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A minimally invasive (sinus tarsi) approach with percutaneous K-wires fixation for intra-articular calcaneal fractures in children

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The aim of this study was to analyze the management of displaced intra-articular calcaneal fractures in children at our pediatric orthopedic and to determine the results following open reduction via minimally invasive sinus tarsi approach and fixation with Kirschner wires (K-wires). Overall, 25 available cases of calcaneal fractures in children with mean age of 9.8 years were treated by open reduction from January 2010 to December 2015. All patients were followed up from 12 to 30 months (mean: 19 months). Clinical functional outcomes were graded using the American Orthopedic Foot and Ankle Society hindfoot scores. Radiographic evaluation included measurement of the Bohler's angle and Gissane's angle of the calcaneus on the lateral view. All fractures healed within 3 months. According to the American Orthopedic Foot and Ankle Society foot scoring system, the mean scores of type II fractures were 92.7 ± 2.1, type III 90.2 ± 1.8, and type IV 89.7 ± 2.7 at the latest follow-up. The preoperative and postoperative Bohler's angles were 17.1° ± 10.7° and 35.9° ± 6.7° in Sanders type II fractures, 14.4° ± 11.5° and 34.7° ± 8.5° in type III, 9.3° ± 9.7° and 35.1° ± 4.9° in type IV, respectively. The preoperative and postoperative Gissane's angles were 102.6° ± 11.5° and 125.7° ± 7.8° in Sanders type II fractures, 101.7° ± 9.1° and 117.5° ± 10.8° ($P < 0.05$) in type III, and 104.7° ± 5.1° and 122.8° ± 9.1° ($P < 0.05$) in type IV, respectively. No secondary arthrosis has been observed so far. No deep infection and wound necrosis occurred. One patient had superficial infection around K-wires that was managed using dressings. Treatment of calcaneal fractures in children by open reduction by sinus tarsi approach and K-wires fixation is a safe and effective method with low incidence of complications. *J Pediatr Orthop B* **27:556–562 Copyright © 2018 The Author(s). Published by Wolters Kluwer Health, Inc.**

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Introduction

Calcaneal fractures are probably the most common fractures in the tarsal bones, accounting for 60% of all tarsal fractures [1]. Some calcaneal fractures are minor injuries, but many are severe, high-energy fractures. These more serious injuries usually occur after falls from height or as results of traffic accident [2]. An increasing number of intra-articular calcaneal fractures are being reported in children [3]. The management of displaced intra-articular calcaneal fractures (DIACFs) in children remains challenging and controversial [4,5]. Most surgeons have favored nonoperative treatment of these fractures in the past [6,7]. However, it is hard to obtain excellent anatomical reduction, especially for displaced calcaneal fractures [5]. Moreover, other problems also occur, such as loss of calcaneal height, increased calcaneal width and uneven articular surface, all leading to calcaneal malunion and traumatic arthritis [5]. An increasing number of studies have shown a trend toward better functional outcomes in the operatively managed groups than those treated nonoperatively [8,9].

Currently, open reduction and internal fixation through the lateral L-shape extensile incision has been considered as the gold standard surgical therapy for calcaneal fractures [10]. This approach provides a large view to expose the fractures, allowing accurate reduction of the deformed posterior facet and convenient placement of the plate to achieve a stable fixation [11]. However, the high incidence (~30%) of complications associated with this approach, including wound dehiscence and deep infection, remains a non-negligible problem [12]. In addition, the conventional plate is difficult to insert, and wide exposure should be avoided for children with small and skeletally immature calcaneus. In an attempt to lower the complication rate, various minimally invasive techniques have been introduced recently [13,14]. As one of the most widely applied minimally invasive techniques, the sinus tarsi approach has the advantage of direct visualization of the posterior articular facet and fewer wound-related complications [15].

