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ORIGINAL PAPER

# Comparison of sinus tarsi approach versus extensile lateral approach for displaced intra-articular calcaneal fractures Sanders type IV

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## Abstract

**Purpose** Displaced intra-articular calcaneus fractures Sanders type IV(DIACFS IV) can result in an unsatisfactory prognosis and a high complication rate. Our investigation intends to compare the outcomes of DIACFS IV treated by open reduction and internal fixation (ORIF) via sinus tarsi approach (STA) with these via extensile lateral approach (ELA).

**Methods** Sixty-nine patients (82 ft) with DIACFS IV who were treated with ORIF (29 in STA group and 40 in ELA group) were retrospectively assessed. Median follow-up was 50 months in two groups. Radiographic results were reviewed pre-operatively and post-operatively, and relative complications were collected. Clinical outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score and visual analog scale (VAS).

**Results** The wound-healing complication rate was 14.28% in STA group and 34.04% in ELA group ($p = .043$), and overall complication rate was 54% and 77% ($p = .056$), respectively. Seven cases of sural nerve injury only occurred in ELA group. The post-operative radiographs of the calcaneus (Böhler's angle, height, width, and length) were significantly different from those measured pre-operatively in each group. And these data were parallel between the two groups. In STA and ELA groups, the average AOFAS was 75.45 versus 72.44 ($p = .496$), and the mean VAS was 23.95 versus 30.93 ($p = .088$), respectively.

**Conclusion** Similar clinical and radiographic outcomes are achieved between STA and ELA. And STA has a lower incidence of wound healing complication and sural nerve injury. Therefore, ORIF via STA can be a considerable management for DIACFS IV.

**Keywords** Calcaneus fracture · Sanders type IV · Minimally invasive · Extensile · Sinus tarsi approach

## Introduction

Displaced intra-articular fractures of the calcaneus are common but difficult to manage, due to the complicated anatomic structure and fragile soft tissue around the bone [1–4]. Sanders classification is generally used for calcaneal fractures which are classified as types I to IV according to the number of articular fracture lines. And displaced intra-articular calcaneal fractures Sanders type IV (DIACFS IV) is the most severe, resulting in poor prognosis. Despite numerous published studies about this topic, the management of DIACFS IV remains controversial [3, 5–9]. All treatment options cannot make obviously satisfactory outcomes, including conservative management [3, 5], open reduction and internal fixation (ORIF) [7, 9], and primary subtalar arthrodesis [6, 8]. As Sanders reported previously, patients with DIACFS IV wound expect inferior operative results [10]. However, with the improvement of imaging technology and implants, ORIF for the treatment of DIACFS IV is mentioned in more and more studies [11–14]. And ORIF via extensile lateral approach (ELA), a classical therapeutic management which has advantages of excellent exposure of the fractures, is suggested by many papers for DIACFS IV [11–14]. However, the complications

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following this approach remain a major reason of sequela [15], owing to its obvious iatrogenic damage to soft tissue around the calcaneus. To overcome the disadvantages, some minimally invasive techniques are proposed, among which, sinus tarsi approach (STA) is often operated. Despite limited exposure, the STA enables direct reduction of the posterior facet, percutaneous reconstruction of calcaneal morphology, and firm fixation with plate and screws and makes good or excellent functional results when treating calcaneus fractures Sanders II/III [2, 7, 16]. However, few articles discuss the function recovery and complication rate of the STA for the treatment of DIACF IV.

Our investigation aims to review and compare the results of DIACF IV of patients treated with surgery through STA or ELA. As far as we know, there has not been such a comparison reported. Our hypothesis is that no significant difference of functional and radiographic outcome will be observed, but there will be less wound-healing complication rate in the STA group.

## Materials and methods

### Patients

We performed a retrospective review of all patients with DIACFS IV, who were admitted to our hospital from January 2009 to April 2016. The study was reviewed and approved by the Institutional Review Board of our hospital. Signed informed consent was obtained from each patient. A total of 69 patients (82 ft) were selected for the present study. The inclusion criteria were set as follows: (1) patients aged more than 18 affected by DIACFS IV, as demonstrated by computed tomography (CT) scan (excluding all open fractures), (2) patients treated with ORIF via STA or ELA, (3) no previous functional damage (including surgery, fractures, osteoarthritis, or inflammatory arthritis) and/or other fresh fractures of the ipsilateral foot and/or ankle, (4) no major underlying medical comorbidities (i.e., uncontrolled hypertension, previous myocardial infarction, cancer, history of stroke or transient ischemic attacks, chronic obstructive lung disease, cardiac arrhythmias, morbid obesity, diabetes mellitus, peripheral vascular diseases, peripheral neuropathies), and (5) a minimal follow-up period of 12 months. According to the operative approaches, these cases were divided into two groups (STA group and ELA group). The first one consisted of 29 consecutive patients (35 ft) treated via STA, while 40 consecutive patients (47 ft) treated via ELA in the other group. The two groups were compared equivalently with respect to demographic data (Table 1). All suregry in two groups were performed by one of four orthopaedic surgeons who were similarly experienced in trauma and foot and ankle surgery (> 15 years), assisted by one or two junior fellows. And all surgeons were familiar with both ELA and STA. Both approaches were used contemporaneously based on surgeon preference.

