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ORIGINAL STUDY

A comparison of two minimally invasive procedures for intra-articular displaced calcaneal fractures in older children

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The purpose of this study was to compare the clinical outcomes of displaced intra-articular calcaneal fractures in older children treated with poking reduction and cannulated screws fixation or with plate fixation using a sinus tarsi approach. From June 2008 to May 2012, fifty patients were randomised to operative stabilisation either by poking reduction and cannulated screws fixation (Group A, 28) or by plates fixation using a sinus tarsi approach (Group B, 22). The two groups were comparable with respect to age, gender, BMI, the affected side, cause of injury, fracture type, time from injury to surgery and follow-up time. We collected data on operative time and radiation time, length of hospitalization, hospital costs, union time, full weight-bearing time, full physical activity time and complications and measured joint function using the American Orthopaedic Foot and Ankle surgery (AOFAS) score.

The average follow-up time of Group A was 36.5±9.3 months and 40.2±10.6 months in Group B. No significant difference between these two groups was found in radiation time, average length of hospitalization, union time, full weight-bearing time, full physical activity time and the average AOFAS score. However, the patients of Group B had longer operation time (38.0±10.6 min vs. 66.5±9.4 min, *P*<0.05) and more hospital costs (6200±800 RMB vs. 15000±2000 RMB, *P*<0.05). The average Bohler's angle and Gissane's angle preoperative were 10.9±5.3 and 141.3±12.1 in Group A, and became 31.2±5.1 and 128.5±5.4 after operation. The average Bohler's angle and Gissane's angle preoperative in Group B were 11.7±4.0 and 138.8±16.2, respectively, and they became 30.9±5.2 and 124.6±6.8 after operation. Bohler's angle and Gissane's angle were significantly restored after surgery (*P*<0.05). Postoperative incision pain was more frequent in Group B than in Group A (*P*<0.05).

Our results indicated that both cannulated screws and plates were efficient methods for intra-articular calcaneal fractures in older children. However, poking reduction and cannulated screws fixation had the advantages of a shorter operative time, fewer hospital costs and less incision pain.

Keywords : children ; calcaneus ; intra-articular fractures ; closed reduction ; minimally invasive procedures ; randomized controlled trial.

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INTRODUCTION

Pediatric calcaneal fractures are rare injuries (*8*) and the treatment of these fractures remains controversial. Operative management has been considered the encouraging treatment for significantly displaced intra-articular (>2 mm) fractures of the calcaneus, as it generally provides good to excellent functional outcomes and the ability to anatomically restore the subtalar joint (*13*). However, displaced calcaneal fractures in older children (>8-year-old) treated with operative management (*4,16*) have been poorly described in the literature (*3,12*). Minimally invasive procedures, such as poking reduction and percutaneous screw fixation and plate fixation using a sinus tarsi approach, are most commonly used methods and their good outcomes are reported by some authors (*2,5,6,17*). However, all the studies are done retrospectively. Moreover, there is presently no study to compare these two minimally invasive methods. As a result, the optimal treatment of displaced calcaneal fractures in older children remains controversial.

The purpose of this prospective study was to compare the clinical outcomes of displaced intra-articular calcaneal fractures in older children treated with poking reduction and cannulated screws fixation or with plate fixation using a sinus tarsi approach. We hypothesized that similar bone union and the same functional outcome could be achieved with either cannulated screws fixation or plating, but the complications would be more frequent in patients treated with plates.

MATERIALS AND METHODS

Patients' Data

Fifty patients with displaced intra-articular calcaneal fractures were treated with poking reduction and cannulated screws fixation (Group A, 28) or with plates fixation using a sinus tarsi approach (Group B, 22) between June 2008 to May 2012 at our hospital. Approval for the study was given by the Ethics Committee and informed consent was obtained from all patients before operation. All fractures were classified according to the Sanders computed-tomography classification system (*14*). The inclusion criteria were as follows: (1) age from 8 to 15 years, (2) fresh closed fractures (within 14 days after injury), (3) intra-articular displaced (>2 mm) calcaneal fractures, (4) follow-up time more than 12 months. The following patients were excluded: (1) ipsilateral or contralateral lower limb fractures and/or dislocation, (2) old fractures, (3) open fractures, (4) associated with nerve or vascular injury requiring repair, (5) combined with severe vital organs and brain injuries, (6) previous ipsilateral lower limb surgery. At admission, type of treatment was chosen at random by drawing from the box containing an equal number of envelopes with either of the two methods. There was no significant difference in the pre-operative variables between the two groups (Table I).