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To further shorten the operative time and decrease the wound complication rate, we introduced, since 2010, percutaneous Kirschner wires (K-wires) fixation and allogeneic bone grafting following open reduction through the sinus tarsi approach. A preliminary clinical study carried out by our team found that this technique reduced subtalar joint stiffness and a reduced wound complication rate, while improving the patients' satisfaction. In this study, we retrospectively analysis the data and report the functional and radiological outcomes of surgical treatment of intra-articular calcaneal fractures in children.

Patients and methods

Our Institutional Review Board approved the protocol for this project. We retrospectively reviewed the medical records and radiographs of 30 children who underwent open reduction for displaced, intra-articular calcaneal fractures at our institution between January 2010 and January 2015. The patients reviewed were younger than 15 years at the time of injury. We excluded cases of avulsion of the apophysis and fractures of the anterior process. Open calcaneal fractures and Sanders type I fractures were also excluded.

Preoperative management

After admission, the affected feet of the patients were fixed using plaster and elevated to relieve the swelling of the soft tissues. All patients were evaluated using preoperative calcaneal radiographs and computed tomography scans and three-dimensional reconstruction of the injured foot. All fractures were subsequently classified according to the Sanders classification [16] (Table 1). All patients underwent general anesthesia. The patient was placed in a supine position on a radiolucent operating table and a tourniquet was applied. Hip and knee joint were flexed.

Surgical technique

We used a straight incision directly over the sinus tarsi which started ~1 cm below the lateral malleolus and continued toward the calcaneocuboid joint for ~5 cm. Dissection was carried carefully proximally to avoid injuring the calcanofibular ligament and the sural nerve. Peroneus longus and brevis tendon were pulled over and the posterior subtalar articular surface and fracture line were exposed.

Table 1 Patients' demographics

Characteristics	*n* (%)
Age (mean) (years)	9.8
Sex	
Males	21 (87.5)
Females	3 (12.5)
Side	
Right	12 (48)
Left	13 (52)
Mechanism of injury	
Fall from over 2 m	17 (70.8)
Fall from below 2 m	3 (12.5)
Car accident	4 (16.7)
Sanders classification	
Type II	6 (24)
Type III	14 (56)
Type IV	5 (20)

Intra-articular hematoma and debris were eliminated through the incision. After moderate exposure of the lateral wall of the calcaneus, a periosteum elevator was inserted into the fractures and placed under the posterior articular surface. Calcaneal tuberosity was pushed backward and the posterior articular surface was pushed upward to correct the length and height of calcaneus with the help of the periosteum elevator. A 2.0- or 2.5-mm K-wire was inserted into the calcaneus tuberosity followed by longitudinally extending it to the anterior part of the calcaneus to correct the Bohler's angle. Bone defect region was filled with allograft bone. Once satisfactory anatomical reduction of the calcaneus was achieved, 1–3 K-wires were inserted from the tuberosity to the anterior part of the calcaneus in different directions to fix the fracture line (Fig. 1). After confirming the height and width of the calcaneus, Bohler's angle and Gissane's angle were reduced under C-arm fluoroscopy, rubber drains were inserted, and the incision was closed in layers followed by compression bandaging.

