



Comparing less invasive plate fixation versus screw fixation of displaced intra-articular calcaneus fracture via sinus tarsi approach

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Abstract

Purpose The purpose of this study was to compare the post-operative radiographic and clinical outcomes of less invasive plate fixation versus screw fixation of displaced intra-articular calcaneus fractures (DIACFs) via sinus tarsi approach.

Methods A total of 165 consecutive DIACFs that underwent open reduction internal fixation via sinus tarsi approach from 2013 to 2018 were reviewed at least a two year follow-up. The methods of fixation were divided into two groups: less invasive plate fixation versus screw fixation of calcaneus fracture (59 vs 106, respectively). The radiographic outcomes including pre- and post-operative Bohler's and Gissane's angles were evaluated. The post-operative function was evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score, the Olerud and Molander Scale and the Visual Analogue Scale (VAS). The complications, the rates of implant removal and cost were also compared.

Results The average follow-up was 44.2 months in the plate groups and 47.9 months in the screw groups ($P > 0.05$). There was no significant difference in the Bohler's angle and Gissane's angle between the plate group and screw group during the pre-operation and the last follow-up. There was no significant difference in the final AOFAS score, Olerud and Molander score and VAS score between the two groups ($P > 0.05$). The total incidence of complications was 6.7% in the plate group and 6.6% in the screw group ($P > 0.05$). The rates of implant removal and total cost during the hospitalization in the plate group were significantly higher compared with screws group ($P < 0.05$).

Conclusion The less invasive plate fixation versus screw fixation of DIACFs via sinus tarsi approach contributed comparable quality of reduction, complications and post-operative functional outcomes. The less invasive plate technique was significantly higher in terms of implant costs and the rate of implant removal.

Keywords Calcaneus fracture · Plate · Screw technique · Sinus tarsi approach

Changjun Guo and Yangbo Xu contributed equally to this work.

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Introduction

Calcaneus fractures are most common injuries of the tarsal bones following high-energy trauma and have a high socioeconomic impact [1]. It has been reported that about 60 to 75% of all calcaneal fractures are displaced intra-articular calcaneus fractures (DIACFs) [2]. The optimal treatment for DIACFs is controversial. Many studies have preferred non-operative treatment for DIACFs due to the high risk of complications [3, 4]. The sequelae following non-operative treatment of calcaneus fractures include post-traumatic subtalar arthrosis, subfibular and calcaneocuboid joint impingement, heel widening, loss of height and varus heel alignment and post-traumatic subtalar arthrosis [5]. In the past decades, surgeons have recommended surgical treatment for the DIACFs in order to avoid complications [1, 6, 7].

The extensile lateral approach (ELA) has been a widely accepted approach to open reduction and internal fixation (ORIF) of the DIACFs [8]. Although the ELA approach provides good exposure of the posterior facet and explicit access to the lateral wall, the high rates of wound complications have been widely reported [9, 10]. Recently, there has become a common tendency using minimal invasive surgical techniques for treating DIACFs, including sinus tarsi approach (STA), percutaneous fixation and arthroscopically assisted fixation.

The STA provides a smaller incision and a direct visualization of the posterior subtalar joint [11]. Many studies have shown that the radiographic results were similar between the ELA and STA, with fewer wound complications in the STA [12–15]. The STA could be a suitable management for displaced intra-articular calcaneus fractures Sanders type IV [16]. Many studies reported the post-operative clinical and radiographic outcomes with a plate or only screw fixation of DIACFs through the STA. There was only one study comparing STA fixation techniques in terms of radiographic angles and post-operative outcomes [17]. It is not clear which type of calcaneal fracture is more suitable for screws or plates and the rates of implant removal via the STA. The aim of our study is to compare anatomic reduction, complications and functional outcomes of the two fixation techniques. We also aimed to identify the rates of implant removal associated with each technique via the STA.

