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Minimally invasive approach with external fixator for intra-articular calcaneal fractures in children

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Abstract

Calcaneal fractures are rare in pediatric population, with more displaced intra-articular fractures encountered due to the increasing number of high-energy trauma. Operative interventions are gaining popularity because of the unsatisfactory outcomes of traditional conservative methods. This study investigated the clinical outcomes of a minimally invasive technique using the sinus tarsi approach and external fixator in the treatment of intra-articular calcaneal fractures in pediatric patients.

Patients who underwent open reduction between January 2010 and January 2018 at our institute were included in this study and reviewed retrospectively. Radiological and clinical parameters were all recorded and analyzed.

Overall, 29 patients were included in the study, including 23 boys and 6 girls (10.2 ± 2.2 years old). The average follow-up was 29.5 months postoperatively (range, 26–72 months). Bohler angle was 15.2 ± 3.3° preoperatively, and 34.0 ± 3.8° postoperatively ($P < .001$); Gissane angle was 101.8 ± 6.2 degrees preoperatively, and 129.7 ± 6.2° postoperatively ($P < .001$). The average length of incision was 3.4 ± 0.7 cm. At the last follow-up, all patients showed satisfactory clinical outcomes and the score was 90.0 ± 2.3 according to American Orthopedic Foot and Ankle Society Scale.

Minimally invasive approach with external fixator is an effective method for treating displaced intra-articular calcaneal fractures in pediatric patients, with a lower incidence of wound-related complications and good cosmetic outcomes.

Abbreviations: AOFAS = American Orthopedic Foot and Ankle Society Scale, CT = computed tomography, KW = Kirschner wire, ORIF = open reduction and internal fixation.

Keywords: calcaneal fracture, minimally invasive, sinus tarsi

1. Introduction

Calcaneal fractures in children are rare, with an incidence of only 1 in 100,000 fractures.[1] The extra-articular calcaneal fractures are more common than intra-articular fractures.[2,3] Conservative methods could achieve satisfactory outcomes in extra-articular fractures.[4,5] As the incidence of high-energy trauma increased, more displaced intra-articular calcaneal fractures have been observed. In severely displaced intra-articular fractures, the clinical outcome of conservative management seems unsatisfactory as the articular congruence cannot be restored.[6] A number of authors advocate operative treatments, including open reduction and internal fixation (ORIF), closed reduction and percutaneous fixation, sinus tarsi approach with Kirschner wire (KW) fixation.[7–12] These methods showed better outcomes, but each has its own limitations. In ORIF, an extensile incision is required, and the wound-related complications always occur.[13–15] In closed reduction and percutaneous fixation, anatomic reduction of the articular surface is impossible in severely displaced fractures. In the sinus tarsi approach with KW fixation, the wound-related complications are less than the traditional ORIF[16]; still, smooth KW cannot provide sufficient support for the articular surface without penetrating the cuboid for severely displaced fractures.

In order to avoid the above-mentioned complications, a novel method using the sinus tarsi approach combined with allogeneic bone grafting and external fixator was adopted at our institute. We assumed that the minimally invasive sinus approach would decrease wound complications, and bone grafting and external fixator could provide sufficient stability and maintain reduction. We have applied this technique to treat intra-articular calcaneal fracture since 2010, and clinical outcomes were reported and analyzed as below.

2. Material and methods

This study was approved by the Institutional Review Board (No: IORG0003571) on June 1st, 2016. Overall, 29 children (29 feet) who underwent open reduction between January 2010 and

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JL, RJ, and RZ contributed equally to this manuscript and are the cofirst authors.

The authors have no conflicts of interest.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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January 2018 at our institute were included in this study and reviewed retrospectively. All the patients were younger than 14 years at the time of injury and followed up for more than 24 months. Patients suffering from avulsion injury of the calcaneal tuberosity and fracture of the anterior process were excluded. Open fractures and pathological fractures were also excluded. Patients suffering from bilateral injuries were excluded, as well. Radiological and clinical parameters were all recorded.

