ± 12.29	
Median	87.0	

A negative correlation was present between the age of the patients and their final results (the younger the age, the better were the results). The mean age of the satisfactory patients was 36.17±11.80 years and that of the unsatisfactory was 44.70±7.52 years, and this difference was statistically significant (p=0.031*, t=1.91).

In this study, type II fractures gave more satisfactory results (90.0%) than type III (75.0%). This difference was found to be statistically significant (x2 =8.93, p =0.0042). There was a significant negative correlation between time lapse before surgery and the final score. Median time lapse before surgery in the satisfactory group was 3 days and that of the unsatisfactory group was 7.5 days. (p=0.0021*, t=19.0).

There was a significant positive correlation between the preoperative Böhler's angle and the postoperative Böhler's angle and the final score: (p=0.018*, t=2.597) (p>.001*, t=7.338) respectively (Table 2).

Table 2: *Relation between the results and preoperative and postoperative Böhler's angle*

Böhler angle	McMaster scoring		T	p
	Satisfactory (n = 16)	Unsatisfactory (n = 4)		
Pre-operative				
Min. –Max.	8.0 –19.0	8.0 –13.0	2.597*	0.018*
Mean ±SD.	15.13 ± 3.36	10.50 ± 2.08		
Median	16.0	10.50		
Post-operative				
Min. –Max.	24.0 –38.0	20.0 –23.0	7.338*	<0.001*
Mean ±SD.	30.87 ± 4.41	21.50 ± 1.29		
Median	31.0	21.50		

There was a significant negative correlation between the preoperative and the postoperative Gissane's angle and the final score (p<0.001*, t=4.573*), (p=0.005*, t=3.232*) respectively (Table 3).

Table 3: *Relation between the results and preoperative and postoperative Gissane's angle*

Gissane	McMaster scoring		T	p
	Satisfactory (n = 16)	Unsatisfactory (n = 4)		
Pre-operative				
Min. -Max.	126.0 -144.0	144.0 -155.0	4.573*	<0.001*
Mean ±SD.	136.4 ± 5.12	149.3 ± 4.57		
Median	138.0	149.0		
Post-operative				
Min. –Max.	120.0 -138.0	134.0 -140.0	3.232*	0.005*
Mean ±SD.	129.6 ± 4.40	137.3 ± 3.20		
Median	130.5	137.5		

There was a significant negative correlation between postoperative width and the final score. The median postoperative width in the satisfactory group was 33.0 millimeter and that of the unsatisfactory group was 36.50 millimeter. (p<0.001*, t=4.522*).

There was a significant positive correlation between the restoration of the postoperative calcaneal height and the final score (p=0.024*, t=0.024*).

Nine of the 12 patients with unsatisfactory results had postoperative varus deformity of the oscalsis while none of the patients with satisfactory results had varus deformity.

There was no statistically significant relationship between the side affected and the final score.