Materials and methods

After ethical committee approval, consecutive patients treated surgically and admitted to our hospital due to DIACFs from January 2013 to January 2018 were selected. Inclusion criteria were DIACFs > 2 mm, patients aged more than 18 years, closed fracture, follow-up time not less than two years and surgery performed by any orthopaedic surgeon using the STA at our hospital. Excluded patients were those with open fractures, use of the ELA approach and lost follow-up.

The age, body mass index (BMI), gender, smoking and diabetes were collected pre-operatively. According to the WHO's standardized proposal on the investigation method of smoking, smokers were divided into regular smokers, more than one cigarette per day, continuously or cumulatively for six months; occasional smokers, more than four cigarettes per week, but less than one cigarette per day on average; and never smokers.

The Sanders and Essex-Lopresti classification were collected according to pre-operative calcaneal and foot radiographs, computed tomography (CT) scans and three-dimensional reconstruction of the traumatic calcaneus. Anteroposterior and lateral radiographs of the ankle and foot and axial views of the heel were obtained post-operatively, at six, 12 weeks, one year and the latest follow-up. The CT scans were obtained post-operatively to check the articular reduction for some cases (Figs. 1 and 2). The indications of post-operative CT assessment are better post-operative assessing the effect of the surgery on the anatomy and as a part of predicting the patient's long-term prognosis. The Bohler's and Gissane's angles were measured both pre-operatively and post-operatively at the latest follow-up. The pre-operative heel alignment was mainly evaluated on the pre-operative CT and the post-operative heel alignment mainly on the axial radiograph at the latest follow-up. The follow-up and radiological review were carried out by all the authors. For the purposes of this study, all the radiographs were again reviewed by the first author.

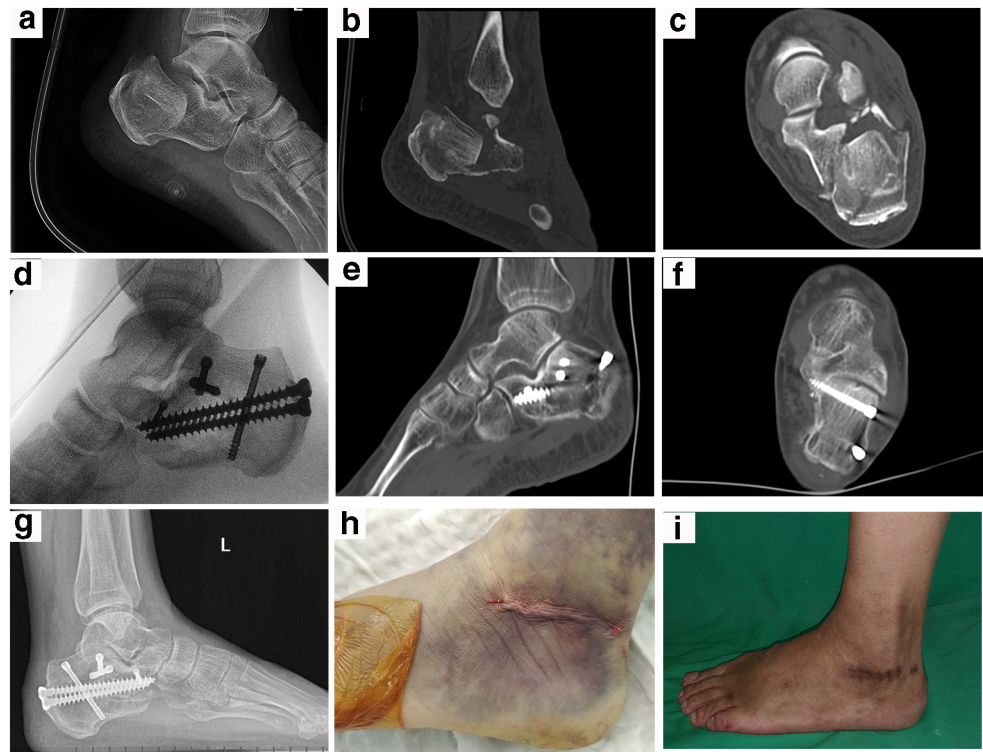
The Olerud and Molander Scale [18], American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot scores and Visual Analogue Scale (VAS) for clinical outcomes were calculated post-operatively at the last follow-up. Since the range of motion of subtalar joint is difficult to measure, we only evaluated manually whether it is rigid or not at the last follow-up. The length of waiting time before the surgery, the length of follow-up, complications, the costs of the hospitalization and the rates of implant removal were also collected. The costs of the hospitalization are defined as the expenses of inpatients for the ORIF of calcaneus fracture. This can be obtained from the patient's hospital bills. The cost of the removal surgery was not included.

