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Original Article

Treatment of the intra-articular calcaneal fractures: an efficacy comparison among closed percutaneous reduction surgery, open reduction via extended L-shaped lateral approach and small sinus tarsi approach

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Abstract: The goal of this study was to retrospectively compare the complications and outcomes of three operations to determine a better approach with less complications and satisfied outcomes. Between 1990 and 2010, 175 patients with intra-articular calcaneal fractures underwent the closed percutaneous reduction (50 feet, PR group), open reduction via an extended L-shaped lateral approach (70 feet, EL group) or minimally invasive small sinus tarsi approach (75 feet, MI group) in our hospital. Outcome parameters included complications, radiographic analysis, the American Orthopaedic Foot and Ankle Society (AOFAS) ankle score and the Short Form 36 (SF-36) score. Although the calcaneal height, length, width, Böhler angle, and Gissane angle were significantly improved in the three groups postoperatively, a more pronounced improvement was observed in the EL and MI groups. At the final follow-up, the foot function seemed to be better recovered by the EL and MI treatments with higher AOFAS and SF-36 scores. The complication incidence was significantly lower in the PR (0%) and MI (5.33%) groups than that in the EL group (22.86%). Furthermore, reoperation occurred in 6 feet (12.00%) in the PR group, 11 feet (15.71%) in the EL group and 2 feet (2.67%) in the MI group. The sinus tarsi approach may be the most effective and safest for the intra-articular calcaneal fractures, with an excellent reduction, but lower complication and reoperation rates.

Keywords: Retrospective study, percutaneous reduction, l-shaped lateral approach, small sinus tarsi approach, outcomes

Introduction

Fractures of the calcaneus are relatively common clinical injuries, accounting for 1-2% of all fractures and 60% of all tarsal fractures. Broadly, calcaneal fractures can be categorized into intra-articular and extra-articular types, among which the intra-articular fractures more frequently occur, comprising approximately 75% of all calcaneal fractures [1]. Because of the injury mechanism of falling from a height or motor vehicle accidents, the prevalence of calcaneal fractures is relatively higher in young male population (21-45 years), causing them unable to work over a considerable period of time and even ending their careers. These results impose a substantially economic burden on a family [2]. To avoid a deteriorating condition, it is necessary to early and appropriately treat these injuries.

The intra-articular calcaneal fractures can be managed by several surgical strategies. Westhues first proposed the use of closed reduction with percutaneous pin leverage and plaster immobilization in 1934 for treatment of intra-articular calcaneal fractures [3]. This technique was subsequently modified by some scholars by introducing a special spike and handle [4], a shoe plaster [5], Kirschner wires [6], and arthroscopically assisted methods [7] to further improve the reduction effect and reduce the complications. Recently, open procedure using internal fixation has been favored as a