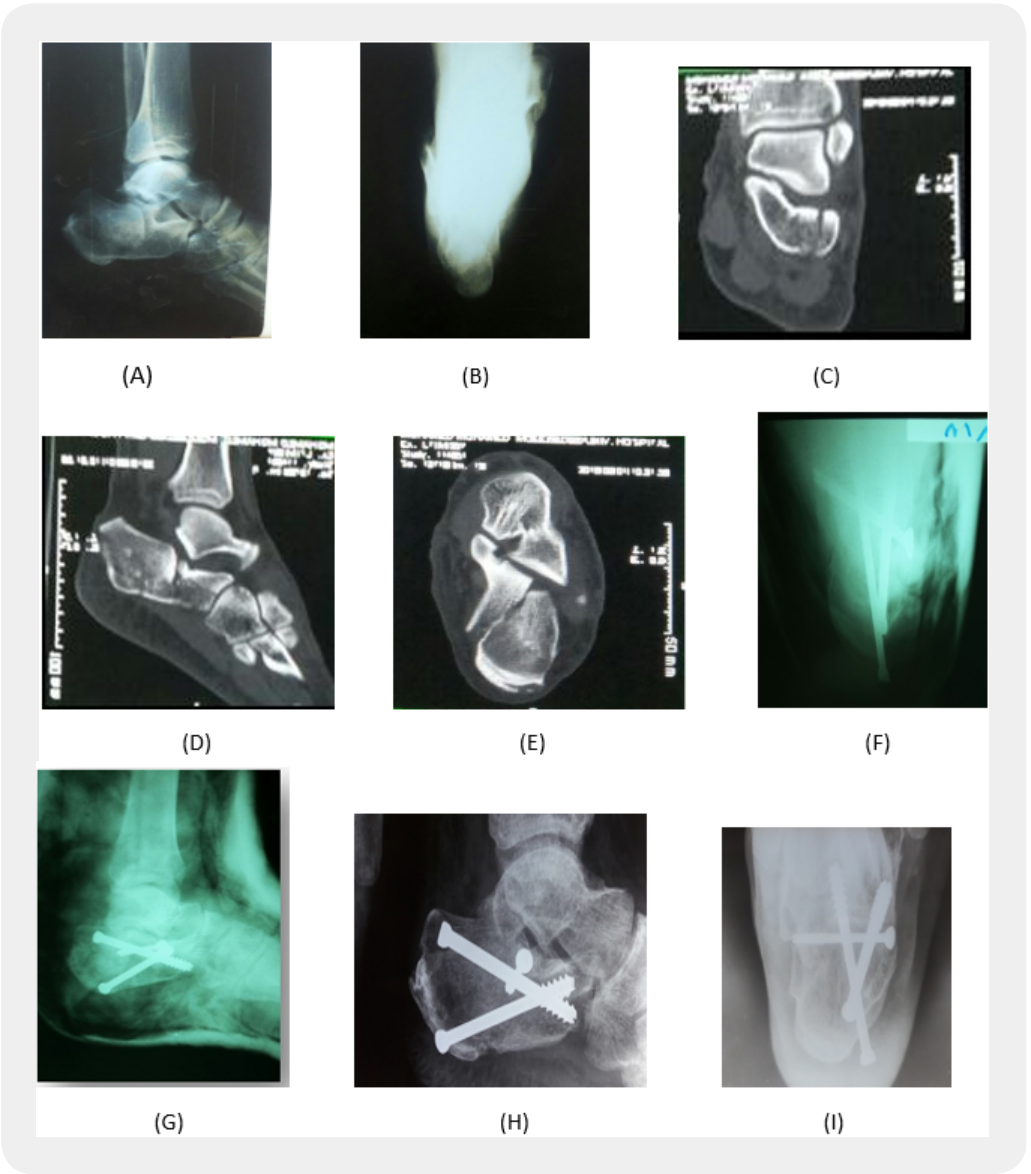

Figure 4: *45 years male patient. (A, B) pre-operative X-ray, (C, D, E) pre-operative CT (F,G) immediate post-operative X-ray, (H,I) follow up X-ray after six months with good result*

Complications

Eighteen patients (30.0%) suffered moderate pain (according to Mc Master score) around the heel necessitating occasional medications. Twelve patients had lateral heel pain; five patients had pain over the posterior aspect of the heel, and one patient from medial heel pain. Three superficial screw track infections (5.0%) were encountered and were treated with local dressing and antibiotics without requiring early removal of the screws. Nine patients (15.0%) suffered from mild to moderate subtalar osteoarthritis with some limitation of subtalar motion after follow up of more than a year which was confirmed by injection of a local anesthetic in the subtalar joint. Nine patients suffered from varus deformity of the heel at the end of follow up. Three patients had prominent screws which caused pain over the posterior aspect of the heel (2 patients), and the medial aspect (one patient) of the heel. This required removal of the prominent screws in the all patients after healing of the fracture

Discussion

The treatment of displaced intra-articular calcaneal fractures remains controversial. Historically, calcaneal fractures were treated non-operatively with unsatisfactory results. As the operative care and the imaging techniques have improved during the last decades, the surgical procedures have become more popular [29,30].

Randle *et al.* reported, in their meta-analysis, a trend for surgically treated patients to have better outcomes. A major concern for most surgeons is the complication rate associated with these procedures [31]. Folk *et al.* reported a complication rate of 25% in 190 fractures [32]. Zwipp *et al* reported superficial wound edge necrosis in 8.3% of their cases [33]. Buckley *et al* reported a superficial wound complication rate of 17% and a deep infection rate of 5% in the operative group treated with open reduction and plate fixation [5].

In an effort to minimize infectious complications, Forgon and Zadravecz developed a technique employing closed reduction and percutaneous fixation for the treatment of displaced intra-articular calcaneal fractures [26]. Their study in (1993), included 265 fractures, with good to excellent results occurring in approximately 85% of patients [26]. In the last ten years minimally invasive osteosynthesis with screws has been used and gained more popularity in treatment of minimally comminuted intra-articular calcaneal fractures. minimally invasive osteosynthesis has the advantages of minimally invasive surgery including: less morbidity, early recovery, decreased rehabilitation period and smaller scars [30].

Minimally invasive procedures offer the attractive benefits of early intervention, minimization of surgical risks, and early return to function. Better visualization of the subtalar joint during minimally invasive procedure represents a prerequisite to obtain optimal long-term outcomes through more accurate reduction of the articular surface [34]. For intra-operative evaluation of reduction, some minimally invasive techniques use subtalar arthroscopic evaluation and some use intra-operative fluoroscopic guidance [35].

