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RESEARCH

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Subtalar joint arthroscopic-assisted reduction and cannulated screw fixation versus open reduction and internal fixation for treating displaced intra-articular calcaneal fractures

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Abstract

Background The treatment of calcaneal fractures is not uniform. This study aimed to compare the functional and imaging results of subtalar joint arthroscopic reduction combined with cannulated screw fixation (SJACF) and the extended lateral approach (ELA) for the treatment of Sanders type II and III displaced intra-articular calcaneal fractures (DIACFs).

Methods From January 2020 to January 2023, 60 patients with calcaneal fractures were treated with SJACF or ELA for foot and ankle surgery at the Second Affiliated Hospital of Anhui Medical University. Changes in calcaneal Böhler's angle, the Gissane angle, and calcaneal length, height, and width were recorded before, after, and at the 1-, 3-, 6-, 12-month, and last follow-up. The preoperative waiting time, operation time, length of hospital stay, and other data of each patient were analyzed. The visual analogue scale (VAS) and American Orthopaedic Foot and Ankle Society (AOFAS) scores were used to evaluate clinical effects.

Results All 60 patients were followed up for at least 12 months. There was no statistical difference in baseline data (age, sex, fracture side, mechanism of injury, and classification) between groups ($P > 0.05$). The preoperative waiting time, length of hospital stay, and intraoperative fluoroscopy times were shorter in the SJACF group than in the ELA group; however, the operative time was greater in the SJACF group ($P < 0.05$). There were no significant differences in Böhler's angle, the Gissane angle, or calcaneal length, height, or width between the two groups at any time point ($P > 0.05$). These imaging values were significantly improved after surgery and at the last follow-up ($P < 0.05$). The VAS scores of the patients in the SJACF group were significantly different from those in the ELA group at the last follow-up ($P < 0.05$). The final AOFAS score and incidence of postoperative complications were better in the SJACF group; however, the difference was not significant ($P > 0.05$). Simultaneously, patients were able to return to work and achieve full weight-bearing earlier in the SJACF group ($P < 0.05$).

Conclusion Both SJACF and ELA improved the clinical outcomes of patients with DIACFs. SJACF reduces surgical wounds and maintains effective reduction and strong internal fixation. It has the advantages of a reduced

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preoperative waiting time, shortened hospital stay, reduced intraoperative fluoroscopy time, alleviated postoperative pain, and accelerated patient recovery.

Keywords Displaced intra-articular calcaneal fracture (DIACF), Subtalar joint arthroscopy, Cannulated screws, Minimally invasive surgery

Background

Calcaneal fracture is the most common type of tarsal fracture, accounting for approximately 1–2% of total body fractures, of which approximately 60–75% involve the articular surface, namely, displaced intra-articular calcaneal fractures (DIACFs) [1]. Calcaneal fracture, a high-energy injury, is mostly caused by falls from a height and car accidents. There is no consensus on the treatment of calcaneal fractures owing to their complexity and high complication rates.

Currently, most DIACFs are treated surgically. A meta-analysis showed that surgical treatment helped patients put on shoes, carry weight, and return to normal work earlier than conservative treatment, and significantly improved their quality of life [2]. Given that uneven articular surfaces increase the incidence of traumatic arthritis, surgical treatment of DIACFs aims to restore calcaneal morphology, especially the articular surface, by restoring the calcaneal length, width, height, and rotation [3]. The extended lateral approach (ELA), first described by Essex-Lopresti in 1952, is the most commonly used surgical approach. Its good field of view facilitates fracture reduction; however, the large incision also increases the incidence of postoperative complications, with ELA associated with 16–43% of wound complications reported in the literature [4–7]. The high incidence of wound healing complications associated with the ELA may be because the lateral calcaneal artery is always located in the vicinity of the incision and that the incision is large, with more extensive soft-tissue involvement. This approach may compromise the blood supply to the entire flap as well as the calcaneal [8]. The high incidence of postoperative complications associated with the ELA has also promoted the development of minimally invasive surgeries. Minimally invasive treatments for calcaneal fractures currently include the tarsal sinus approach, percutaneous closed reduction, and arthroscopy-assisted small incision reduction, all of which have been developed in recent years. The tarsal sinus approach was once considered the new standard to replace the ELA in the treatment of calcaneal fractures; however, its limited field of view increased the difficulty of articular surface reduction during surgery, and it was technically more difficult than ELA for younger medical workers [9]. Percutaneous closed reduction is also a common surgical method mainly applied to simpler and less comminuted calcaneal fractures; however, articular surface reduction limits its use, which is technically challenging. With the proposal of some modified percutaneous approaches and the application of arthroscopy in recent years, the application of the percutaneous approach has been further amplified, and some complex calcaneal fractures can also be effectively treated [10–12]. Therefore, current research is in the pursuit of good fracture reduction based on minimally invasive surgery and the effective reduction of postoperative complications.

