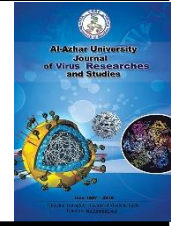




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Minimally Invasive Approach for Treatment of Displaced Intra-articular Calcaneal Fractures by mini-plate and Percutaneous Cannulated Screws

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Abstract

Intra-articular fractures of the calcaneus are one of the most challenging fractures to orthopedic surgeons. To achieve anatomical reduction of the subtalar joint, maintaining length & alignment to achieve a good functional outcome. In this series, the sinus tarsi approach was the standard approach by which the patients were treated. This study included 23 patients with unilateral intra-articular fracture calcaneus. The patients will treat by open reduction and internal fixation through minimal invasive sinus tarsai approach using miniplate and cannulated screws for fixation. All patients were evaluated clinically (Using AOFAS ankle / hindfoot score) and radiologically. The mean follows up duration was 6 months. Immediate postoperative X-rays showed anatomical articular reduction. In this study the mean AOFAS ankle/hindfoot score was 83 ± 4 . The mean follows up duration was 6 months. Complications included superficial wound infection in two patients and hardware irritation in two patients. In this study minimally invasive sinus tarsi approach gives good reduction aided by percutaneous reduction and screw fixation. The technique is more effective in patients with type II & III Sander's classification especially in risky patients. The timing of operation can be as soon as possible. Reduced rate of soft tissue morbidity and good range of motion are possible with these techniques compared with the extensile lateral procedure.

Keywords: AOFAS; ATLS; ORIF; MIPO.

1. Introduction

The calcaneus is the most frequently injured tarsal bone comprising 1-2% of all fractures and about 75% of those affecting the foot. Approximately 75% of calcaneal fractures are intraarticular [1]. Some calcaneal fractures are minor fractures, but many are severe, high-energy fractures. These more serious injuries usually occur after a fall from a height, often from scaffolding or a ladder, or as a result of a

road traffic accident [2]. The economic importance of the injury is considerable, as 80% to 90% occur in men in their prime working years. As a result, they may be disabled for several years after the injury, and many are unable to return to their original occupation [3]. Approximately 50% of the foot's weight bearing occurs through the calcaneus and the complexity of its articular surfaces makes intraarticular

fractures a significant challenge. Historically, intra-articular calcaneal fractures have been associated with poor outcomes, so they were treated conservatively to avoid the additional morbidity of a surgical procedure. There are still proponents of closed treatment, but with technological advances in imaging, such as computed tomography (CT), innovative surgical techniques and fixation devices, surgeons are finding improved results with open reduction and fixation. Better results have been associated with exact anatomic reduction [4]. Treatment of intra-articular calcaneal fractures can be divided into conservative and operative management. The latter comprises open reduction and internal fixation, percutaneous reduction fixation and primary arthrodesis [5]. Conservative treatment might be considered in non-displaced or minimally displaced fractures, compromised soft-tissues and in patients with physical contra-indications (e.g., peripheral vascular disease, psychic patient). Open reduction and internal fixation are considered the gold standard treatment for displaced intra-articular fractures of the calcaneus by most experts as it generally provides overall good to excellent results and the ability to anatomically restore the subtalar joint [5]. Several open surgical approaches have been described in the past, of which the extended lateral approach has been applied most frequently. Its main disadvantages are wound dehiscence and infection, which may occur in up to 30% of patients. Alternative surgical approaches to the calcaneus include the limited lateral approach. Many methods of fixation were described including plates and screws, screws, k wires and external fixators [5]. Because of the high risk of soft tissue problems and since stable fixation with plates does not offer the possibility of early weight bearing, limited approach and minimal fixation to avoid compromising the already damaged soft tissue coverage on the lateral side may be favored [6]. The

aim of this study is to evaluate the effectiveness of minimally invasive fixation of intra-articular calcaneal fractures using mini plate through sinus tarsi approach and percutaneous cannulated screws to achieve the subtalar articular congruity and restoring the calcaneal geometry with avoiding soft tissue complications.