**Table 1** Patients' demographics

| Characteristics | STA group | ELA group | *p* value |
|---|---|---|---|
| Age, year | 36 (18–55) | 38 (27–45) | 0.652 |
| Sex, male/female, *n* | 22/7 | 33/7 | 0.554 |
| Side of injury, Rt/Lt, *n* | 21/14 | 29/18 | |
| Aetiology | | | 0.777 |
| Fall from a height | 23 | 30 | |
| Motor vehicle accident | 6 | 10 | |
| Worker's compensation, *n* | 10 | 13 | 0.863 |
| Tobacco, *n* | 8 | 15 | 0.389 |

### Pre-operative management

All cases were pre-operatively evaluated by calcaneal radiographs, computed tomography (CT) scans, and two-dimensional reconstruction of the traumatic foot. The patients were not operated until a positive wrinkle test, within 14 days after the injury. All the patients received 24 hours of antibiotic prophylaxis with intravenous cephalosporin, starting 30 minutes before the operation. After either epidural or spinal anaesthesia, the patients were placed in the lateral or semi-lateral decubitus position. Then tourniquets were applied routinely.

### Sinus tarsi approach

The STA was operated as described by Paul Hospodar [17]. An approximately 4-cm incision was made from the tip of the lateral malleolus to the base of the fourth metatarsal (Fig. 1). With this approach, the posterior facet and, if necessary, the calcaneocuboid joint was visualized clearly. And then reduction techniques were used, including both direct and indirect reduction methods. Firstly, the lateral wall of the calcaneum was levered, and subsequently, middle depressed fractures of the posterior facet could be manipulated. Secondly, the middle depressed fractures were aligned with medial sustentaculum fragment by a periosteal elevator and fixed transversely with K-wires, with the depressed posterior facet reduced to the talus. Thirdly, a Schanz screw was inserted into tuberosity of the calcaneum, if necessary. With gentle manual distraction longitudinally and compression transversely under direct visualization and C-arm radiograph, reduction of morphology (length, width, valgus) of the calcaneum was attempted. As deemed necessary by the surgeon, bone grafting of the defect below the posterior facet was performed. Finally, an anatomical calcaneum plate and

