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# Therapeutic Advantages of Internal Fixation with Kirschner Wire and Bone Grafting via Limited Tarsal Sinus Incision Approach for Displaced Intra-Articular Calcaneal Fractures of Children

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Statistical Analysis C
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**Background:** 

Displaced intra-articular calcaneal fractures (DIACF) are a serious injury and are clinically considered to be an important source of disability. This study investigated therapeutic effects of internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision in pediatric DIACF.

Material/Methods:

This retrospective study included pediatric DIACF patients admitted to our department from June 2010 to February 2014. Patients were divided into Sanders II, Sanders III, and Sanders IV groups. Patients were also divided into pre-operation and post-operation groups. All patients underwent the internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision operation. Bohler angles, Gissane angles, and modified American Orthopedic Foot and Ankle Society Score (AOFAS) were evaluated.

Results:

Four weeks after surgery, all patients had clinical healing and no complications appeared. According to CT and X-ray results, the operation had satisfactory reduction effects for pediatric DIACF of childhood and adolescence. The operation significantly enhanced the Bohler angle of patients in Sanders II, III, and IV patients in the post-operation group compared to the pre-operation group (p<0.05). The operation significantly increased Gissane angle in the post-operation group compared to the pre-operation group in Sanders II, III, and IV patients (p<0.05). The operation significantly improved AOFAS scores of patients in the Sanders II, III, and IV groups (p<0.05).

**Conclusions:** 

Internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision approach is safe and effective for pediatric DIACF. This approach exhibited advantages of satisfactory reduction for articular surface, solid fixation, and no complications due to infection or tissue necrosis.

MeSH Keywords:

Bone Wires • Internal Fixators • Intra-Articular Fractures

Full-text PDF:

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# **Background**

The displaced intra-articular calcaneal fractures (DIACF) are a serious injury and are clinically considered to be an important cause of disability [1,2]. DIFCF is also been known to have post-operative clinical complications. Therefore, DIACF is a serious articular fracture that is difficult to treat, and the clinical outcomes of therapy are unsatisfactory for patients and surgeons alike [3]. Clinically, pediatric DIACF is caused by a low-energy injury with a slight shift or no shift. Therefore, the low-energy injury-caused DIACF receives expectant treatment, which yields better clinical outcomes. However, in recent years, the incidence of high-energy injury-caused DIACF has also been increasingly reported in children [4,5]. A previous study [5] found no significant differences in clinical characteristics between pediatric DIACF and adult DIACF.

In clinical practice, DIACF can be treated with non-surgical or surgical methods, but both have disadvantages [6]. For adult DIACF, a lateral L incision is commonly used clinically, but it is associated with disadvantages and complications of multiple tissue dissection, and great trauma, as well as risk of skin necrosis, infection of an incisional wound, and osteonecrosis [7,8]. However, when treating pediatric DIACF with this method, the multiple tissue dissections affects the development of calcaneus. For adult DIACF, plate fixation is widely used, but it is not suitable for pediatric DIACF because of the small volume of calcaneus of children. Especially for comminuted fractures, it is difficult to fix the plate. Therefore, it is critical to select the appropriate surgical method for treating pediatric DIACF in clinical practice.

This study included 26 patients with pediatric DIACF from June 2010 to February 2014 in our hospital. All of the patients underwent internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision. This method not only avoids complications, it also cannot affect the development of calcaneus. Kirschner wire internal fixation also has simple manipulation and firm fixation.

## **Material and Methods**

#### Subjects

This retrospective study was conducted on pediatric DIACF patients admitted to our department from June 2010 to February 2014. All of the surgical procedures were conducted by the same professional surgeon. This study included 26 cases of pediatric DIACF (27 feet, with 1 case of bilateral). The patients were ages 2–15 years and the group included 14 left feet and 13 right feet. The main reasons for injury were accident injury (22 cases) and falling injury (4 cases). The present study was approved by the Ethics Committee of Tongji Medical College,

Huazhong University of Science and Technology, Wuhan, China. Verbal informed consent for participation was obtained from all of the pediatric DIACF patients enrolled in this study.