2. Patients and Methods

This study included 23 patients with intra-articular fracture calcaneus from December 2020 to September 2021. The patients were treated by open reduction and internal fixation through minimal invasive sinus tarsai approach using miniplate and cannulated screws for fixation. All patients were operated upon at AL-Zahraa University Hospitals.

2.1 Inclusion Criteria

- Age: skeletally mature patients.
- Sander's type II, III fractures.
- Closed fractures.

2.2 Exclusion Criteria

- Extra-articular fractures.
- Sander's type I and IV fractures.
- Neglected fractures more than 3weeks.
- Open fractures.
- Vascular compromise.

2.3. Surgical Technique

All patients were appropriately consented, operated under spinal Anaesthesia. Lateral decubitus placing the affected limb upwards on a radiolucent operating table under C-arm guide with above knee tourniquet.

2.4 Surgical Approach

A skin incision of 3 cm was done over the sinus tarsi at about 2 cm distal and anterior to the tip of the lateral malleolus. Deep dissection and removing the sinus tarsi fat was done to facilitate exposure of posterior facet Figure. 1.

2.5 Reduction and Fixation

Elevation and reduction of the posterior facet was performed assisted by hindfoot inversion and temporary stabilization with K-wires. Reduction was checked in the lateral and Broden's views and Giussani angle was evaluated through image intensifier. Elevation and reduction of the posterior facet was performed assisted by hindfoot inversion and temporary stabilization with K-wires. Reduction was

checked in the lateral and Broden's views and Giussani angle was evaluated through image intensifier. One 2.4 mm mini plate was used to stabilize the reduced posterior facet fragment to the anterior part of calcaneus. Varus malalignment of the tuberosity fragment was aligned with the calcaneal body on the medial fragment which is the guide of reduction by using 5mm stiemen pin in the tuberosity fragment which for manipulation and the reduction was stabilized by insertion of two percutaneous 4 mm cannulated screws from the tuberosity fragment directed anteriorly to prevent varus malalignment and to maintain the calcaneal length. One or two additional cranially directed 4 mm cannulated screws were used to additionally support the posterior facet, to maintain calcaneal height, and to stabilize separated planter fragment of the tuberosity in some cases.