Postoperative management and evaluation

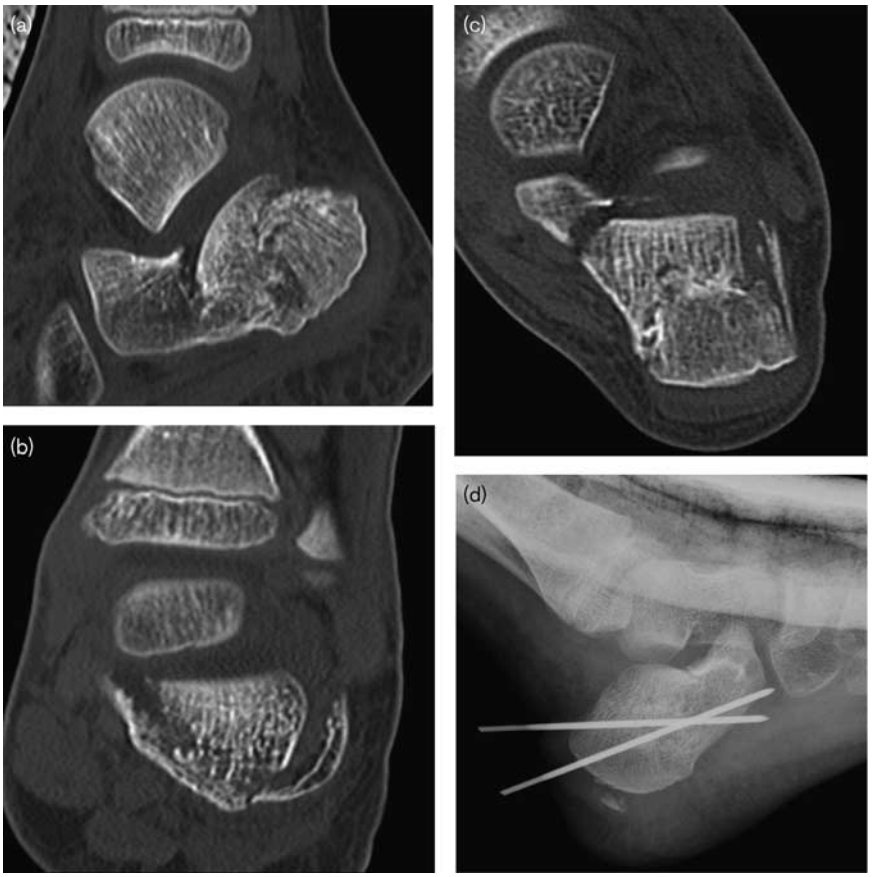
Postoperatively, the affected limbs of patients were elevated to minimize swelling and immobilized by plaster cast. Prophylactic antibiotics were given to prevent surgical site infection. Rubber drainage was extracted after 48 h, and incision was cleaned every 2 days until sutures were removed ~2 weeks after surgery. Each patient received follow-up at 1, 3, 6, and 12 months postoperatively. K-wires and cast were removed after 1 month postoperatively when the fracture was healed clinically, and full weight-bearing was not allowed until bony union was confirmed on radiographs, which was ~3 months postoperatively.

Radiographs were taken postoperatively to measure the calcaneal anatomical parameters, including Bohler's angle and Gissane's angle. Clinical functional outcomes were graded using the American Orthopedic Foot and Ankle Society scale at the 12-month follow-up [17]. The postoperative wound-related complications were also recorded.

Statistical analysis

All data are expressed as mean ± SD and analyzed by SPSS statistical package program (version 19.0; SPSS Inc., Chicago, Illinois, USA). The preoperative and postoperative calcaneal anatomical parameters were compared by paired *t*-test, and χ^2-test was performed to compare the functional outcomes between the different Sanders classification. Fisher's exact test was used instead when the expected frequency was less than 5. The level of significance was set at P less than 0.05.

Fig. 1



Radiographic evaluations of a 7-year-old male patient with Sanders type III calcaneal fracture. Preoperative computed tomography scans show significantly reduced Bohler's angle and Gissane's angle (a–c). Postoperative radiograph shows significant correction of Bohler's angle and Gissane's angle (d).

Results

Of the 30 patients treated since 2010, 24, including one who had bilateral fractures, were available for interview and examination. The mean age was 9.8 years (range: 5.6–14.5 years). The fractures were presented in three girls and 21 boys. The mechanisms of injury included falls from over 2 m in 17 patients, falls from below 2 m in three, and severe mangling injuries from car accidents in four. According to the Sanders classification, the fracture patterns of these 25 intra-articular injuries could be further characterized as six Sanders type II, 14 Sanders type III, and five Sanders type IV. All fractures were closed. Average postoperative clinical and radiological follow-up was 19 months (range: 12.0–30.0 months) (Table 1).

