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Original Article

PERCUTANEOUS CANNULATED SCREWS FOR TREATMENT OF DISPLACED INTRA-ARTICULAR CALCANEAL FRACTURES: A PROSPECTIVE STUDY

Hossam El-Azab, Khalaf Fathy Elsayed Ahmed(*), Abdelrahman Hafez Khalefa & Ashraf Rashad Marzouk

Orthopaedics and Traumatology dept., Faculty of Medicine, Sohag Univ., Sohag, Egypt

*E-mail: khalaffathy@med.sohag.edu.eg

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Abstract

***Background**: Treatment of displaced intra-articular calcaneal fractures (DIACFs) remains controversial and challenging to orthopaedic surgeons. Several procedures were used to treat DIACFs. There is no single approach that is universally applicable to all DIACFs. Objective:-The aim of this prospective study was to evaluate functional and radiographic outcomes of closed reduction and percutaneous cannulated screws fixation in treatment of Sanders type II & III DIACFs. **Patients and methods**: A prospective study was conducted on 14 patients (17 feet) with Sanders' type II or III DIACFs, treated by closed reduction and fixation using cannulated screws, at orthopedics department of Sohag university hospital, between June 2020 and April 2022. Functional assessment was done by AOFAS score and VAS for pain. Radiographic assessment was done by measurement of three calcaneal angles (Gissane, Böhler's and posterior facet inclination angles) and three calcaneal distances (height, length and width of calcaneus). **Results**: The mean age of patients at time of operation was 34.8 years. Vast majority of patients were males (78.6%). Involvement of right side was 57.1%. Mean operative time was 57 minutes. Mean AOFAS score was 85.9 points. Mean time of radiographic union was 8.9 weeks. **Conclusion**: The technique avoided wound complications associated with ORIF with advantage of shorter hospital stay. Patients are satisfied and had lower rate of subtalar arthritis.*

Keywords: *Percutaneous fixation, Intra-articular calcaneal fractures, Minimally invasive surgery, Cannulated screws, Prospective study.*

1. Introduction

The calcaneus is the largest and the most considerable weight-bearing tarsal bone, which makes it vulnerable to injury. Calcaneal fractures constitute about 1-2% of all skeletal fractures. About 75% of these fractures are intra-articular and frequently occurring in active young patients mostly due to axial loading mechanisms resulting from falling from height [1]. The optimal treatment for DIACFs is still controversial and challenging to the orthopaedic surgeons. The goals of treatment of DIACFs are anatomical reduction of the articular surfaces of the subtalar and calcaneocuboid joints, restoration of the calcaneal width, height, and length, and correction of varus malalignment and lateral wall explosion of calcaneus so that the normal kinematics of the foot and ankle are restored [2,3]. Conservative treatment have been associated with poor results due to significant complications that may occur in up to 25% of cases including; chronic pain, peroneal impingement, calcaneal malunion with varus

or valgus heel deformity, secondary subtalar arthritis and persistent painful gait [4,5]. Open reduction and internal fixation (ORIF) through extensile lateral approach is the traditional treatment for DIACFs but can be associated with significant soft tissue complications as wound dehiscence, necrosis and infection in up to 16% - 30% of patients with high cost of infectious complications [6-8]. Several authors have described minimally invasive surgical (MIS) techniques for the treatment of DIACFs. Achievement of anatomical or "near anatomical" reduction of the articular components and the overall shape and alignment of the bone indirectly through a ligamentotaxis without jeopardizing the soft tissue envelope forms the basis of MIS. The MIS techniques have yielded promising results, with a decreased rate of deep infections and wound related complications, but carry the risk of inadequate reduction, especially with complex fracture patterns [9,10]. Controversy exists regarding the appropriate indications for open versus percutaneous fixation techniques and the long-term outcomes with respect to mobility, function, patient satisfaction, degree of arthritis, and the need for additional revision surgery or implant removal [11]. The aim of this current prospective study was to evaluate functional and radiographic outcomes of closed reduction and percutaneous cannulated screws fixation in treatment of Sanders type II & III DIACFs.

2. Patients and methods

2.1. *Patients*

The current prospective study was conducted on 14 patients (17 feet) with Sanders' type II or III DIACFs (3 patients with bilateral fractures and 11 patients with unilateral fracture), at orthopedics dep. of Sohag university hospital, between April 2020 and February 2022. Adult patients with closed fractures of duration ≤ 14 days were included. Open fractures, fracture >14 days, non-displaced fractures, extra-articular fractures, fractures in children, or previously fractured calcaneus were excluded. At first presentation to the emergency unit detailed history was taken and general examination for detection of any associated injuries or fractures was done for all patients. Local examination of the injured foot for side of injury, swelling, and neurovascular condition was done. Informed written consents with risk explanation were obtained from all patients. The study was approved by Scientific and Ethical committees of Sohag faculty of medicine.

