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Original Article

PERCUTANEOUS KIRSCHNER WIRES FOR THE TREATMENT OF DISPLACED INTRA-ARTICULAR FRACTURES OF CALCANEUS: A PROSPECTIVE STUDY

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Abstract

Displaced intra-articular calcaneus fractures (DIACFs) are sources of potential disability to the patient, economic burden to the society and a treatment challenge to the average orthopaedic surgeon. Up to date, there is no single approach that is universally applicable to all DIACFs. ORIF can be associated with significant wound complications. Conservative treatment may not be acceptable in a young active patient because of malunion and secondary subtalar osteoarthritis. The minimally invasive surgery (MIS) for DIACFs strives to strike a balance between ORIF and conservative treatment. The aim of this prospective study was to evaluate the functional and radiographic outcomes of closed reduction and percutaneous multiple K-wires fixation as a minimally invasive technique for treatment of Sanders type II & III DIACFs. This prospective study was conducted on 14 patients (9 males and 5 females) with 17 displaced intra-articular calcaneal fractures, managed by closed reduction and multiple K-wires fixation in Sohag university hospitals. The results were assessed at the end of follow up clinically using AOFAS ankle-hind foot scale and radiographically by plain radiographs. The mean age at time of operation was 36.57 ± 12.005 (range, 23-57) years. The right side was affected in 6 (42.9%) patients, while the left in 5 (35.7%) and there were 3(21.4%) patients with bilateral involvement. The patients were consecutive; 9 (64.3%) were males and 5 (35.7%) were females. The most common mechanism of injury was falling from height in 11(78.6%) patients. Four (28.6%) patients were smokers. The mean time lapsed to surgery was 5.07 ± 4.35 (range, 1-14) days. The mean length of follow-up was 10.07 ± 3.95 (range, 6-17) months. The mean AOFAS score at the final follow up was 74.4 ±12.73 (range, 45−90) points. There was a significant reduction of the mean VAS score for pain from 7.31 pre-operatively to 3.54 at the 4th week post-operatively, and to 1.69 at the final follow-up, (P values <0.001). Radiographic evaluation of the hindfoot revealed post-operative improvement of Böhler's angle, angle of Gissane, posterior facet inclination angle, calcaneal width, length, and height. Closed reduction and minimally invasive internal fixation through percutaneous multiple K-Wire fixation is an effective treatment for carefully selected cases of DIACFs with acceptable functional and radiographic results and fewer complication rates.

Keyword: *Percutaneous fixation, Intra-articular calcaneal fracture, Closed reduction, Minimally invasive surgery, K-wires*

1. Introduction

Calcaneus is the most commonly fractured tarsal bone; accounting for 60% of tarsal bones fractures, 30% of fractures in the foot, 1-2% of all fractures, and less than 10% of these fractures are open [1,2]. Males are affected more frequently than females due to the industrial nature of the accidents. Approximately 90% of calcaneal fractures occur in young male patients at age of 21- 45 years, with the majority being in industrial workers and thus the socioeconomic implications of these frac-