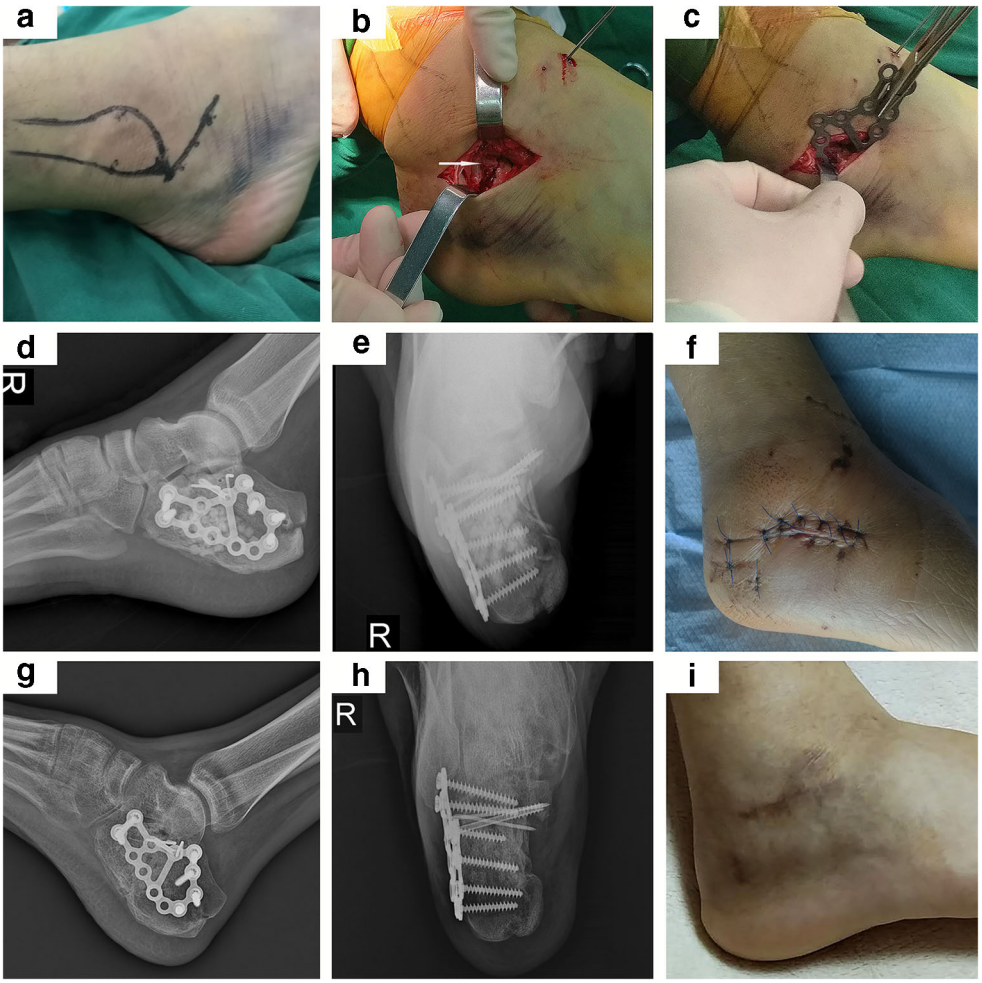


**Fig. 1** A patient suffered DIACFS IV, who was treated through STA. **a** Anatomic scheme showing the landmarks for STA. **b** Approach during surgery, allowing direct visualization and reduction for the posterior facet (arrow). **c** The anatomical plate was squeezed into this approach and fixed by inserted screws. **d**, **e** Post-operative X-rays (lateral and axial) after surgery through STA. **f** The STA showing good skin condition and healed wound in 14 days after surgery. **g**, **h** X-ray (lateral and axial) of this patient 12-month follow-up after STA. **i** Clinical appearance of the foot and cicatrization when 12-month follow-up after STA

screws were inserted and fixed, possibly combined with additional screws. After the fixation was made sure, the incision site was washed and closed by layers over a drain.

## Extensile lateral approach

The standard ELA was performed for reduction and fixation [18, 19]. Firstly, an L-shaped incision was made with a smooth curve (Fig. 2). The full-thickness flap was separated at the periosteum level and held in place with three 2.5-mm K-wires. In the next step, the thin lateral wall was retracted and the reduction of articular fragments was completed by K-wires. The calcaneal morphology was reduced by gentle compression and distraction. Then, an anatomical calcaneal lateral plate was generally used for fixation. Bone grafting was performed according to the surgeon's consideration. The wound was washed and closed by layers over a drain.

The post-operative therapy protocol was similar in both groups [20]. The traumatic leg was elevated for swelling control on the first two days. Active and passive activity exercise of the foot and ankle joints was started if there was no concern for wound healing. Gradual partial weightbearing and gait training were started at four to eight weeks post-operatively. Full weightbearing was allowed at generally 12 weeks. The follow-up radiographic assessment consisted of the lateral, axial radiographs, and CT scans (Figs. 3 and 4). The radiographic views were taken post-operatively, at four and 12 weeks, at six and 12 months, and once a year later after surgery. The CT scans were obtained post-operatively to check the articular reduction. Wound-healing complication was evaluated during hospitalization. Sural nerve injury, peroneal tendinitis, and subtalar compartment syndrome were determined by chart review. Subtalar arthritis and calcaneal malunion were determined according to radiographic views at 12-month follow-up. All patients were contacted to return for American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score and visual analog scale (VAS) for pain. A total of 47 patients returned for these visits (27 in ELA and 20 in STA). The median follow-up for patients returning for a research visit was 50 months in STA group (range, 15–84 months) versus 50 in ELA group (range, 12–79 months) ($p = .961$, $1\text{-}\beta = 0.05117$).