2.2. *Methods*

2.2.1. Radiographic evaluation

a) Plain radiography; Lateral and axial views of hindfoot and calcaneus with radiographic interpretation of three calcaneal angles and three calcaneal distances. The three calcaneal angles measured were; tuber angle of Böhler's (normally 20°-40°), crucial angle of Gissane (normally 120°-145°), and posterior facet inclination angle (normally 55°–75°) [12]. The three calcaneal distances measured (in mm) were; calcaneal height, length, and width, fig. (1) [12]. **b)** CT scan of the fractured calcaneus in axial, coronal and sagittal planes.

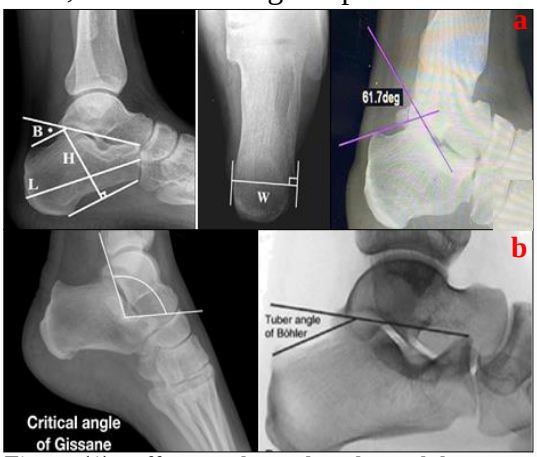

Figure (1) Different calcaneal angles and distances; **a.** Posterior facet inclination angle, **b.** Böhler's angle, L: length of calcaneus, H: Height of calcaneus, W: width of calcaneus.

2.2.2. Classification of fractures

Sanders' [13].and Essex-Lopresti [14]. classification systems were used for all fractures.

2.2.3. Operative technique

Patients were operated within the first two weeks of trauma. We didn't depend on wrinkle sign in determination of surgical timing as we used percutaneous approach. Patient was positioned in a lateral position with affected side up on radiolucent operating table. Operations were done under spinal anaesthesia with C-arm guidance. **a)** Percutaneous reduction of fractures; In tongue-type fractures, 3-4 mm Schanz screw was inserted into the facet fragment in line with deformity. Reduction of displaced fracture by manipulation was done. The Schanz screw used for reduction usually bent to an angle greater than 30 degrees at end of reduction, fig. (2-a). In joint-depression fractures, at first reduction of calcaneal tuberosity was done by manipulation using a 6.5 mm Schanz screw inserted from lateral to medial into calcaneal tuberosity perpendicular to the its length. The Schanz screw was used to do distraction by axial traction. Manipulation was done for reduction of fracture and posterior facet fragment. If posterior facet was not reduced, 1-2 cm small lateral incision was done at the sinus tarsi, then a periosteal elevator or curved artery forceps was inserted to elevate up the depressed posterior facet fragments, fig. (2-b). **b)** Percutaneous cannulated screws fixation; Temporary fixation of the reduced posterior facet was done by using a guide wire for 4 mm cannulated screw, inserted at subarticular level directed to sustentaculum tali. Drilling the hole over the guide wire was done using cannulated drill bit, then fixation by 4.0 mm partially threaded cannulated screw with a washer. Then, temporary fixation of fracture by guide wires from the tuberosity fragment to sustentaculum and to anterior process of calcaneus. Fixation of fracture fragments was done by using partially threaded cannulated screws 7.3 mm (32mm threads) with washers. Confirmation of the final screws lengths and positions was done by lateral and axial views, fig. (3). **c)** Compression of the heel between two hands for reduction of widening and evacuation of haematoma. **d)** Closure of sites of screws insertion with sutures.

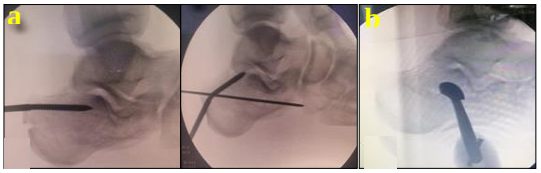

Figure (2) **a.** Percutaneous reduction techniques for tongue-type fractures, **b.** Percutaneous elevation of the depressed posterior facet fragments in joint-depression fractures.