Operative procedures

All operations were performed by the same group of surgeons (CH, SLJ, and LD). Surgery was delayed an average of 3 days (range, 1–7 days) to allow for resolution of soft tissue swelling. For Group A, the patient was in a prone position and a tourniquet was employed. The knee of affected side was bent about 45 degrees. Using fluoroscopy in two directions, a 3.5-mm S-wire were inserted in the frontal, transverse direction through both the talus and the tuber of the calcaneus, outside the apophyseal line. After ensuring proper placement, this S-wire was maneuvered as a joystick to lower the calcaneal tuberosity and elevate the posterior facet. Pocking reduction of the depressed subtalar fragment was achieved using a punch introduced plantar. Manual compression was then applied on both sides of the calcaneus with the palms of hands to achieve further reduction of the width and height of the calcaneus. Manual longitudinal axial distraction was applied to correct varus, lateral and anterior displacements of the tuberosity. If reduction was anatomical, the heel was compressed manually to lock the reduced fragments in position. Temporary fixation was achieved using guidewires. Cannulated cancellous screws (3.5 mm) were used for fragment fixation (Figure 1A-1D). Care should

Table I. — Baseline characteristics between the two groups

Characteristics	Group A	Group B	t/χ^2	*P*
Age (y)	8.2±2.5	8.6±2.6	0.55	0.584
Sex (male: female, n)	19:9	15:7	5.97	0.981
BMI (Kg/m^2)	16.2±1.6	16.4±1.3	0.48	0.637
Fracture side (left: right, n)	11:17	10:12	0.19	0.661
Fracture type (Sanders II: III, n)	19:9	13:9	0.41	0.522
Cause of injury (road accident: fall, n)	25:3	21:1	7.45	0.785
Injury to surgery time (d)	4.0±3.0	4.5±2.5	0.63	0.533

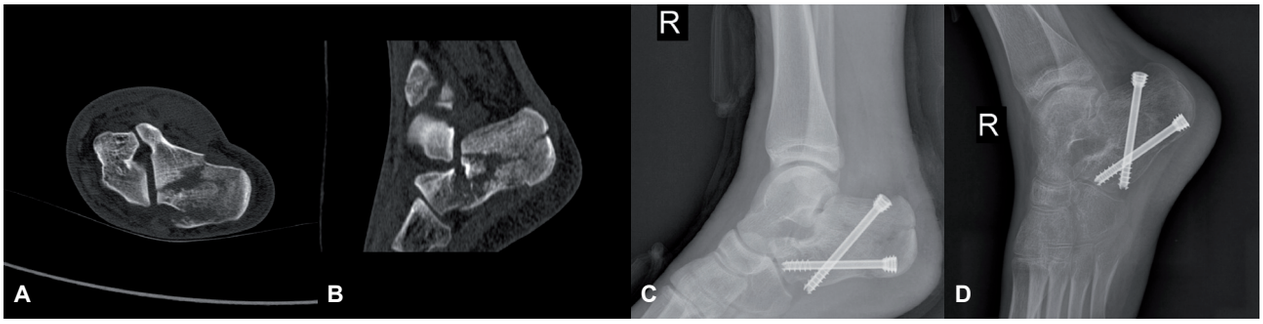

***Fig. 1.* — 1A-1B,** A 14-year-old boy who fell from a height induced to right calcaneus fracture (Sanders type IIA). **1C** Immediate postoperative radiograph demonstrating restoration of Bohler's angle and Gissane's angle. **1D,** Nine-month postoperative lateral radiographs showing a normal Bohler's angle and Gissane's angle and no evidence of subtalar joint osteoarthritis.

be taken to avoid damaging to the calcaneal physis particularly during the initial dissection and during screw placement. Additional screws were placed as necessary. The S-wires and guidewires were removed.