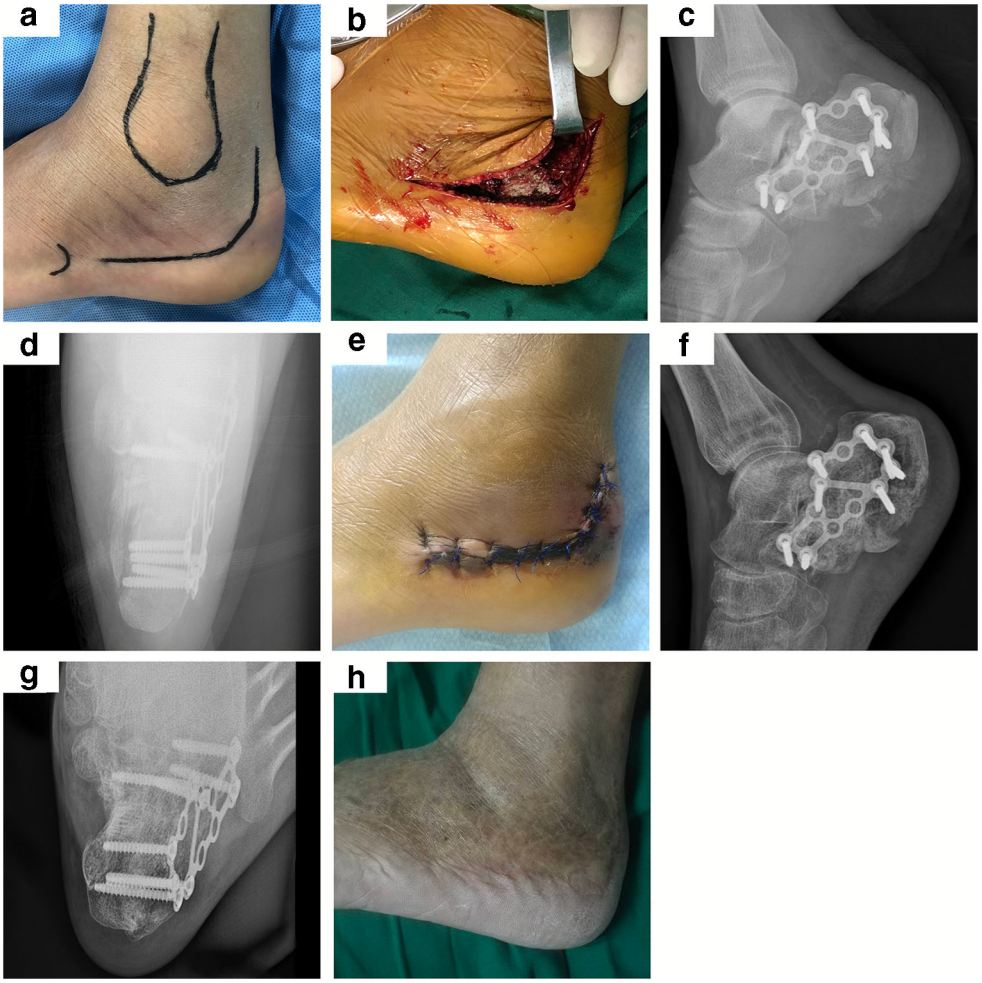


**Fig. 2** A patient suffered DIACFS IV, who was treated through ELA. **a** Anatomic scheme showing the landmarks for ELA. **b** Approach during surgery, exposing the view of the calcaneus, giving access for reduction. **c**, **d** Post-operative X-rays (lateral and axial) after surgery through ELA. **e** The ELA showing skin condition and healed wound in 14 days after surgery, with a little wound-edge necrosis which was treated by dressing change. **f**, **g** X-ray (lateral and axial) of this patient when the final follow-up after ELA. **h** Clinical appearance of the foot and cicatrization when final follow-up after ELA

## Statistical methods

Standard descriptive statistics were calculated including frequencies and percentages, median and range, and means ± standard deviation as appropriate. The unpaired *t* test was used to determine the significance of inter-group differences in demographic data and other measurement data of homogeneity of variance in a normal distribution. The paired *t* test was used for interior-group radiographic outcomes pre-operatively and post-operatively. The Mann-Whitney *U* test was used for measurement data of non-normal distribution. And Pearson's chi-square test was used for the prevalence of complications. A $p$ value < 0.05 was considered statistically significant. All statistical calculations were done using the computer program SPSS version 20 for Microsoft Windows.

## Results

In the STA group, we detected a lower incidence of wound healing complications (5 ft in STA group [14.28%] and 16 ft in ELA group [34.04%]; $p = .043$) (Table 2). Moreover, some complications only occurred in the ELA group, such as seven cases of sural nerve injury and two cases of deep infections.

