Comparison of the modified sinus tarsi approach versus the extensile lateral approach for displaced intra-articular calcaneal fractures

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Background: This study sought to assess and compare the clinical efficacy and complications of a modified sinus tarsi approach (MSTA) and the extensile lateral approach (ELA) in the treatment of displaced intra-articular calcaneal fractures.

Methods: This retrospective study enrolled 108 patients (117 feet) with Sanders II–IV calcaneal fractures, including 52 patients (56 feet) in the MSTA group and 56 patients (61 feet) in the ELA group. The functional and radiological results of the affected feet were analysed retrospectively. Functional evaluation included American Orthopaedic Foot and Ankle Society (AOFAS), visual analog scale (VAS), and Short Form-36 Health Survey (SF-36). Radiological evaluation included preoperative and postoperative changes in the Bohler Angle, Gissane Angle, length, width, and height of the calcaneus. The postoperative complications were also collected and analysed. The independent-samples *t*-test and analysis of variance (ANOVA) were employed to compare differences between the two groups. Differences within the same group were compared by paired Student's *t*-test, and categorical variables were compared using the chi-square test.

Results: The postoperative functional and radiological results showed that the mean AOFAS, VAS and physical component summary of SF-36 scores in the MSTA group were higher than those in the ELA group ($P<0.05$). After surgery, the Bohler and Gissane angles were significantly improved in both groups, as were the length, width, and height of the calcaneus; no statistically significant differences existed between the two groups. The incidences of wound healing complications and postoperative sural nerve injury were lower in the MSTA group than in the ELA group ($P<0.000$).

Conclusions: The MSTA can achieve similar effects to the ELA in terms of anatomical reconstruction and functional recovery. It also can also effectively reduce the incidences of wound healing complications and postoperative sural nerve injury, and shorten the length of hospital stay.

Keywords: Calcaneal fractures; sinus tarsi approach (STA); extensile lateral approach (ELA); minimally invasive

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Introduction

Calcaneal fractures are the most common type of tarsal bone fracture (1). Intra-articular calcaneal fractures, which comprise approximately 75% of all calcaneal fractures, can seriously affect locomotion (2). In patients with displaced intra-articular calcaneal fractures (DIACFs), conservative treatment is associated with malunion, subtalar arthritis, subfibular impingement, and other sequelae, which can ultimately lead to dysfunction or disability (3). Therefore, open reduction and internal fixation (ORIF) is generally recommended for DIACF (4). The primary goal of ORIF in the treatment of DIACFs is to restore the congruence of the subtalar joint. This fixation not only requires the anatomical reduction of the calcaneus, subtalar articular surface, and heel tubercle, but also stable and firm internal fixator support to facilitate early rehabilitative exercise (5).

The extensile lateral approach (ELA) has become a routine approach in the surgical treatment of DIACF. Although the ELA has the advantages of fully exposing the fracture location and permitting direct joint reduction, it can cause multiple complications, including superficial or deep infection, wound-edge necrosis, sural nerve injury, peroneal tendon injury, and subtalar arthritis (6,7). In efforts to reduce the iatrogenic damage and wound-related complications caused by the ELA, numerous scholars have used a variety of minimally invasive approaches to treat intra-articular calcaneal fractures. The sinus tarsi approach (STA) is a frequently used minimally invasive method which allows the surgeon to reduce the subtalar joint surface under direct vision and expose the calcaneal joint by extending the incision if necessary. Furthermore, through the STA, locking plates can be inserted to attain firm fixation in the affected limb and minimize soft-tissue damage.

In the present study, we aimed to evaluate and compare the clinical efficacy and complications of a modified STA (MSTA) and the ELA in the treatment of intra-articular calcaneal fractures after ORIF. We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/atm-21-1226).

Methods

Patients

Our study was a retrospective cohort study. We retrospectively reviewed the cases of all patients who were admitted to our hospital for the repair of intra-articular calcaneal fractures between July 2016 and September 2018. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). The study was reviewed and approved by the ethics committee of the Second Affiliated Hospital of Soochow University, and informed consent was obtained from all participants. The inclusion criteria were as follows: (I) aged between 20 and 70 years old; (II) patient had closed intra-articular calcaneal fractures classified as Sander's type II–IV; (III) patient received ORIF via a MSTA or the ELA; (IV) patient had no major medical comorbidities, such as severe hypertension, diabetes, cancer, history of myocardial infarction, or stroke; and (V) patient was followed up for at least 12 months. The exclusion criteria were as follows: (I) patient suffered an extra-articular or open calcaneal fracture; (II) other fresh fractures or neuromuscular injuries existed on the affected side of foot; (III) patient had rheumatoid arthritis or osteoarthritis, severe osteoporosis, severe peripheral vascular disease, or a history of calcaneal fractures; and (IV) patient was followed up for less than 12 months.