Subtalar arthroscopy has been widely used in recent years; however, there are few studies on its application for DIACFs, which mainly involve minimally invasive incisions assisted by subtalar arthroscopy. In these studies, arthroscopy is used to observe the degree of reduction [13, 14]. Therefore, in this study, we investigated the therapeutic effect of subtalar joint arthroscopic reduction combined with cannulated screw fixation (SJACF) for DIACF. This method not only meets the requirements of effective reduction and strong internal fixation but also eliminates the need for additional incisions, which reduces intraoperative soft tissue dissection and the incidence of postoperative complications, as well as enables a clearer observation of fracture reduction by subtalar arthroscopy. The number of intraoperative fluoroscopies performed has also reduced.

To further explore the surgical efficacy of SJACF in the treatment of DIACFs, we compared the efficacy and incidence of complications associated with the ELA and SJACF in the treatment of DIACFs.

Methods

General materials

This was a retrospective randomized controlled study. We analyzed patients with DIACFs admitted to our Foot and Ankle Surgery Department of the Second Affiliated Hospital of Anhui Medical University from January 2020 to January 2023. Patients were randomized into either the ELA or SJACF groups. The inclusion criteria were as follows: (1) age 16–60 years old; (2) unilateral closed, displaced intra-articular calcaneal fracture > 2 mm, type II and type III DIACFs [15]; and (3) follow-up time > 12 months. The exclusion criteria are as follows: (1) open fracture; (2) bilateral calcaneal fracture; and (3) poor ankle joint function before this injury, such as traumatic arthritis, and congenital ankle joint deformity.

Preoperative management

After hospital admission, the affected limb was elevated, ice packs were applied, and other symptomatic treatments were provided until the tissue edema settled (wrinkle sign appeared). Before surgery, lateral calcaneal radiography and calcaneal computed tomography (CT) of the affected side were routinely performed to determine the fracture type. Surgery was performed after swelling of the affected limb subsided and soft tissue conditions were allowed. All surgeries were performed by three senior orthopedic surgeons (all with > 10 years of experience) in the foot and ankle specialties of our hospital. Antibiotics were administered 30 min before surgery in both groups to prevent infection.

Surgical techniques

Group SJACF: Following the administration of general anesthesia and successful tracheal intubation, a high thigh tourniquet was applied and inflated to 260 mmHg. The patient was placed in the lateral position, and the operative area was disinfected with iodine. After diverting the blood of the lower limb, the major portals for subtalar joint arthroscopy consist of the middle, anterolateral, and posterolateral portals (Fig. 1 A–C). These portals were used to clean the synovium and hematoma clots, expose the subtalar articular surface, clean the fracture ends, and clean the crushed bone fragments along the original fracture line. A 2.5-mm Kirschner wire was driven into the calcaneal tuberosity to the opposite side, and another 2.5-mm Kirschner wire was driven into the ankle joint (dorsiflexion) from the anterior border of the fibula; the Kirschner spreader is used to stretch the distance between the two 2.5-mm Kirschner wire while restoring the height and length of the calcaneal initially. The varus of the calcaneal tuberosity can be corrected by increasing the strength of the medial extension. With the guidance of the arthroscope, we can release the fracture ends and restore the calcaneocuboid joint under the naked eye. Then, a 3.5-mm Kirschner wire was inserted into the posterior subtalar joint from the posterior and upper direction of the calcaneal bone to reduce the articular surface and correct the calcaneal varus. Simultaneously, both sides of the calcaneal were squeezed to correct the calcaneal width. During the operation, each fracture block was temporarily fixed with 1.5 mm Kirschner wire (Fig. 1 D–F). After good reduction, lateral and axial imaging data of calcaneal were obtained by C-arm X-ray. Then four to six cannulated screws (ZhengTian Medical Instrument Co., Ltd., TianJin, China) were fixed on the calcaneal bone. The specific number of cannulated screws required was determined based on the degree of fracture displacement (generally included one sustentaculum tali screw, one-to-two subtalar articular screws, and two axial screws). Re-fluoroscopy showed that the calcaneal fracture was well-reduced, the internal fixation position was normal, and the screw length was appropriate. The incisions were repeatedly rinsed with a large amount of normal saline and iodine and sutured layer-by-layer. (Fig. 1 G–I).