The mean AOFAS hindfoot score was 75.45 ± 14.66 for the STA group and 72.44 ± 14.99 for the ELA group ($p = .496$). The mean VAS score was 23.95 ± 13.63 and 30.93 ± 13.52 for the STA and ELA group, respectively ($p = .088$). In addition, the STA group had a statistically less days of hospitalization (16.2 ± 9.3 days, range 6–42) than the ELA group (22.0 ± 13.3 days, range 5–46) ($p = .05$).

## Complications

There were 21 (25.61%) operative wound-healing complications developing in 2 groups (Table 2): the superficial infection (4 in the STA group and 11 in the ELA group) was resolved with dressing change and intravenous antibiotics; the deep infection (only 2 in the ELA group) required hardware removal; two cases of four feet with the wound-edge necrosis (1 in the STA group and 3 in the ELA group, Fig. 5) were managed with debridement and dressing change, and others with local wound care. In addition, subtalar arthrosis (11 in the STA group and 13 in the ELA group) was

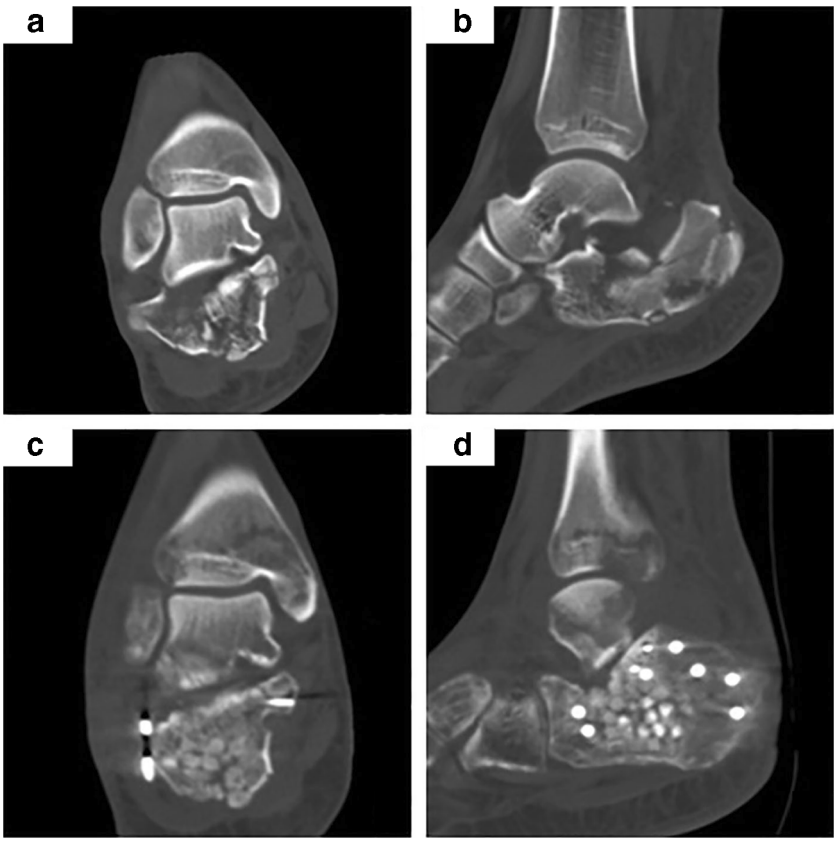


**Fig. 3** A patient treated through STA. **a**, **b** Pre-operatively computed tomography scan showed the comminuted posterior articular facet. **c**, **d** Post-operatively computed tomography scan showed a nearly anatomic reduction of the articular facet