A total of 108 patients (117 feet) who met these inclusion criteria were enrolled for the analysis. Fifty-two patients (56 feet) who were treated using the MSTA were included as the MSTA group, and 56 patients (61 feet) who were treated using the ELA were included as the ELA group. All procedures were performed by the same surgeon (Bo Jiang). All of the patients were required to cease alcohol consumption and smoking after being diagnosed with the calcaneal fractures.

The MSTA group comprised 39 males (75.00%) and 13 females (25.00%) with an average age of 41.69±10.57 years. According to the Sander's classification, there were 19, 31, and 6 feet with type II, III, and IV fractures, respectively. The time elapsed from injury to surgical intervention ranged from 2 to 8 days, with the average interval being 4.11±1.27 days. The total length of hospital stay for patients in the MSTA group was 8.23±1.73 days. The ELA group comprised 43 males (76.79%) and 13 females (23.21%) with an average age of 44.95±10.62 years. According to the Sander's classification, there were 19, 37, and 5 feet with type II, III, and IV fractures, respectively. The time elapsed from injury to surgical intervention ranged from 5 to 12 days, with the average interval being 7.05±1.45 days. The total length of hospital stay for patients in the ELA group was 12.66±2.26 days. Demographic data were also collected for patients in both groups, including the injured side and the mechanism of injury (*Table 1*).

Table 1 Demographic data of the patients

Variable	MSTA group	ELA group	P value
Sex (male/female)	39/13	43/13	0.828
Age (years, mean ± SD)	41.69±10.57	44.95±10.62	0.114
Side (right foot/left foot)	30/26	34/27	0.814
Etiology, n (%)			0.639
Fall from a height	46 (82.14)	48 (78.69)	
Traffic accidents	10 (17.86)	13 (21.31)	
Sanders classification, n (%)			0.816
Type II	19 (33.93)	19 (31.15)	
Type III	31 (55.36)	37 (60.65)	
Type IV	6 (10.71)	5 (8.20)	
Wait time from injury to surgery (days, mean ± SD)	4.11±1.27	7.05±1.45	0.000
Length of hospital stay (days, mean ± SD)	8.23±1.73	12.66±2.26	0.000

Figure 1 The surgical incision marker (arrow) and sural nerve marker (purple lines) in a patient treated with the MSTA. MSTA, modified sinus tarsi approach.

MSTA

In the MSTA group, general anesthesia or spinal anesthesia was administered to all patients. While under anesthesia, the patient was placed in the lateral position with the affected side on top, and a pneumatic tourniquet was applied to the thigh on the affected side. If the patient had a bilateral calcaneal fracture, they were placed in the prone position instead. An incision was made from the tip of the lateral malleolus to the point of the anterior calcaneal process. The direction of the incision was parallel to the plane of the plantar (*Figure 1*). The main sural nerve was located in the area below the incision and did not need to be exposed during the dissection. The subcutaneous tissue, and inferior extensor retinaculum were cut along the skin incision to expose the peroneal tendon sheath, which was pulled downward. Maintaining the integrity of the tendon sheath and surrounding subcutaneous tissue was crucial. The extensor digitorum brevis terminal tendon was carefully stripped off, and the sinus tarsi was exposed. To explore the posterior articular surface of the calcaneus, the subtalar joint capsule was cut open, and the hematoma and adipose tissue were cleaned. Sharp dissection was performed through the sinus tarsi incision to strip the lateral calcaneal wall, and the calcaneus ligament was cut off. It was then possible to expose and further reduce the collapsed posterior articular surface of the calcaneus through the use of a periosteum stripper (*Figure 2A*). A Kirschner wire was drilled below the articular surface along the direction of the sustentaculum tali for temporary fixation. A percutaneous Steinmann pin was drilled into the calcaneal tuberosity to reduce the varus deformity of the calcaneus and comminuted lateral wall. Percutaneous Kirschner wires were then drilled along the calcaneal long axis for temporary fixation. Next, C-arm fluoroscopy was used to observe the lateral and axial positions of the calcaneus to ensure that the length, width, and height of the calcaneus, the posterior articular surface, and the Bohler and Gissane angles had been satisfactorily restored. Finally, a locking plate was inserted and placed on the lateral side of the calcaneus through the modified