Technique

The patient was placed in a lateral position with unilateral calcaneal fracture and in the prone position with bilateral calcaneal fractures with a tourniquet at the thigh.

An incision was made from the lateral malleolar tip directed toward the fourth metatarsal base. A deep dissection was carefully performed while preserving the soft tissue. The peroneal tendons and sural nerve were retracted inferiorly. If the fractures involve the calcaneocuboid joint, and the extensor brevis muscle was pulled as far as the calcaneocuboid joint. In most cases, the calcaneofibular ligament was not incised; however, the calcaneofibular ligament was incised with some

Fig.1 A 51-year-old male patient suffered DIACF, who has used screw fixation through STA. **a** Pre-operative X-rays (lateral view) of foot. **b, c** Pre-operative computed tomography scan showed the comminuted posterior articular facet. **d** Final reduction and screw fixation were confirmed using fluoroscopy. **e, f** Post-operative computed tomography scan showed a good reduction of the articular facet. **g** Weight-bearing X-ray (lateral view) of the patient 26-month follow-up. **h** Clinical appearance of the approach after surgery. **i** Clinical appearance of the foot at 26-month follow-up

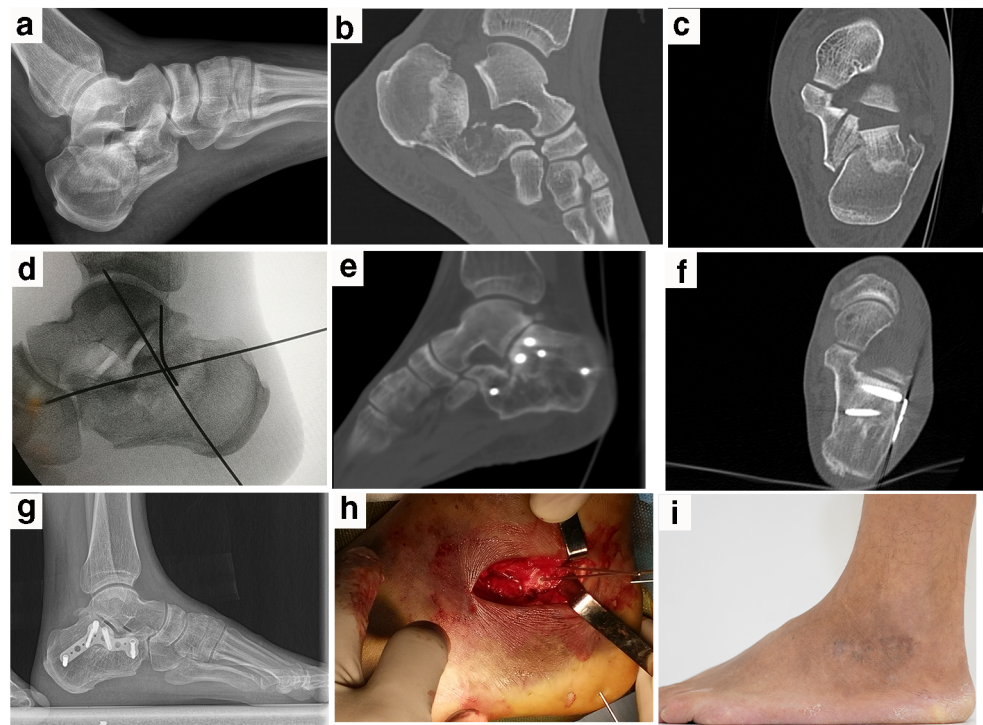


depressed fracture for acceptable exposure and later repaired if possible. After exposure of subtalar joint, the displaced posterolateral fracture fragment can be seen clearly.