tures are high and striking [3]. Calcaneus is the largest of 7 tarsal bones and is a part of the hindfoot which includes the calcaneus and the talus. It is an odd-shaped bone with a very thin cortical shell enclosing cancellous bone that is well designed to sustain high tensile, bending, and compressive forces [4]. It articulates with the talus and the cuboid at subtalar and calcaneocuboid joints respectively. The subtalar joint is a composite of 3 discrete joints; anterior, middle and posterior. The posterior subtalar joint is the primary weight-bearing, oriented facing anteriorly and superiorly by about 45°, and supported by strong compression trabeculae under its surface called the thalamic portion of the bone. The internal trabecular pattern of calcaneus is composed of tensile trabeculae (primary and secondary) radiating from the inferior cortex and compressive trabeculae (primary and secondary) converging to support the posterior and anterior articular facets [5]. Calcaneus has a number of important soft tissue attachments which allow for its unique weight-bearing function. The posterior extension of the calcaneus from the coronal midline of the tibia allows it to act as a lever arm of the triceps surae through the attachment of the Achilles tendon along the posterior and inferior aspect of the tuberosity. This attachment is continuous with the plantar fascia [6]. Approximately 75% of calcaneus fractures are intra-articular and results from an axial loading mechanism due to a falling from height or motor car accidents. The primary fracture line propagates near the angle of Gissane, travels through an area known as Ward's neutral triangle which underlies the posterior facet of the calcaneus with a relative hypodensity of trabecular bone, and exits the calcaneus plantarly. Secondary fracture lines are created that extend to the tuberosity resulting in either a tongue-type pattern, where the posterior facet remains in continuity with the tuberosity, or a joint-depression type where the posterior facet is separated as Essex-Lopresti classified [7,8]. Extra-articular calcaneal fractures account for 25% of calcaneal fractures and are avulsion low energy injuries. Intra-articular fractures have a poorer prognosis than extra-articular fractures. Calcaneal fractures may be associated with other axial load injuries such as spine, pelvis and tibial plateau fractures. Of patients with calcaneal fractures, 10% have associated spine fractures, 26% are associated with other extremity injuries, and 10% have bilateral calcaneus fractures [9]. Clinically, calcaneal fractures are diagnosed by history of trauma, pain and tenderness overlying the fracture, swe-lling of the soft tissues, inability of weight-bearing, and bruising of the heel. Careful neurovascular assessment and exclusion of compartment syndrome are mandatory. Proper radiographic evaluation of calcaneal fractures by obtaining lateral radiograph of hindfoot and Harris (axial) view of calcaneus is essential. Radiographs should be assessed for presence of displacement of articular surface at the subtalar joint, and measurement of Böhler's and Gissane's angles. All patients suspected or diagnosed to have a DIACF should undergo Computed Tomography (CT) scan of hind foot in three planes sagittal, coronal and axial [10-12]. Sanders' CT classification; using the coronal section CT scans with the widest undersurface of the posterior facet of the talus as a measure, the articular surface is divided into three columns by two lines, the A and the B line. The third line, the C line, is the lateral edge of the sustentaculum tali. These three lines divide the posterior facet into four potential pieces: the lateral, central, medial, and sustentaculum. Type I: Minimally or non-displaced fracture; type II A, B, or C: two-parts fracture subclassified by location of fracture line; type III AB, AC, or BC: three-parts fracture with a central area of depression and subclassification depending on the location of the two main fracture lines; type IV: four-parts fracture with severe comminution [13]. Although calcaneal fractures have been treated by closed methods since the

time of Hippocrates, the management of calcaneal fractures remains challenging to the orthopaedic surgeon due to, complex anatomy, complex articulations with other tarsal bone, delicate soft tissue coverage, and associated complications [14]. The treatment options for displaced intra-articular calcaneal fracture have ranged from conservative to aggressive ORIF. The choice of treatment plan is determined by many factors such as; age and health status of the patient, fracture type and displacement, surrounding skin and soft tissue status, presence of associated injuries or polytrauma and experience of the surgeon. The principles of treatment of intra-articular fractures apply to calcaneal fractures as well. The common goals to all types of treatment of calcaneal fractures are restoration of congruency of the posterior facet of the subtalar joint, height of the calcaneus, reduction of the width of the calcaneus and realignment of the calcaneal tuberosity into normal valgus position. ORIF can be associated with significant soft tissue complications as wound dehiscence, necrosis and infection with high cost of infectious complications [15]. Conservative treatment as an alternative to ORIF may not be acceptable in all patients; while it may be preferred or equal to any operative intervention in cases of severe comminution, elderly low demand patients, and non-displaced fractures, it may not be acceptable in a young, active patient with displaced fracture because of malunion, secondary osteoarthritis and persistent painful gait. The minimally invasive surgery (MIS) for DIACFs strives to strike a balance between ORIF and conservative treatment. Achievement of anatomical or "near anatomical" reduction of the articular components and the overall shape and alignment of the bone through a ligamentotaxis, without jeopardizing the soft tissue envelope, forms the basis of MIS [16]. These approaches are not new, in a review compiled in 1938, C.W. Goff of Hartford, described and illustrated more than 40 different operative treatment methods for displaced calcaneal fractures, most of which included some forms of percutaneous reduction and skeletal traction [17]. The first precutaneous operation was closed reduction with percutaneous pin leverage and subsequent plaster immobilization as introduced by the German surgeon Westhues in 1934 [18]. It was later modified and popularized by Gissane and Essex-Lopresti [8,19]. Later on, a considerable number of percutaneous and minimally invasive techniques have been used to treat calcaneal fractures as arthroscopic-assisted percutaneous fixation [20], Ilizarov circular external fixator [21,22], interlocking calcaneal nails [23], sinus tarsi approach and percutaneous plate positioning [24,25], and percutaneus reduction and fixation by screws or K-wires. There is no consensus among different authors regarding the ideal fixation method. This prospective study aimed at evaluation of the functional and radiolographic results of closed reduction and percutaneous multiple K-wires fixation as a minimally invasive technique for treatment of DIACFs.