2.1. Preoperative management

Temporary immobilization using short leg cast for injured feet of the patients was performed at admission. Calcaneal radiographs of the injured foot were taken, and for severely displaced fractures, computed tomography (CT) scan was taken to facilitate Sanders classification.[17]

2.2. Surgical technique

Under general anesthesia, the patient was placed on a radiolucent operative table in a supine position with a pad underneath the ipsilateral hip. A straight incision 3 to 5 cm in length using the sinus tarsi approach was performed to expose the subtalar articular surface (See Fig. 1). Hematoma and debris were removed, followed by saline lavage. Normally, the lateral wall of the calcaneus was broken, a periosteum elevator was inserted and placed under the posterior surface. Calcaneal tuberosity was pushed backward, and the posterior articular surface was pushed upward with the help of the periosteum elevator, to restore the length and height of the calcaneus. The bone defect was filled with allogenic bone (Shanxi Auri Biomaterial Co., Ltd). Then, a Schanz pin (3.0–5.5 mm in diameter) was inserted from the calcaneal tuberosity to the anterior part of the calcaneus to provide buttress to the subtalar articular surface. Another 3 mm Schanz pin was inserted at the first metatarsal, and 2 Schanz pins (3–5.5 mm) were inserted at the medial side of the tibia. The pins were connected, while the surgeon holds the foot in his hands with the thumbs on the plantar arch apex. Additional K-wires might be inserted if the lateral wall or the fracture line in the posterior body of the calcaneus required fixation. Bohler angle and Gissane angle were reduced and confirmed under fluoroscopy. Rubber drain or drainage tubes might be placed accordingly. In the end, the incision was sutured in layers.

2.3. Postoperative management and follow-up

The injured limb was elevated on a pad to minimize swelling without additional immobilization by the cast. Rubber drainage or drainage tubes were removed within 48 hours after surgery. Sutures were removed 14 days postoperatively. Follow-up was performed at out-patient clinics every 2 weeks, and the external fixator was removed after 6 to 8 weeks according to the radiographic changes. After the removal, the follow-up was performed every 2 to 3 months at outpatient clinics. Clinical and functional outcomes were evaluated using the American Orthopedic Foot and Ankle Society Scale (AOFAS) at the 24-month follow-up.[18]

An 8-year-old boy suffered from displaced calcaneal fracture (see Fig. 2). A 9-year-old boy with calcaneal fracture due to an accidental fall was treated (see Fig. 3). An 11-year-old girl suffered from displaced calcaneal fracture and tibia-fibular fracture, and the appearance of incision and ankle function is shown in Figure 4.