The displaced posterolateral posterior fragment was identified and elevated under direct vision with subtalar articular surface as guidance. Once an anatomic reduction of the pos-

terior facet was accomplished, K-wires were temporarily fixed in order to hold the reduction. The heel alignment was then confirmed under the fluoroscopic guidance in calcaneal axial views. If the heel varus was present, a Schanz pin was introduced into the calcaneal tuberosity to correct the varus and restore the length of the calcaneus with the joystick technique.

Fig.2 A 40-year-old male patient suffered DIACF, who has used less invasive plate fixation through STA. **a** Pre-operative X-rays (lateral view) of foot. **b, c** Pre-operative computed tomography scan showed the comminuted posterior articular facet. **d** Reduction and K-wires fixation were confirmed using fluoroscopy. **e, f** Post-operative computed tomography scan showed a good reduction of the articular facet. **g** Weight-bearing X-ray (lateral view) of the patient 30-month follow-up. **h** Direct visualization of the posterior articular facet through the STA. **i** Clinical appearance of the foot at 30-month follow-up



The tuberosity fragment is pulled downward and medially below the sustentaculum. Once an anatomic reduction was achieved under the C-arm guidance, the fragments are temporarily fixed with K-wires.

Screws

After the fluoroscopic lateral, Broden and axial views were confirmed the reduction and alignment, one or two (more if needed) 4.0 cannulated screws were inserted from lateral to medial on the posterior facet, and at least one screw was inserted into the sustentaculum as possible to stabilize the fragment of the calcaneus.

Two cancellous or hollow screws (6.5 mm in diameter) were inserted percutaneously from each side of Achilles tendon to maintain calcaneal body fracture. Final reduction and fixation were confirmed using direct visualization and fluoroscopy (Fig. 1d). The bone graft was not performed, and the wound was closed layer by layer with a drainage inserted.

Less invasive plate

Restoration of the anatomic shape of the calcaneus was checked under the fluoroscopic lateral, Broden and axial views. One screw was inserted into the sustentaculum as possible to stabilize the fragment of the calcaneus. A plate (Acumed, OR, USA) was placed on the lateral wall of the calcaneus connecting to the anterior process. The cortical or locking screws were firstly achieved to the anterior process and then to the posterior facet. Once the plate was assured, direct visualization and fluoroscopic images were accomplished to confirm anatomic reduction (Fig. 2d) and suitable hardware placement. The bone graft was not performed, and the wound was closed layer by layer with a drainage inserted.

Statistical analysis

All the continuous variables are described as means \pm standard deviations. Mann-Whitney *U* test or Student's *t* test was used for continuous variables, depending on the data distribution. Fisher exact test was performed for the categorical variables. The alpha level was set at less than 0.05. Statistical analyses were using Stata statistical software (version 15, StataCorp, College Station, TX).

Results

General results

Two hundred thirty calcaneus fractures met the inclusion criteria. Patients with L-shaped incision (6 cases), extra-articular fracture (10 cases), multiple injuries (8 cases) and lost follow-up (41

cases) were excluded. Finally, 165 calcaneus fractures (159 patients) were identified for inclusion with 59 fractures using a less invasive sinus tarsi plate and 106 using screws alone. Patients' parameters were displayed in Table 1. The average length of waiting time before the surgery was no significant difference between the two groups. The average follow-up was 44.2 months in the plate groups and 47.9 months in the screw groups ($P > 0.05$). The total cost during the hospitalization had significant difference between the two groups ($P < 0.05$). There was statistically significant difference in the rate of implant removal between the two groups ($P < 0.05$).

Radiographic evaluation

There was no significant difference in the pre-operative heel varus between the two groups (Table 1). The heel alignment was maintained at the last follow-up in both groups. As shown in Table 2, there was no significant difference in the calcaneal Bohler's angle and Gissane's angle between the plate groups and screw groups during the pre-operation and the last follow-up.