Group ELA: The ELA approach was used for all patients in this group, and the surgical procedure was performed as previously described [16].

Postoperative management and evaluation

All patients in the three groups were treated with the same rehabilitation regimen. Following surgery, deep vein thrombosis was avoided mechanically or chemically. Antibiotics were stopped on the first postoperative day, One day after surgery, ankle pump exercises were performed on the affected limb (3–4 times a day, 20–30 sets each time) under the guidance of a doctor, and a lateral radiograph of the calcaneal axis was reviewed. The dressing was changed regularly from 3 days after the operation, and patients were discharged when the incision was free of redness, swelling, and exudation. The incision suture was removed two weeks after surgery, and the patients were instructed to carry out weight-bearing training on the affected limbs and gradually increase the weight until they achieved full weight-bearing. The time needed to achieve full weight-bearing and the time needed to return to work were recorded during follow-up.

The patients were evaluated clinically and radiologically. Clinical assessments, including the visual analog scale (VAS) and American Orthopedic Foot and Ankle Society (AOFAS) hindfoot score, were performed preoperatively and at 1 year postoperatively. The VAS scores

(See figure on next page.)

Fig. 1 **A** 38-year-old male patient with a 3-day left calcaneal fracture caused by a fall from a height was treated in our hospital with subtalar arthroscopic reduction combined with cannulated screw fixation (SJACF). The appearance of the affected limb before surgery showed soft tissue swelling and obvious subcutaneous congestion. **B** Patient's body position and preoperative arthroscopic incision marking. **C** Preoperative fluoroscopy. **D** The subtalar articular surface was significantly displaced and collapsed during the operation. **E** Length and width of the calcaneal with bilateral distraction reduction. **F** Arthroscopic restoration of the articular surface and temporary fixation with a Kirschner wire. **G** Intraoperative fluoroscopy confirmed that the calcaneal force line recovered well, and the articular surface of the posterior subtalar joint and calcaneocuboid joint were well repositioned. **H** Four cannulated screws were fixed, and fluoroscopy again confirmed that the reduction was good, and the length and position of the screws were appropriate. **I** Postoperative incision appearance