2. Patients and Methods

2.1. *Patients*

- 17 feet with displaced intra-articular calcaneal fractures in 14 patients (3 cases were bilateral) had been treated by closed reduction and percutaneous fixation by multiple K-wires at Sohag university hospitals between June 2020 and January 2022. - Adult patients with closed DIACFs, Sanders classification type II or III, with duration of fractures before operation ≤ 14 days were included. Patients presented with an open fracture, extra-articular fractures, Sanders type I or IV fractures, old fractures (>14 days), or children were excluded. - Pre-operative demographic data recorded were including age, sex, mechanism of injury, side of fracture, type of fracture, smoking or not, duration of time between injury and operation, occupational status, place of trauma and other associated comorbidities. -The patients were followed for at least 6 months post-operatively.

2.2. *Methods*

2.2.1. Diagnosis

a) History taking. **b)** General examination following the ATLS protocol for detection of any associated injuries or fractures. Local examination of injuried foot for side of injury, deformity at hindfoot and early signs of compartment syndrome. **c)** Routine pre-operative laboratory investigations. **d)** Plain radiography: including lateral view of the hindfoot and calcaneal (axial) view. The protocol of radiological evaluation in this study involved measuring 3 angles and 3 distances. The 3 angles measured were: Böhler's angle, the crucial angle of Gissane and the posterior facet inclination angle, fig. (1) [26].

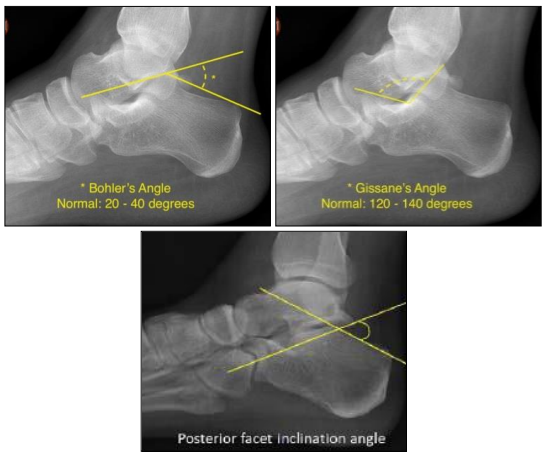


Figure (1) Three angles used in evaluation of calcaneal fractures.

- The tuber angle of Böhler was measured between a line drawn from the highest point of the anterior process of the calcaneus to the highest point of posterior facet and a line drawn tangential to the upper surface of calcaneal tuberosity. It is normally 20°- 40° [27]. -The Gissane angle is the angle between the posterior facet and a line from the calcaneal sulcus to the tip of the anterior process of the calcaneus, it normally 120º -145º [8]. -The posterior facet inclination angle [26], is the angle formed by two intersecting lines drawn along the surface of the posterior facet, and along the upper surface of the calcaneal tuberosity, it normally 50º-75º, fig. (1) [26]. -The 3 distances measured (in mm) are calcaneal length, width, and height, fig. (2). - The length of the calcaneus was measured in the lateral view from the most posterior point of the tuberosity to the calcaneocuboid joint. - The height of the posterior facet was measured by a line perpendicular on the calcaneal axis to the highest point of the posterior facet. - The width of the calcaneus was measured on the axial view. **e)** Computed Tomography (CT) scans of the hindfoot to assess for Sanders type of fracture, articular extension and fracture configuration.

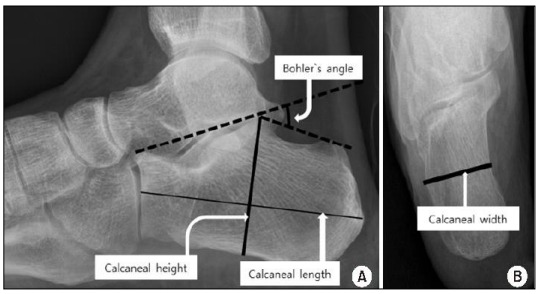


Figure (2) Posterior facet height, Calcaneal length and calcaneal width.

2.2.2. Classification of fractures

All fractures were classified according to Sanders classification and Essex-Lopresti classification systems.