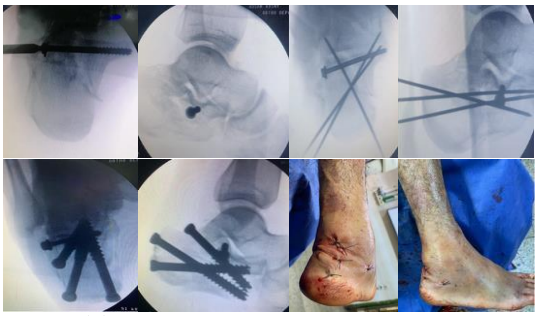

Figure (3) Steps of percutaneous cannulated screws insertion.

2.2.4. Follow up evaluation

At outpatient clinic of Sohag university hospitals. Clinical evaluation by AOFAS ankle-hindfoot scoring system [15], and VAS scale for pain [16]. Measurements of subtalar ROM (inversion and eversion) were done by goniometer using a technique of Kimberly [17]. Radiographic evaluation for adequacy of reduction of subtalar joint, stability of fixation, and fracture union, restoration of normal anatomy, and measurement of 6 radiographic calcaneal parameters. Evaluation of subtalar arthritis was done by PGS [18].

2.3. *Statistical analysis*

Statistical package for social sciences (IBM-SPSS), version 25 (IBM-Corporation, Chicago, USA; August 2017) was used for statistical data analysis. Data was expressed as mean, standard deviation (SD), number and percentage. Mean and standard deviation were used as descriptive value for quantitative data. Paired t-test was used to compare means of the same variable at different periods of time, and Wilcoxon test was used for non-parametric data. For all these tests, the level of significance (P-value) was explained as: (no significance $P > 0.05$, significance $P < 0.05$, and high significance $P < 0.001$).

3. Results

This study was conducted on a total of 17 DIACFs in 14 patients that were treated by closed reduction and percutaneous cannulated screws fixation. The demographic characteristics of the study patients are demonstrated in tab. (1). The vast majority of patients in this study had isolated DIACFs and only 2 (14.3%) patients had associated injuries.

Table (1) Demographics characteristics of the study patients.

Characteristics		Value
Total patients : Feet		14:17
Age at time of operation (years)		
Mean ± SD (Range)		34.79 ± 9.26 (22-55)
Sex		
Males, no (%)		13 (92.9%)
Females, no (%)		1 (7.1%)
Side affected		
Unilateral, no (%)	*Right*	8 (57.2%)
	Left	3 (21.4%)
Bilateral, no (%)		3 (21.4%)
Mechanism of injury		
Falling from height, no (%)		12 (85.7%)
Falling down stairs, no (%)		1 (7.1%)
Road traffic accident, no (%)		1 (7.1%)
Sanders' classification		
Type II		5 (29.4%)
Type III		12 (70.6%)
Essex-Lopresti classification		
Joint depression type		12 (70.6%)
Tongue type		5 (29.4%)
Smoking		
Non-smokers		8 (57.1%)
Smokers		6 (42.9%)
Time lapsed from trauma to surgery (days)		
Mean ± SD (Range)		6 ± 4.54 (1-14)
Operative time (minutes)		
Mean ± SD (Range)		57.06 ± 5.88 (45-65)
Hospital stays (days)		
Mean ± SD (Range)		1.64 ± 0.50 (1-2)
Follow up period (months)		
Mean ± SD (Range)		12.36 ± 3.69 (8-18)
Place of trauma		
Home, no (%)		9 (64.3%)
Work, no (%)		4 (28.6%)
Street, no (%)		1 (7.1%)

3.1. *Functional outcomes*

Satisfactory AOFAS score at the final follow up was obtained. Improvement of the mean VAS score for pain was noted by the patients. Satisfactory subtalar ROM (inversion and eversion) was obtained. Minor complications were reported, tab. (2).

Table (2) Functional outcomes of the study patients.