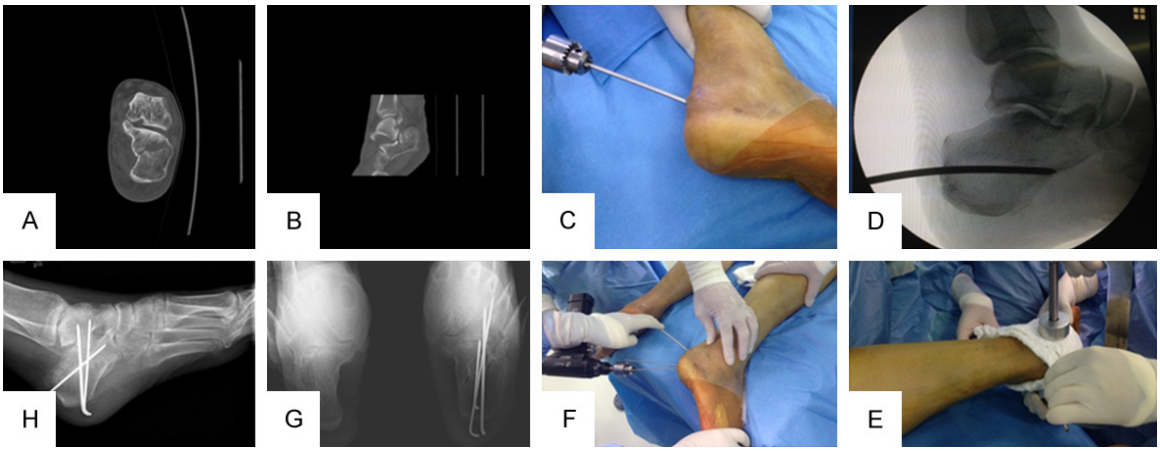

Figure 1. Percutaneous Steinmann pin reduction surgery. Preoperative X-ray showed the intra-articular calcaneal fractures (A, B); The Steinmann pin was driven to poke the collapsed articular surface (C). After satisfied positioning was obtained, the broken ends of fractured bone were poked (D) and the calcaneus was squeezed (E) to correct the calcaneal width. The width of calcaneus was corrected by driving into Kirschner wire (F); Postoperative X-ray showed that the calcaneal height, Böhler angle, and Gissane angle were significantly improved and the calcaneal width was recovered well (G, H).

standard surgical therapy for the intra-articular calcaneal fractures. The common extended L-shaped lateral approach provides a more superior access for exposure of the fracture and allows direct restoration of the deformed posterior facet. Unfortunately, wound complications of this procedure, including wound swelling, deep or superficial infections, dehiscence, and necrosis, have been reported to occur in up to 30% of patients [8-10]. Subsequently, the small incision approach at sinus tarsi was advocated, which avoids compromising the already damaged soft tissues, thereby reducing the risk of operative and wound complications but also permitting reduction of the displaced posterior facet, anterolateral fragment, and the tuberosity varus [11-13]. Previous studies have attempted to compare the clinical outcomes between two different approaches, including the closed percutaneous reduction and open reduction via extended L-shaped lateral approach [14, 15], as well as open reduction via extended L-shaped lateral approach and small sinus tarsi approach [16, 17]. However, the optimal management of intra-articular calcaneal fractures has been yet unclear [18]. Furthermore, no study has been performed to compare among the above three approaches.

The goal of this study was to retrospectively analyze the 175 patients with intra-articular fractures of the calcaneus from 1990 to 2010, and evaluate the efficacy of these three surgical procedures by comparing the surgical process indicators, radiographic results, foot function recovery, the incidence of complications and reoperation.

Materials and methods

Description of patients

After obtaining institutional review board approval, this retrospective review was performed for operatively managed intra-articular calcaneal fractures between 1999 and 2010 in our hospital. The enrolled patients met the following inclusion criteria: (1) over 18 years of age; (2) acute closed fracture of calcaneus; (3) Sanders type II or III fractures [19]; (4) fractures were treated via closed percutaneous reduction (PR group) or open reduction via an extended L-shaped lateral (EL group) or minimally invasive small sinus tarsi approach (MI group); and (5) a minimum of 12 months of clinical follow-up. The exclusion criteria were (1) the time of injury was greater than 3 weeks (calculated from injury to 8 am on the day of surgery); and (2) history of calcaneal, ankle or other foot fractures.

Surgical procedures

After admission, a careful examination was performed to determine the status of the skin and soft-tissue swelling followed by pressure dress-