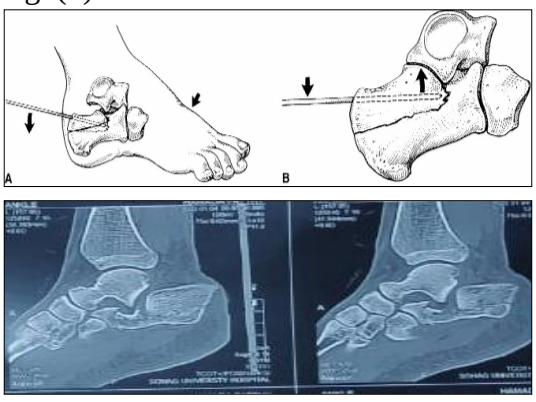
2.2.3. Operative technique

It depended upon indirect reduction of the fracture under fluoroscopic control and fixation of the fracture fragments by percutaneous K-wires. **a)** Timing of surgery; as early as possible once the general condition was stable. - Early surgery within the first 2 weeks of trauma, the presence of the "wrinkle sign," was not considered in the determination of surgical timing as the approach was percutaneous. - In case of massive swelling and fracture blisters, surgery was delayed. **b)** Anaesthesia; all operations were done under spinal anaesthesia. **c)** Patient positioning and imaging; the patient was placed in a lateral decubitus position with the affected side up on radiolucent operating table. The affected leg was positioned flat on a firm bump to support a perfect lateral position of the foot with or without use of tourniquet. The surgeon stood posterior to the patient, which facilitates fracture reduction and placement of K-wires. The C-arm entered

the operative field from the opposite side of the surgeon at the end of the operating table and positioned perpendicular to the foot. The surgeon ensured that satisfactory lateral, Broden, and Harris views were easily obtained. The patients were placed in prone position in bilateral fractures. **d)** Reduction of fracture; under complete sterilization and draping with the foot and leg left free.

2.2.4. Closed reduction techniques for tongue-type fractures

1) A 3 to 4 mm Schanz screw was inserted into the facet (tongue) fragment from postero-superior lateral to the achilles tendon directed towards the antero-inferior margin of the posterior facet fragment in line with the deformity. **2)** A scrubbed assistant performed an Essex-Lopresti reduction in three steps [28]: - Holding the dorsum of the foot with the palm of one hand and the Schanz screw with the other hand. Both thumbs were placed on the plantar surface of the foot approx.-imately under the middle of the calcaneus. First, the fracture fragments were disengaged by exaggerating the varus/lateral angulation of the fracture. Second, the Schanz screw was used as a joystick to achieve reduction, the midfoot and Schanz screw were forced plantarward (by employing downward pressure) using the thumbs as a fulcrum, so the fragment was pushed firmly against the corresponding articular surface of the talus. Finally, the foot was forced into valgus to bring the posterior facet adjacent to the sustentaculum. The Schanz screw used for reduction usually bent to an angle greater than 30 degrees, fig. (3).



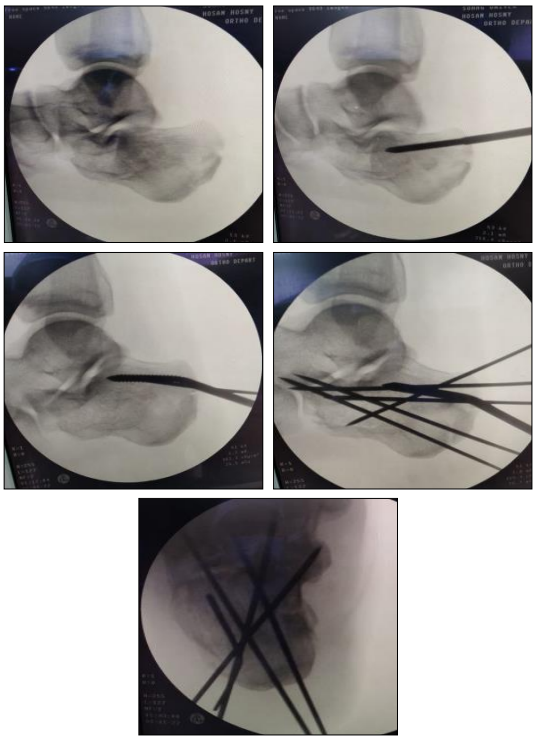


Figure (3) The Essex-Lopresti reduction for calcaneal fractures.

