

## Original Article

# Extensive lateral versus tarsal sinus approach to internal fixation for intra-articular calcaneal fractures

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**Abstract:** Objective: To investigate the clinical outcomes of the extensive lateral approach versus the tarsal sinus approach in the treatment of calcaneal fractures. Methods: From January 2014 through December 2016, 120 patients with calcaneal fractures admitted to the orthopedic wards in our hospital were randomly assigned to the extensive lateral approach group or the tarsal sinus approach group. The two groups were compared with regard to the surgery-related outcomes (operation time and intraoperative blood loss) and the outcomes of postoperative recovery (wound healing time, wound healing rate, hospital stay, complications, preoperative and postoperative numerical values for height and width of calcaneus, Gissane angle and Böhler angle and Maryland scores). Results: The general data were well balanced between the two groups. The operation time, intraoperative blood loss, wound healing time and hospital stay of patients in the tarsal sinus approach group improved significantly and the wound healing rate was significantly higher, as compared with the lateral approach group (All  $P < 0.001$ ); the overall rate of complications among patients in the sinus tarsi approach group was 6.70%, lower than that (31.70%) of the extensive lateral approach group ( $P < 0.001$ ); more significant improvements in postoperative values for height and width of calcaneus, Gissane angle and Böhler angle were noted in the sinus tarsi approach group (All  $P < 0.001$ ). The Maryland score and the good-excellent rate of the patients in the sinus tarsi approach group were significantly higher than those in the extensive lateral approach group (All  $P < 0.001$ ). Conclusion: When compared with the extensive lateral approach, the sinus tarsi approach to open reduction and internal fixation in the treatment of calcaneal fractures was associated with better function and outcomes in patients.

**Keywords:** Tarsal sinus approach, extensive lateral approach, calcaneal fracture, internal fixation

## Introduction

Calcaneal fracture, a common tarsal fracture, is generally caused by high-energy stress trauma involving the subtalar joints, which has a serious impact on the patients' quality of life and work [1, 2]. Due to anatomical complexity of the calcaneus and its surroundings as well as delicate soft tissues, open reduction and internal fixation for calcaneal fractures is more effective than non-surgical treatment [3]. However, the optimal approach to operation for calcaneal fractures and its impact on surgical outcomes are still controversial [4, 5]. The plate internal fixation via the extensive lateral approach provides a wide vision and a full exposure of the fracture site, and allows direct open reduction and internal fixation, but the surgery comes with a large area of dissected soft tissue,

impaired blood supply at the broken end of fracture, large trauma, multiple complications and slow postoperative recovery [6, 7]. Recently, minimally invasive plate internal fixation via the tarsal sinus approach in the management of calcaneal fractures has attracted growing attention, but the efficacy of the approach remains unclear [8-10]. Therefore, this study was designed to compare the clinical efficacy between the tarsal sinus approach and the extensive lateral approach in the management of calcaneal fractures.

## Materials and methods

### Case selection and assignment

The Hospital Ethics Committee was in approval of this study and all patients gave informed

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**Figure 1.** Schematic diagrams illustrating the extensive lateral approach.



**Figure 2.** Schematic diagrams of the tarsal sinus approach group.

written consent as required. From January 2014 to December 2016, a total of 120 patients with calcaneal fractures meeting the diagnostic criteria for calcaneal fractures, who were admitted to the Department of orthopedics in our hospital, were selected as participants [11]. Patients were eligible for this study if they were 18 to 60 years old, initial unilateral intra-articular calcaneus fractures of higher than Sanders II, no previous foot or ankle fracture, no previous calcaneus surgery or diabetes mellitus, no ankle skin nerve nor vascular disease. Patients were excluded if they had open fracture, combined with talus fractures, severe hepatorenal dysfunction or cardio-cerebrovascular disease; or were intolerant to surgery or unable to cooperate with the investigators.

The eligible patients were assigned to the extensive lateral approach group or the tarsal sinus approach group in terms of the random digit table.