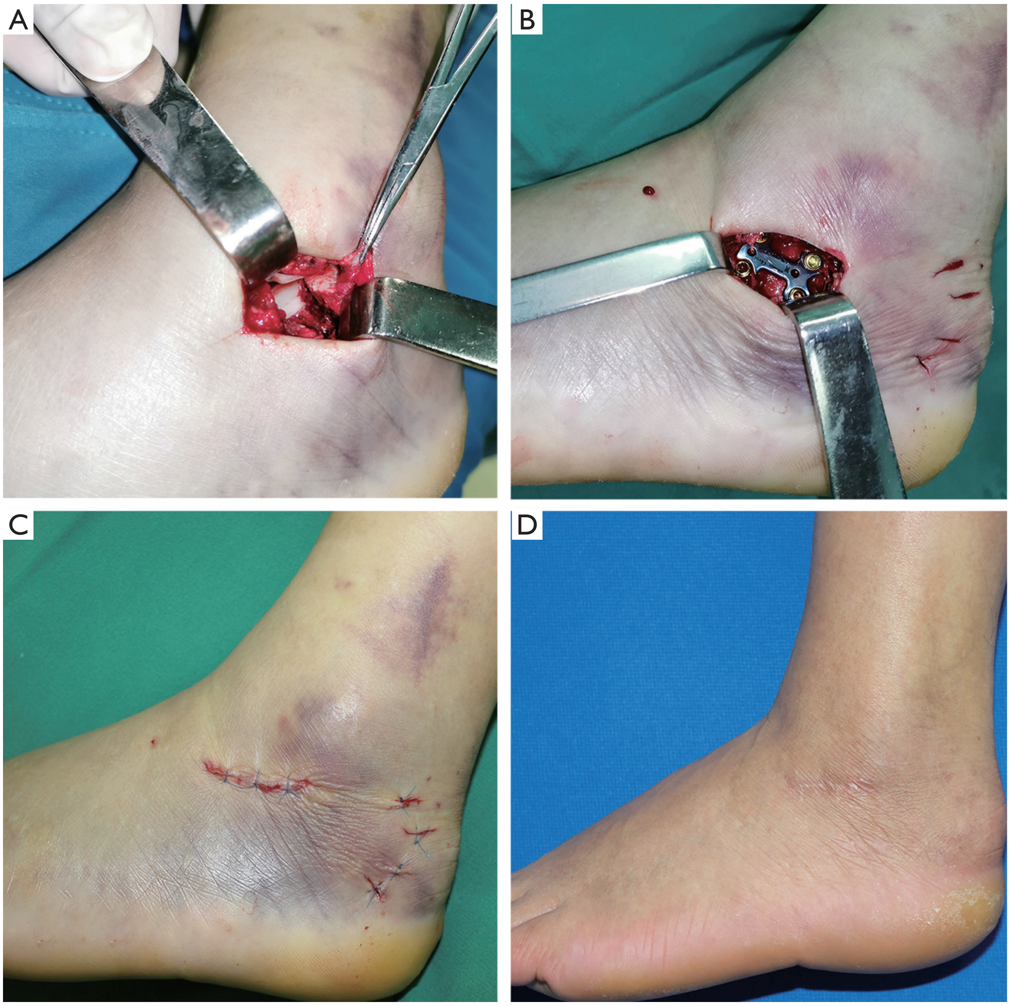

Figure 2 Intraoperative and postoperative photos of a patient treated through the MSTA. (A) The posterior articular surface of the calcaneus was exposed; (B) a locking plate was inserted and placed on the lateral side of the calcaneus; (C) the MSTA incision was sutured; (D) the appearance of the incision scar at 12 months after surgery. MSTA, modified sinus tarsi approach.

sinus tarsi incision (*Figure 2B*). Several small incisions were made on the lateral calcaneal skin according to the location of the screw holes, into which the screws were inserted (*Figure 2C,D*). In the MSTA group, none of the patients underwent ligamentum calcaneus repair, or bone grafting on the bone defect. The incision was sutured after the placement of a negative-pressure drainage ball or a drainage strip. The affected limb was fixed with plaster or braces for 2 to 3 weeks following surgery, and weight-bearing began at the 8th week postoperatively.

ELA

In the ELA group, the standard ELA was used to reduce and fix the calcaneal fractures. First, a smooth L-shaped incision was made from between the lateral malleolus and the Achilles tendon to the bottom of the 5th metatarsal (*Figure 3A*). The full-thickness flap which contained the sural nerve and peroneal tendons was separated at the level of the periosteum and fixed temporarily with 3 Kirschner wires. Next, the collapsed articular surface was pried up, with the articular fragments fixed with Kirschner wires. The calcaneus was restored to its normal shape through extruding and pulling. After the length, width, and height of calcaneus, the posterior articular surface, and the Bohler and Gissane angles had been satisfactorily restored, a calcaneal locking plate was used for fixation (*Figure 3B*). Postoperative management for the ELA group was the same