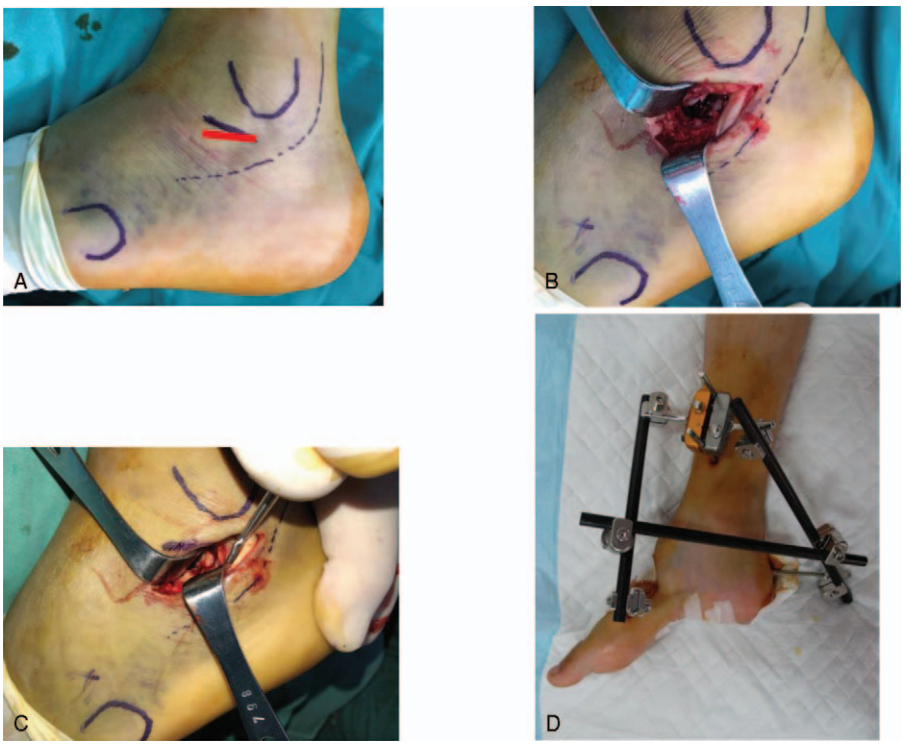

Figure 1. Procedures of sinus tarsi approach. (A) Skin mark of the incision. (B) Exposure of the fracture and posterior articular surface. (C) Reduction of the articular surface. (D) Appearance of the foot after surgery.

Figure 2. An 8-year-old boy suffering from calcaneal fracture. (A) Sagittal plane of CT scan of the calcaneal fracture before surgery. (B) Cross-section of CT scan of the calcaneal fracture before surgery. (C) Lateral X-ray of calcaneum after surgery. (D) Lateral X-ray of calcaneum at first month follow-up. (E) Lateral X-ray of calcaneum at third month follow-up. (F) Lateral X-ray of calcaneum at sixth month follow-up.

2.4. Statistical analysis

All clinical data are expressed as mean ± SD and analyzed using SPSS (version 19.0; SPSS Inc., Chicago, IL). The calcaneal anatomical parameters were compared by paired t-test. χ^2-test was performed to compare the functional outcomes between the different groups of Sanders classification. $P < .05$ was considered statistically significant.

3. Results

A total of 59 pediatric calcaneal fractures were reviewed, and ultimately, 29 patients were included in this study, comprising 23 boys and 6 girls (10.2 ± 2.2 years). The average follow-up was 29.5 months (range, 26–72 months). In 22 patients, fractures were caused by fall injuries. In the other 7 patients, fractures were caused by road traffic accidents (Table 1). There were 7 type II, 15 type III, 7 type IV fractures, according to Sanders classification.

The average duration between injury and surgery was 3.5 days. As summarized in Table 2, Bohler angle was 15.2 ± 3.3° preoperatively and 34.0 ± 3.8° postoperatively ($P < .001$); Gissane angle was 101.8 ± 6.2° preoperatively and 129.7 ± 6.2° postoperatively ($P < .001$).

In type II fractures, Bohler angle was 13.4 ± 3.3° preoperatively and 33.1 ± 4.0° postoperatively ($P < .001$); Gissane angle was 101.9 ± 6.4° preoperatively and 131.4 ± 6.0° postoperatively ($P < .001$). In type III fractures, Bohler angle was 16.3 ± 2.7°