Schepers *et al* used percutaneous screw fixation after skeletal traction for 50 patients with 61 fractures with a minimum follow up of 1 year were available, 72% had good to excellent result [30]. Tomesen *et al* used percutaneous screw fixation after reduction of fracture by Forgon and Zadravecz technique with some

modifications for 39 displaced intra-articular calcaneal fractures with follow up period of at least 24 months, 73% had good to excellent result [36]. The results of Schepers *et al* and Tomesen *et al* were inferior to our results and this might be because their studies were conducted on all types (sander's II, III, IV) calcaneal fractures, especially sander's IV which had more severe soft tissue injury and bony comminution in about one third of their cases.

Rammelt *et al* used arthroscopic assisted reduction and percutaneous fixation for 33 patients with sander's type II displaced intra-articular calcaneal fractures and minimum follow up of 24 months, the average American Orthopaedic Foot and Ankle Society (AOFAS) score was 92.1 (range, 80-100). The superior results of this study could be attributed to being conducted on sander's type II fractures only and with accurate arthroscopic assisted reduction [37].

Stulik *et al* used minimally invasive reduction and Kirschner wires fixation in their series of 345 displaced intra-articular calcaneal fractures and reported (72%) with good to excellent results [38]. Walde *et al* evaluated retrospectively 67 calcaneal fractures treated with closed reduction and percutaneous Kirschner wires fixation with an average follow up of five to seven years, resulting in (61%) good to excellent results, (35.8%) fair, and (3.2%) poor results [39]. The use of Kirschner wires as a method of fixation for these difficult fractures entails the risk of redisplacement of the fracture after fixation and can explain the relative inferior results of the previously mentioned two studies.

Magnan *et al.* used a minimally invasive procedure using percutaneous reduction and external fixation for 54 closed displaced intra-articular calcaneal fractures followed for a mean of 49 months, (90.7%) good to excellent results, (3.7%) fair, and (5.6%) poor results [40]. Fernandez and Koella , used combined percutaneous and minimal internal fixation with bone grafting (through a postero-lateral approach with open reduction and screw fixation of the posterior facet, bone grafting, and percutaneous pinning of the body) in displaced intra-articular calcaneal fractures and they found that (80%) of their cases were satisfactory [41].

There was a significant negative correlation between time lapse before surgery and the final score. This could be due to difficulty in posterior facet reduction with increasing time lapse before surgery. Rammelt *et al* reported Inferior results in cases where delay in surgery exceeded 2 weeks [37]. Abidi *et al* reported that the extended time between injury and surgery was a risk factor for complications in the wound after open reduction and internal fixation of the calcaneal fractures [42].

The mean final scores of Sanders type II fractures were higher than that of type III fractures; this probably because of the more comminution and displacement in type III which prevented acceptable reduction of the fracture and destruction of the articular surfaces with chondral damage predisposing to subtalar arthritis. This coincided with the results presented by Huang *et al.* who found that 83% of type II fractures had good to excellent results, and 70% of type III fractures had good to excellent results [43].

In this study, there was significant correlation between the clinical outcome and the degree of restoration of Böhler's and Gissane's angles. This coincided with the finding of Stephenson [44] and Thermann [45].

On the other hand, Hutchinson *et al.* found that there was no correlation between restoration of Böhler's angle and their final outcome [46]. Buckley concluded that ORIF of displaced intra-articular calcaneal fractures did successfully increase Böhler's angle, yet this cannot be correlated with improved scores [5]. Tomesen *et al.* reported that a better restored Böhler's angle did not necessary correspond with better functional outcome scores [36]. This could be explained by the initial chondral damage occurring at the time of injury which will affect the outcome regardless the method of treatment.

Three superficial screw track infections (5.0%) were encountered and were treated with local dressing and antibiotics without requiring early removal of the screws. Folk *et al.* reported a 25% wound complication rate (48 out of 190 fractures); forty patients required operative intervention and debridement: 22 necessitated hardware removal, 11 required free flap coverage, and four ended with amputation [32]. Abidi *et al.* reported a 32% wound healing complication rate (20 out of 63 fractures). Five patients required operative intervention with surgical debridement; two required free flap coverage [42].

This very low rate of wound related problem is considered a major advantage of the minimally invasive approach compared to the traditional open reduction approach of calcaneal fractures. Moreover, the contraindications to surgery in this study were more limited than the open reduction studies because we used a minimally invasive incision which entails less risk in case of diabetic patients, smokers and patients with vascular impairment.

Conclusion

In conclusion, treatment of displaced intra-articular calcaneal fractures by minimally invasive osteosynthesis technique is a reliable method for obtaining satisfactory reconstitution of the fracture fragments and avoids the common wound related complications of the conventional open reduction approach. This technique allows reduction of posterior facet which is an important factor in obtaining satisfactory results. The fixation with percutaneous screws entails delayed weight bearing to avoid failure of fixation.

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Declaration of Conflicting Interests Statement

The Authors declare that there is no conflict of interest.

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