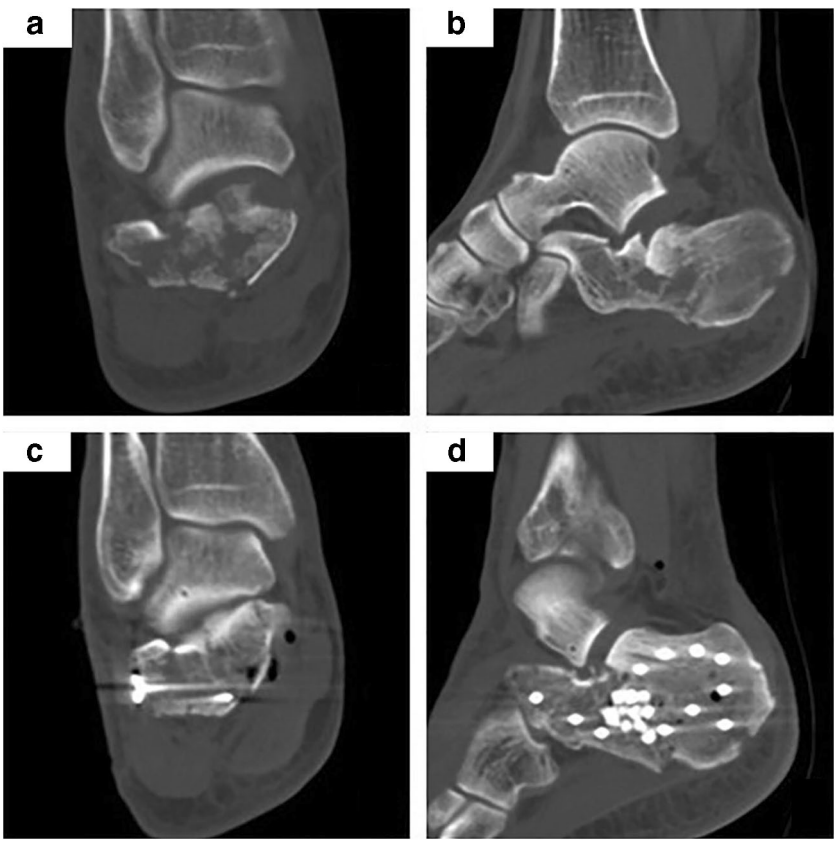


**Fig. 4** A patient treated through ELA. **a**, **b** Pre-operatively computed tomography scan showed the comminuted posterior articular facet. **c**, **d** Post-operatively computed tomography scan showed a nearly anatomic reduction of the articular facet

**Table 2** Complications of the STA and ELA groups

| Complications | STA group ($N = 35$) | | ELA group ($N = 47$) | | |
|---|---|---|---|---|---|
| | No. of feet | Percentage (%) | No. of feet | Percentage (%) | $p$ value |
| Wound-healing complications | 5 | 14.28 | 16 | 34.04 | .043 |
| Superficial infection | 4 | 11.43 | 11 | 23.40 | .165 |
| Deep infection | 0 | – | 2 | 4.26 | – |
| Wound-edge necrosis | 1 | 2.86 | 3 | 6.38 | .830 |
| Subtalar arthritis | 11 | 31.43 | 13 | 27.66 | .711 |
| Sural nerve injury | 0 | – | 7 | 14.89 | – |
| Peroneal tendinitis | 4 | 11.43 | 7 | 14.89 | .898 |
| Calcaneal malunion | 6 | 17.14 | 8 | 17.02 | .988 |

recognized by diminished joint space, no joint space, or subchondral sclerosis. Sural nerve injury only occurred in ELA groups (7 cases). Peroneal tendinitis occurred in four in the STA group and seven in the ELA group ($p = .898$). Calcaneal malunion occurred in six in the STA group and eight in the ELA group ($p = .988$). Among these cases with subtalar arthrosis, peroneal tendinitis, and calcaneal malunion which were often occurred in the same case, eight cases (3 in the STA group and 5 in the ELA group) were treated with resection of the lateral calcaneal wall and subtalar arthrodesis.

## Radiologic results

In the STA group, post-operative radiographic data of the calcaneus were significantly different from those measured pre-operatively, including Böhler's angle (22.25 [range − 1.87–35.58] versus 6.65 [range − 38.56–31.09], $p < .001$), height (48.75 ± 4.44 versus 36.95 ± 4.92, $p < .001$), width (43.59 [range 35.97–51.89] versus 53.09 [range 33.07–73.93], $p < .001$), and length (80.80 ± 3.97 versus 71.87 ± 5.89, $p < .001$), although not all post-operative data restored to normal limits (Table 3). Similarly, in the ELA group, post-operative radiographic data of the calcaneus were significantly different from those measured pre-operatively, including Böhler's angle (18.91 [range − 13.70–36.70] versus 8.84 [range − 48.24–53.09], $p < .001$), height (46.61 ± 8.40 versus 37.90 ± 5.84, $p < .001$), width (45.37 [range 34.87–67.41] versus 54.87 [range 39.82–82.55], $p < .001$), and length (82.62 ± 6.04 versus 80.39 ± 7.46, $p < .001$). Furthermore, no significant difference between the two groups was detected regarding the post-operative radiograph parameters, including Böhler angle ($p = .404$, 1-$\beta = 0.3310$), Gissane angle ($p = .746$, 1-$\beta = 0.0614$), height ($p = .350$, 1-$\beta = 0.5686$), length ($p = .126$, 1-$\beta = 0.5274$), and width ($p = .371$, 1-$\beta = 0.4111$) of the calcaneus (Table 3).