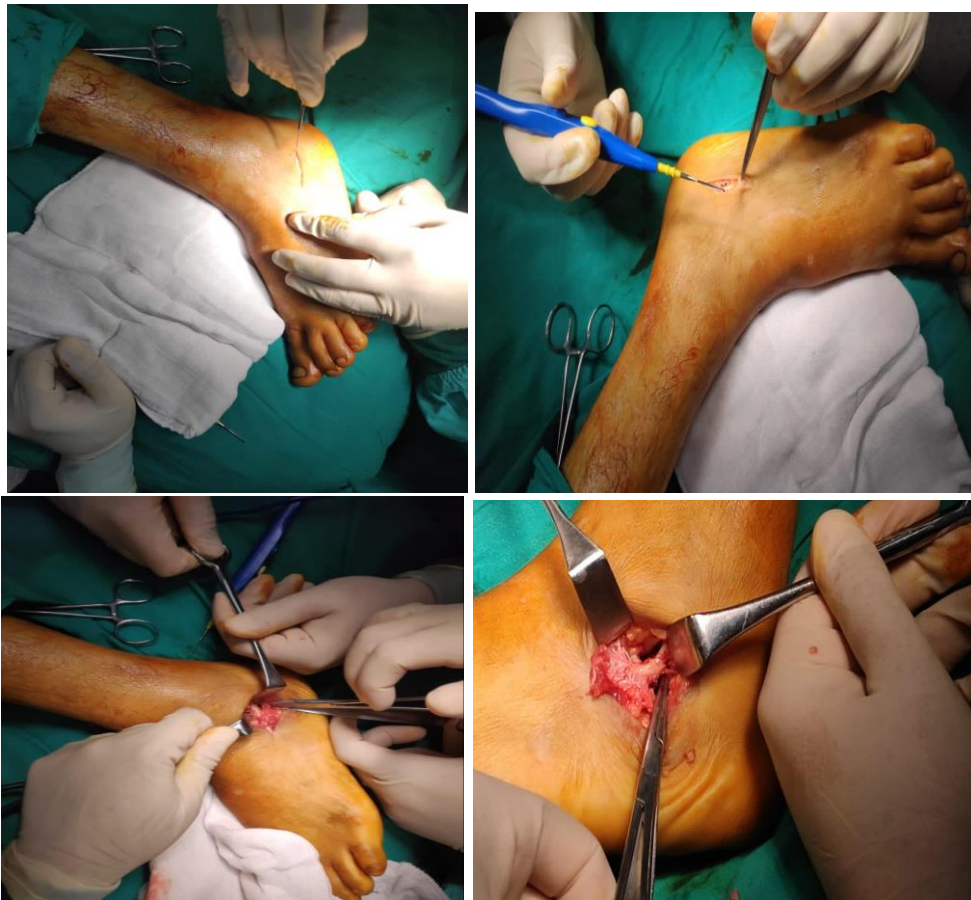


Figure (1): Intraoperative photograph showing the sinus tarsi approach.

Ankle-Hindfoot Scale (100 Points Total)	
Pain (40 points)	
None	40
Mild, occasional	30
Moderate, daily	20
Severe, almost always present	0
Function (50 points)	
<i>Activity limitations, support requirement</i>	
No limitations, no support	10
No limitation of daily activities, limitation of recreational activities, no support	7
Limited daily and recreational activities, cane	4
Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	0
<i>Maximum walking distance, blocks</i>	
Greater than 6	5
4-6	4
1-3	2
Less than 1	0
<i>Walking surfaces</i>	
No difficulty on any surface	5
Some difficulty on uneven terrain, stairs, inclines, ladders	3
Severe difficulty on uneven terrain, stairs, inclines, ladders	0
<i>Gait abnormality</i>	
None, slight	8
Obvious	4
Marked	0
<i>Sagittal motion (flexion plus extension)</i>	
Normal or mild restriction (30° or more)	8
Moderate restriction (15°-29°)	4
Severe restriction (less than 15°)	0
<i>Hindfoot motion (inversion plus eversion)</i>	
Normal or mild restriction (75%-100% normal)	6
Moderate restriction (25%-74% normal)	3
Marked restriction (less than 25% normal)	0
<i>Ankle-hindfoot stability (anteroposterior, varus-valgus)</i>	
Stable	8
Definitely unstable	0
Alignment (10 points)	
Good, plantigrade foot, midfoot well aligned	15
Fair, plantigrade foot, some degree of midfoot malalignment observed, no symptoms	8
Poor, nonplantigrade foot, severe malalignment, symptoms	0
Total=	100
American Orthopaedic Foot and Ankle Society	

2.6 Statistical Methods

Data management and statistical analysis were done using SPSS vs.25. (IBM, Armonk, New York, United States). Numerical data were summarized as means and standard deviations or medians and ranges. Categorical data were summarized as numbers and percentages. Böhler's and Gisanne angles were compared pre- and post-operative and post-operative angles were compared to contra-lateral one using

paired t-test. All P values were two sided. P values less than 0.05 were considered significant. Baseline characters of included patients with displaced intra-articular calcaneal fractures. 16 patient (69.5%) were classified as Sander II and 7 patient (30.5%) were classified as Sander type III Figure (3).