2.2.5. Closed reduction techniques for joint-depression fractures

1) Reduction of the calcaneal tuberosity was the first step in the procedure. The depressed facet did not reduce until the calcaneal tuberosity is moved out of an obstructing position. Manipulation of the calcaneal tuberosity fragment by a 6.5 mm Schanz screw inserted from lateral to medial in the calcaneal tuberosity perpendicular to the length of calcaneus. Starting point should be posterior in the tuberosity and midway from top to bottom. **2)** The Schanz screw was used to do distraction by axial traction while counter-traction is provided by an assistant at the forefoot level with the ankle held in plantar flexion. The force was directed laterally for correction of the varus angulation of the tuberosity if needed to be corrected. Manipulation was done to restore the length and the height of the calcaneus and to achieve correction of the inferior and medial translation. Apply manual traction on laparotomy gauze on both sides of the Schanz screw. **3)** Assessment of reduction of the articular posterior facet fragment or fragments on the lateral hindfoot and axial

calcaneal views. If not reduced, 1-2 cm small lateral incision was done below and anterior to the tip of the lateral malleolus at the sinus tarsi area, through which a periosteal elevator or curved artery forceps was inserted to elevate the depressed posterior facet fragments up to achieve anatomical reduction on C-arm guidance.

2.2.6. K-wires fixation

- Multiple K-wirs of 1.6, 1.8, or 2 mm K-wires were inserted. The number of which varied according to the type of fracture and the degree of comminution. - K-wires secured both the reduced articular surface and the overall alignment and arranged perpendicular to fracture lines as possible. - Two K-wires were inserted from the posterolateral aspect and directed medially to the sustentaculum tali. Two K-wires were inserted on each side of tendon Achilles insertion (medial and lateral) directed subarticularly to the anterior process of calcaneus. Additional K-wires may be inserted as needed. - The appropriate length and position of K-wires were confirmed by using the C-arm then K-wires were cut and bent outside the skin, fig. (4). - The bent Schanz screw used for reduction was removed after insertion of multiple K- Wires.

Figure (4) K-wires cut and bent outside the skin.

2.3. *Reduction of calcaneal widening & evacuation of hematoma*

By compressing the heel between the palms of the hands, after the articular fragments have been reduced.

2.3.1. Skin closure

- Small incisions were closed with absorbable sutures. -Sterile dressings were done around stitches and K-wires.

2.3.2. Post-operative care

- A below knee splint was done in neutral ankle position. - Immediate post-operative check X-rays in AP, lateral and calcaneal views were done and measurement of the three angles: Gissane angle, Böhler's angle and posterior facet inclination angle. - Leg elevation with active movement of toes and ankle for all patients. - I.V antibiotics were given to all patients for 2 days then completed oral for 2 weeks. - Analgesics were given. - Close monitoring for early signs of compartment syndrome. -Patients were discharged from the hospital 1-2 days postoperatively. - Post operative non-weight bearing with crutches mobilization was used for 6-12 weeks according to radiographic fracture union.

2.3.3. Follow up evaluation

- At outpatient clinics of Sohag University hospitals at scheduled intervals: 2 weeks, 6 weeks, 12 weeks, 6 months, and at 12 months. - Patient evaluation during follow ups was done clinically and radiographically.

2.3.3.1. *Clinical evaluation*

- Patients were assessed for pain, infections, ability of shoes wearing, return to work, quality of life, walking ability and development of other possible complications, fig. (5-a, b). - Pain was assessed according to the VAS score of pain. - Assessment of ROM of subtalar joint and ankle joint. - Six weeks post-operatively, K-wires were removed. K-wires were left for longer time if union was unreliable. - Partial and full weight-bearing was allowed according to fracture union. - The patients were evaluated by the AOFAS ankle-hind foot scoring system at 6 months post-operatively. ***AOFAS ankle-hind foot scale*** [29]: Maximum points possible (100 points). The results were classified as follow: Excellent; total score of 90-

100 points, Good; total score of 75-89 points, Fair; total score of 50-74 points, and Poor: total score < 50 points.

2.3.3.2. *Radiographic evaluation*

- Hindfoot lateral and axial (calcaneal) views were obtained for all patients immediately after surgery, at 6 weeks, at 12 weeks and at 6 months, fig. (5-c, d). - Patients were evaluated for adequacy of reduction, stability of fixation, fracture union and restoration of normal anatomy by measurement of 3 calcaneal angles (Gissane angle, Böhler's angle and posterior facet inclination angle) and 3 calcaneal distances in mm (length, width, and height). - Loss of reduction was defined as > 2 mm displacement. - Subtalar arthritis was graded according to the Paley and Hall grading system (PGS).