### *Interventions*

**Extensive lateral approach:** The procedures of the extensive lateral approach was as follows: an incision was made starting from 2 cm above the lateral malleolus, going in parallel with the Achilles tendon at posterior sural nerve up to the sole of the foot, then an arc turn was made to the anterior, along the junction between the lateral dorsal normal skin and the plantar skin to the calcaneocuboid joints, where an arc dorsal incision of 1 cm was made, as seen **Figure 1**. The whole layer of skin flap was separated to give full exposure to the lateral wall of calcaneus, subastragalar joint, subtalar joint and calcaneocuboid joint. A Kirschner wire was drilled to

restore the articular surface and fracture reduction. Artificial bone was utilized to fill the bone defects. When the reduction was satisfactory under fluoroscopy guidance, a steel plate was inserted for internal fixation. The fracture end, calcaneal plate and screw location were confirmed by C-arm fluoroscopy. If everything is satisfactory, the lesions were cleaned thoroughly with normal saline. A catheter was inserted for drainage and the incision was sutured.

**Sinus tarsi approach:** The procedures of the sinus tarsi approach went as follows: a 3 cm-long incision was made starting from approximately 1 cm below the ankle, along the long axis direction of the fibula as seen in **Figure 2**, separated layer by layer to fully expose the tarsal sinus. A Kirschner wire was inserted for fracture reduction and joint facet restoration. Artificial bone was utilized to fill the bone defects. When the reduction met the criteria, a steel plate was inserted for internal fixation. After the operation had been confirmed to be satisfactory by C-arm fluoroscopy, the wound was rinsed, the catheter drained, and the incision sutured by layer by layer.

All the patients in the two groups received similar postoperative care after operation. The injured limb of each patient was lift up by 30°, and the catheter was removed within the first 48 hours. Conventional antibiotics were administered for anti-infection. The patients were permitted to ambulate at 2 weeks postoperatively and walking with the help of crutches at 8-12 weeks. They were restricted in physically strenuous activity within the first six months after operation.

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**Table 1.** General data of the patients

Variable	Extensive lateral approach	Sinus tarsi approach	t/ $\chi^2$ value	P value
Case	60	60		
Male/Female (n)	37/23	40/20	1.874	0.602
Age (year)	35.8±4.4	38.6±5.6	1.529	0.687
BMI (kg/m <sup>2</sup> )	24.1±1.4	23.5±1.5	1.563	0.673
Sanders type (n)				
II	33	35		
III	17	18	3.088	0.367
IV	10	7		
Injury cause				
Falling	23	22		
Traffic incident	17	19	1.029	0.782
Falling from height	20	19		
Injury time (h)	7.9±3.8	8.7±4.3	2.223	0.542

### Follow-up and outcome measures

**Follow-up:** All the patients were followed for 1 year. After discharge, they were followed at least once a month by outpatient appointments or telephone visits. During each follow-up, all the outcome measures were performed. Moreover, the imaging examination was made every six months.

**Primary outcomes:** The primary outcomes included the calcaneal height and width, Gissane angle and Böhler angle of the patients measured by radiography before and after operation; the postoperative efficacy of the patients was assessed in accordance with the Maryland foot scoring system. The scoring system is classified into the pain (45 points) and function sections (55 points), with 90 to 100 scores indicating excellent results, 75 to 89 good, 50 to 74 moderate, and less than 50 poor. The formula states:

Good-excellent rate of efficacy = (excellent + good)/total number of cases \* 100%.

**Secondary outcomes:** The secondary outcomes included comparisons of operation time, intraoperative blood loss, wound healing time, the rate of wound healing and hospital stay of patients; comparisons of the incidence of postoperative complications with regard to foot pain, infection or nerve injury of patients between the sinus tarsi approach group and the extensive lateral group.

### Statistical analysis

All the data analyses were performed with the use of the statistical software, version SPSS 17.0. Measurement data were represented as mean ± standard deviation, and the independent sample t-test was utilized for between-group comparisons of measurement data; count data were represented as percentages or rates, and the chi-square test was used for between-group comparisons of count data. P<0.05 was considered to be statistically significant.

### Results

#### General data of the patients

Among the 120 eligible patients, there were 77 males and 43 females, with a mean age of 37.2±5.1 years, body mass index (BMI) at 23.8 kg/m<sup>2</sup>, Sanders II in 68 cases, Sanders III in 35 cases, and Sanders IV in 17 cases and mean time from injury to operation of 8.3±4.1 h. The causes for injuries included falling in 45 cases, traffic incidents in 36 cases, and falling from height in 39 cases. No significant differences were seen in age, sex ratio, BMI, Sanders classification, injury cause and injury time (**Table 1**).