For Group B, the patient was in a supine position on a standard radiolucent table and a thigh tourniquet was also employed. An incision was done longitudinally beginning 3cm above the tip of the lateral malleolus along the posterior border of the distal fibula. The peroneal tendons were retracted toward the plantar side. Carrying distally to the level of the calcaneal-cuboid joint, the incision was directed toward the base of the fourth metatarsal at the tip of the fibula. The incision was initially deepened to the subcutaneous tissue, where the sural nerve was identified within the wound and protected. The surfaces of the fragments were cleaned and the soft tissues were elevated anteriorly as a full-thickness flap that included the peroneal tendons in their intact sheath. The distraction was released and the tuberosity levered medially into a slightly over-reduced position behind the sustenacular fragment. The fracture was then reduced and held with provisional K-wire fixation. The reduction is then continued along the angle of Gissane to the anterior process and its cuboid facet. The anterior process was reduced to the sustentaculum fragment, the lateral articular fragment was reduced and pinned and the tuberosity was reduced loosely and provisionally pinned from posteriorly with pins into the sustentaculum or anterior process. The lag screws are either independent or applied through the plate depending on the fracture pattern. A calcaneal plate (Synthes, Paoli, PA) was then placed laterally and fixed to the anterior process and calcaneal tuberosity using 3.5-mm cortical or 4.0-mm cancellous screws (Figure 2A-2D). Satisfactory articular reduction is gained and confirmed clinically and fluoroscopically with lateral, axial heel and Broden's views. Bone graft substitutes were not used. Once the fixation

Table II. — Ankle-hindfoot clinical rating criteria as published by the american foot and ankle society

Parameter	Degree	Score
Pain	None	40
	Mild, occasional	30
	Moderate, daily	20
	Severe, always	10
Function	No limitation, no support	10
	No limitations of daily activities, limitation of recreational activities, no support	7
	Limited daily and recreational activities, cane	4
	Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	0
Maximum walking distance, blocks	>6	5
	4-6	4
	1-3	2
	<1	0
Walking surface	No difficulty on any surface	5
	Some difficulty on uneven terrain, stairs, ladders	3
	Severe difficulty on uneven terrain, stairs, ladders	0
Gait abnormality	None, slight	8
	Obvious	4
	Marked	0
High score		68

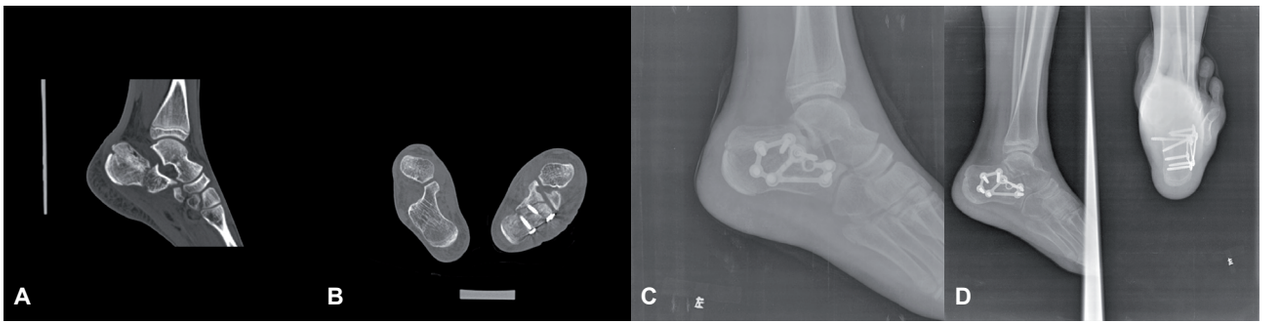

Fig. 2. — An 11-year-old boy with trauma to the left foot in a traffic accident. Computed tomography scan showing that Bohler's angle and Gissane's angle was decreased and the posterior subtalar joint surface was comminuted. **2B-2C,** Immediate postoperative radiograph and Computed tomography scan demonstrating restoration of Bohler's angle and Gissane's angle. **2D,** ten-month radiograph demonstrating that the fracture had healed and that Bohler's angle and Gissane's angle was normal.

is complete and final fluoroscopic images obtained, the wound is closed by careful re-approximation of the divided fascia and interval, and by running sutures to the skin.

Postoperative management

Postoperative treatments in both groups were the same. No patients had cast immobilization. Toe passive training was performed in 24 hours after the operation. Ankle active movement started at 48 hours postoperatively. Postoperatively, patients were all made non-weight bearing initially. Advancement to partial weight bearing occurred and to full weight bearing based on a radiographically healed fracture and lack of pain with weight bearing.