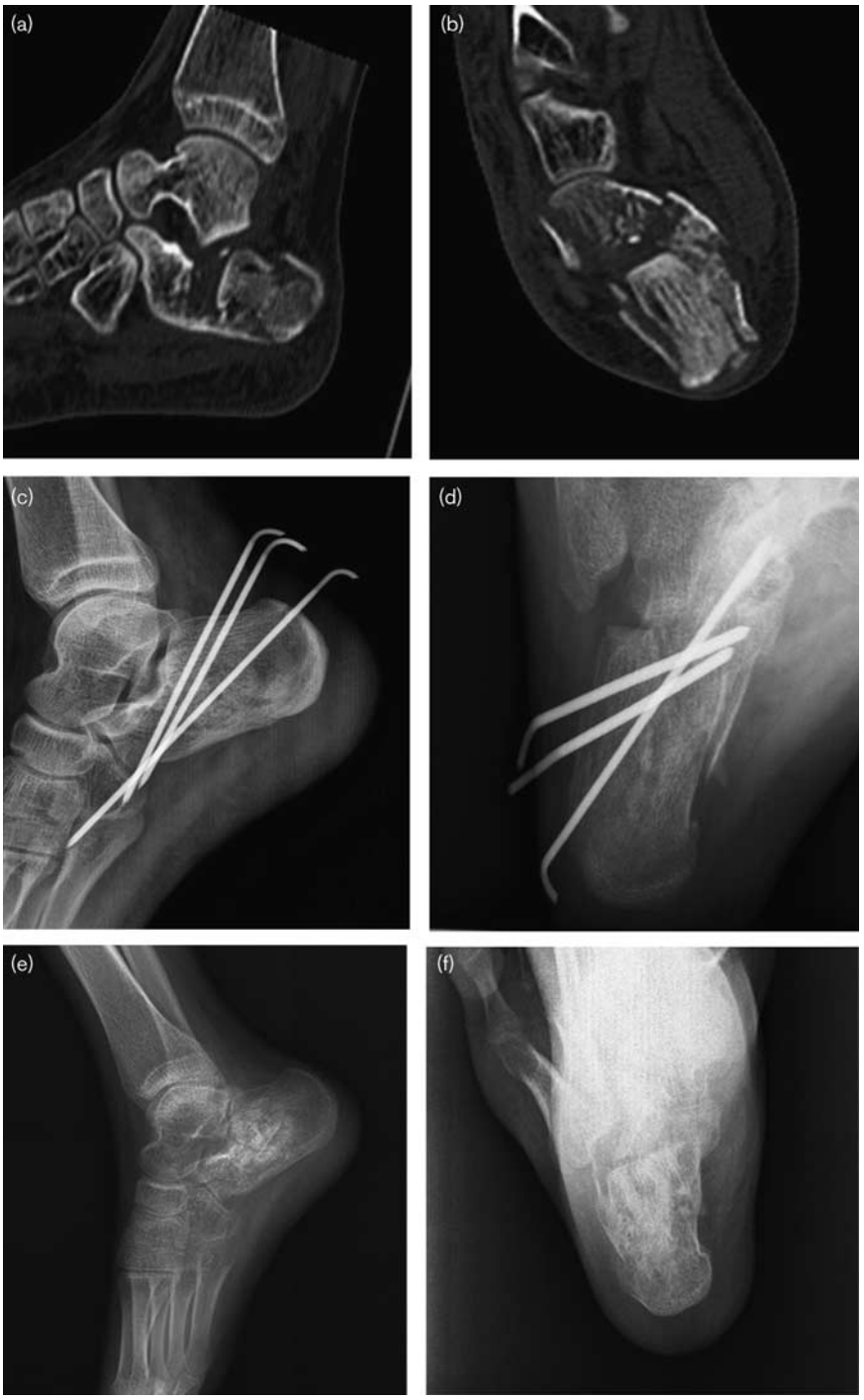
The average time from initial injury to operation was 3 days (range: 2.0–5.0 days) in this study. The mean hospital stay was 10 days (range: 8.0–12.0 days), and the mean operative time was 75 min (range: 65–90 min). No deep infection and wound necrosis occurred. One patient had superficial infection around K-wires, which was resolved by dressings and oral antibiotics administered for 3 days.