#### Perioperative and wound healing outcomes

When compared with the extensive lateral approach group, operation time, intraoperative blood loss, and wound healing time as well as hospital stay among the patients in the sinus tarsi approach group decreased significantly, but the rate of wound healing increased substantially (All P<0.001; **Table 2**).

#### Complication outcomes

In the extensive lateral approach group, skin flap necrosis occurred in 5 patients, wound infection in 3, foot pain in 3, neurological injury in 4 and subtalar stiffness in 4, with an overall rate of complications of 31.7%. In the sinus tarsi approach group, skin flap necrosis occurred in 1 patient, wound infection in 1, foot pain in 1 and subtalar stiffness in 1, with no occurrence of neurological injury and an overall rate of complications of 6.7%. The overall rate of complications differed substantially between the two groups (P<0.001; **Table 3**).

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**Table 2.** Perioperative and wound healing outcomes

Group	Case	Operation time (min)	Intraoperative blood loss (mL)	Wound healing time (d)	Wound healing rate (%)	Hospital stay (d)
Extensive lateral approach	60	62.4±6.58	71.4±5.16	13.4±3.17	87.6%	12.6±2.68
Sinus tarsi approach	60	39.5±4.17	21.6±3.45	5.75±2.64	97.1%	6.2±2.25
t/χ <sup>2</sup> value		12.486	13.378	14.546	13.394	15.834
P value		<0.001	<0.001	<0.001	<0.001	<0.001

**Table 3.** Complication outcomes (n, %)

Group	Case	Flap necrosis	Wound infection	Foot pain	Nerve injury symptoms	Subtalar stiffness	Total
Extensive lateral approach	60	5 (8.3)	3 (5)	3 (5)	4 (6.7)	4 (6.7)	19 (31.7)
Sinus tarsi approach	60	1 (1.7)	1 (1.7)	1 (1.7)	0 (0.0)	1 (1.7)	4 (6.7)*
χ <sup>2</sup> value		1.049	1.918	1.918	2.038	2.287	15.491
P value		0.307	0.163	0.163	0.159	0.114	<0.001

Note: \*P<0.001 for comparison with the extensive lateral approach group.

**Table 4.** Height and width of calcaneus, Gissane angle and Böhler angle

Group		Calcaneal height (mm)	Calcaneal width (mm)	Gissane angle (°)	Böhler angle (°)
Extensive lateral approach	Preoperative	34.6±3.81	38.5±2.19	131.5±5.56	12.5±2.76
	Postoperative	39.2±2.87*	34.1±2.48*	120.4±4.51*	27.2±3.22*
Sinus tarsi approach	Preoperative	33.9±3.65	38.8±2.75	130.7±5.38	12.6±2.68
	Postoperative	41.9±2.95*	32.3±2.14*	116.5±4.82*	31.5±3.35*

Note: \*P<0.000 for comparison within the same group preoperatively.

### *Height and width of calcaneus, Gissane angle and Böhler angle*

No significant differences were noted in the values for preoperative height and width of calcaneus, Gissane angle and Böhler angle among patients in the sinus tarsi approach group as compared those in the extensive lateral approach group (P>0.05), but striking differences were found postoperatively vs. preoperatively (All P<0.001). The magnitude of improvements in the above variables in the sinus tarsi approach group was markedly greater than that in the extensive lateral approach group (P<0.001; **Table 4** and **Figure 3**).