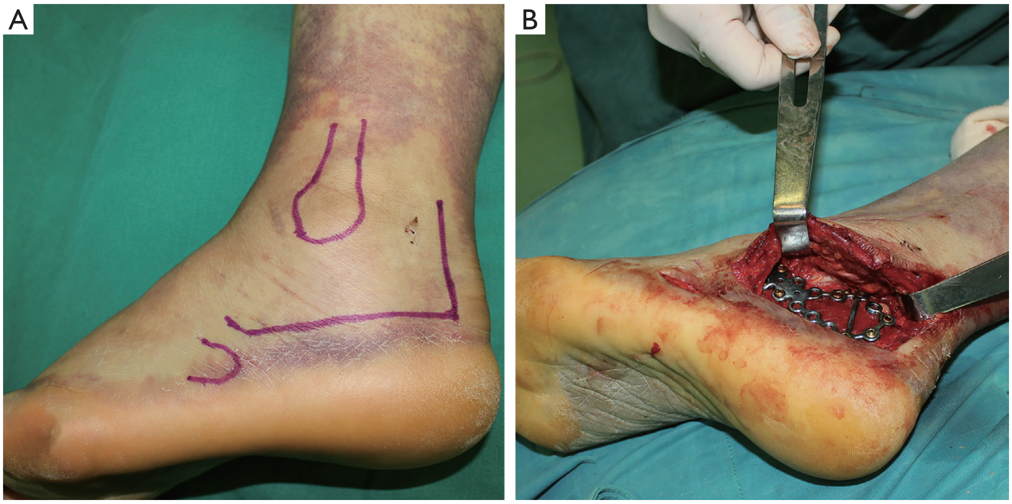

Figure 3 Preoperative and intraoperative photos of a patient treated through the ELA. (A) The surgical incision marker of ELA; (B) a locking plate was inserted and placed on the lateral side of the calcaneus. ELA, extensile lateral approach.

as that described above for the MSTA group.

Functional and radiological evaluations

All patients underwent clinical and radiological evaluations pre- and postoperatively. The clinical evaluation results were obtained from the American Orthopaedic Foot and Ankle Society (AOFAS) and included ankle–hindfoot score, the visual analogue scale (VAS), and the Short Form-36 Health Survey (SF-36) questionnaire. The postoperative complications experienced by all participants in the study were also collected. The AOFAS score assigns a score (maximum of 100 points) to normal hindfoot and ankle joints with respect to pain (50 points), function (40 points), and alignment (10 points). We considered 90–100 as an excellent score, 75–89 as good, 50–74 as medium, and below 50 as poor. The VAS, which ranges from 0 (no pain) to 10 (extreme pain, seriously affects work and life), was used to measure the level of pain. The SF-36 questionnaire contains 36 items grouped into the following 8 domains: physical function, role physical, bodily pain, general health, vitality, social function, role emotional, and mental health. Based on all of these items, a physical component summary (PCS) and a mental component summary (MCS) of health can be calculated. The SF-36-PCS comprises physical function, role physical, bodily pain, and general health. The SF-36-MCS comprises vitality, social function, role emotional, and mental health.

Radiological assessment indicators included the following aspects. Preoperative lateral and axial X-ray imaging and a computed tomography (CT) scan were performed to evaluate the condition of the damaged calcaneus and to classify the fractures. Lateral and axial X-ray radiographs of the damaged calcaneus were performed at 4 weeks, 3 months, and 12 months after surgery. Then, the changes in the Bohler and Gissane angles, and the calcaneal length, width, and height before and after the operation were calculated based on the results of X-ray imaging and CT scan (*Figures 4,5*). The healing of the calcaneal fractures and the incidence of complications were also evaluated.

Statistical analysis

Statistical analyses were performed using SPSS 19.0 software (SPSS, Chicago, Illinois, USA). Continuous variables were expressed as the means ± standard deviations (SDs), and categorical variables were expressed as numbers (N) and percentages (%). The independent-samples *t*-test and analysis of variance (ANOVA) were employed to compare differences between the two groups. Differences within the same group were compared by paired Student's *t*-test, and categorical variables were compared using the chi-square test. $P<0.05$ was considered to be statistically significant.

Figure 4 A patient treated through the MSTA. (A,B) Preoperative and postoperative lateral CT scan, respectively; (C,D) preoperative and postoperative axial CT scan, respectively. MSTA, modified sinus tarsi approach.