Figure (5) 12 months follow up radiographs and clinical photo.

2.3.4. Ethical considerations

- An informed written consents with risk explanation were obtained from all participating patients. The study was approved by Scientific and Ethical committees of Sohag faculty of medicine.

2.3.5. 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 Wilcoson 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 multiple K-wires fixation; 11 (78.6%) cases were unilateral and 3 (21.4%) cases were bilateral. The patients were consecutive; 9 (64.3%) were males and 5 (35.7%) were females. The mean age was 36.57± 12.005 (range, 23-57) years. The right side was affected in 6 (42.9%) patients, while the left in 5 (35.7%) and there were 3 (21.4%) patients with bilateral involvement. - The mechanism of injury was falling from height in 11(78.6%) patients, falling down stairs in 1(7.1%) patient and road traffic accidents in 2 (14.3%). Four (28.6%) patients were smokers. The mean length of follow-up was 10.07±3.95 (range, 6-17) months. – According to Sanders classification, 5 (29.4%) fractures were classified as type II, and 12 (70.6%) were type III. According to Essex-Lopresti classification 13 (76.5%) fractures were joint-depression type and 4 (23.5%) were tongue type. - The mean time lapsed to surgery was 5.07 ± 4.35 (range, 1-14) days. The mean duration of surgery was 42.06±5.6 (range, 35-50) minutes. The mean hospital stay was 1.7± 0.6 (range, 1-3) days. The place of trauma was at home in 10 (71.4%) patients, at work place in 2 (14.3%) patient, and at street in 2 (14.3%) patients, tab. (1).

Table (1) Demographics and baseline data of the included patients

Categories		No (%)	Mean ± SD (Range)
Total patients: feet		14:17	
Age at time of operation (years)			36.57 ± 12 (23-57)
Sex	Male	9 (64.3%)	
	Female	5 (35.7%)	
Side affection	Right	6 (42.9%)	
	Left	5 (35.7%)	
	Bilateral	3 (21.4%)	
Mechanism of injury	Falling from height	11 (78.6%)	
	Falling down stairs	1 (7.1%)	
	Road traffic accident	2 (14.3%)	
Smoking		4 (28.6%)	
Sanders fractures classification	Type II	5 (29.4%)	
	Type III	12 (70.6%)	
Essex-Lopresti fractures classification	Joint-depression type	13 (76.5%)	
	Tongue type	4 (23.5%)	
Duration of follow up (Months)			10.07 ± 3.95 (6-17)
Time lapsed to surgery (Days)			5.07 ± 4.35 (1-14)
Duration of surgery (Minutes)			42.06 ± 5.6 (35-50)
Hospital stay (Days)			1.7 ± 0.6 (1-3)
Place of trauma	Home	10 (71.4%)	
	Work place	2 (14.3%)	
	Street	2 (14.3%)	

3.1. *Functional outcomes*

- At the final follow-up, it was found that the mean AOFAS score was 74.4 ± 12.73 (range, 45−90) points. Satisfactory results were obtained in 10 (58.82%) fractures among which 2 (11.76%) fractures achieved excellent and 8 (47.06%) fractures achieved good results, while unsatisfactory results were observed in 7 (41.18%) fractures among which 6 (35.3%) fractures were fair, and poor results achieved in only one fracture (5.88%). - The mean VAS score for pain decreased from 7.31 ± 0.48 (range, 7-8) preoperatively to 3.54 ± 0.87 (range, 2-5) at the fourth week postoperatively, and to 1.69 ± 0.85 (range, 1-3) at the final follow-up. - At the final follow up, all patients showed a normal range of motion of the ankle joint (active dorsiflexion and plantar flexion). The mean subtalar range of motion (active inversion and eversion) was 18.52 ± 4.59 (range, 10 to 30) degrees. - The mean full weight-bearing time was 15.86 ± 1.65 (range, 12-18) weeks. The patients returned to work after a mean of 5 (range, 3-7) months, tab. (2).

Table (2) Functional results of the included patients.