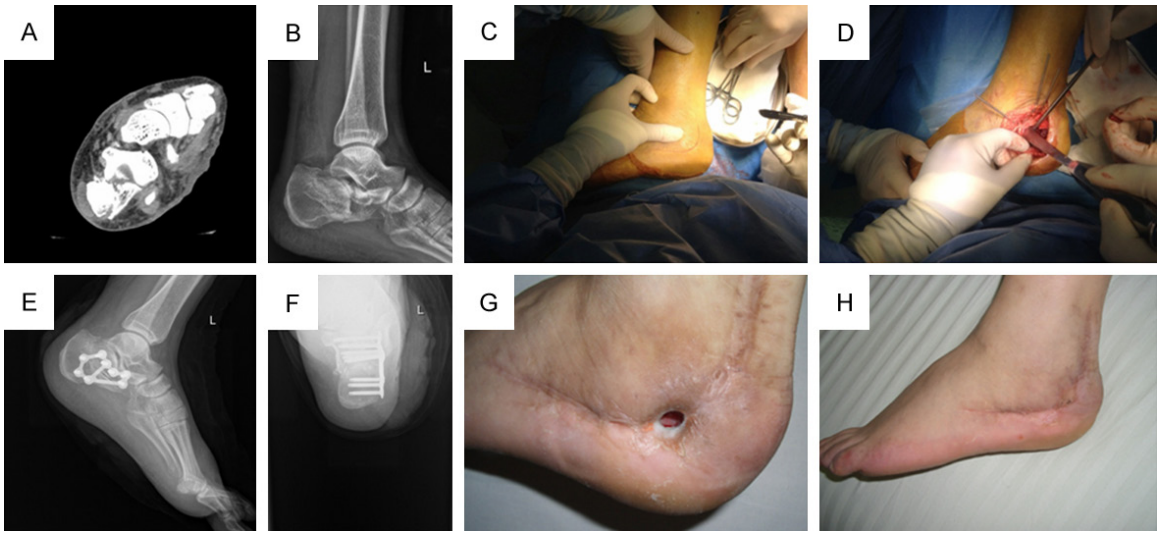

Figure 2. Open reduction via an extended L-shaped lateral approach. Preoperative lateral X-ray showed the intra-articular calcaneal fractures, with decreased calcaneal height, Gissane angle, and Böhler angle (A, B); The L-shaped incision was made (C) and the paries lateralis was opened to expose the fracture ends and poke (D); Postoperative X-ray showed that the calcaneal height, Böhler angle, Gissane angle, and calcaneal width were recovered (E, F); Incision healed was delayed, but resolved after one month by dressing change (G, H).