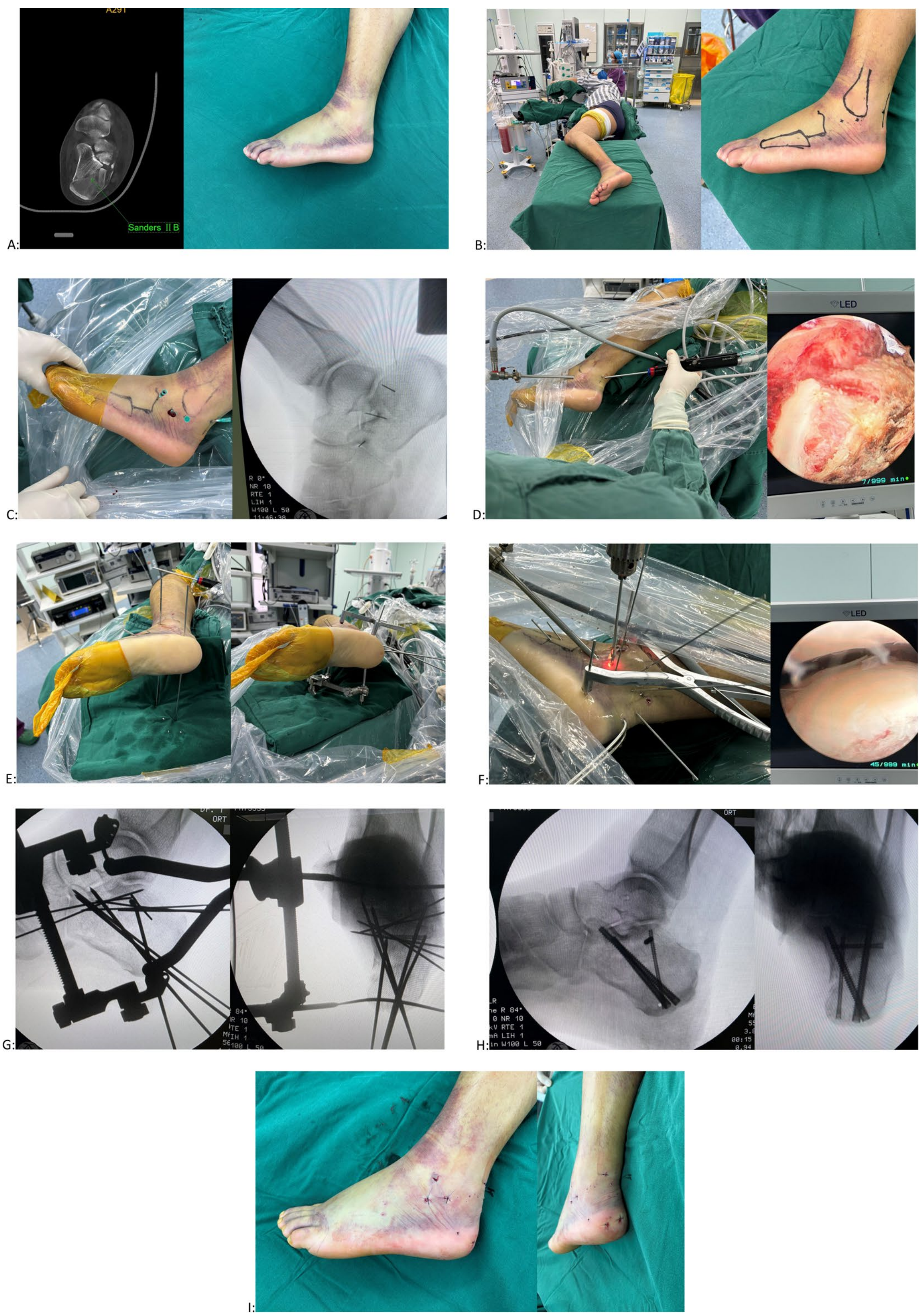

Fig. 1 (See legend on previous page.)

ranged from 0 to 10 points. The AOFAS scores range from 0 to 100, with 90–100 being excellent, 75–89 good, 50–74 average, and < 50 poor. Radiological assessments, including axial and lateral radiographs, were performed before, after, and at 1, 3, 6 months, and 1 year after surgery, including axial and lateral radiographs. Anatomical parameters, such as calcaneal length and height, and Bohler and Gissane angles, were measured laterally, and calcaneal bone width was measured axially. Complications, such as loss of correction, bone nonunion, delayed healing, wound infection, rejection, and deep vein thrombosis, were recorded during follow-up.

Statistical analysis

SPSS software (version 25.0) was used for the statistical analysis. Classified data were statistically analyzed using the chi-squared test or Fisher's exact test ($n<40$ or $t<1$). Continuous data conforming to a normal distribution were expressed as means ± standard deviations. The anatomical parameters of the calcaneal were compared using a paired t-test before and after surgery. Statistical significance was set at $P<0.05$.

Results

Patient characteristics

A total of 60 patients were included in this study, with 29 in the SJACF group and 31 in the ELA group. The SJACF and ELA groups were designated as groups A and B, respectively.