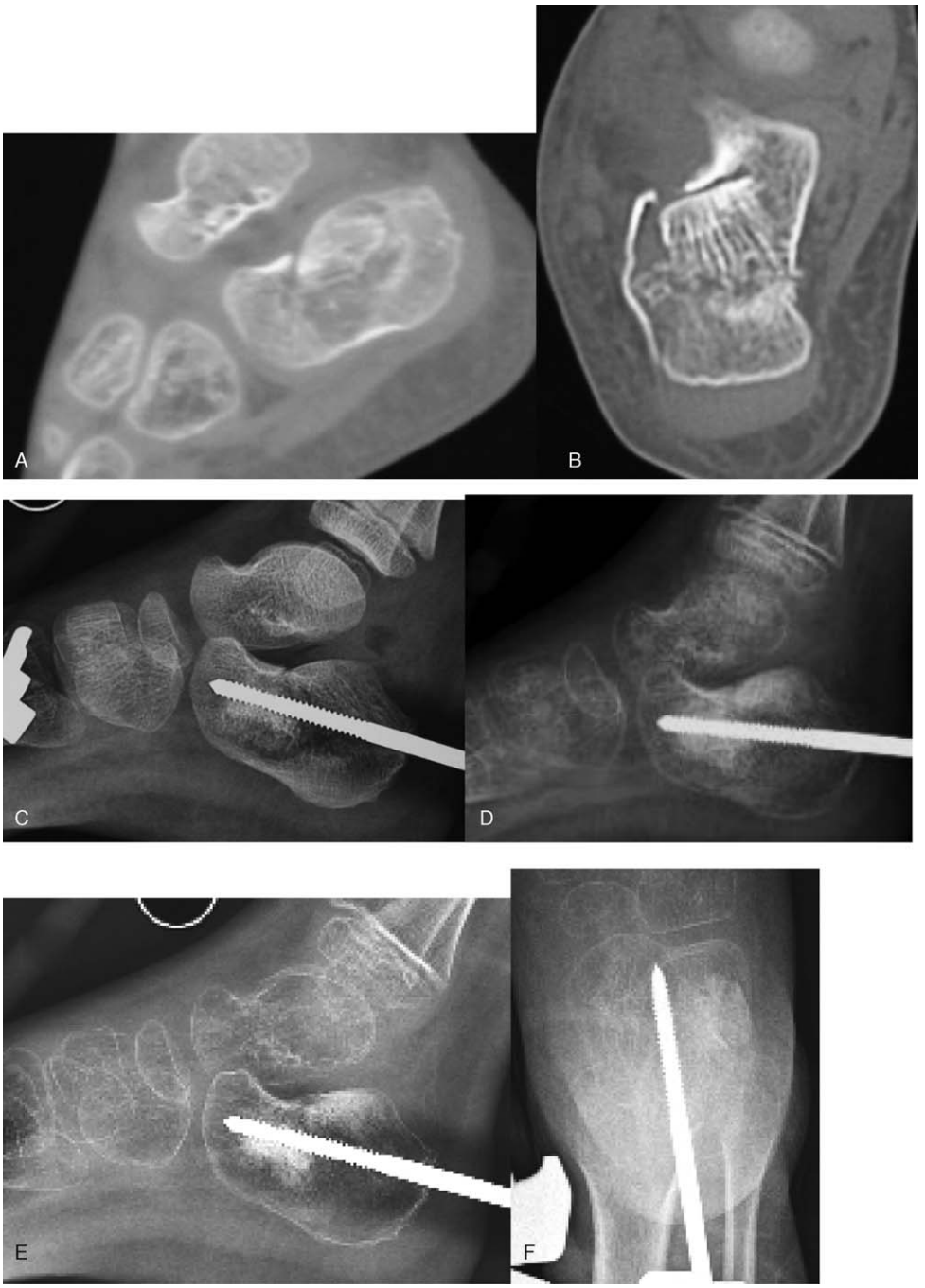

Figure 3. A 9-year-old boy of calcaneal fracture. (A) Sagittal plane of CT scan of calcaneal fracture before surgery. (B) Cross-section of CT scan of calcaneal fracture before surgery. (C) Lateral X-ray of calcaneum after surgery. (D) Lateral X-ray of calcaneum at first month follow-up. (E) Lateral X-ray of calcaneum at second month follow-up. (F) Axial view of calcaneum at second month follow-up.

preoperatively and $34.7 \pm 3.9°$ postoperatively ($P < .001$); Gissane angle was $102.5 \pm 6.6°$ preoperatively and $128.7 \pm 6.1°$ postoperatively ($P < .001$). In type IV fractures, Bohler angle was $14.7 \pm 3.2°$ preoperatively and $33.3 \pm 3.0°$ postoperatively ($P < .001$); Gissane angle was $100.3 \pm 4.2°$ preoperatively and $130.1 \pm 5.9°$ postoperatively ($P < .001$).

The average length of incision was 3.4 ± 0.7 cm. No cases of wound breakdown or dehiscence occurred. Only 1 patient showed a superficial infection, and it was ameliorated with oral antibiotics. At the last follow-up, all patients showed satisfactory clinical outcomes (Table 3). According to the AOFAS scale, the score was 90.0 ± 2.3. The score in type II fracture was 92.1 ± 2.2; the score in type III was 90.0 ± 1.4; the score in type IV was 88.0 ± 2.3.