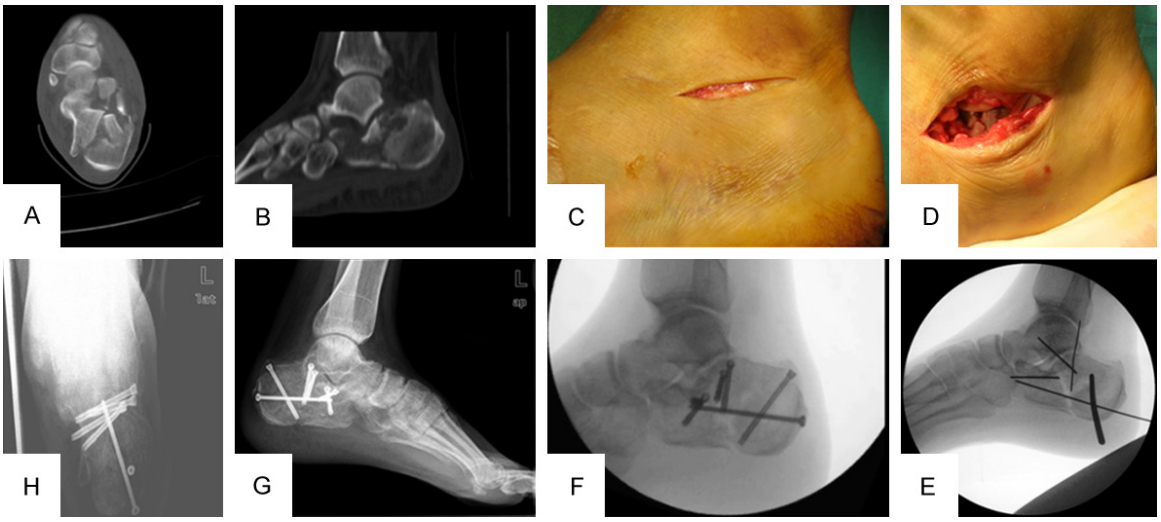

Figure 3. Percutaneous fixation via a small sinus tarsi approach. The photograph and radiograph of the small sinus tarsi approach. Preoperative lateral X-ray showed the intra-articular calcaneal fractures, with decreased calcaneal height, Gissane angle, and Böhler angle (A, B); an incision was made from the tip of the medial malleolus to the bases of the fourth metatarsals to expose rupture and collapsed articular surface (C, D); After traction, poking reduction, Kirschner wire was used to fix temporarily (E) followed by screw fixation (F); Postoperative X-ray showed that the calcaneal height, Böhler angle, Gissane angle, and calcaneal width were recovered (G, H).

ing and drug treatment until a stable status was achieved. Lateral, axial radiographs and CT scans with sagittal three-dimensional reconstructions were obtained on all patients to identify the fractures of articular surface and the degree of collapse. The use of surgery methods was based on both the preference and the skill of the different surgeons.

The fractures in the PR group were reduced by introducing a 3 mm Schanz pin into the calcaneus percutaneously along the outer edge of Achilles tendon (**Figure 1C**). After satisfied positioning was obtained under C-arm fluoroscopy (**Figure 1D**), the calcaneal tuberosity was manually manipulated to reduce widening and varus rotation (**Figure 1E**). The reduced length and

Table 1. Demographic and clinical characteristics of patients in each group

	PR	EL	MI	*P1*	*P2*	*P3*
Age (years)	40.3 ± 11.2	44.6 ± 12.3	41.0 ± 9.6	0.071	0.738	0.106
Gender, male (n, %)	30 (60.0)	40 (57.1)	53 (70.7)	0.852	0.249	0.119
Smoking (n, %)	15 (30.0)	30 (42.9)	33 (53.3)	0.182	0.135	1.000
Diabetes (n, %)	2 (4)	10 (14.3)	10 (13.3)	0.073	0.121	1.000
Injury mechanism				0.157	0.079	0.865
Falling from a height	11 (22.0)	25 (35.7)	30 (40.0)			
Traffic accidents	39 (78.0)	45 (64.3)	45 (60.0)			
Sanders classification (feet)				0.139	0.716	0.244
Type II (n, %)	28 (56.0)	29 (41.4)	39 (52.0)			
Type III (n, %)	22 (44.0)	41 (58.6)	36 (48.0)			
Time from injury to surgery (d)	4.32 ± 0.25	4.34 ± 0.28	4.44 ± 0.51	0.681	0.125	0.150

PR, closed percutaneous reduction; EL, open reduction via an extended L-shaped lateral approach; MI, open reduction via a small sinus tarsi approach (minimally invasive). *P1*, the difference between PR and EL groups; *P2*, the difference between PR and MI groups; *P3*, the difference between EL and MI groups. $P < 0.05$ was considered to indicate a significant difference.

height of calcaneus fragments were recovered with Kirschner wires (**Figure 1F**). The plaster was finally used to fix the limb after closing the wound and incision [4, 14].

The standard L-shaped incision was used in the EL group, in which the vertical incision was made midway between the fibula and Achilles tendon, and the horizontal incision was located in line with the base of the fifth metatarsal (**Figure 2C**). The full-thickness flap was stripped to expose the lateral wall of the calcaneus and the subtalar joints (**Figure 2D**), followed by poking reduction with the use of a Schanz pin and then fixation with a suitable plate. According to the collapse of articular surfaces and degree of bone defects, the iliac bone graft was selectively implanted [16, 17, 20].

In the MI treatment group, a lateral incision was made from the tip of the medial malleolus to the bases of the fourth metatarsals to expose the ruptured and collapsed articular surface (**Figure 3C**, **3D**). A 3.5 mm Schanz pin was inserted into the calcaneus tuberosity to correct the calcaneus length, height, width, Böhler and Gissane angle. Once the fractures were reduced, a temporary Kirschner wire fixation was used to hold the fragments in place (**Figure 3E**). Screws (**Figure 3F**) were finally to fix the subtalar articular surface, anterior process of the calcaneus, and the sustentaculum tali. Once a rigid fixation was achieved under C-arm fluoroscopy, the incision was closed in a layered fashion [16, 17, 20].