3 .Results

Our results showed significant improvement in the mean Bohler angle from 5 ± 2 degrees preoperatively to 25 ± 4 degrees postoperatively which is statistically significant with p-value less than 0.001 Table .2. Our results showed significant improvement in the mean of Gissane from 147 ± 5 degrees preoperatively to 135 ± 2 degrees postoperatively. which is statistically significant with p-value less than 0.001, Table .3. According to the American orthopedic foot and ankle society score (AOFAS). More than (90%) had excellent results, (80%-90%) had good results, (70%-80%) had fair results and less than (70%) had poor results. in our thesis: 5 patients had excellent result (21.8%),15 patients had good results (65.2%), 3patients

had fair results (13%), no poor results documented. The final mean of the American orthopedic foot and ankle society score (AOFAS) was 83.00 ± 4.00 . The final mean visual analogue of pain (VAS) score was 3 Range (1-5). 3 patients had no pain postoperatively (13%), 16 patients had mild pain (69.5%), 4 patients had moderate pain (17.5%). Weight bearing was allowed after 12 weeks. Complications were reported in 4 patients in the form of superficial wound infection which was treated by intravenous administration of antibiotics and daily dressings. Two patients were in need for another hospital admission during the follow up period in order to remove the prominent cannulated screws. 19 patients are satisfied with the procedure and 4patients are not satisfied.

Table (1): Demographic characteristics and clinical data among the studied groups.

Total	N=23
Age (years)	45.5±14.4
	Number (%)
Sex:	
Male	15 (65.2%)
Female	8 (34.8%)
Smokers	6 (26.1%)
Comorbidities	DM in 3 (13%)
Side of fractures	
Right	9
Left	14
mechanism of injury	
Fall from height	17 (73.92)
Traffic accident	6 (26.08%)
Impact	
High-energy trauma	7 (30%)
Low energy trauma	16 (70%)
Sander classification	
Grade II	16 (69.5%)
Grade III	7 (30.5%)
vascularity	Intact vascular (23 patient)
Bohler angle	From 5 ±2
Gissane from	From 147±5

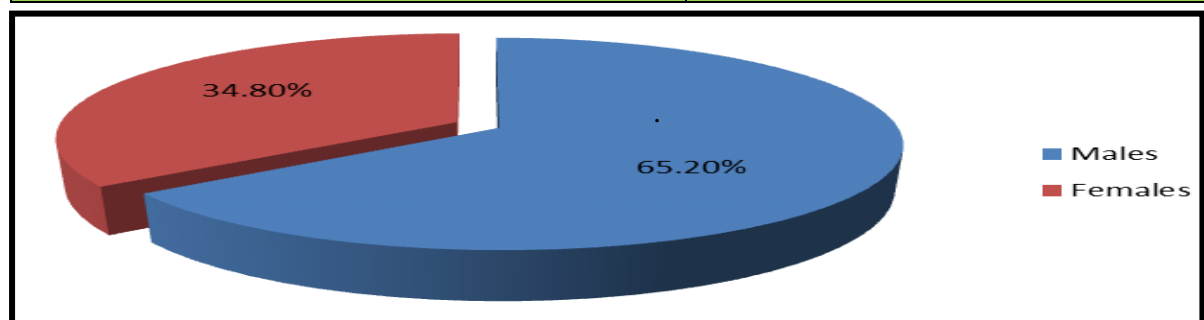


Figure (2): Males and Females.