Results

Functional evaluation

The follow-up time in the MSTA group ranged from 12 to 24 months, with an average follow-up of 16.65±2.74 months. The follow-up time in the ELA group ranged from 12 to 30 months, with an average follow-up of 17.63±3.22 months. After the last follow-up, the AOFAS score of the MSTA group was 67–99, with the average score being 80.57±7.80. In the ELA group, the AOFAS score was 53–99, with an average score of 77.34±8.29 (P=0.033). The favorable outcome rate of the affected feet was 80.36% and 72.13% in the MSTA and ELA groups, respectively. The preoperative mean VAS score was 6.80±1.30 and 6.79±1.18 for the MSTA and ELA groups, respectively (P=0.942). After the last follow-up, the mean VAS score was 1.66±0.98 in the MSTA group and 2.03±0.98 in the ELA group (P=0.043). The results of the SF-36 questionnaire showed that the average PCS scores of the MSTA and ELA groups were 77.91±5.03 and 74.20±5.07 (P<0.000), respectively. The average MCS scores of the MSTA and ELA groups were 74.84±7.77 and 72.70±8.21 (P=0.153), respectively (*Table 2*).

Radiological evaluation

In both groups, postoperative lateral and axial calcaneal radiographs showed good fracture reduction and

Figure 5 A patient treated through the ELA. (A,B) Preoperative and postoperative lateral CT scan, respectively; (C,D) preoperative and postoperative axial CT scan, respectively. ELA, extensile lateral approach.

Table 2 Functional evaluation parameters of the two groups

Outcomes	MSTA group	ELA group	P value
Follow-up time (months, mean ± SD)	16.65±2.74	17.63±3.22	0.096
AOFAS (score, mean ± SD)	80.57±7.80	77.34±8.29	0.033
Excellent	17.86%	13.11%	–
Good	62.50%	59.02%	–
Fair	19.64%	27.87%	–
Preoperative-VAS	6.80±1.30	6.79±1.18	0.942
Postoperative-VAS	1.66±0.98	2.03±0.98	0.043
SF-36-PCS	77.91±5.03	74.20±5.07	0.000
SF-36-MCS	74.84±7.77	72.70±8.21	0.153

Table 3 Radiological evaluation parameters of the two groups

Parameters	MSTA group			ELA group			MSTA *vs.* ELA	
	Preoperative	Postoperative	Within P value	Preoperative	Postoperative	Within P value	P value preoperative	P value postoperative
Bohler angle	13.07±7.87	27.27±3.97	0.000	11.20±7.13	28.61±4.71	0.000	0.179	0.101
Gissane angle	118.16±113.23	124.70±6.87	0.000	117.85±12.97	126.59±4.55	0.000	0.899	0.079
Length	71.11±3.88	77.14±2.98	0.000	71.38±3.00	77.44±3.00	0.000	0.589	0.766
Width	54.07±5.20	46.05±3.89	0.000	55.33±5.86	46.84±4.74	0.000	0.333	0.386
Height	39.73±3.22	45.04±3.65	0.000	38.54±3.10	44.36±2.82	0.000	0.044	0.263

Table 4 Postoperative complications

Complications	MSTA group		ELA group		P value
	No.	Proportion	No.	Proportion	
Wound healing complications	3	5.36	9	14.75	0.000
Superficial infection	3	5.36	5	8.20	
Deep infection	0	0	2	3.28	
Wound-edge necrosis	0	0	2	3.28	
Sural nerve injury	1	1.79	4	6.56	0.000
Subtalar arthritis	1	1.79	2	3.28	0.000

fixation compared with the preoperative results, and the postoperative Bohler angle, Gissane angle, and calcaneal width, length, and height were all significantly corrected. However, no significant intergroup differences were observed for any of these variables (P>0.05) (*Table 3*).

Postoperative complications

After surgery, the incidence of wound healing complications was 5.36% and 14.75% in the MSTA and ELA groups (P<0.000), respectively. In the MSTA group, superficial infection of the surgical incision occurred in 3 feet, which healed after dressing change. In the ELA group, 5 feet had superficial infection of the surgical incision, which healed after dressing change. And 2 feet had deep soft-tissue infection with skin necrosis at the wound edge, which were cured by local debridement and dressing change. During the follow-up period, 1 foot in the MSTA group suffered sural nerve injury and dorsolateral foot numbness; at 1 year after the operation, these symptoms had subsided without special treatment. In the ELA group, sural nerve injury occurred in 4 feet, with obvious numbness on the dorsolateral side of the foot. At 1 year after the operation, the symptoms had improved in 3 feet, but 1 foot showed no significant changes. During the follow-up period, 2 feet in the ELA group developed subtalar arthritis and tolerable pain requiring no special treatment. There were no cases of calcaneal malunion in either of the groups. The incidences of sural nerve injury and subtalar arthritis in the MSTA group were lower than those in the ELA group (*Table 4*).