All 60 patients in this study were followed up for at least 12 months. There were no statistically significant differences between the two groups in terms of age, sex, fracture side, Sanders classification, fracture cause, smoking status, and follow-up time ($P>0.05$; Table 1). The preoperative waiting time, length of hospital stay, and intraoperative fluoroscopy time were significantly shorter in Group A than in Group B ($P<0.05$; Table 1); however, it is worth noting that the operation time of Group A patients was longer than that of Group B patients ($P<0.05$; Table 1).

Radiographic outcomes

All data were measured independently by three observers who were unaware of the grouping, and the final results were averaged from the measurements of the three observers. There were no significant differences in Böhler's angle, Gissane angle, or calcaneal length, width, and height between the two groups before and after surgery and at the last follow-up ($P>0.05$; Table 2). The above imaging values in Groups A and B were significantly improved after surgery compared to those before surgery, and the difference was statistically significant ($P<0.05$; Table 3). These improvements were maintained at the final follow-up ($P>0.05$; Table 3).

Functional outcomes

At the last follow-up, the average AOFAS score of Group A was not significantly different from that of Group B ($P>0.05$; Table 4). The proportion of patients in Group A (41.3%) was higher than that in Group B (32.3%).

Table 1 Demographic characteristics of the two study groups

Characteristics	Group A	Group B	Statistics	P-value
Age	46.586 ± 9.829 (28–60)	43.806 ± 9.898 (21–60)	− 1.090	0.28
Sex			0.002	0.962
Male	28 (96.552%)	30 (96.774%)		
Female	1 (3.448%)	1 (3.226%)		
Fracture side			0.243	0.622
Left	15(51.724%)	13(41.935%)		
Right	14(48.276%)	18(58.065%)		
Mechanism of injury				
Traffic accident	2 (6.897%)	3 (9.677%)	0.152	0.697
Falling from height	27 (93.103%)	28 (90.323%)		
Sanders classification			0.029	0.866
II	20 (68.966%)	22 (70.968%)		
III	9 (31.034%)	9 (29.032%)		
Smoking			1.632	0.201
Yes	16 (55.172%)	12 (38.710%)		
No	13 (44.828%)	19 (61.290%)		
Time from injury to operation (days)	5.931 ± 3.504 (3–16)	8.419 ± 4.759 (3–23)	2.293	0.025
Intraoperative fluoroscopy images	3.379 ± 0.677 (3–5)	4.258 ± 0.631 (3–6)	5.206	0
Operative time (min)	90.414 ± 5.308 (78–101)	82.645 ± 6.422 (65–100)	−5.088	0
Hospital stays(days)	10.379 ± 2.541 (7–17)	15.258 ± 5.668 (7–31)	4.348	0
Follow-up period (months)	13.28 ± 1.099 (12–15)	13.84 ± 1.485 (12–17)	1.659	0.102

Table 2 Radiographic outcomes of the two study groups

	Group A	Group B	Statistics	P-value
Angle of Gissane, mean ± SD (range) (°)				
Pre-op	109.138 ± 6.186 (98–121)	110.097 ± 10.374 (84–136)	0.431	0.668
Post-op	124 ± 4.234 (116–134)	124.613 ± 4.295 (115–137)	0.556	0.580
Final follow-up	123.655 ± 4.466 (116–133)	124.065 ± 4.501 (114–135)	0.353	0.725
Böhler's angle, mean ± SD (range) (°)				
Pre-op	7.862 ± 7.234 (− 12–17)	7.968 ± 9.196 (−14–18)	0.049	0.961
Post-op	30.138 ± 4.612 (21–38)	32.226 ± 5.334 (21–42)	1.617	0.111
Final follow-up	29.655 ± 4.631 (21–37)	31.484 ± 4.675 (20–40)	1.521	0.134
Calcaneal length, mean ± SD (range) (mm)				
Pre-op	74.51 ± 5.083 (57.13–84.4)	75.242 ± 4.068 (65.25–84.96)	0.618	0.539
Post-op	78.791 ± 5.071 (62.15–89.66)	79.233 ± 3.667 (73.81–88.36)	0.389	0.699
Final follow-up	78.576 ± 4.997 (61.85–89.15)	78.895 ± 3.502 (73.11–87.36)	0.289	0.774
Calcaneal width, mean ± SD (range) (mm)				
Pre-op	42.771 ± 3.572 (35.21–53.01)	43.171 ± 3.131 (38.19–51.34)	0.461	0.646
Post-op	37.974 ± 4.608 (28.3–50.4)	36.542 ± 2.059 (32.62–40.59)	− 1.536	0.133
Final follow-up	38.090 ± 4.705 (28.52–50.62)	36.794 ± 2.117 (31.35–41.2)	− 1.360	0.182
Calcaneal height, mean ± SD (range) (mm)				
Pre-op	38.260 ± 3.511 (32.42–50.42)	38.411 ± 2.783 (32.29–45.3)	0.185	0.854
Post-op	44.809 ± 3.684 (36.64–53.1)	45.541 ± 2.400 (40.6–51.56)	0.905	0.370
Final follow-up	44.584 ± 3.709 (36.21–52.86)	45.35 ± 2.445 (40.26–51.16)	0.938	0.353