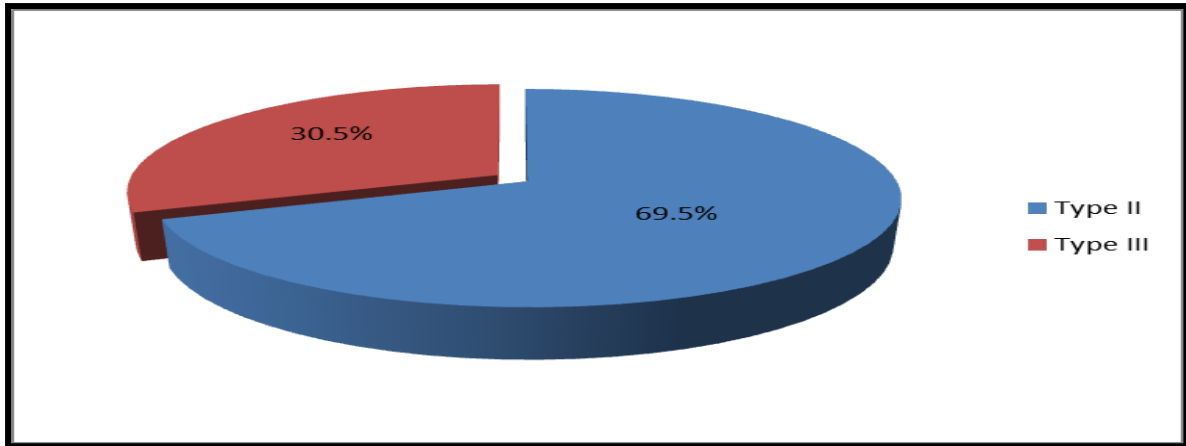


Figure (3): Sander Types.

Table (2): Bohler angle.

Bohler angle		No. = 23
Pre-operative	Mean ±SD	5.00 ± 2.00
Post-operative	Mean ±SD	25.00 ± 4.00
Paired t-test		63.245
P-value		<0.001 (HS)

Table (3): Gisanne angle.

Gisanne angle		No. = 23
Pre-operative	Mean ±SD	147.00 ± 5.00
Post-operative	Mean ±SD	135.00 ± 2.00
Paired t-test		-31.514
P-value		<0.001 (HS)

Table (4): Post-Operative complications.

Complications	Number (percentage)	Treated by
Superficial wound infection	4 (17%)	intravenous administration of antibiotics and daily dressings
Fibular impingement	0 (0%)	--



Figure (4): Preoperative axial and lateral x rays of the patient.



Figure (5): Preoperative CT showing coronal cuts of the calcaneus.