Items	Outcomes
AOFAS ankle-hindfoot score at final follow up (points)	
Mean ± SD (Range)	85.9 ± 8.3 (70-100)
Excellent, no (%)	10 (58.82%)
Good, no (%)	4 (23.53%)
Fair, no (%)	3 (17.65%)
Poor, no (%)	0 (0.0%)
VAS score for pain (points), Mean ± SD (Range)	
Pre-op	6.8 ± 0.9 (5-8)
4^{th} weeks Post-op	3.3 ± 1.3 (2-6)
Final follow up	1 ± 0.8 (0-3)
Subtalar ROM (eversion & inversion) in (°)	
Mean ± SD (Range)	25 ± 5.3 (15-35)
Time of full weight-bearing (weeks)	
Mean ± SD (Range)	12 ± 1.1 (10-14)
Time of return to work (months)	
Mean ± SD (Range)	4.3 ± 0.8 (3-6)
Complications	
Superficial infections	0 (0%)
Deep infections	0 (0%)
Peroneal tendons subluxation	1 (5.88%)
Prominent hardware	1 (5.88%)
Subtalar joint arthritis (PGS)	
Grade 0	11 (64.7%)
Grade 1	4 (23.5%)
Grade 2	2 (11.8%)
Grade 3	0 (0%)

3.2. *Radiographic outcomes*

Overall significant improvement of the post-operative and final follow up measurements of calcaneal angles and distances compared to the pre-operative measurements. No significant changes in post-operative versus final follow up measurements of all radiographic parameters which meant that the calcaneal screws had the ability to maintain and prevent loss of reduction, tab. (3).

Table (3) Radiographic outcomes of the study patients.

Outcomes	Value	P-values		
		Pre-op vs post-op	*Pre-op vs final*	*Post-op vs final*
Time of radiographic solid union (weeks)		---	---	---
Mean ± SD (Range)	8.9 ± 1.6 (6-12)			
Number of screws or k-wires, no (%)				
Range	2-4			
2	6 (35.3%)			
3	8 (47.05%)			
4	3 (17.65%)			
Angle of Gissane, Mean ± SD (Range), (°)				
Pre-op	130.2 ± 9.8 (112.4 -146.4)	0.333	0.221	0.28
Post-op	129 ± 4.1 (120.7-134.6)			
Final follow up	127.9 ± 6.7 (119.6-148)			
Böhler's angle, Mean ± SD (Range), (°)				
Pre-op	9.7 ± 11.6 ((-10) - 25.6)	0.00026	0.00074	0.365
Post-op	25.2 ± 7.2 (12 - 36.3)			
Final follow up	24.3 ± 7.7 (10 - 40)			
Posterior facet inclination angle, Mean ± SD (Range), (°)				
Pre-op	48.3 ± 10.6 (23.1- 63.6)	0.003	0.0036	0.471
Post-op	58.3 ± 9.1 (42.4-74.5)			
Final follow up	58 ± 9.2 (40-73)			
Calcaneal height, Mean ± SD (Range), (mm)				
Pre-op	44.8 ± 3 (38.7-50)	<0.0001	<0.0001	0.252
Post-op	49.7 ± 3 (45.7-53)			
Final follow up	49.3 ± 2 (45-53)			
Calcaneal length, Mean ± SD (Range), (mm)				
Pre-op	85 ± 4.6 (73.6-89.7)	0.01	0.008	0.489
Post-op	88.6 ± 3.9 (83.4-95.5)			
Final follow up	88.5 ± 3.4 (83-94)			
Calcaneal width, Mean ± SD (Range), (mm)				
Pre-op	54.6 ± 2.6 (49.5 - 58.7)	<0.0001	0.167	0.167
Post-op	46.6 ± 1.9 (44 - 51)			
Final follow up	47.3 ± 2.5 (44.5 -52)			

4. Discussion

The mean AOFAS ankle-hindfoot score at the final follow up was 85.9 ± 8.34 (range, 70-100) points. The overall satisfactory (excellent and good) results were obtained in 82.4% of fractures. Comparing the current results with other studies used calcaneal screws only for fixation of DIACFs, SM Abdelgaid [19], treated 47 patients (60 cases) with DIACFs by closed reduction and percutaneous screw fixation, according to the AOFAS Score, 38.3% of all cases (22 cases) had excellent results, 41% good (25 cases), fair results in 15% (9 cases), and poor results in 5% (4 cases). The overall satisfactory results (excellent and good) were 79.3% with the mean AOFAS score was 89.26 points, and Secondary collapse of fragments was seen in three cases. Yeung et al [20], retrospectively reviewed 24 patients (25 feet) who received percutaneous calcaneal screw fixation, and found that the Maryland Foot Score rated 13 out of 25 injured limbs (52%) as excellent, 9 (36%) as good, and 3 (12%) as fair. There were no patients rated as poor. The three patients with fair results complained of pain and stiffness at the subtalar joint. Long et al. [21], retrospectively reviewed 32 patients with 33 DIACFs treated by three-step closed reduction (distracting, elevating, and clamping) and percutaneous screw fixation, and found that the average AOFAS ankle hindfoot score was 91.7 ± 6.7. Comparing the current results with other types of MIS techniques in DIACFs, the satisfactory results in this current study were comparable to that was achieved by Fascione et al [22], who retrospectively reviewed 15 patients (9 men and 6 women) with

