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MINIMALLY INVASIVE TREATMENT OF CALCANEUS FRACTURE

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ABSTRACT – ***Objective:*** The management of calcaneal fractures remains a topic of ongoing debate in the literature. This study aims to compare the functional outcomes of patients treated with an external fixator (EF) after percutaneous reduction with those treated using minimally invasive open reduction and internal fixation with a locking plate (LP).

Patients and Methods: This retrospective study included 27 patients with 28 calcaneal fractures (Sanders type II and III), 12 with EF and 16 with LP, treated at Carlo Poma Hospital (Mantua, Italy) from 2014 to 2018. The average patient age at the time of surgery was 46.3 years. The mean follow-up period was 123.3 months for the EF group and 101.2 months for the LP group. American Orthopaedic Foot and Ankle Society (AOFAS) scores were recorded, patients' satisfaction based on AOFAS scores was considered, and all underwent CT scans to assess calcaneal geometry, subtalar joint restoration, and post-traumatic arthritis.

Results: The mean AOFAS score for patients treated with EF was 74.1 (range 37-100). Of these, 66.7% rated their results as excellent or good. The mean AOFAS score for patients treated with LP was 76 (range 55-88), with 75% reporting excellent or good outcomes. The mean increase in Böhler's angle was 18.9° following EF and 15.9° following LP. One case of algodystrophy and one case of secondary subtalar arthrodesis were observed.

Conclusions: The functional and radiographic outcomes of the two surgical methods are comparable. Both LP and EF offer the benefits of minimally invasive procedures, enabling adequate fracture reduction and restoration of calcaneal volume. Minimally invasive reduction and osteosynthesis yield results similar to open surgery while reducing postoperative complications.

KEYWORDS: Heel fractures, External fixator, Locking plate, Calcaneal fracture, Intra-articular calcaneal fractures.

INTRODUCTION

The calcaneus is the most commonly fractured bone in the foot, with 65-70% of fractures being intra-articular[1]. The management of calcaneal fractures has been controversial for over a century[2-8]. Despite advancements in diagnostic and therapeutic techniques, complications persist following open reduction and internal fixation[9,10].

Minimally invasive techniques aim to restore joint function and promote healing with fewer complications, offering an alternative treatment for displaced intra-articular calcaneal fractures[11].

Displaced calcaneal fractures typically occur in young and middle-aged male industrial workers[12]. Approximately 20% of patients with lower extremity fractures are unable to return to work one year after the injury, and few patients resume their previous level of activity or sport following an intra-articular calcaneal fracture[12,13].

Patients who sustain displaced intra-articular calcaneal fractures exhibit poorer general health status (as assessed by the SF-36 questionnaire) compared to those who have suffered myocardial infarctions or undergone organ transplants[14].

In literature, several surgical techniques are described, from the extensile lateral approach to the minimally invasive. Our clinical-surgical experience has always been based on minimally invasive surgery, according to the advantages that this entails. Over the years, at our hospital, we have employed two different techniques (external and percutaneous fixation) based on the experience of the operating surgeons (MB and AP).

This study aims to evaluate the long-term outcomes of two different surgical treatments for Sanders type II and III calcaneal fractures using percutaneous and minimally invasive techniques: locking plates (LP) with a sinus tarsi approach and external fixation (EF).

PATIENTS AND METHODS

This retrospective study included 27 patients with 28 Sanders type II or III calcaneal fractures, treated at Carlo Poma Hospital (Mantua, Italy) from January 2014 to December 2018.

The study protocol was approved by the local Ethics Committee (Val Padana 39/2018) on June 19, 2019.

The data were collected from a minimum 6-year follow-up (range 6-10 years).

The patients' ages ranged from 21 to 72 years (mean 46.3) at the time of surgery, with 16 males and 11 females. Fifteen fractures occurred in the right heel, and 13 in the left (Table 1). The fractures resulted from falls in 15 cases and motor vehicle accidents in 12.

The first 12 fractures were treated with percutaneous reduction and EF (Orthofix® mini-fixator, Figure 1), while the subsequent 16 fractures were treated with percutaneous plate fixation (Zimmer-Biomet®, Figure 2) using a minimally invasive sinus tarsi approach. Preoperative CT scans were performed for surgical planning.