#### Patient demographic data and trial grouping

The demographic data of patients were collected, including age, sex, injured side, and time to surgery. According to the X-ray and computer tomography (CT) superposition three-dimensional examination and Sanders typing criteria, patients were divided into a Sanders II group (n=6 feet), a Sanders III group (n=14 feet), and a Sanders IV group (n=7 feet). All demographic data are listed in Table 1.

Based on undergoing the internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision operation, the patients were also divided into a pre-operation group and a post-operation group.

#### **Parameters examination**

Bohler angles and Gissane angles were evaluated by using the methods described in previous studies [9,10]. The modified American Orthopedic Foot and Ankle Society Score (AOFAS) for pain was used to evaluate functional recovery [11,12]. The maximum possible AOFAS score is 68 scores, including a maximum pain score of 40 and maximum function score of 28. Higher AOFAS indicates better functioning.

#### Pre-operative preparation

The routine calcaneal lateral position or axial-position X-ray and three-dimensional reconstruction of CT plain scan were conducted to evaluate the fractures. One patient had the complication of L1 vertebral fracture and had to lie in bed with a pillow at waist position. For all the patients, the injured limbs were raised and an ice pack was used to alleviate swelling before the operation. When the swelling was alleviated, open reduction internal fixation and bone grafting were performed. For 2 patients with the complication of comminuted fracture of the tibia on the same side, we used tibial open reduction and internal plate fixation.

#### Surgery method

All of the patients received general anesthesia, the surgery was conducted by using a tourniquet, and we used the hip-flexion and knee-bending position. A lateral calcaneus limited tarsal sinus incision was made, as previously described [13,14]. The procedures for Kirschner wire (K-wire) internal fixation were performed according to the method described in previous studies [15,16], with some modifications, as follow. If there was obvious displacement of the intercepting fracture

**Table 1.** Demographics of pediatric DIACF population.

Characteristics	Sander II group (n=6)	Sander III group (n=14)	Sander IV group (n=7)	p Values
Age (mean, years)	8 (4–12)	10.4 (2–15)	10.1 (7–15)	>0.05
Gender (male/female)	6/0	14/0	7/0	>0.05
Side of injury (left/right)	2/4	8/6	4/3	>0.05
Sub-sander type				
lla	4	_	<del>-</del>	N/A
IIb	2	_	_	N/A
Illab	_	6	_	N/A
IIIbc	-	3	-	N/A
Illac	-	5	_	N/A
IV	-	_	7	N/A
Inteval of injury to injury (mean, days)	8 (7–11)	11.1 (5–32)	9.7 (8–12)	>0.05
Reasons for injury (n)				>0.05
Accident injury	1	2	1	
Falling injury	5	12	6	

of calcaneus, no fixation was performed. The routine calcaneal lateral position or axial position X-ray was used to confirm the good reset of line force of calcaneus, posterior articular surface, fracture blocks of interior calcaneus, and calcaneal joint. Finally, when the Bohler angle and Gissane angle were recovered well, the incisions were closed and indwelling negative-pressure drains were placed.

# Post-operative treatment

All patients received mild-ankle flexion Tuo plaster external fixation and were encouraged to move their toes and other flexible joints. The plaster board and K-wires were removed and joints were excised to recover functions at 4 weeks after the surgery.

#### Statistical analysis

All data were analyzed using GraphPad Prism software 5.0 (GraphPad Software, Inc., La Jolla, CA, USA). Quantitative data were recorded as mean  $\pm$  standard deviation (SD) and analyzed using the t test for comparisons between 2 groups (for Bohler angle and Gissane angle). Tukey's post hoc test was used to validate ANOVA for comparing measurement data among groups (for the AOFAS scores). Categorical variables (recorded as percentage) were analyzed using a chi-square test. All data were obtained from at least 6 independent tests or experiments. Statistical significance was defined as p < 0.05.