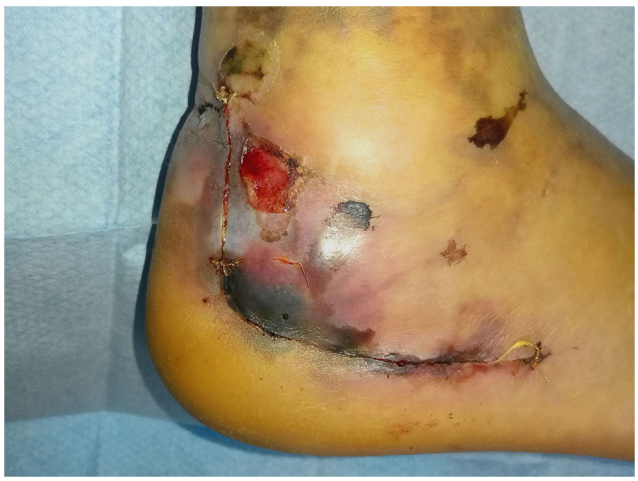

**Fig. 5** View of incision for ELA, accompanied with the complication of wound-edge necrosis

## Clinical results

AOFAS hindfoot score was calculated according to the published research [21]. And the difference did not attain statistical significance in the mean AOFAS hindfoot score ($p = .496$) between the two groups (Table 4). 50.00% and 37.04% excellent or good rating were yielded in STA and ELA groups, respectively. Twelve patients (5 in the STA group and 7 in the ELA group) had changed to work requiring less heavy labour. For the VAS pain scale, we asked patients to rate their pain on a graphic chart labeled from 0 to 100 during moderate activity. VAS was 30.93 ± 13.52 in the ELA group versus 23.95 ± 13.63 in the STA group, and the difference was not significant ($p = .088$).

# Discussion

The calcaneus is the most frequently fractured tarsal bone in the setting of trauma. Furthermore, DIACFS IV remains one type of the more challenging fractures to manage [10].

**Table 3** Pre-operative and post-operative radiographic parameters in the two groups

| Outcomes | STA group | ELA group | *p* value |
|---|---|---|---|
| Pre-operative | | | |
| Böhler angle, degree | 6.65 (− 38.56–31.09) | 8.84 (− 48.24–53.09) | .978 |
| Gissane angle, degree | 114.09 ± 17.18 | 114.71 ± 20.71 | .887 |
| Height, mm | 36.95 ± 4.92 | 37.90 ± 5.84 | .350 |
| Length, mm | 71.87 ± 5.89 | 80.39 ± 7.46 | < .001 |
| Width, mm | 53.09 (33.07–73.93) | 54.87 (39.82–82.55) | .371 |
| Post-operative | | | |
| Böhler angle, degree | 22.25 (− 1.87–35.58) | 18.91 (− 13.70–36.70) | .404 |
| Gissane angle, degree | 112.37 ± 16.72 | 111.18 ± 16.39 | .746 |
| Height, mm | 48.75 ± 4.44 | 46.61 ± 8.40 | .114 |
| Length, mm | 80.80 ± 3.97 | 82.62 ± 6.04 | .126 |
| Width, mm | 43.59 (35.97–51.89) | 45.37 (34.87–67.41) | .214 |

Because of the comminuted articular facet, the fragile soft tissue, and the injured anatomical morphology, outcomes of the comminuted calcaneal fractures tend to be unsatisfactory whatever the treatment options are [3, 5–9, 22, 23]. For one thing, conservative management often results in a poor outcome or even permanent disability [4, 22]. In addition, primary reduction and articular fusion may be an alternative, but it brings an even higher morbidity than ORIF and a high rate of complications which is similar with open reduction [6, 8].

The ideal goal of ORIF in these fractures is to recreate the calcaneal width, height, length, the subtalar joint congruency, and the soft tissue balancing. Although several previous studies suggest that operative treatment of DIACFS IV is difficult [2, 11, 24], some authors suggest that ORIF should be applied to the type IV calcaneal fractures [11–14]. These studies report that, in general, surgery can reduce the time to return to work and the progression to subtalar fusion, with less expenses [5]. Among approaches of ORIF, ELA is classical, which has advantages of the excellent exposure of fractures [25]. However, the soft tissue around calcaneus will be damaged severely by this approach, which led to a high rate of complications after surgery, especially in DIACFS IV [15]. To overcome the disadvantages, sinus tarsi approach (STA) is published to be widely used and ameliorate complication rate obviously in Sanders type II/III [16, 20]. Moreover, as a research of micro-circulation demonstrated, the region of the approach which was similar to STA showed significantly higher blood flow, compared to the regular extended lateral approach [26].