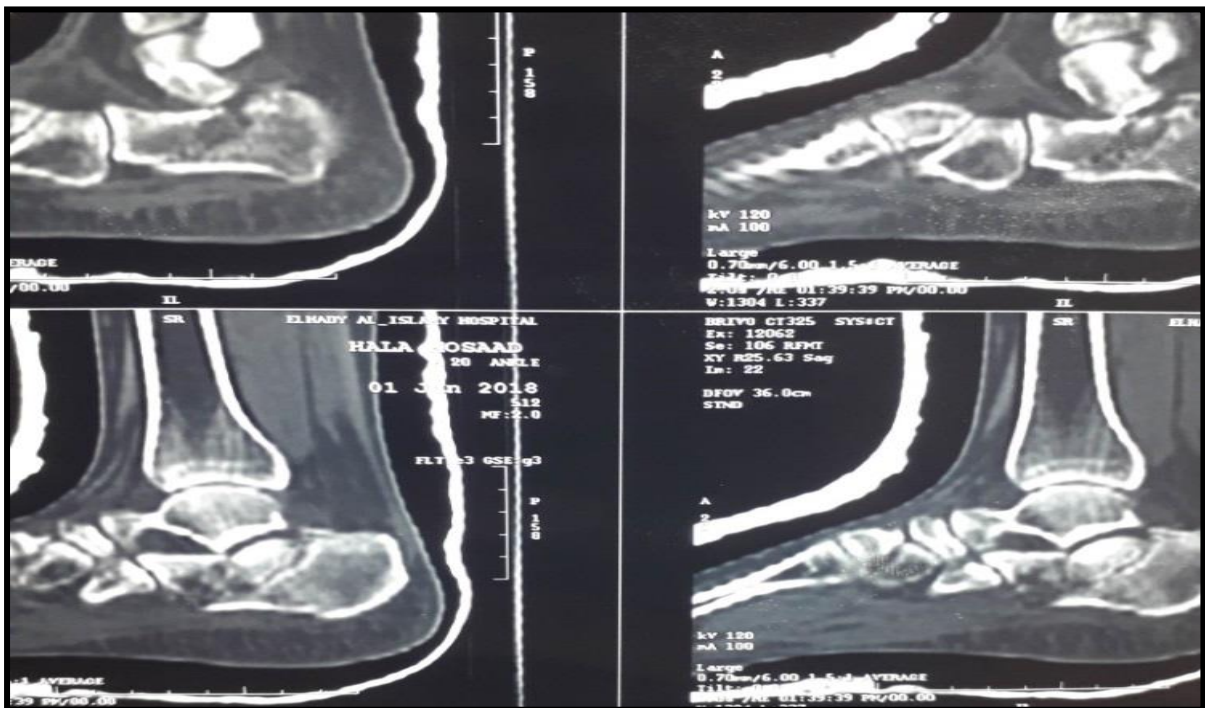


Figure (6): Preoperative CT showing sagittal cuts of the calcaneus and joint depression.



Figure (7): Intraoperative radiographic images showing reduction and fixation of the calcaneus by plate and Screws.



Figure (8): Photograph showing 3-month skin condition.

4. Discussion

Intra-articular calcaneal fractures constitute about 75% of all calcaneal fractures [7]. The treatment of calcaneal fractures currently remains controversial because of the suboptimal results of treatment and the incidence of complications [8].

The goal of surgery is to obtain anatomic reduction while retaining the geometry and structure of the calcaneus and restoring the joint axis of the ankle [7]. A variety of techniques have been proposed for the fixation of calcaneal fractures, but the optimal fixation technique has not yet been identified [9]. Open reduction internal fixation (ORIF) via extensile lateral

approach is the classic procedure for this fracture, but with increased risk of skin complications [10].

In recent years, the minimally invasive sinus tarsi approach has gained considerable popularity among surgeons operating on those fractures [11, 12]. Many surgeons have reported on using k-wires [3], Screws [4] through this approach.

Giannini et al. [13], reviewed the advantages and disadvantages of different minimally invasive sinus tarsi techniques in the treatment of calcaneus fracture. Based on their report, the minimally invasive sinus tarsi approach provides direct visualization of the subtalar joint by

allowing the anatomical reduction with minimal hardware implication, thereby reducing wound complications remarkably [13].

K-wires are associated with risk of introducing infection, loss of reduction and need for later removal [14]. Screws only technique does not support comminuted lateral blow out [10].

Therefore, this study operated for combining the 2 techniques (percutaneous screws and mini plate through a minimally invasive approach) and assessment of the post-operative clinical and functional outcomes in attempt for benefits maximization and minimization of post-operative adverse events.

	Shariatzadeh H (2020)	Cong Jin et al (2017)	Y.Khira (2016)	This study (2021)
Number of patients	62	64	28	23
Number of fractures	62%	64	30	23
Males	95%	48.43%	71.42%	65.2%
Females	5%	51.5%	28.57%	34.8%
Contralateral calcaneal fractures	0	0	7.14%	0%
Associated fractures	Not mentioned	10.9%	Not mentioned	0%
Medical comorbidities	Not mentioned	Not mentioned	Not mentioned	3 cases with DM
Sander's classification	65% type 2 35% type 3	65.57% type 2 37.5% type 3	33.3% type 2 66.7% type 3	69.5% type 2 30.5% type 3
Mean time to operation(days)	8.3	6.2	4	8±2
Mean follow up(months)	21	16	22	6±2

Regarding baseline characters of included patients, the mean age was 45.5 ± 14.4 years, 65% were males, 6 were smokers and 3 patients with diabetes mellitus. The mechanisms of fracture were fall from height in 73.92% and traffic accident in 26.08 % of included patients causing high-energy trauma in 30% and low-energy trauma in 70% of included patients. 16 patients had calcaneal fractures sander II while 7 patients had calcaneal fractures sander III.