After surgery, a negative drainage tube was placed for 24 to 48 hours and antibiotics were routinely given for 2 days to prevent the wound infection. Follow-up visits were scheduled at every 3 months within 1 year as well as every 6 months one year later.

Evaluation of therapeutic efficiency

The therapeutic efficiency of three treatments was evaluated by collecting the following indexes: surgery process [operation time (from the cut to the suture of the incision, min), length of stay (day), operation cost (hundred yuan)], radiographic results (calcaneal height, width, length, Böhler angle, and Gissane angle preoperatively and postoperatively by X-ray), foot function surveys {the American Orthopaedic Foot and Ankle Society (AOFAS) score [21] and Short Form 36 (SF-36) score [22]}, the incidence of complications and reoperations.

Statistical analysis

Statistical analysis was performed with the Statistical Analysis System (SAS) software (SAS Institute, Inc., Cary, North Carolina). The chi-square test was used for testing the categorical data between groups. The measurement data were compared among three groups using analysis of variance (ANOVA) followed by Student-Newman-Keuls (SNK) test. $P < 0.05$ was considered to indicate a significant difference.

Results

A total of 175 patients were found to meet all inclusion criteria: 46 cases (50 feet) underwent

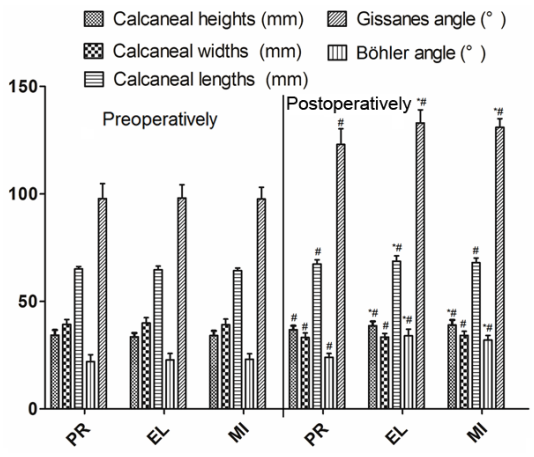

Figure 4. Radiographic test results between three groups preoperatively and postoperatively. PR, closed percutaneous reduction; EL, open reduction via an extended L-shaped lateral approach; MI, open reduction via minimally invasive small sinus tarsi approach. *compared with the PR group, $P < 0.05$; #compared with the corresponding preoperative outcome, $P < 0.05$.

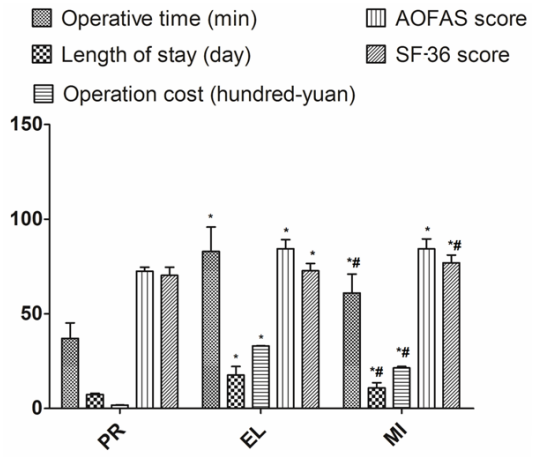

Figure 5. Clinical outcomes between three groups intraoperatively and postoperatively. AOFAS: American Orthopaedic Foot and Ankle Society, SF-36: short-form health survey; PR, closed percutaneous reduction; EL, open reduction via an extended L-shaped lateral approach; MI, open reduction via minimally invasive small sinus tarsi approach. *compared with the PR group, $P < 0.05$; #compared with the EL group, $P < 0.05$.

closed percutaneous reduction with Steinmann pins, 61 cases (70 feet) were treated with open reduction via an L-shaped lateral approach, and 68 cases (75 feet) were treated via a small sinus tarsi approach. The average follow-up was 39 months (12-70 months). Demographic data including age, gender, smoking, the presence or absence of diabetes, injury mechanism, Sanders classification, the time from injury to surgery, and the preoperative radiographic results were shown in **Table 1** and **Figure 4**, which were demonstrated to be not statistically significant, indicating the comparability among three treatments.