Numbers of publications mentioned ORIF through STA as operative treatment for DIACFS IV but, as far as we know, few detailed studies about these topics were reported [7, 14, 16, 27–29]. Tao Zhang et al. reported 16 patients with comminuted intra-articular calcaneal fractures were treated with STA [14]. In this study, the rate of good to excellent results according to the AOFAS scoring system was 56.3%, and much better than that in minimally invasive longitudinal approach group. However, no more detailed data was reported. Tin Schepers reviewed 8 studies about calcaneal fractures and mentioned 25 cases of DIACFS IV treated with STA, however, without related outcomes [27]. And other studies mentioned this operation or other minimally invasive techniques for DIACF IV, but no detailed data or no enough cases were reported [7, 16, 28, 29].

Our study indicated that the management of ORIF via STA or ELA for DIACFS IV could produce similar clinical and radiographic outcomes. Furthermore, a significantly lower rate of wound-healing complications occurred in the STA group than in the ELA group, as well as the rate of sural nerve injury. Moreover, some complications only occurred in the ELA group, such as deep infection and sural nerve injury. Post-operative radiographic data, including Böhler's angle, height, width, and length of the calcaneus, were recovered significantly compared with those measured pre-operatively in two groups, though not to normal limits. In these radiographic outcomes, Böhler's angle was reported to highly correlate with therapeutic outcomes [30]. Meanwhile, the clinical

**Table 4** The AOFAS hindfoot score

| Group | Means ± SD | *p* value | Excellent (%) (score 100–90) | Good (%) (score 89–80) | Fair (%) (score 79–70) | Poor (%) (score < 70) |
|---|---|---|---|---|---|---|
| ELA (*n* = 27) | 72.44 ± 14.99 | .496 | 2 (7.41) | 8 (29.63) | 8 (29.63) | 9 (33.33) |
| STA (*n* = 20) | 75.45 ± 14.66 | | 3 (15.00) | 7 (35.00) | 4 (20.00) | 6 (30.00) |

outcomes, assessed by AOFAS score and VAS pain score, seemed both acceptable compared with other therapeutic protocols published [7, 16, 27]. Buch et al.1 reported 14 cases with DIACFS IV, who were treated with primary subtalar arthrodesis and followed up after a mean time of 26 months [31]. The mean AOFAS score at follow-up was 72.4. Gurkan et al. reported 64 cases with DIACFS IV, and the mean AOFAS score was 72 at a mean follow-up of 51 months [5].

Although our data display that the outcomes of STA for DIACFS IV are acceptable, the complication rates are both high in the two groups. The high incidence may be due to that traumatic violence and bone fragments have caused severe soft tissue damage when DIACFS IV occurs. Therefore, different choices of surgical approaches do not completely avoid high complications. That may be one of the reasons why evidence to support ORIF for this injury is weak in several meta-analyses, when compared with non-operative treatment [1, 23, 32]. In consideration to complication reported in previous studies, combined with the above reasons, the high rate of complication and sequelae is natural [8, 18]. Alex et al. reported 29.1% wound-healing complications in patients with only Sanders II/III intra-articular calcaneal fractures treated with ORIF through ELA [18]. Therefore, a bit higher rate of wound-healing complication is acceptable in a patient affected by DIACF IV. Moreover, Potenza et al. reported 6 patients with comminuted intra-articular calcaneal fractures who were treated with primary subtalar arthrodesis [8]. And different levels of pain remained in 4 patients at the mean time of 12 months after surgery.

Our study has limitations. First, there is no randomization due to the inherent of its retrospective design. Second, our minimum follow-up period is 12 months, so some long-term complications and prognosis are not observed. In the future, the prospective and long-term follow-up design should be performed. Nevertheless, the strengths of our study include case-control study design and the comparison with the same demographic characteristics, same fixation method by anatomical plates and screws, and the use of objective and subjective measures of physical function in the two groups.

In conclusion, our study demonstrates that ORIF via STA can make similar and relatively good outcomes for DIACFS IV, when comparing to the ELA. The restoration of width, height, and length of the calcaneus and the reconstruction of the articular congruency are acceptable. Lower wound-healing complication rates and fewer occurrence of sural nerve injury in the STA group are reported compared with those in the ELA group. Therefore, though the management of DIACFS IV continues to be difficult, we believed open reduction and internal fixation via sinus tarsi approach can be a considerable management for the fractures.

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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 research was approved by the ethics department of The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Zhejiang. We have consensus with all participants. We also followed the Declaration of Helsinki and relevant policies in China.

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