Discussion

A minimally invasive incision approach is considered the future direction in the development of calcaneal fracture treatment (8). The traditional L-shaped incision cuts off the blood supply to the center and front of the lateral calcaneal wall and destroys the vascular network of the plantar flap. Therefore, the complication rate of wound healing is 11–24.9%, which seriously affects the treatment of these fractures (6,9). Meanwhile, because of its minimally invasive nature and lower incidence of wound healing complications, the STA has been used increasingly frequently in the treatment of calcaneal fractures. In this study, the rate of

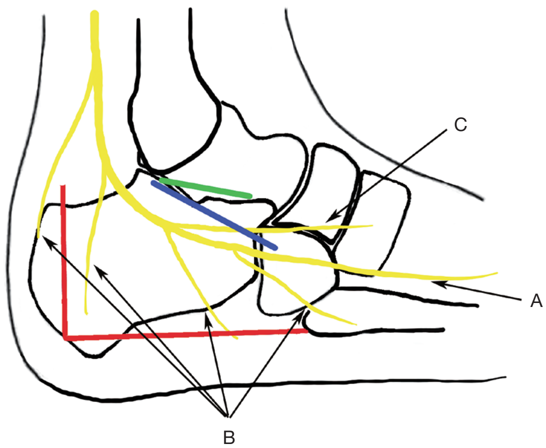

Figure 6 The anatomical diagram of the sural nerve. (A) The sural nerve trunk; (B) lateral calcaneal branches (LCBs); (C) anastomotic branch (AB). Red line: incision marker of ELA. Blue line: incision marker of traditional STA. Green line: incision marker of MSTA. ELA, extensile lateral approach; MSTA, modified sinus tarsi approach.

wound complications in the ELA group was 14.75%, which was significantly higher than that in the MSTA group (5.36%) and similar to the rates reported in relevant reports (10).

One major focus of our study was to compare the incidence of sural nerve injury between the two groups. According to the study of Smyth (11), the sural nerve is known to give rise to a variable number of lateral calcaneal branches (LCBs) and might give rise to an anastomotic branch connecting to the intermediate dorsal cutaneous nerve (*Figure 6*). Lawrence and Smyth demonstrated that in 34 cadaveric foot specimens, each specimen had at least 1 LCB (11,12), with the number of LCBs ranging from 1 to 5. Although the ELA incision route did not pass through the main sural nerve, the position of the LCBs put them at significant risk of transection when the full thickness flap was elevated off the calcaneus. This may be one of the reasons for the sural nerve symptoms seen following ORIF of the calcaneus. According to relevant studies, the incidence of sural nerve symptoms after surgery with the ELA is 6.68–7.69% (7,11).

Meanwhile, in the anatomical study of Smyth, 12% of the specimens showed the sural nerve trunk intersecting with the traditional STA path, and 53% of the specimens showed an anastomotic branch intersecting with the STA path. Because of this, there was still a 3–5% chance of sural nerve damage in the treatment of calcaneal fractures through traditional STA (13-15). Through these studies, it can be observed that since the traditional STA incision is a 4- to 5-cm-long incision running diagonally downward from the tip of the lateral malleolus to the base of the 4th metatarsal bone, it brings the probability of injury to the peroneal tendons, the sural nerve trunk, and its anastomotic branch. Therefore, to minimize sural nerve injury and wound complications, we chose a modified sinus tarsi incision approach, in which the incision ran from the tip of the lateral malleolus to the apex of the anterior process of the calcaneus, basically parallel to the plantar plane. Both the peroneal tendons and the sural nerve trunk were located in the area below the incision (*Figure 6*). During the operation, there was no need to expose the peroneal tendons and the sural nerve, and only dissection of the surface of the calcaneal lateral wall was needed. After the locking plate had been placed correctly, several small incisions were made in the skin at the positions corresponding to the screw holes. Then, the incisions were expanded from the inside to the outside with vascular forceps by blunt separation, which allowed locking screws to be fixed with minimal damage to the sural nerve branch and subcutaneous small blood vessels. Notably, the length of the incision in the MSTA group was only 3–4 cm.

In the present study, 4 dorsolateral feet (6.56%) in the ELA group experienced numbness, compared with only 1 in the MSTA group (1.79%). Among them, 3 feet in the ELA group and 1 foot in the MSTA group had experienced spontaneous remission at 1 year after surgery. We considered that these cases were related to excessive pulling of the skin and soft tissue, and were not complications of sural nerve trunk injury.