Additionally, there was no statistically significant difference in the VAS scores between the two groups before surgery ($P > 0.05$; Table 4). The VAS scores of patients in the SJACF group at the last follow-up were significantly different from those in the ELA group ($P < 0.05$; Table 4). Compared with Group A patients, Group B patients took longer to achieve full weight bearing. The time to return to normal life was longer in Group B than in Group A ($P < 0.05$; Table 4). During the entire follow-up period, two patients in Group B developed soft tissue infections, which improved after symptomatic treatment, such as dressing changes and administration of antibiotics. No patients experienced screw loosening, implant breakage, bone disunion, or malunion (Table 4).

Discussion

The annual incidence of calcaneal fractures is approximately 11.5 per 100,000 individuals, with a significantly higher incidence in men (16.5 per 100,000 individuals) than in women [17]. In this study, we found that calcaneal fractures occurred more frequently in men who engaged in physical labor. Therefore, timely and effective diagnosis and treatment of calcaneal fractures are of great significance in improving patients' quality of life and reducing the economic and medical burden.

In DIACFs, the presence of a calcaneal articular step or gap not only destroys articular consistency but also increases the incidence of traumatic arthritis after the fracture, which emphasizes the necessity for surgical treatment. Additionally, surgical treatment is useful for reducing the likelihood of malunion, calcaneal height or width loss, and debility following injury, and for allowing normal function of the ankle, hind foot, and Achilles tendon as much as possible [18]. Regarding the choice of surgical method, we should not be limited to the most classical or latest approach. Anatomical reduction of the articular surface, postoperative complications, functional recovery of the patient, and the experience of the surgeon

Table 3 Radiographic outcome measurement of the included patients in the two study groups

Item	Measurements			P-value		
	Pre-op	Post-op	Final follow-up	Pre-op versus post-op	Pre-op versus final	Post-op versus final
Group A						
Angle of Gissane, mean ± SD (range) (°)	109.138 ± 6.186 (98–121)	124 ± 4.234 (116–134)	123.655 ± 4.466 (116–133)	< 0.001	< 0.001	0.358
Böhler's angle, mean ± SD (range) (°)	7.862 ± 7.234 (− 12–17)	30.138 ± 4.612 (21–38)	29.655 ± 4.631 (21–37)	< 0.001	< 0.001	0.109
Calcaneal length, mean ± SD (range) (mm)	74.51 ± 5.083 (57.13–84.4)	78.791 ± 5.071 (62.15–89.66)	78.576 ± 4.997 (61.85–89.15)	< 0.001	< 0.001	0.129
Calcaneal width, mean ± SD (range) (mm)	42.771 ± 3.572 (35.21–53.01)	37.974 ± 4.608 (28.3–50.4)	38.090 ± 4.705 (28.52–50.62)	< 0.001	< 0.001	0.511
Calcaneal height, mean ± SD (range) (mm)	38.260 ± 3.511 (32.42–50.42)	44.809 ± 3.684 (36.64–53.1)	44.584 ± 3.707 (36.21–52.86)	< 0.001	< 0.001	0.041
Group B						
Angle of Gissane, mean ± SD (range) (°)	110.097 ± 10.374 (84–136)	124.613 ± 4.295 (115–137)	124.065 ± 4.501 (114–135)	< 0.001	< 0.001	0.104
Böhler's angle, mean ± SD (range) (°)	7.968 ± 9.196 (− 14–18)	32.226 ± 5.334 (21–42)	31.484 ± 4.675 (20–40)	< 0.001	< 0.001	0.06
Calcaneal length, mean ± SD (range) (mm)	75.242 ± 4.068 (65.25–84.96)	79.233 ± 3.667 (73.81–88.36)	78.895 ± 3.5022 (73.11–87.36)	< 0.001	< 0.001	0.108
Calcaneal width, mean ± SD (range) (mm)	43.171 ± 3.131 (38.19–51.34)	36.542 ± 2.059 (32.62–40.59)	36.794 ± 2.117 (31.35–41.2)	< 0.001	< 0.001	0.111
Calcaneal height, mean ± SD (range) (mm)	38.411 ± 2.783 (32.29–45.3)	45.541 ± 2.400 (40.6–51.56)	45.35 ± 2.445 (40.26–51.16)	< 0.001	< 0.001	0.151