Categories		No (%)	Mean ± SD (Range)
AOFAS score (Points)	Excellent	2 (11.76%)	74.4 ± 12.73 (45−90)
	Good	8 (47.06%)	
	Fair	6 (35.3%)	
	Poor	1 (5.88%)	
VAS score	Pre-op		7.31 ± 0.48 (7-8)
	4 weeks post-op		3.54 ± 0.87 (2-5)
	Final follow up		1.69 ± 0.85 (1-3)
Subtalar ROM (Degrees)			18.52 ± 4.59 (10 to 30)
Full weight-bearing (Weeks)			15.86 ± 1.65 (12-18)
Return to work (Months)			5 (3-7)

3.2. Radiographic outcomes

- Radiographic evaluation revealed, bone union was achieved in all fractures and the mean time of radiographic evidence of solid union was 12.71 ± 1.72 (range, 8-14) weeks. - The number of wires used in this study ranged 2-6 wires. - Lateral and calcaneal (axial) X-ray images of the hindfoot showed significant improvement of Böhler's angle, angle of Gissane, calcaneal width, length, and height, tab. (2).

Table (3) Radiographic parameters measurement of the included patients.

Item	Measurements			P value		
	Pre-op	Post-op	Final follow up	Pre-op vs post-op	Pre-op vs final	Post-op vs final
Gissane's angle	125.85 ± 16.34	122.17 ± 7.46	111.89 ± 13.82	0.415	**0.010**	**0.009**
Böhler's angle	9.95 ± 11.27	27.24 ± 6.73	22.2 ± 7.11	**0.001***	**0.003***	**0.034**
Posterior facet inclination angle	44.34 ± 14.29	57.07 ± 14.1	51.23 ± 12.99	**0.008**	**0.004**	0.241
Height	34.10 ± 3.09	42.27 ± 5.47	41.44 ± 4.61	**0.004**	**0.007**	**0.007**
Length	69.77 ± 11.15	76.22 ± 12.78	78.03 ± 10.85	**0.009**	**0.008**	0.280
Width	46.77 ± 3.70	39.63 ± 4.76	47.0 ± 10.15	**0.002**	0.623	**0.030**

***** *Wilcoson test was used instead of paired t-test due to non-parametric data*

3.3. *Complications*

Regarding complications; Subtalar joint osteoarthritic changes at the final follow up according to PGS; Grade 0: one (7.1%) cases, Grade I: one (7.1%) cases, Grade II: 11 (78.7%) cases and Grade III: one (7.1%) cases, all of them managed conservatively. Two patients (14%) had pin tract infections which were treated by daily dressing, no wires migration was reported. There were no cases of deep infection. No peroneal tendon impingement or sural neuritis was reported in any patient. None of the patients underwent further surgeries until the last follow up.

4. Discussion

The most important finding of this study**,** after a mean follow up of 10 months, the mean AOFAS score obtained was 74.4 ± 12.73 points, satisfactory results were obtained in 10 (58.82%) fractures among which 2 (11.76%) fractures achieved excellent and 8 (47.06%) fractures achieved good results, while unsatisfactory results were observed in 7 (41.18%) fractures among which 6 (35.3%) fractures were fair, and poor results achieved in only one fracture (5.88%). This is higher than that achieved by Potter and Nunley [30], they operated 81 fractures in 73 patients with mean AOFAS ankle-hindfoot score 65.4, also it is higher than that achieved by Ibrahim, et al. [31], they operated 15 fractures with mean AOFAS score was 70. In the current study, we treated 17 DIACFs with multiple K-wires and we found that 2 (11.76%) fractures were excellent, 8 (47.06%) fractures were good, 6 (35.3%) fractures were fair, and only one fracture (5.88%) was poor. Comparing these results with ORIF of calcaneal fractures, the satisfactory results in this study are nearly matched with those achieved by Asik et al. [32], they treated 19 fractures in 14 patients with ORIF and their mid-term results were excellent in five feet (26%); good in eight feet (42%); fair in four feet (21%); and poor in two feet (11%). In the current study, the average length of the surgery was 42 minutes which is considerably less than the average length of surgeries utilizing ORIF which is 77 (range, 45-175) minutes [33,34]. Regarding time lapsed to surgery and hospital stay, in the current study, the mean time lapsed to surgery was 5.07 ± 4.35 (range, 1-14) days, and the mean hospital stay was 1.7 ± 0.6 (range, 1-3) days. Zeman, et al. [35] treated 33 fractures in 29 patients by ORIF with a calcaneal locking compression plate (LCP) from an extensile lateral approach, they found that the average time lapsed to surgery was 11.7 days of injury, and average hospital stay was 18.2 days. Comparing with similar minimally invasive techniques in calcaneal fractures, in the current study the mean AOFAS score