4. Discussion

This study presents a minimally invasive approach to treat displaced intra-articular calcaneal fractures in children. Anatomic reduction and bone grafting could be achieved through sinus tarsi, and large diameter Schanz pin provides strong support to

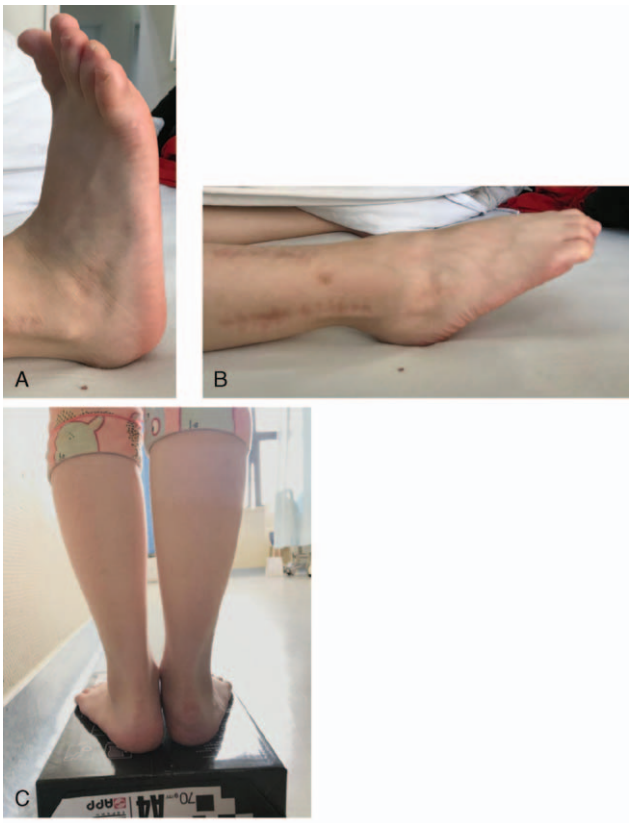

Figure 4. An 11-year-old girl suffering from calcaneal fracture and concomitant lower leg injuries. (A) Appearance of the sinus tarsi incision. (B) Plantar flexion of the ankle. (C) Posterior view of the ankle.

Table 1

Demographic parameters.

Clinical parameters	N (%)
Age (mean, yr)	10.2±2.2
Sex	
Male	23 (79.3)
Female	6 (20.7)
Affected side	
Right	12 (41.4)
Left	17 (58.6)
Mechanism of injury	
Fall from over 2 m	13 (44.8)
Fall from below 2 m	9 (31.0)
Road traffic accident	7 (24.1)
Sanders classification	
Type II	7 (24.1)
Type III	15 (51.7)
Type IV	7 (24.1)

Table 3

Clinical outcomes.

AOFAS Scale	Type II	Type III	Type IV	All (II+III+IV)
Total (100)	92.1±2.2	90.0±1.4	88.0±2.3	90.0±2.3

P (II/III) = .04; *P*(III/IV) = .06; *P*(II/IV) <.001.

the articular surface. The normal curvature of the foot arch was maintained with the external fixator without additional plaster cast.

The optimal treatment for displaced intra-articular calcaneal fractures remains controversial. For minimally displaced fractures, conservative methods produced satisfactory outcomes,[2,3] but in severely displaced or comminuted fractures, more and more authors favor operative methods.[7–12] However, the results varied in different studies.

Closed reduction and percutaneous fixation was reported,[19] but the method seemed to be suitable for minimally or moderately displaced fracture or noncomminuted ones. In severely displaced or comminuted fractures, closed reduction cannot achieve the anatomic reduction of the articular surface. Therefore, open reduction was performed in our study.