#### Results

#### Postoperative general condition

All of the patients were followed up, and the mean follow-up time was 21 months (range, 8–30 months). Four weeks after the operation, all of the patients had clinical healing and had the K-wires removed. There were 16 feet that achieved to bone healing 2 months after the operation, and 11 feet achieved bone healing 3 months after the operation. No patients had any complications of surgical incision infection, bone infection, nonunion of bone, necrosis of soft tissue, chronic peroneal tendon tenosynovitis, or subtalar osteoarthritis.

# The operation produced satisfactory reduction effects in pediatric DIACF patients

The X-ray and three-dimensional reconstruction of the CT plain scan were used to evaluate the internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision operation. Figure 1 shows the imaging results of a 7-year-old patient who was diagnosed as having a comminuted fracture of the calcaneal joint and was defined as Sanders II type. The articular surface was seriously damage, which made the Gissane angle difficult to measure (Figure 1A). The CT images showed the articular surfaces were comminuted (Figure 1B, 1C) and the fracture line affected the dice joint (Figure 1D). Figure 1E illustrates the internal fixation with Kirschner wire and bone

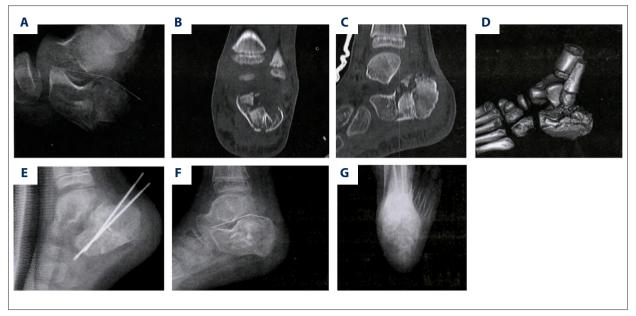


Figure 1. CT and X-ray images for calcaneal fracture caused by falling injury. (A) The Gissane angle and Gissane angle. The comminuted articular surfaces (B, C) and the fracture line affected the dice joint (D) according to the CT images. (E) Internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision image. (F) X-ray imaging shows the fracture healing with appropriate Bohler angle and Gissane angle. (G) Axial X-ray shows better line force of calcaneus.

grafting via limited tarsal sinus incision. The X-ray showed better fracture healing, with appropriate Bohler angle and Gissane angle (Figure 1F). An axial X-ray also showed better line force of calcaneus (Figure 1G).

# The operation produced satisfactory reduction for pediatric DIACF patients

A 13-year-old DIACF patient was also included and underwent the internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision (Figure 2). Figure 2A illustrates the intra-articular fracture of the calcaneus. The CT images show the articular surfaces were comminuted and the fracture line affected the dice joint (Figure 2B–2D). Figure 2E illustrates the internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision. A lateral position X-ray inhibited better fracture healing (Figure 2F).

## The operation enhanced Bohler angle of patients in the Sanders II, III, and IV groups

To evaluate the effects of internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision operation, the Bohler angle was assessed and compared between preoperation and post-operation groups. The results showed that the Bohler angles in the post-operation group (36.8 $\pm$ 7.5) were significantly increased compared to the pre-operation group (16.8 $\pm$ 2.9) in Sanders II patients (Figure 3A, p<0.05). In Sanders III patients, the Bohler angles were significantly increased in

the post-operation group (34.4 $\pm$ 9.1) compared to the pre-operation group (15.4 $\pm$ 4.1) (Figure 3B, p<0.05). Bohler angles were also significantly enhanced for Sanders IV patients in the post-operation group (34.7 $\pm$ 5.3) compared to the pre-operation group (8.6 $\pm$ 0.5) (Figure 3C, p<0.05).

# The operation increased Gissane angle of patients in Sanders II, III, and IV groups

For the Sanders II patients, the Gissane angles in the post-operation group (124.3 $\pm$ 9.6) were significantly higher compared to the pre-operation group (104.8 $\pm$ 12.8) (Figure 4A, p<0.05). The Gissane angles were significantly increased in the post-operation group (119.8 $\pm$ 11.7) compared to the pre-operation group in the Sanders III group (100.6 $\pm$ 10.1) (Figure 4B, p<0.05). Gissane angles were also significantly enhanced in the post-operation group (121.4 $\pm$ 8.9) compared to the pre-operation group (105.4 $\pm$ 4) in the Sanders IV group (Figure 4C, p<0.05).