Another important finding of our study was that due to the protection of the soft tissue and blood supply, the wait time of patients in the MSTA group from injury to surgery was significantly shorter than that in the ELA group (4.11±1.27 *vs.* 7.05±1.45 days, P<0.000). A study by Shuler *et al.* (16) showed that the longer the interval between injury and surgery for DIACF, the higher the incidence of wound healing complications. Their study reported that in patients treated through the ELA, the incidence of wound complications was 16.6% among those who received surgery 4.8 days after injury and 42.5% among those who received surgery 9.9 days after injury. Similarly, Kwon *et al.* (17) concluded that the delayed fixation of closed DIACF was associated with an increased incidence of wound complications in STA treatment. In their study, a delay in the fixation of fractures of more than 2 weeks saw a significant increase in the incidence of wound-related complications, up to 15.2%, while the incidence of wound complications was only 2.1% among patients treated within 1 week of injury. However, Li (18) arrived at the opposite conclusion, suggesting that a 6-day recovery period for soft tissue may be necessary for safety in the STA treatment, and a recover period of less than 6 days would lead to a higher incidence of complications and severe wound complications. The present study validates the views of Shuler and Kwon by indicating that patients in the STA group did not need to wait for limb swelling to completely disappear under the condition of similar injury severity and surgical technique. In our study, 13 feet (23.21%) in the MSTA group underwent surgery while tension blisters were still present, and no wound healing complications occurred postoperatively. However, patients in the ELA group needed to wait for the swelling to subside and skin lines to appear in order to avoid as many surgical incision healing complications as possible. As a result, the overall length of hospital stay in the MSTA group was shorter than that in the ELA group, which reduced the economic burden on the MSTA patients, and ensured favorable prognosis and satisfaction with the treatment.

It is worth noting that, according to previous reports, although the occurrence of soft-tissue complications can be effectively reduced through the use of minimally invasive techniques, the STA still provides poor visualization, inadequate reduction, and unreliable fixation compared to the ELA (19). More specifically, the reduction of incision-related complications requires minimal incisions, and intra-articular fractures require good anatomic reduction (4,20). Due to the fragility of the calcaneus, strong internal fixation is required, especially in the treatment of older patients with comminuted calcaneal fractures, severely compressed articular surface calcaneal fractures, and osteoporotic fractures. Interestingly, we found that despite providing limited intraoperative exposure, the MSTA allowed us to directly reduce the posterior facet joints and place the calcaneal locking plate. Combined with percutaneous nailing, we were able to minimize the incision while providing more powerful internal fixation support than screws, Kirschner pins, or miniature steel plates. After surgery, the Bohler angle, Gissane angle, and the length, width, and height of the calcaneus were significantly improved in both the MSTA group and the ELA group, and there were no statistically significant differences between the two groups. The VAS and SF-36 scores of the two groups also showed no significant difference, and the AOFAS hindfoot score of the MSTA group was higher than that of the ELA group. The results showed that the MSTA combined with locking plate internal fixation could achieve anatomical reconstruction of the calcaneus and was slightly superior to the traditional ELA in terms of postoperative foot function recovery. A recent meta-analysis of Sanders type II/III DIACF involving 721 feet showed significantly less wound healing complications in the STA compared to ELA. No other differences, such as calcaneal anatomy restoration, functional outcomes, implant removal and injury to the peroneal tendons and sural nerve, were found in outcomes (9). The results of this study were consistent with our findings.

Through our analysis, we found that MSTA is a challenging technique that requires a thorough understanding of the fracture type and calcaneal anatomy, and carries a steep learning curve for young physicians. However, once mastered, this technique can effectively reduce the incidence of postoperative sural nerve injury and wound healing complications, and shorten the length of hospital stay. However, our study suffered from several limitations. First, our study on severe complex calcaneal fractures was insufficient. While this study proved that the STA has good applicability in the treatment of Sanders II/III calcaneal fractures, which was consistent with previous studies (21-23), it did not involve many cases of Sanders IV, senile, or osteoporotic calcaneal fractures; therefore, it is not representative of these fracture types. Second, the follow-up time was short, and this study lacked a long-term efficacy evaluation and randomized controlled study design. Therefore, it is necessary to conduct further studies with a larger sample size, longer follow-up time, and randomized controlled trial design to obtain more accurate efficacy evaluation.

Conclusions

In conclusion, our study showed that for DIACF, the MSTA was able to achieve similar effects of anatomical reconstruction and postoperative foot function recovery as the ELA, while effectively reducing the incidence of postoperative sural nerve injury and wound healing complications, and shortening the length of hospital stay. Therefore, the MSTA has become our preferred method for the treatment of DIACF in clinical practice.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/atm-21-1226). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). The study was reviewed and approved by the ethics committee of the Second Affiliated Hospital of Soochow University, and informed consent was obtained from all participants.