### *Postoperative Maryland scores*

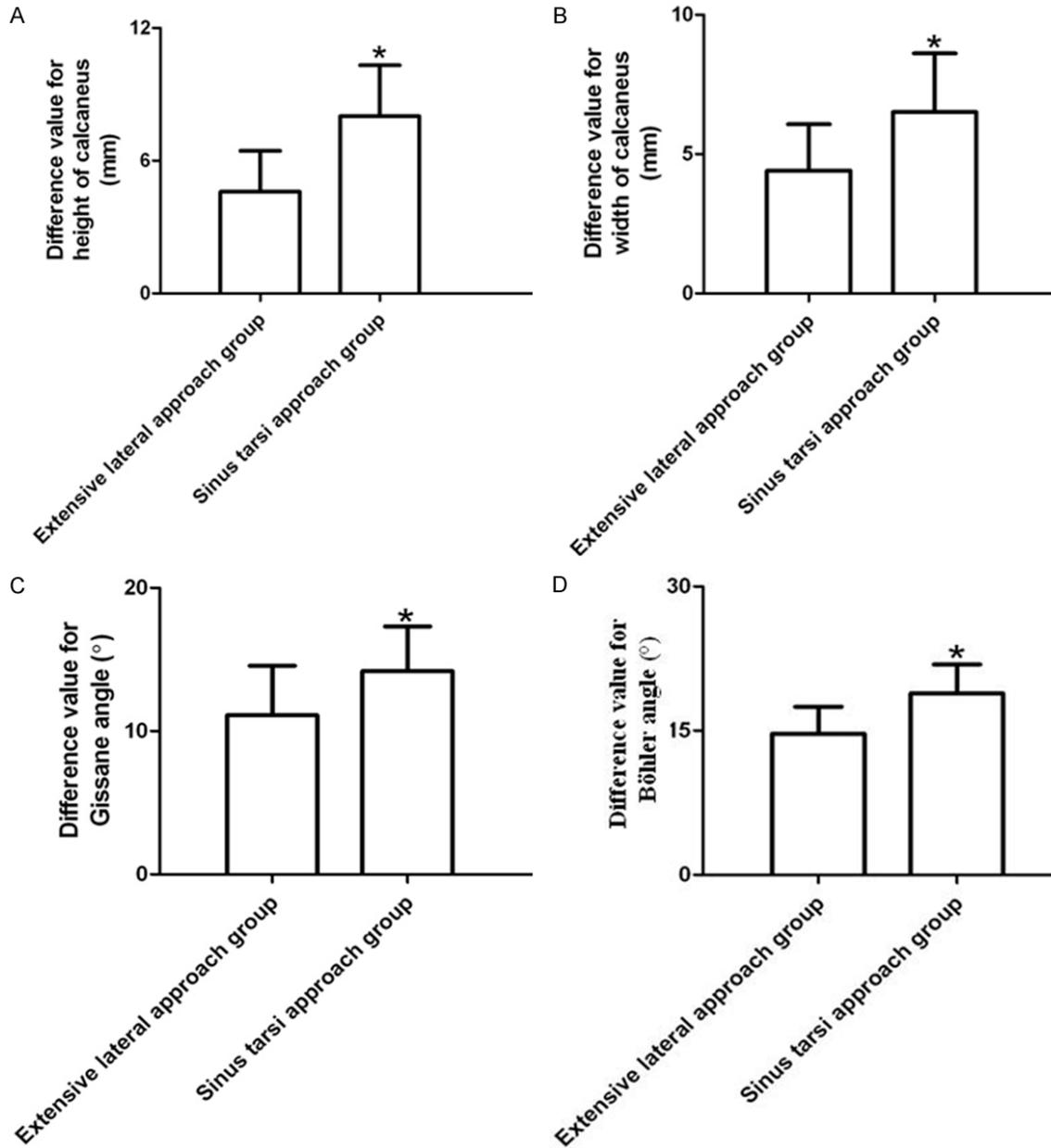
The functional outcomes of intra-articular calcaneal fractures at 1 year postoperatively were assessed according to the Maryland foot scoring system. Of 60 patients in the extensive lateral approach group, 23 were excellent and 24 were good, with a good-excellent rate of 78.3%; of 60 patients in the sinus tarsi approach

group, 29 were excellent and 25 were good, with a good-excellent rate of 90%; the differences between the two groups in the good-excellent rate were statistically significant (P<0.001; **Table 5**). As compared with the extensive lateral approach group (83.8±4.2), the Maryland score in the sinus approach group (91.2±4.8) was markedly higher (P<0.001; **Table 5**).

### **Discussion**

In all fractures, calcaneus fractures represent approximately 2% [12]. Despite the complex calcaneal anatomy, the choice of any operation technique in clinical treatment is aimed to restore the flat joint facet, width and height of calcaneus, and the fibular gap [13]. In the treatment of calcaneal fractures with internal fixation, restoration of the values for height and width of calcaneus, Gissane angle and Böhler angle to a normal range has shown to have positive effects on the long-term prognosis of patients [14, 15]. To achieve these objec-

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**Figure 3.** Difference values between preoperative and postoperative height and width of calcaneus, Gissane angle and Böhler angle. A: Height of calcaneus; B: Width of calcaneus; C: Gissane angle; D: Böhler angle. \*P<0.05, the extensive lateral approach group vs. the tarsal sinus approach group.