Table 4 Functional outcomes of the two study groups

	Group A	Group B	Statistics	*P*-value
AOFAS ankle-hindfoot score at final follow-up (points)				
Mean ± SD (range)	89 ± 4.496 (79–95)	87.290 ± 4.444 (74–95)	− 1.481	0.144
Excellent, no. (%)	12(41.38%)	10(32.26%)		
Good, no. (%)	17(58.62%)	20(64.51%)		
Fair, no. (%)	0 (0.0%)	1(3.23%)		
Poor, no. (%)	0 (0.0%)	0 (0.0%)		
VAS score for pain (points), mean ± SD (range)				
Pre-op	6.724 ± 0.960 (5–9)	7.065 ± 0.964 (5–9)	1.370	0.176
Final follow-up	0.86 ± 0.639 (0–2)	1.323 ± 0.979 (0–3)	2.141	0.037
Time to full weight-bearing (weeks)	4.724 ± 0.882 (4–7)	8.452 ± 1.261 (6–12)	13.184	0.000
Time to return to work (weeks)	9 ± 1.134 (8–12)	13.258 ± 1.365 (12–16)	13.091	0.000
Complications			1.935	0.164
No	29 (100%)	29 (93.548%)		
Yes	0	2 (6.452%)(Superficial infection)		

are all factors that must be considered before selecting a surgical method. Therefore, we compared the efficacy of the classical ELA and the latest treatment method, SJACF, for DIACFs to provide a reference for DIACF treatment.

Long wait periods and prolonged operation times are risk factors for postoperative incision infection [19]. The

Fig. 2 Group A typical case of a 40-year-old male, left calcaneal fracture, Sanders IIIBC type. **A** Preoperative radiographs. **B** Postoperative radiography showed that the length, height and width of the calcaneal were corrected, and the varus deformity was corrected. **C**, **D**, **E** Postoperatively 1, 3, and 6 months. **F** One year after surgery, the fracture was well healed, and the reduction was not lost

ELA currently has a high associated incidence of postoperative soft tissue complications. In this study, two patients in Group B had wound infections, whereas no patients in Group A had postoperative soft tissue complications. Considering the potential risk of deep tissue dehiscence and infection caused by the large incision, the extensive intraoperative soft tissue stripping, and injury to the calcaneal branch of the common peroneal artery, the waiting time before surgery for ELA patients is longer [20]. Rammelt et al. showed that when surgery was delayed for > 2 weeks, the incidence of deep infection and marginal necrosis in superficial wounds was higher [21]. At the same time, an excessively long waiting time before surgery also leads to difficulties in intraoperative reduction, thus increasing the operation time and the number of intraoperative fluoroscopies required. However, the SJACF method adopted by us does not require extensive stripping of soft tissues around the calcaneal, which greatly reduces damage to the blood flow of the calcaneal. Moreover, this method also reduces the preoperative waiting time. Furthermore, screw fixation also reduces direct contact between the internal fixation device and soft tissue, decreases the probability of needing a second operation to remove the internal fixation, and reduces damage to the local soft tissue.