Table 1 Patients' parameters for two groups

| Parameter | Plate(59) | Screws(106) | <i>P</i> value |
|-------------------------------|---------------------|-------------------|----------------|
| Mean age, years | 47.0 \pm 11.2 | 50.6 \pm 12.1 | 0.06 |
| Mean follow-up, months | 44.2 \pm 10.0 | 47.9 \pm 18.0 | 0.08 |
| Mean waiting time, days | 4.28 \pm 2.45 | 4.61 \pm 2.65 | 0.44 |
| BMI | 23.9 \pm 3.65 | 24.0 \pm 4.86 | 0.90 |
| Gender, no. | | | 0.79 |
| Male | 54 | 94 | |
| Female | 5 | 12 | |
| Smoking status, no. | | | 0.41 |
| Regular | 7 | 12 | |
| Occasional | 17 | 21 | |
| Nonsmoker | 35 | 73 | |
| Diabetic patients, no. | 1 | 5 | 0.42 |
| Location, no. | | | 0.00 |
| Right | 21 | 51 | |
| Left | 26 | 50 | |
| Bilateral | 12 | 5 | |
| Heel varus, no. | 19 | 20 | 0.06 |
| Essex-Lopresti classification | | | 0.05 |
| Tongue | 12 | 38 | |
| Depression | 47 | 68 | |
| Sanders classification, no. | | | 0.504 |
| IIA | 12 | 32 | |
| IIB | 4 | 13 | |
| IIC | 3 | 6 | |
| IIIAB | 25 | 33 | |
| IIIAC | 8 | 13 | |
| IIIBC | 4 | 3 | |
| IV | 3 | 6 | |
| Implant removal, no. | 36 | 46 | 0.03 |
| Cost, \$ | 8080.5 \pm 2122.8 | 4944 \pm 2949.5 | 0.00 |

BMI body mass index

Functional outcomes

As shown in Table 2, there was no significant difference in the final AOFAS score between the plate group (88.7 ± 9.7) and the screw group (87.3 ± 9.4) at the last follow-up ($P > 0.05$). There was no significant difference in the final Olerud and Molander score between the plate group (86.8 ± 4.89) and the screw group (86.9 ± 4.97) at the last follow-up ($P > 0.05$). There was no significant difference in the final VAS score between the plate group (1.95 ± 1.56) and the screw group (1.66 ± 1.49) at the last follow-up ($P > 0.05$). There were three cases of subtalar joint stiffness in the plate group and nine cases in the screw group at the last follow-up ($P > 0.05$).

Complications

There had no wound or nonunion complications in the both two groups. There were two cases of sural nerve injury and one case of peroneus longus and peroneus brevis injury in the plate group. There was one case of sural nerve injury, one case of peroneus longus and peroneus brevis injury and two cases of prominent screw heads in the screw group. During the follow up, four patients developed mild subtalar arthritis (1 case in the plate group and 3 cases in the screw group). No patients had undergone subtalar arthrodesis in both groups. The total incidence of complications was 6.7% in the plate group and 6.6% in the screw group ($P > 0.05$).

Discussion

We demonstrated less invasive plate and screw of fixation of the DIACFs through the STA. When comparing the screws and plate techniques, both techniques showed improvement in Bohler's and Gissane's angles compared with pre-operative measurements. Furthermore, there was no statistically significant difference in the rate of loss of reduction between initial and final post-operative radiographs. This would recommend that the two techniques have comparable power in both accomplishing and maintaining an acceptable radiographic reduction over time.

The wound complications of surgical DIACFs were amplified in patients with comorbidities such as smoking and diabetes preventing many surgeons from advocating ORIF in these patients [1]. The STA is a vast step forward in the treatment of displaced intra-articular calcaneus fractures. In our study, smoking and diabetes were not the factors in decision-making for the surgery. The average length of waiting time before the surgery was less than five days in both groups, which was shorter than the ELA approach [2]. We found that there was no wound complication in both groups, and the rates of complication in the two techniques tested to be much lesser than the rates of complications of ELA treatment of calcaneus fractures, with reports of wound complications ranging from 17 to 25% [1, 6, 19].