was slightly lower than that, was reported in Aroram et al. [36] study using closed reduction and percutaneous fixation using K-wires in 23 DIACFs; they reported excellent and good results in 68.4% of their patients. However, here excellent and good results were found in 58.82% of fractures. In the current study, there was a significant reduction of the mean VAS score of pain from 7.31 pre-operatively to 3.54 at the 4th week post-operatively, and to 1.69 at the final follow-up, (*P values* <0.001), the mean full weight-bearing time was 15 weeks and patients returned to work after a mean of 5 months. This was comparable with the results of Shamsm et al. [37], they treated 46 calcaneal fractures in 40 patients by minimally invasive osteosynthesis using cannulated screws and they found that, the mean VAS score of pain decreased from 7.3 ± 05 preoperatively to 1.2 ± 0.7 at the final follow-up, (p <.001), the mean full weight-bearing time was 12.3 (range 12-14) weeks, and the patients returned to work after a mean of 5 months. In the current study, at the final follow up, all patients showed a normal range of motion of the ankle joint (active dorsiflexion and plantar flexion) and the mean subtalar range of motion (active inversion and eversion) was 18.52 ± 4.59 degrees, this was comparable to the results in Schepers, et al. [38] study, where they can obtain 70% of the healthy side range of motion in 61 calcaneal fractures treated by percutenous cannulated screws or K-wires fixation after a mean follow up of 35 months. Regarding radiographic evaluation in the current study, the measurements of 3 calcaneal angles (Gissane's angle, Böhler's angle and posterior facet inclination angle) and 3 calcaneal distances (length, width, and height) were improved significantly post-operatively and at final follow up compared to the pre-operative data, with exception of Gissane's angle which showed slight loss of maitainance of its post-operative correction at final follow up. These findings were similar to those observed by Kapil Mani, et al. [39], who used a minimally invasive technique with transverse and axial screws, tab. (3). Several studies reported a strong correlation between the restoration of normal anatomy (Böhler's angle, Gissane angle's, calcaneal height, and width as assessed radiologically) and a satisfactory functional outcome, and also mentioned that functional outcomes will be compromised in the cases where anatomical restoration of subtalar joint is not possible [40, 41]. In the current study, the mean final follow up of Böhler's angle was 22.2º which was better and near to normal compared to the Böhler's angle reported by Aroram, et al. [36] which was reduced to 15.6º at the final follow-up. Regarding the posterior facet inclination angle, we achieved a significant immediate postoperative improvement of 57.07º from a preoperative angle of 44.34º which was comparable to the correction obtained in Abdelgaid [42] study where he had posterior facet inclination angle improvement from 27º to 59º. In the current study, bone union was achieved in all fractures and the mean time of radiographic evidence of solid union was 12.71 ± 1.72 (range, 8-14) weeks. This finding was similar to those observed by Kapil Mani, et al. [39], who used a minimally invasive technique with transverse and axial screws for treatment of intra-articular calcaneal fractures and found that, the time of union of fractures was 11.06 ± 1.82 (range 8–16) weeks. Regarding the complications in this study, two patients (14%) had pin track infections and there were no cases of deep infection. Significant subtalar arthritis according to PGS developed in 7% of cases at the final follow up. None of the patients underwent further surgeries until the last follow up. The rate of complications in the current study is lower than those described by Stulik, et al. [16], they treated 287 intra-articular fractures of the calcaneus in 247 patients by minimally invasive reduction and K-wire fixation, and they found that; 20 cases (7%) of superficial pin track infection, five cases (1.7%) of deep infection, spontaneous fusion of the subtalar joint occurred

in eight patients (3.2%) with highly comminuted fractures, and mild to moderate signs of post-traumatic subtalar osteoarthritis, evaluated radiologically as narrowing of the joint space and subchondral sclerosis were present in 246 fractures (85.7%) but pain in the subtalar joint was present in only 37 (12.9%). The limitations of this study are the relatively low number of patients and the absence of a control group for comparison.

5. Conclusion

Closed reduction and minimally invasive internal fixation by percutaneous multiple K-Wires fixation for DIACFs of Sanders type II & III is an effective treatment with acceptable functional and radiographic outcomes and fewer complication rates. This technique avoids most of the wound complications associated with ORIF with advantages of shorter hospital stay, shorter operative time, and simple K-wires removal.

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