These Results This fracture pattern may be justified with Daqiq et al., [15] who concluded that more than mechanism of injury, the magnitude of the impact and the position of the foot are important in predicting fracture classification in the calcaneus.

In this study the cases were operated after a mean time of 8 ± 2 days in plate. Shariatzadeh et al [16] operated after mean time of 8.3 days and Khira [17] operated his

cases at mean time of 4 days. In this study the mean follows up time was 6 ± 2 months, 21 months in Shariatzadeh et al [16] study, 16 months in Cong Jin et al [17] study, 22 months in Khira [18] study .

Sinus tarsi approach allow for early intervention without more delay decreasing the preoperative hospitalization in comparison to treatment with the classic extensile lateral approach which render early operative intervention is catastrophic regarding soft tissue complications [19].

Based on the results of the present study, Bohler and Gissane angles, as well as the height and length of the calcaneus significantly improved after the treatment of calcaneus fracture with minimally invasive sinus tarsi approach.

The radiographs demonstrated significant corrections of the calcaneal width, length, height, Böhler angle, and Gissane angle from preoperatively to 3 months postoperatively with minimally invasive

sinus tarsi approach and the last follow-up [20].

According to our results, AOFAS, VAS. 21.8% had excellent result, 65.2% had good results, 13% had fair results. The postoperative AOFAS score was 83 ± 4.5 . The postoperative visual analogue of pain (VAS) score was 3 Range (1-5). 3 patients had no pain postoperatively (13%), 16 patients had mild pain (69.5%), 4 patients had moderate pain (17.5%). Weight bearing was allowed after 12 weeks.

In this study the mean AOFAS ankle/hindfoot score was 83 ± 4 . It was comparable to the MIPO group in the study of Cong Jin et al with mean score of 84.4. It was also comparable to the score of the extensile lateral approach in the study of Cong Jin et al which was 83.9 but it was more than the mean score in Shariatzadeh et al study which was 79.6.

This was comparable to the result of Shariatzadeh et al [16] study that had good/excellent results in 95% of cases, and the results of Cong Jin et al [17] (MIPO group) study that had good/excellent results in 94% of cases but exceed the results of Khira [18] who had good/excellent results in 64.3% of cases.

Regarding post-operative complication only 4 patients had superficial wound infection. These superficial wound infections were treated with intravenous antibiotics with daily sterile dressings and two healed and another Two patients were in need for another hospital admission during the follow up period in order to remove the prominent cannulated screws. Smoking is reported as a factor increasing the risk of surgical site infection [21]. Open

reduction and internal fixation of calcaneus fractures through a sinus tarsi approach allows adequate reduction with low risk of wound-healing complications [22]. The sinus tarsi approach decreased wound complications and preoperative waiting time [19].

Regarding hardware irritation, 8.6% of the patients (2 cases) had hardware irritation which were needed for hospitalization and hardware removal during follow up period. In Tantavisut et al., [23] study, at the 3-month follow-up, there were 1% superficial infections and 1% rate of screw irritation.

In this study, patients were not allowed to weight bear before 12 weeks for fear of collapse and failure of reduction. The strengths of this study include the use of the same preoperative evaluation, operative technique for all patients and the patients were operated upon in 2 different hospitals. In this study there is minimal skin complication rate, and this is the most important value of use the minimally invasive approach. The weaknesses of this study are the limited number of patients included in the study, the limited follow up time. All patients were below the age of fifty and this study did not correlate with satisfaction rate of work compensation.

5. Conclusion

Treatment by minimal invasive sinus tarsi approach with miniplate and cannulated screws is an effective method for achieving articular reduction, early range of motion and reducing wound complications and malalignment.

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