**Table 5.** Maryland scores for functional outcomes of intra-articular calcaneal fractures at 1-year postoperatively

Group	Case	Maryland scores	Excellent	Good	Moderate	Poor	Good-excellent rate (%)
Extensive lateral approach	60	83.8±4.2	23	24	13	0	78.3
Sinus tarsi approach	60	91.2±4.8	29	25	6	0	90.0*

Note: \*P<0.001 for comparison with the extensive lateral approach group.

tives, it is crucial to select the optimal surgical approach to calcaneal fractures [16].

Currently, the common surgical approaches for calcaneal fractures include the lateral

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approach, the medial approach and the combined lateral and medial approach, with the lateral approach being the most widely used in clinic practice [17, 18]. In the current study, we took the plate internal fixation via the extensive lateral approach as the control surgical method, and the height and width of calcaneus, Gissane angle and Böhler angle as outcome measures to assess calcaneal morphology, severity and efficacy of calcaneal fractures. The results indicated that significant differences were observed in improvements in values for height and width of calcaneus, Gissane angle and Böhler angle between the extensive lateral approach group and the sinus approach group before and after operation; moreover, the magnitude in the improvements in the above aspects in the sinus tarsi approach group was much greater than that of the extensive lateral approach group. Of note, as compared with the extensive lateral approach to plate internal fixation, the tarsal sinus approach allows better exposure of the posterior joint facet and the anterolateral bone fragments, as well as anatomical reduction of the posterior calcaneal facet and the subtalar facet. Maryland score was deemed as outcome measure for quantitative evaluation of foot and ankle functions. The findings in the current study demonstrated that Maryland score increased substantially among patients in the sinus tarsi approach group than those in the extensive lateral approach group; furthermore, the good-excellent rate in the sinus tarsi approach group achieved 90%, significantly higher than that of the extensive lateral approach group (78.3%). These results also suggest that the plate internal fixation via the sinus tarsi approach achieves reduction of the calcaneus fractures, effectively restores the anatomic morphology and functions of the calcaneus, which are largely consistent with the reports in previous studies [19, 20]. In addition, the extensive lateral approach to the plate internal fixation has requirements for selection of the surgical timing. The surgery is generally performed with improved soft tissue condition, and the time to preoperative preparation is longer. On the contrary, the sinus tarsi approach allows early surgical treatment, no need of long preoperative wait [21]. In this study, the time needed for preoperative waiting was not studied profoundly as there were no obvious lesions in the peripheral skin around the calcaneus fractures in the eligible patients.

In the current study, we found that when compared with patients in the extensive lateral approach group, operation time, wound healing time, intraoperative blood loss and hospital stay among those in the tarsal sinus group reduced significantly, with a markedly higher rate of wound healing; the rate of complications was 6.70%, significantly lower than 31.7% of the extensive lateral approach group. This may be attributed to the smaller trauma caused by the sinus tarsi approach to plate internal fixation and early postoperative functional exercise. Furthermore, the extensive lateral approach is prone to damage lateral calcaneal artery, destroy the blood flow at the fracture ends, resulting in flap ischemia or even necrosis. The dense vascular distribution surrounding the tarsal sinus is more likely to lead to formation of collateral circulation. The sinus tarsi approach to internal fixation in the treatment of calcaneal fractures has a minor effect on the flap blood supply, so it is easy to make postoperative re-establishment of blood flow. The approach also has positive effects on reducing the complications and promoting postoperative rehabilitation. What's more, via the minimally invasive incision, the approach allows a direct exposure of the subtalar facet, direct vision of the reduction of articular surface, leading to small soft tissue injuries, and precluding flap retraction and peroneal muscle tendon and sural nerves, with diminished damages to the vascular network surrounding the calcaneus [22]. However, the sinus tarsi approach as a typical minimally invasive technique for calcaneal fractures, inevitably leads to incomplete exposure of the vision of the operation area and the lateral calcaneus; it also requires the operator who is skilled in operation and has rich anatomical knowledge, so that accurate reduction and fixation can be achieved.

In conclusion, with smaller trauma, faster postoperative recovery and fewer complications, the sinus tarsi approach was superior to the extensive lateral approach to internal fixation in the treatment of calcaneal fractures. Thus, it is worthy of extensive clinical use. This study had some limitations, such as the lack of systematic research on the operation approaches, the small sample size, and absence of a long-term follow-up and a comparative analysis on the clinical outcomes of the patients with diversely severe calcaneal fractures; however, it points out the direction for future studies.

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### Disclosure of conflict of interest

None.

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