# The operation improved AOFAS scores in Sanders II, III and IV groups

The results indicated that the AOFAS score was 65.2 for the Sanders II patients (Figure 5) and the AOFAS scores were 67.0 and 65.0 for Sanders III and Sanders IV patients, respectively (Figure 5). Compared with the maximum possible AOFAS score (68 scores), all of the AOFAS scores of the Sanders II, III and IV patients showed good functional improvement.

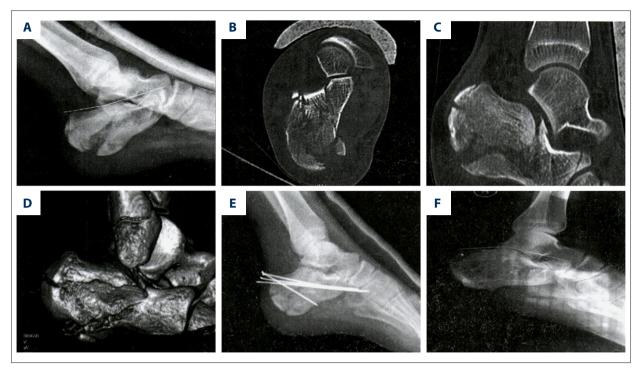


Figure 2. CT and X-ray images of a calcaneal fracture of a 13-year-old DIACF patient. (A) Intra-articular fracture of calcaneus. The articular surfaces were comminuted and fracture line affected the dice joint (B-D) according to CT images. (E) Internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision image. (F) Lateral position X-ray shows better fracture healing.

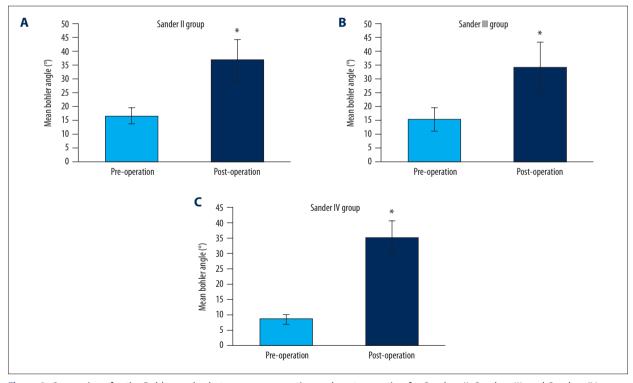


Figure 3. Comparison for the Bohler angles between pre-operation and post-operation for Sanders II, Sanders III, and Sanders IV group. (A) Bohler angles of Sanders II group. (B) Bohler angles of Sanders III group. (C) Bohler angles of Sanders III group.

\* p<0.05 vs pre-operation group.

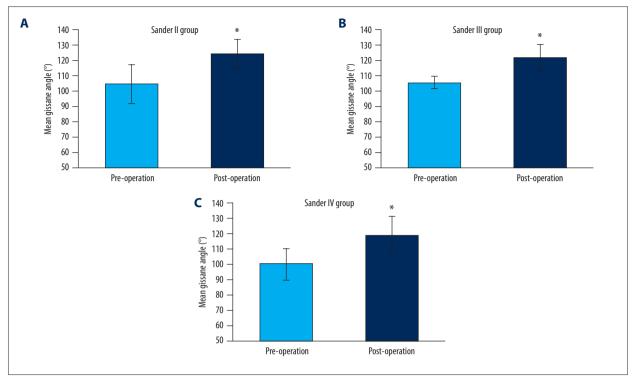


Figure 4. Comparison for the Gissane angles between pre-operation and post-operation for Sander II, Sanders III, and Sanders IV groups. (A) Gissane angles of Sanders III group. (B) Gissane angles of Sanders III group. (C) Gissane angles of Sanders III group. \*p<0.05 vs pre-operation group.

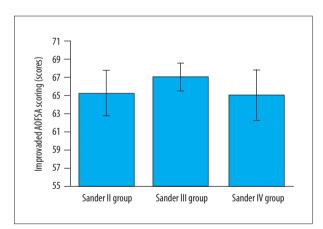


Figure 5. Comparison for the improved AOFAS scores among Sanders II, Sanders III, and Sanders IV groups.