Table 2 Radiographic results for the three groups

	Type II	Type III	Type IV
Bohler's angle (deg)			
Before operation	17.1 ± 10.7	14.4 ± 11.5	9.3 ± 9.7
After operation	35.9 ± 6.7	34.7 ± 8.5	35.1 ± 4.9
Gissane's angle (deg)			
Before operation	102.6 ± 11.5	101.7 ± 9.1	104.7 ± 5.1
After operation	125.7 ± 7.8	117.5 ± 10.8	122.8 ± 9.1

Marked improvements in the Bohler's angle and Gissane's angle were noticed in all patients (Table 2). The mean preoperative and postoperative Bohler's angles were 17.1° ± 10.7° and 35.9° ± 6.7° ($P < 0.05$) in Sanders type II fractures, 14.4° ± 11.5° and 34.7° ± 8.5° ($P < 0.05$) in type III, and 9.3° ± 9.7° and 35.1° ± 4.9° ($P < 0.05$) in type IV, respectively. The mean preoperative and postoperative Gissane's angles were 102.6° ± 11.5° and 125.7° ± 7.8° ($P < 0.05$) in Sanders type II fractures, 101.7° ± 9.1° and 117.5° ± 10.8° ($P < 0.05$) in type III, and 104.7° ± 5.1° and 122.8° ± 9.1° ($P < 0.05$) in type IV, respectively. No case of loss of reduction was noticed at the follow-up (Fig. 2).