Compared with the PR group, the operative time, length of stay and the operation cost were significantly increased in the EL and MI groups. Identically, the operative time, length of stay and the operation cost of the EL group were also significantly higher than those of the MI group (**Figure 5**).

In comparison with the preoperative outcomes, the calcaneal height, length, Böhler angle, and Gissane angle were significantly enhanced, but the calcaneal width was significantly reduced in the three groups postoperatively. Furthermore, a more pronounced improvement could be observed postoperatively in the EL and MI groups compared to PR, but no significant differences in the calcaneal height, length, Böhler angle, and Gissane angle were present when compared to each other (**Figure 4**).

At the final follow-up, the foot function seemed to be more improved by the EL and MI treatments with the significantly higher mean AOFAS and SF-36 scores in the EL and MI groups compared to PR. However, no significant difference in the AOFAS was found between the EL and MI groups at the final follow-up (**Figure 5**).

Surgical complications occurred in 20 feet (10.25%). No infected wound and nonunion existed in the PR group. In the EL group, 16 feet (22.86%) developed complications, including wound swelling, wound dehiscence, and sign of exudate in 12 feet which were resolved by dressing changes, as well as deep infection and plate exposure in 4 feet which were resolved by anti-infection therapy, vacuum sealing drainage and flap coverage. In the MI group, superficial infection occurred in 4 feet (5.33%). The statistical analysis showed that the complication incidence was significantly lower in the PR and MI groups than that in the EL group (**Table 2**). Furthermore, the reoperation was required due to the deep wound infection, collision over the lateral wall, subtalar joint fusion, and a dissatisfactory reduction after the first operation. Reoperation occurred in 19

Table 2. The complication of three approaches before and during operation

	PR	EL	MI	*P1*	*P2*	*P3*
Wound complication (n, %)	0 (0)	16 (22.86)	4 (5.33)	< 0.001	0.149	0.003
Reoperation (n, %)	6 (12.00)	11 (15.71)	2 (2.67)	0.608	0.059	0.008

PR, closed percutaneous reduction; EL, open reduction via an extended L-shaped lateral approach; MI, open reduction via a small sinus tarsi approach (minimally invasive). *P1*, the difference between PR and EL groups; *P*2, the difference between PR and MI groups; *P*3, the difference between EL and MI groups. $P < 0.05$ was considered to indicate a significant difference.

feet, including 6 feet (12.00%) in the PR group, 11 (15.71%) feet in the EL group and 2 feet (2.67%) in the MI group. The reoperation rate was significantly lower in the MI group than that in the EL and PR groups, but there was no significant difference between PR group and EL group (**Table 2**).

Discussion

Although various treatment methods have been advocated, the optimal management of intra-articular calcaneal fractures remains not completely coincident because of different assessment criteria of the clinical and radiological outcomes in different studies [23]. This retrospective study aimed to further compare the therapeutic outcomes of the percutaneous reduction with Steinmann pins, open reduction via L-shaped lateral approach or small sinus tarsi approach for 175 patients with intra-articular fractures of the calcaneus, which, to our knowledge, has not been performed.

The goals of operative intervention of intra-articular calcaneal fractures are to achieve an anatomic reduction of the articular surface of the subtalar joint and restore the height, width, and alignment of the calcaneus [24]. Thus, the radiological results of three approaches were first compared. Our results showed that the calcaneal height, length, Böhler angle, and Gissane angle were more significantly improved after the EL and MI treatments, compared with the PR treatment. This may be attributed to the wide scope to be exposed by the open procedures which allows the surgeon more conveniently to correct the posterior facet fragment [25]. However, DeWall et al. [14] reported the similar improvement in Böhler angle after surgery between PR group and open group (22.4 vs 25.3, $P = 0.31$), which may be different from our results owing to different sample sizes and population sources.