To the best of our knowledge, almost all previous studies using ORIF chose the extensile lateral approach.[7–11] ORIF, using this approach, comes with various complications. Among the complications, the wound-related complications, including incision edge necrosis, dehiscence, hematoma with/without deep infection, remain a major challenge for orthopedic surgeons.[20] The incidence of wound-related complications was 7% to 11% in different studies,[9–11] comparably less than that in adults.[21] This approach provides adequate exposure of the fracture and allows accurate reduction of the depressed posterior facet. Randomized control trials have reported shorter surgical time and lower incidence of complications in the sinus tarsi approach compared with the extensile lateral approach.[22] Therefore, the sinus tarsi approach was adopted in our study to achieve an anatomic reduction of the articular surface. In our study, only 1 patient showed a superficial infection around the incision, which was ameliorated by oral antibiotics. Besides, Yu et al[10] reported the average AOFAS score was 65.2 in 9 fractures of 8 children; Al-Ashhab[11] reported more satisfactory outcomes with an average AOFAS score as 95.8. In our study, the average AOFAS score was also satisfactory with 90.0±2.3.

Minimally invasive sinus tarsi approach has been reported in pediatric patients,[12] but in this study, cortical screws were used to stabilize the fracture, which might require removal afterward. Besides, the sample size in this study was quite small; only 2 cases were reported. In another report,[23] the sinus tarsi approach with percutaneous KW fixation was used for calcaneal fractures in children. Multiple KWs were used to stabilize the fracture after the reduction was achieved through the sinus tarsi approach.

Table 2

Radiographic results.

Sanders classification	Bohler angle, degree			Gissane angle		
	Before	After	*P*	Before	After	*P*
Type II	13.4±3.3	33.1±4.0	<.001	101.9±6.4	131.4±6.0	<.001
Type III	16.3±2.7	34.7±3.9	<.001	102.5±6.6	128.7±6.1	<.001
Type IV	14.7±3.2	33.3±3.0	<.001	100.3±4.2	130.1±5.9	<.001
All (II+III+IV)	15.2±3.3	34.0±3.8	<.001	101.8±6.2	129.7±6.2	<.001

However, the small-diameter smooth KW might not provide sufficient support for the articular surface, especially in teenagers. Besides, in comminuted fractures, larger diameter (more than 3 mm) KW has also been used in clinical practice. Still, without being clamped to the external fixator, the KW might have to penetrate cuboid to provide sufficient stability. In contrast, in our study, the large diameter Schanz pin was able to provide a buttress for the articular surface, and the Schanz pin was connected with the pins in the tibia to provide sufficient stability without penetrating the cuboid. Moreover, the external fixator maintained the foot in a position of normal foot arch without additional application of plaster cast, which reduces the incidence of pressure sore around the heel.

Bone grafting in intra-articular calcaneal fracture remains controversial. Cao et al[24] reported that there was no statistically significant difference in the short-term outcomes between bone grafting group and non-bone grafting for Sanders type III calcaneal fractures. Duymus et al[25] reported that although there was no difference between 2 groups in clinical outcomes, more satisfactory radiological results were obtained in the bone grafting group. A meta-analysis in 2018 suggested operative treatment with bone grafts achieved better AOFAS scores than the non-bone grafting group, and no increased risk of postoperative complications was identified.[26] In our study, allogeneic bone was used to fill the bone defect after open reduction. It not only provided mechanical support but also might stimulate quicker healing without loss of reduction. In our study, there was no patient of noticeable loss of reduction during the follow-up visits. Besides, the incidence of complications showed no increase in our study compared with previous reports.

The current study has certain limitations. First, the sample size was relatively small, and the follow-up was relatively short; Second, it was a retrospective study without a control group, partially due to the rarity of displaced intra-articular calcaneal fractures in children.

5. Conclusion

Minimally invasive approach with external fixator is an effective method for treating displaced intra-articular calcaneal fractures in pediatric patients, with a low incidence of wound-related complications and good cosmetic outcomes.

Author contributions

Conceptualization: Pan Hong.
Data curation: Rui Jin, Renhao Ze.
Formal analysis: Ruikang Liu.
Investigation: Rui Jin, Renhao Ze, Xin Tang.
Resources: Renhao Ze.
Software: Ruikang Liu.
Supervision: Jin Li, Pan Hong.
Validation: Xin Tang.
Writing – original draft: Pan Hong.
Writing – review & editing: Jin Li, Saroj Rai, Yudong Liu, Pan Hong.

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