Anatomical reduction of the articular surface of the calcaneal bone is a key factor that directly affects the functional recovery of patients at later stages. The wide field of view of the ELA reduces the difficulty in reducing the articular surface of the calcaneal bone. Additionally, the combination of plate internal fixation has exhibited certain advantages in restoring the width of the calcaneal bone, maintaining Böhler's angle, and reducing the intra-articular step. Moreover, the failure rate of the internal

Fig. 3 A typical case from Group B was a 58-year-old male with a left calcaneal fracture and Sanders IIC type. **A** Preoperative radiographs. **B** Postoperative radiography showed that the length, height and width of the calcaneal were corrected, and the varus deformity was corrected. **C**, **D**, **E** Postoperative;y 1, 3, and 6 months. **F** One year after the operation, the fracture was well healed with no residual internal fixation

plate fixation was low [22]. Compared with the ELA, subtalar arthroscopy can more directly observe some small articular steps and facet fractures, which cannot be achieved via intraoperative X-ray [23]. Arthroscopic reduction also reduces the number of intraoperative fluoroscopies required. Additionally, combined screw fixation can maintain effective internal fixation. Plate fixation is generally considered the preferred method for reducing DIACF reduction failures. One study reported that cannulated screw fixation has a narrow indication and is more suitable for treating mild Sanders II or III fractures. With the development of new surgical techniques, many studies have shown that screws can achieve biomechanical stability comparable to that of plate fixation, except for comminuted fractures [24–27]. This was confirmed by the imaging results in the present study. Effective reduction was achieved in both groups after surgery, and the reduction was well-maintained at the last follow-up (Figs. 2 and 3). During the entire follow-up period, none of the patients experienced internal fixation loosening or reduction failure.

Based on its ability to provide good articular surface reduction, strong internal fixation, and low postoperative soft tissue risk, SJACF provides patients with an opportunity to carry weight earlier. Our results show that, compared with the ELA, SJACF can help patients carry weight and return to work at an earlier time. Additionally, the postoperative VAS pain and AOFAS functional scores of the patients also showed certain advantages.

The clinical application of subtalar arthroscopy is much lower than that of arthroscopy of the hips, knees, shoulders, and other large joints. Subtalar arthroscopy was first described in 1985 by Parisien et al.; however, its technical aspects may be challenging owing to the unique anatomy of the subtalar joint [28]. Nonetheless, with the advancement of surgical techniques and instruments, the scope of the clinical application of subtalar arthroscopy has gradually expanded. Its application has shifted from simple examination to treatment. In our study, we faced the problem of higher operational difficulty and a longer learning process of reduction under subtalar arthroscopy, which also makes the operation time for SJACF longer than for the ELA; however, we believe that this situation can be improved with the accumulation of operator experience.

There are some limitations to this study: (1) the sample size was small, and a larger clinical sample size needs to be collected for the overall study; (2) this was a retrospective study. Thus, it would be worthwhile to conduct prospective studies in the future; and (3) although the measurement of imaging data is averaged by three measurements, there may still be data errors.

Conclusion

In this study, the use of the ELA and SJACF in the treatment of DIACFs achieved good imaging results. SJACF had advantages over the ELA in reducing patients' preoperative waiting time, intraoperative fluoroscopy times, length of hospital stay, and postoperative complications, in addition to accelerated postoperative rehabilitation and functional recovery. Therefore, SJACF is a safe and effective treatment option for DIACF.

Abbreviations

AOFAS	American orthopaedic foot and ankle society
ELA	Extended lateral approach
DIACFs	Displaced intra-articular calcaneal fractures
SJACF	Subtalar joint arthroscopic reduction combined with cannulated screw fixation
VAS	Visual analogue scale

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Authors' contributions

JZ developed the idea of the study. HY participated in its design and helped draft the manuscript. SZ, QZ, CH, and NZ contributed to the acquisition and interpretation of data. JZ revised the manuscript. HY, SZ, and QZ contributed equally to this work. All authors read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate

This study has been approved by the Hospital Ethics Committee of our institution and all patients provided informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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