Prior studies have also demonstrated the advantage of the sinus tarsi approach for the improvement in functional outcomes [15, 20]. The final AOFAS scores and Olerud and Molander scores in both groups had no significant difference. The range of motion of subtalar joint will be subject to a certain of stiffness due to surgical reasons, and the proportion of subtalar joint stiffness in the ELA approach is high. The

Table 2 Radiographic parameters, clinical outcomes and complications in the two groups

| Parameter | Plate(59) | Screws(106) | P value |
|--|------------------|------------------|---------|
| Pre-operative Böhler, deg | 15.3 ± 13.6 | 16.5 ± 12.8 | 0.58 |
| Pre-operative Gissane, deg | 105.4 ± 13.1 | 106.3 ± 11.7 | 0.66 |
| Final Böhler, deg | 30.6 ± 7.4 | 29.1 ± 6.3 | 0.15 |
| Final Gissane, deg | 117.7 ± 11.6 | 115.9 ± 9.4 | 0.28 |
| Final AOFAS score | 88.7 ± 9.7 | 87.3 ± 9.4 | 0.36 |
| Final O-M score | 86.8 ± 4.89 | 86.9 ± 4.97 | 0.83 |
| Final VAS | 1.95 ± 1.56 | 1.66 ± 1.49 | 0.24 |
| Subtalar joint stiffness | 3 | 9 | 0.54 |
| Complications | 4 | 7 | 1.00 |
| Sural nerve injury | 2 | 1 | |
| Peroneus longus and peroneus brevis injury | 1 | 1 | |
| Prominent screw | 0 | 2 | |
| Subtalar arthritis | 1 | 3 | |

AOFAS American Orthopaedic Foot and Ankle Society, deg degrees, O-M Olerud and Molander Scale, VAS Visual Analogue Scale

total proportion of subtalar joint stiffness in the STA approach is 7.3% (12/165), and there was no significant difference between the two groups.

Most literature reported in relatively simple without comminution fracture model, screws achieve similarly with plate fixation biomechanically [21–23]. The calcaneal fracture models using osteotomies are not representative of the real fracture in which fracture lines are not that well equipped and the neutral triangle of the calcaneus is empty after pulling the posterior fragment out of the calcaneal body [24]. In our study, there were no morphological characteristics of the classification of fracture that may have guided the surgeon's decision to choose one method over the other. Generally, there were surgeons who used less invasive plates and surgeons who used screws determined by familiarity and the economic cost. However, for severe depression type of fractures, especially comminuted fractures of the medial wall of the calcaneus, we personally prefer plate fixation to provide better stability. However, the rates of implant removal and total cost during the hospitalization in the plate group were significantly higher compared with screw group.

There was one study that compared the screws and plate fixation techniques following reduction via the STA [17]. Our study is different from the previous literature: firstly, our sample size is 165 cases, and the Pitts et al. [17] reported cases are 61 cases; secondly, the mean follow-up of our cases is 46.6 months longer than the Pitts et al. [17] reported.

There are several limitations to this study. First, the follow-up period is relatively short. It is important to recognize the long-term clinical outcomes of calcaneus fractures through the STA approach. Second, this is a not a randomized control study.

Conclusions

When using the sinus tarsi approach for DIACFs, fixation with screws versus a plate and screws resulted in similar quality of reduction, complications and postoperative functional outcomes. The less invasive plate technique was significantly higher in terms of implant costs and the rate of implant removal.

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Compliance with ethical standards

The manuscript submitted does not contain information about medical device(s)/drug(s).

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Our study was approved by the Ruijin North Hospital Ethics Committee, Shanghai JiaoTong University School of Medicine. Written consent was provided by participants to be included in the study. Written informed consent for publication was obtained from all participants.

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