Outcomes assessment

All patients were reviewed at 1st, 3rd, 6th months, final follow-up and evaluated objectively by radiological and physical examination. A trained

examiner (ZSY) whom not involved in the patients' care reviewed all radiographs. Radiographic evaluation consisted of Bohler's angle and Gissane's angle obtained preoperatively and postoperatively immediately. The operation time was defined as the incision of skin to incision suture. Fluoroscopy time was obtained from the fluoroscopy logger. Moderate daily pain was defined as consistent complaints of pain and mild occasional pain was defined as intermittent complaints of pain, whereas absence of pain was defined as no complaints of pain. Fracture union was defined as the absence of pain and the presence of bridging callus seen on the radiographic views of the calcaneus. Hospital costs only include hospitalization for fracture fixation without secondary hardware removal. We also recorded complications, length of stay, and the time of full weight-bearing. In the last follow-up, functional outcome was assessed using the subjective portions of the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score (*9*) (Table II).

Statistical analysis

All statistical analyses were performed with SPSS version 17.0 software (SPSS Inc, Chicago, Illinois). The patient demographics (sex, injury side, causes of injuries, fracture type, postoperative complications, incision pain and AOFAS) and fracture characteristics of the two groups were compared using the Pearson's chi-square test or Fisher's exact test for nonparametric categorical variables. Independent sample t test was used to compare the patients' age, BMI, time from injury to operation, fluoroscopy time, operation time, length of hospitalization, hospital costs, duration of follow-up, bone healing time, the time of full weight-bearing and full physical activity time. The level of significance was set at $P< 0.05$.

RESULTS

The follow-up was 36.5 months (range, 21 to 72 months) in Group A and 40.2 months (range, 22 to 73 months) in Group B. All fracture had healed during follow-up. No significant difference between these two groups was found in radiation time, union time, full weight-bearing time, full physical activity time and average length of hospitalization. However, the patients of Group B had longer operation time (38.0±10.6 min vs. 66.5±9.4 min, $P<0.05$) and more hospital costs (6200±800 RMB vs. 15000±2000 RMB, $P<0.05$, Table III). There were no complications such as skin flap necrosis, Bohler's angle loss and implant failure in

Table III. — Clinical outcomes of the two groups

	Group A	Group B	t/χ^2	*P*
radiation time (sec)	14.9±8.8	11.3±3.3	1.82	0.075
operation time (min)	38.0±10.6	66.5±9.4	9.91	0.000
length of hospitalization (d)	5.15±0.58	5.26±0.63	0.64	0.525
hospital costs (RMB)	6200±800	15000±2000	21.26	0.000
union time (d)	64.2±10.4	60.9±9.7	1.15	0.257
full weight-bearing time (d)	84.7±11.5	86.9±13.1	0.57	0.569
full physical activity time (m)	9.7±2.5	8.9±3.1	1.01	0.317
AOFAS score (n)	63.1±8.9	66.0±8.3	1.18	0.245
Complications (n) incision infection heel pain peroneal tendon irritation	1 0 1 0	2 1 0 1		1.000

Table IV. — Radiologic outcomes of the two groups

		preoperative	postoperative	t	*P*
Group A	Bohler's angle	10.9 ± 5.3	31.2 ± 5.1	14.60	0.000
	Gissane's angle	141.3 ± 12.1	128.5 ± 5.4	5.11	0.000
Group B	Bohler's angle	11.7 ± 4.0	30. 9±5.2	13.73	0.000
	Gissane's angle	138.8 ± 16.2	124.6±6.8	3.79	0.005

Table V. — Incision pain of the two groups

	Group A	Group B	χ^2	*P*
Incision pain(n)				
no pain	27	11	14.56	0.000
mild occasional pain	1	6	3.95	0.047
moderate daily pain	0	5	4.47	0.029

the two groups. However, in Group B, one patient suffered mild peroneal tendon irritation with mild pain 2 years after surgery and one patient suffered incision infection. In Group A, one patient suffered heel pain.

The average Bohler's angle and Gissane's angle preoperative were 10.9±5.3 and 141.3±12.1 in Group A, and became 31.2±5.1 and 128.5±5.4 after operation (P<0.05). The average Bohler's angle and Gissane's angle preoperative in Group B were 11.7±4.0 and 138.8±16.2, respectively, and they became 30.9±5.2 and 124.6±6.8 after operation (P<0.05). Bohler's angle and Gissane's angle both were significantly restored after surgery (P<0.05, Table IV).