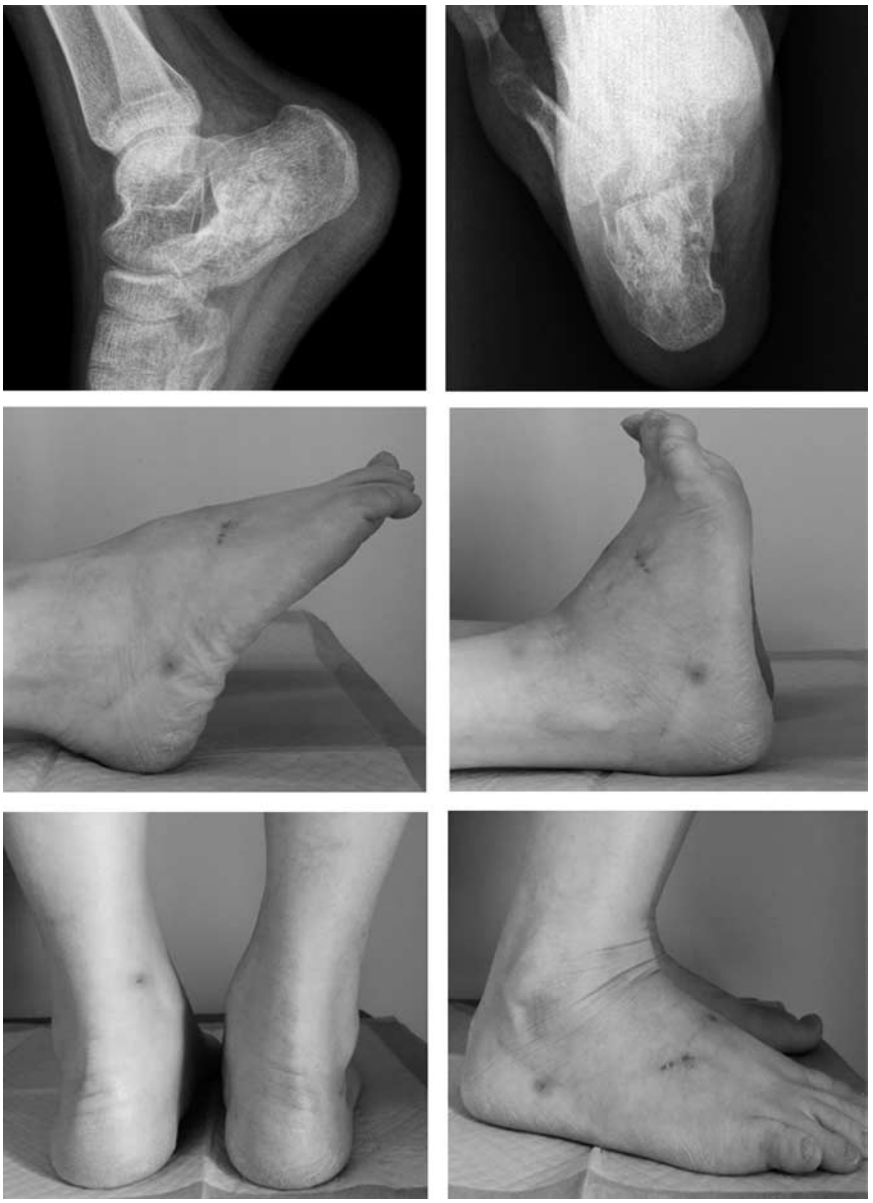
Fig. 2



Radiographic evaluations of a 13-year-old female patient with Sanders type III calcaneal fracture. Preoperative computed tomography scans show significantly reduced Bohler's angle and Gissane's angle (a, b). Postoperative radiographs show anatomical reduction of the subtalar articular surface and significant correction of Bohler's angle and Gissane's angle (c, d). Three-month follow-up radiographs show no obvious decrease in Bohler's angle and Gissane's angle (e, f).

All patients were free of pain and had a normal range of motion in the subtalar joint (Fig. 3). Gait was not impaired. No secondary arthrosis has been observed and no patient required orthopedic shoes. According to the American Orthopedic Foot and Ankle Society scoring system, the mean scores of type II fractures were 92.7± 2.1, type III 90.2±1.8, and type IV 89.7±2.7 at the latest follow-ups. We did not find

Fig. 3



Radiographic and clinical evaluations of the 13-year-old female patient with Sanders type III calcaneal fracture in Fig. 2. The 12-month follow-up photographs show no obvious decrease in Bohler's angle and Gissane's angle and normal range of motion in the subtalar joint.

statistically significant differences among these three groups ($P > 0.05$) (Table 3).

Discussion

Fractures of the calcaneus make up ~2% of all fractures and are the commonest fracture of the tarsal bones [1]. The optimal management of DIACFs remains controversial [18]. Many surgeons have favored nonoperative treatment of these fractures; however, Thermann *et al.* [19] reported arthritic changes in the subtalar joint in 65.2% of type II fractures and in 81.7% of type III and type IV fractures, and radiological follow-up evaluation showed arthritic changes in the subtalar joint in 44% of cases. Certain randomized controlled trials supported surgical treatment can better reconstruct the anatomy of the calcaneus, lower the subtalar fusion rate, and offer protection against early subtalar arthrodesis in DIACFs [9].

Schneidmueller *et al.* [20] aimed to restore articular surface through surgery to prevent early arthritis. They reported surgical treatment is recommended when the disruption of the three subtalar facets is more than 2 mm. Depending on the outcome score used, an overall good to excellent result was reached in 90% of cases, without wound complication. Pickle *et al.* [21] reported a group of

Table 3 The outcome according to American Orthopedic Foot and Ankle Society scale for the three groups

AOFAS scale	Type II	Type III	Type IV
Pain ($n=40$)	40	40	40
Function ($n=50$)	42.7 ± 2.1	40.2 ± 1.8	39.7 ± 2.7
Alignment ($n=10$)	10	10	10
Total ($N=100$)	92.7 ± 2.1	90.2 ± 1.8	89.7 ± 2.7

AOFAS, American Orthopedic Foot and Ankle Society.

seven pediatric intra-articular calcaneal fractures surgically treated with internal fixation. In our study, all patients were free of pain and had a normal range of motion of the subtalar joint. In agreement with these authors, reconstruction of the joint alignment and satisfactory functional outcomes were achieved by surgery for DIACFs in our study.