## **Discussion**

DIACF caused by a high-energy injury always induces a seriously displaced fracture and collapse of the posterior articular surface, both of which should be treated surgically. Rammelt et al. [17] reported that DIACF must be treated surgically, and operative reduction must be considered when the fracture of the posterior articular surface is offset by more than 1 mm. Therefore, in this study, we performed surgical reduction for all patients with DIACF caused by high-energy injury.

The L-shaped extension incision is commonly used for treating intra-articular calcaneal fractures that induced severe soft-tissue injury have high risk of skin necrosis at the incision [18]. Ebraheim et al. [19] presented tarsal sinus incision for the first time, which has the merits of less trauma and less effects on blood supply and calcaneus bone scale. The present study selected the tarsal sinus incision approach for treating 26 cases (27 feet) of pediatric DIACF, and no complications such as incisional infection and soft-tissue necrosis occurred. Therefore, we believe that the lateral calcaneus tarsal sinus limited incision is the best operation to use for pediatric intra-articular fracture of calcaneus.

For the internal fixation approach of calcaneal fracture, plate fixation is the most frequently used technique [20]. However, it is difficult to use for fixing the smaller calcaneus fracture blocks of pediatric DIACF patients, and it easily causes iatrogenic fragmentation of fractural blocks. In this study, we used the Kirschner wire combined with bone grafting and observed satisfactory clinical outcomes, including improvement of Bohler angle and Gissane angle. We also found that the Kirschner wire internal fixation was appropriate for pediatric DIACF in both children and adolescents in this study. All children (Figure 1) and adolescents (Figure 2) were diagnosed as having comminuted fractures and healed without any infection or deficient blood supply, illustrating that this is a low-cost and simple operation.

X-ray imaging is the most frequently applied technology for evaluating the Bohler angle and Gissane angle [9]. However, when the calcaneus of a child is not mature, it is difficult to assess the Bohler and Gissane angles. In addition, X-rays cannot reveal the degree of severity of comminuted fractures of the posterior articular surface, especially for young children. Therefore, for pediatric DIACF, the routine coronal- and axial-position CT examination and three-dimensional reconstruction are used. According to the facies articularis ossium condition observed by using X-ray and CT, Sanders typing was conducted in the present study, which is critical for method selection and prognosis judgement of DIACF [12]. Recovering the Bohler angle and Gissane angle is required for calcaneal fracture reduction. A previous study reported that the normal Gissane angle ranges from 120° to 145° [21] and is 110° to 140° for Chinese [22]. Our results indicated that the Gissane angles were significantly increased in the pre-operation group compared to the post-operation group in Sanders II, III, and IV patients undergoing the internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision operation. The post-operative Gissane angles of Sanders II, III, and IV patients were 124.3°, 119.8°, and 121.4°, respectively, all of which are close to normal values for the Chinese population. Bohler angels were also significantly increased in the post-operation group compared to the preoperation group of all Sanders II, III and IV patients. Therefore, our results suggest that internal fixation with Kirschner wire

and bone grafting via limited tarsal sinus incision operation was effective for calcaneal fracture reduction.

AOFAS has been extensively applied for calcaneal fractures in previous studies [23,24]. Our results indicated that the AOFAS scores were 65.2, 67.0, and 65.0 for Sanders II, Sanders III, and Sanders IV patients, respectively. The AOFAS scores of Sanders II, III and IV patients were close to the maximum possible AOFAS score (68 scores) in this study, which suggests that pain was significantly reduced and functioning was improved.

#### **Conclusions**

The internal fixation with Kirschner wire and bone grafting via limited tarsal sinus incision operation is safe and effective for displaced intra-articular calcaneal fractures of children. This operation has the advantages of solid fixation and satisfactory reduction of the articular surface, as well as significant improvement of Bohler angel, Gissane angle, and AOFAS scores. The operation did not induce the complications of infection or tissue necrosis.

#### **Conflict of interest**

None.

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