Mean AOFAS score was 63.1 points (range, 53 to 68 points) in Group A and 66.0 (range, 53 to 68 points) in Group B. No significant difference was found between these two groups in total AOFAS score (P>0.05, Table III). Twenty-seven patients had no pain and 1 suffered mild occasional pain and no patients had moderate daily pain in Group A while 11 patients had no pain and 6 suffered mild occasional pain and 5 had moderate daily pain in Group B. The incidence of postoperative incision pain was more frequent in Group B than in Group A (P<0.05) (Table V).

DISCUSSION

In recent literatures, displaced intra-articular calcaneal fractures in older children (>8-year-old) are mainly managed operatively (*4,5*). Poking reduction and cannulated screws fixation, plates fixation using a sinus tarsi approach are popular minimally invasive treatment for these fractures (*1,4,15*). Pickle et al. (*12*) demonstrated that poking reduction and cannulated screws fixation yielded encouraging results. Abdelgawad et al. (*1*) found that plate fixation using a sinus tarsi approach had a good clinical outcome with few complications. In our study, the incidence of total complications was 6% (3/50) and the good and excellent rate of AOFAS score was 100%. These further confirmed that above two minimally invasive methods were effective ways to treat displaced intra-articular calcaneal fractures in older children. Moreover, our research was the only prospective study comparing the two methods.

From our data, the patients of Group B needed longer operation time than those of Group A (P<0.05). The cause was that poking of the fracture could achieve satisfied reduction quickly and subsequent stabilizing the fracture using cannulated screws was also faster than that using a plate. When we adopted a sinus tarsi approach, it would take more time to retract the peroneal tendons, to expose the lateral calcaneal wall, to insert plate and adjust its position, to fix screws and plate. Open reduction and increasing operation time also might increase the risk of incision infection (*7,15*). Besides, although no significant difference between the two groups was found in radiation time, full weight-bearing time, union time and

length of hospitalization, cannulated screw was more economically than plate and this could reduce health care costs.

The incidence of reported complications about these two minimal invasive procedures ranged from 3% to 11% (*10,18*). Yu et al. (*18*) described one patient (11%) whose wound breakdown occurred 10 days postoperatively and the complication was cured completely with dressing changes. Mou et al. (*10*) reported one out of 14 pediatric displaced intra-articular calcaneus fracture treated with a minimal invasive sinus tarsi approach emerged pain of subtalar joint. The incidence of total complications in our study was within the range of previous reported data. In Group A, one patient (3.6%) suffered heel pain. In Group B, one patient (4.5%) suffered mild peroneal tendon irritation with mild pain and one patient (4.5%) had incision infection. The overall incidence of complications was no significant difference between the two groups (P=1.000) (Table III). Consequently, we could conclude that plate and screws stabilization had similar incidence of complications.

Judged from radiology, Bohler's angle and Gissane's angle of the two groups were both significantly restored after surgery (Table IV). This showed good reduction effect of the two methods. Several studies also showed that these two minimal invasive procedures could both correct these angles (abnormality of fractures) (*11,19*). Petit et al. (*11*) reported the average preoperative and postoperative Bohler's angles of 14 fractures in 13 patients were 11.8 and 28.4 degrees, respectively. Zhang et al. (*19*) reported tarsal sinus approach for reduction were applied in the treatment of 9 children (10 feet) with intraarticular fracture of calcaneus. In their series, the Bohler's angle and Gissane's angle preoperative were 20.2±5.2 and 138.6±8.5, and became 33.6±1.5 and 124.7±2.8 after operation. However, the incision pain rate was more frequent in Group B than in Group A. The exact cause of incision pain was unclear, but it really was a major problem.

Several limitations existed in our study. First, this study enrolled only a small number of patients, but children calcaneal fractures were uncommon. To further convince these results, high quality randomized controlled trials with larger sample size were still needed. Second, although patients were allocated randomly to either surgical group, it was impossible to perform blindness to both the surgeon and patients, which might influence the results. Nevertheless, the groups were similar regarding patient demographics and fracture characteristics, which the authors believed made comparison of the treatment methods reasonable.

CONCLUSION

The results of this study demonstrated that significantly displaced intra-articular (>2 mm) calcaneal fractures can be treated successfully in old children with minimally invasive operative stabilization. Our results indicated that both cannulated screws and plates were efficient methods with few complications for treating intra-articular calcaneal fractures in older children. However, poking reduction and cannulated screws fixation had the advantages of a shorter operative time, fewer hospital costs and less incision pain.

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