Closed reduction and percutaneous fixation have been reported to significantly reduce the incidence of wound healing complications [22]. However, this treatment seems to be more suitable for cases with moderately displaced fracture or noncomminuted calcaneus fracture because of the limited fixation strength. We found the articular surface of the immature calcaneum is difficult to restore by closed reduction because of their high resilience and low rigidity. Surgical treatment with open reduction and internal fixation is increasingly recommended in the literature [11]. Alternative surgical approaches to the calcaneus include the lateral L-shape, Palmer approach, and Kocher approach [23,24]. The lateral L-shape extensile incision provides excellent exposure of the fractures and allows accurate reduction of the deformed posterior facet and convenient placement of the plate to achieve a stable fixation. However, open reduction and internal fixation through this approach comes with various complications, among which, the wound complications, including edge necrosis, dehiscence, hematoma, and/or deep infection, remain a major concern [23].

Many minimally invasive techniques were developed to overcome this disadvantage [8,14]. Xia *et al.* [14] reported shorter surgical times and lower wound complications using the minimally invasive sinus tarsi approach compared with an extended L-shaped lateral approach. They reported the overall rate of wound complications was 6% in the patients treated with sinus tarsi approach. In this study, an incision (4–5 cm) was made from the level of the tip of the lateral malleolus and continued toward the calcaneocuboid joint. K-wires were used to fix the fractures and the incision was only used to assist the repositioning and filling of the bone graft. There is no need for extensive periosteal dissection to provide the internal fixation space, which is necessary in operation for adults. We need to reduce the length of the incision and the dissection of the periosteum during the operation. This type of small incision greatly decreases the effect on local skin blood supply. Only one patients in our study had superficial infection around K-wires, which was resolved by dressings and oral antibiotics administered for three days. Compared with conventional treatment, sinus tarsi approach substantially decreased the risk of wound complications. In addition, K-wires can be inserted percutaneously, thus eliminating the need for the creation of a complete subcutaneous tunnel, which can avoid injuries to the peroneal tendons and the sural nerve.

Stulik *et al.* [25] reported 13 (4.5%) cases of loss of reduction in patients treated with closed reduction and percutaneous fixation using K-wires. In our study, allogeneic bone was used to fill the calcaneal defect followed by open reduction. Although bone grafts do add mechanical support, and may stimulate quicker fracture healing, the calcaneus heals rapidly with reconstitution of the cancellous bone within 3 months after surgery without loss of reduction.

Conclusion

Good treatment results were obtained in all of the fractured calcaneus in this study. Our excellent results may also be attributable to the sinus tarsi approach, percutaneous K-wires fixation, and allogeneic bone graft. There are several advantages such as (i) the articular surface was well exposed, and the restoration can be performed under direct vision; (ii) sinus tarsi approach facilitates bone graft, which can increase bone strength and reduce the risk of collapse; and (iii) it is easy to insert and remove the K-wires. Moreover, there is no need for extensive periosteal dissection to provide the internal fixation space. No additional operation is required to remove the K-wires. However, there are still some limitations in this technique. This minimally invasive sinus tarsi approach with K-wires fixation technique is still difficult for exposure and restoration of fractured fragments of the medial wall of the calcaneus. The long-term complications of calcaneal fractures in children include osteoarthritis and loss of calcaneal height in the process of development. Further investigation with large sample size and longer follow-up time is still needed to obtain a more precise clinical efficacy.

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All authors have participated sufficiently in this work concerning conception and design of this study, drafting the article, critical revision for important intellectual content, and final approval.

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Conflicts of interest

There are no conflicts of interest.

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