References

1. Buzzi R, Sermi N, Soviero F, et al. Displaced intra-articular fractures of the calcaneus: ORIF through an extended lateral approach. Injury 2019;50 Suppl 2:S2-S7.
2. Bai L, Hou YL, Lin GH, et al. Sinus tarsi approach (STA) versus extensile lateral approach (ELA) for treatment of closed displaced intra-articular calcaneal fractures (DIACF): A meta-analysis. Orthop Traumatol Surg Res 2018;104:239-44.
3. Pitts CC, Almaguer A, Wilson JT, et al. Radiographic and Postoperative Outcomes of Plate Versus Screw Constructs in Open Reduction and Internal Fixation of Calcaneus Fractures via the Sinus Tarsi. Foot Ankle Int 2019;40:929-35.
4. Veltman ES, Doornberg JN, Stufkens SA, et al. Long-term outcomes of 1,730 calcaneal fractures: systematic review of the literature. J Foot Ankle Surg 2013;52:486-90.
5. Xu J, He Z, Zhang G, et al. An experimental study on the digital precision of internal fixation via the sinus tarsi approach for calcaneal fractures. J Orthop Surg (Hong Kong) 2019;27:2309499019834072.
6. Zhan J, Hu C, Zhu N, et al. A modified tarsal sinus approach for intra-articular calcaneal fractures. J Orthop Surg (Hong Kong) 2019;27:2309499019836165.
7. Seat A, Seat C. Lateral Extensile Approach Versus Minimal Incision Approach for Open Reduction and Internal Fixation of Displaced Intra-articular Calcaneal Fractures: A Meta-analysis. J Foot Ankle Surg 2020;59:356-66.
8. Carr JB. Surgical treatment of intra-articular calcaneal fractures: a review of small incision approaches. J Orthop Trauma 2005;19:109-17.
9. Nosewicz TL, Dingemans SA, Backes M, et al. A systematic review and meta-analysis of the sinus tarsi and extended lateral approach in the operative treatment of displaced intra-articular calcaneal fractures. Foot Ankle Surg 2019;25:580-8.
10. Daws SB, Neary K, Lundeen G. Short-Term Radiographic Outcomes of Calcaneus Fractures Treated With 2-Incision, Minimally Invasive Approach. Foot Ankle Int 2019;40:1060-7.
11. Smyth NA, Zachwieja EC, Buller LT, et al. Surgical approaches to the calcaneus and the sural nerve: There is no safe zone. Foot Ankle Surg 2018;24:517-20.
12. Lawrence SJ, Botte MJ. The sural nerve in the foot and ankle: an anatomic study with clinical and surgical implications. Foot Ankle Int 1994;15:490-4.
13. Kline AJ, Anderson RB, Davis WH, et al. Minimally

invasive technique versus an extensile lateral approach for intra-articular calcaneal fractures. Foot Ankle Int 2013;34:773-80.
14. Yeo JH, Cho HJ, Lee KB. Comparison of two surgical approaches for displaced intra-articular calcaneal fractures: sinus tarsi versus extensile lateral approach. BMC Musculoskelet Disord 2015;16:63.
15. Zhang T, Su Y, Chen W, et al. Displaced intra-articular calcaneal fractures treated in a minimally invasive fashion: longitudinal approach versus sinus tarsi approach. J Bone Joint Surg Am 2014;96:302-9.
16. Shuler FD, Conti SF, Gruen GS, et al. Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures: does correction of Bohler's angle alter outcomes? Orthop Clin North Am 2001;32:187-92, x.
17. Kwon JY, Guss D, Lin DE, et al. Effect of Delay to Definitive Surgical Fixation on Wound Complications in the Treatment of Closed, Intra-articular Calcaneus Fractures. Foot Ankle Int 2015;36:508-17.
18. Li S. Wound and Sural Nerve Complications of the Sinus Tarsi Approach for Calcaneus Fractures. Foot Ankle Int 2018;39:1106-12.
19. Bedigrew KM, Blair JA, Possley DR, et al. Comparison of Calcaneal Exposure Through the Extensile Lateral and Sinus Tarsi Approaches. Foot Ankle Spec 2018;11:142-7.
20. De Boer AS, Van Lieshout EM, Den Hartog D, et al. Functional outcome and patient satisfaction after displaced intra-articular calcaneal fractures: a comparison among open, percutaneous, and nonoperative treatment. J Foot Ankle Surg 2015;54:298-305.
21. Kikuchi C, Charlton TP, Thordarson DB. Limited sinus tarsi approach for intra-articular calcaneus fractures. Foot Ankle Int 2013;34:1689-94.
22. Basile A, Albo F, Via AG. Comparison Between Sinus Tarsi Approach and Extensile Lateral Approach for Treatment of Closed Displaced Intra-Articular Calcaneal Fractures: A Multicenter Prospective Study. J Foot Ankle Surg 2016;55:513-21.
23. Lin J, Xie C, Chen K, et al. Comparison of sinus tarsi approach versus extensile lateral approach for displaced intra-articular calcaneal fractures Sanders type IV. Int Orthop 2019;43:2141-9.

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