DIACFs who were consecutively treated using a minimally invasive locking nail (Calcanail), and found that the post-operative mean AOFAS score was 85 (range, 60-96) after a mean final follow-up of 18 months (range, 12-24). The mean AOFAS score in this study was higher than that achieved by Schepers et al. [23], they operated 61 fractures in 50 patients percutaneously, with mean AOFAS score of 83 points, after a mean follow-up period of 35 months. Comparing the current results with the results of ORIF in DIACFs, the satisfactory results in this current study were higher than those achieved by Makki et al. [24], they carried out a retrospective review of 47 intra-articular fractures of the calcaneum in 45 patients, treated by ORIF by AO calcaneal plate, and according to AOFAS scale, excellent and good results were achieved in 35 patients (74.5%). Several studies had compared the results of ORIF with the results of MIS techniques in trearment of DIACFs. Ming Li et al. [25], investigated the outcomes of 59 patients with DIACFs treated by percutaneous reduction and hollow screw fixation (PRHCF) as group A versus ORIF as group B, with patients were randomly allocated between the two groups and were followed up for at least 12 (range, 12–24) months, and found that Group A showed significantly more advantages than group B in term of operative time, intraoperative blood loss, time to operation, postoperative hospital stay, and postoperative pain relief during the first 3 days (P<0.001). However, more intraoperative fluoroscopy was required in group A than in group B (P< 0.001). The calcaneal width, height, length, Böhler's angle, and Gissane angle in each group were significantly improved postoperatively (all P<0.001), although not significantly different in the postoperative comparisons between both groups. The AOFAS scores were slightly superior in group A than in group B (88.3 *vs.* 86.4, P=0.08). The rate of incidence of postoperative complications was lower in group A than in group B, although there was no significant difference (P=0.337). They demonstrated that PRHCF was a safe and effective alternative in treating DIACFs. Emara and Allam [26] reported the outcome of 12 patients with Sanders' Type III fractures treated by Ilizarov external fixator and compared them with the outcome of a control group having the same type of fracture but treated with ORIF. Using the AOFAS score to assess the outcome, they found similar functional outcomes: 88.2 in the Ilizarov group and 88.6 in the ORIF group. They concluded that the use of Ilizarov for reduction and fixation seems to be a safe and effective alternative to ORIF in patients with poor skin condition. The mean VAS for pain in the current study decreased from 6.8 ± 0.9 preoperatively to 3.2 ± 1.3 at the 4^{th} week postoperatively, and to 1 ± 0.83 at the final follow-up. Ebrahimpour et al [27], compared the results of closed reduction internal fixation (CRIF) with ORIF in treatment of DIACFs and found that, postoperatively, at seventh day, the VAS in the CRIF group (4.2 ± 1.1) was meaningfully lower than those of the ORIF patients group (4.7 ± 1.2, $P = 0.04$). In the current study, we didn't perform direct kinematic evaluation of the ankle and hindfoot, but our surgical goals were based on the restoration of the calcaneal anatomy and joint congruency which was proved to be directly linked to restoration of the normal biomechanics of the foot and ankle after these complex fractures [3]. The main concern with fixation of DIACFs by screws only is the secondary loss of reduction. The assessment of the radiographic outcomes of the patients in our study showed significant improvement of the post-operative and final follow up measurements of all radiographic parameters and we didn't report any case with major loss of reduction or displacement of the posterior facet of ≥ 2mm at the final follow-up. In the current study, the average operative time was 57 minutes which was considerably less than the average length of ORIF surgeries which is 77 (range, 45-175) minutes [28,29].

Regarding the complications in this study, there were no cases of superficial or deep infections. Subtalar arthritis of grade 1 according to PGS developed in 4 (23.5%) feet, grade 2 in 2 (11.8%) feet, and there were no cases with grade 3. None of the patients underwent further surgeries until the last follow up. One foot developed peroneal subluxation which was managed conservatively, and one foot developed prominent screw which was managed by removal after solid union.

5. Conclusion

Cannulated screws technique in treatment of DIACFs provided good restoration of the subtalar joint and the calcaneal angles with the advantages of a minimally invasive approach avoiding most of wound complications associated with ORIF. It was effectively used in Sanders types II and III. Patients are satisfied and had lower rate of subtalar arthritis.

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