The better reduction of the calcaneus may lead to better foot function recovery. As expected, our findings indicated that the effects of PR on foot function outcome may be inferior to the EL and MI treatments with the significantly lower mean AOFAS and SF-36 scores. Our conclusion seemed to be not consistent with the study of De Boer et al. who observed that the AOFAS and SF-36 scores had no statistically significant relations with the different treatments (EL or PR) [15]. Nevertheless, when the individual subdomains of SF-36 were analyzed, the median physical component summary score was slightly lower in the PR group than that in the EL group (50 vs 52) [15]. Our results also showed no significant difference in the foot function at the final follow-up after the EL and MI treatments when AOFAS was utilized. Due to the use of various evaluation scores, the comparison results between EL and MI treatments performed by different scholars varied. For example, according to the Maryland foot score, an excellent and good rate was achieved in 93.8% of MI group and 86.8% in the EL group, indicating the better improvement in the MI group [16]. However, Kline et al. [17] found that the foot function recovery seemed to be similar between the MI and EL treatments using the foot function index (FFI) and SF-36. Therefore, we suggest to combining a series of score systems to comprehensively assess the improvement role for foot function.

In addition to the goal of calcaneal reduction, the need to minimize the operative and wound healing complications is also a major concern in the treatment of intra-articular calcaneal fractures. Although the excellent therapeutic outcomes could be obtained, the application of extended lateral approach is still limited because of the high percentage of superficial and deep wound complications [8-10, 26]. In our study, we also found that the incidence of complications in the EL group (22.7%) was significantly higher than that in the PR (0%) and MI (5.3%) groups. The proposed mechanism is impaired microvascularization in the soft tissue envelope of the calcaneus [27]. Smoking and

diabetes have been demonstrated as independent risk factors for wound complications [28, 29], but no significant difference in the number of patients with smoking and diabetes in three groups, thus excluding their influences on complications. In addition, it is reported that the operative time might be closely related with wound complication [30]. In this study, the L-shaped lateral approach indeed required more time to accomplish the operation than other approaches. However, the recent study performed by Ho et al. indicated the surgical timing may not affect postoperative infection rates in calcaneal fractures [31]. The possible cause may be that the surgery is performed by experienced hands because the association between wound complications and the experience level of the surgical team has been proved in the study of Schepers et al. [32]. The more postoperative complications inevitably result in longer time to heal the wound, longer length of stay and more cost. As anticipated, the length of stay and the operation cost of the EL and MI groups were also significantly higher than those of the PR group.

There are potential weaknesses in our study. Firstly, as a retrospective, but not randomized controlled trial, patients were not randomly assigned to receive the different surgical procedures. The choice of surgery might be biased by the surgeons' preference based on the preoperative condition of the patient and technique development. Secondly, only the patients with the Sanders type II or III fractures were selected because the Sanders type II and III fractures were common indications for all the three approaches we performed in clinic. The goal of the present study was to compare the differences of the three approaches, thus the differences in the Sanders types were excluded. Furthermore, a recent study indicated that the Sanders classification was not related with the AOFAS and SF-36 function outcome scores [33]. Therefore, we did not display our results according to the Sanders types. Thirdly, the follow-up period of some patients was not long, although no patients were lost to follow up. Therefore, future studies with larger sample size and longer-term monitoring should be performed to verify our results.

In conclusion, our present findings suggest that the minimally invasive sinus tarsi approach may be the most effective and safest for the reduction and fixation of intra-articular fractures of the calcaneus, with an excellent restoration of the calcaneal height, width, alignment, and foot function, but lower complication and reoperation rates.

Acknowledgements

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Disclosure of conflict of interest

None.

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