Fractures were classified as type II (6 cases) and type III (22 cases) according to the Sanders classification[15]. Inclusion criteria were calcaneus height loss >1.5 cm, subtalar joint displacement >1 mm, and varus malalignment >5°. Exclusion criteria included Sanders type I and IV fractures, compound fractures, follow-up <6 years, associated long-bone fractures, and patients under 16 or over 75 years of age.

The mean follow-up period was 123.3 months for the EF group and 101.2 months for the LP group.

Böhler's and Gissane's angles[16,17] were measured on the pre- and post-operative lateral radiographs (Figure 3a-d).

Surgical Techniques

Patients were positioned in the lateral decubitus position to expose the lateral surface of the heel. The procedure was performed under general or locoregional anesthesia with an Esmarch tourniquet.

Table 1. Patients' data.

	External fixation	MIS
Sex	5 females, 7 males	6 females, 9 males
Side	5 R, 7 L	10 R, 6 L (1 both sides)
Sanders II	3	3
Sanders III	9	13
Mean age (range)	45.2 years (21-63)	47 years (22-72)
Hospital stay (range)	8.5 days (4-15)	7.2 days (3-14)
Operation time (range)	76.7 minutes (45-115)	92.3 minutes (60-130)

Minimally invasive surgery (MIS).

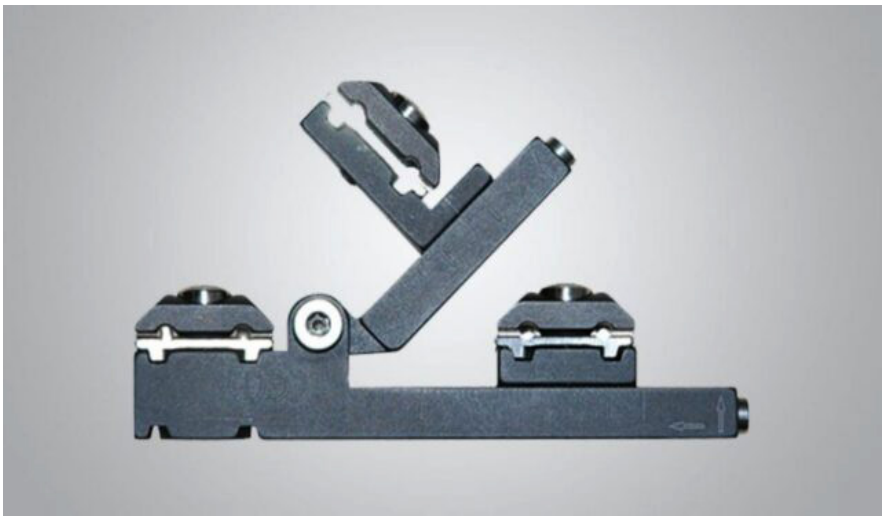

Figure 1. Orthofix® mini-fixator.

In the sinus tarsi approach, a 4 cm incision is started just below the tip of the lateral malleolus, in line with the anterior malleolar cortex, heading towards the base of the fourth metatarsal. The next step is to bluntly dissect soft tissues above the peroneal tendons, avoiding injury to either the tendons or the sural nerve.

The lateral wall of the calcaneus is then bluntly dissected using a large Cobb elevator, allowing for plate insertion and the restoration of the subtalar articular surface and calcaneal volume. Provisional fixation was achieved with K-wires, and the plate was inserted using a targeting guide. Percutaneous screws were then placed under guidance (Figure 4a-b).

For external fixation, a 1 cm lateral incision was made over the sinus tarsi, and a small lever was used for percutaneous reduction. Two pins were placed in the main fracture fragments, and the mini fixator body was used to position additional pins based on the fracture pattern. After applying the fixator, further reduction and elevation of the fracture fragment were performed.

All surgeries were performed by experienced surgeons. The operations were completed within 11 days post-trauma (mean 92.3 minutes for LP, range 60-130 minutes; 76.7 minutes for EF, range 45-115 minutes). The average hospital stay was 8.5 days (range 4-15) for the EF group and 7.2 days (range 3-14) for the LP group (Table 1).

Figure 2. Zimmer-Biomet® mini-invasive plate.

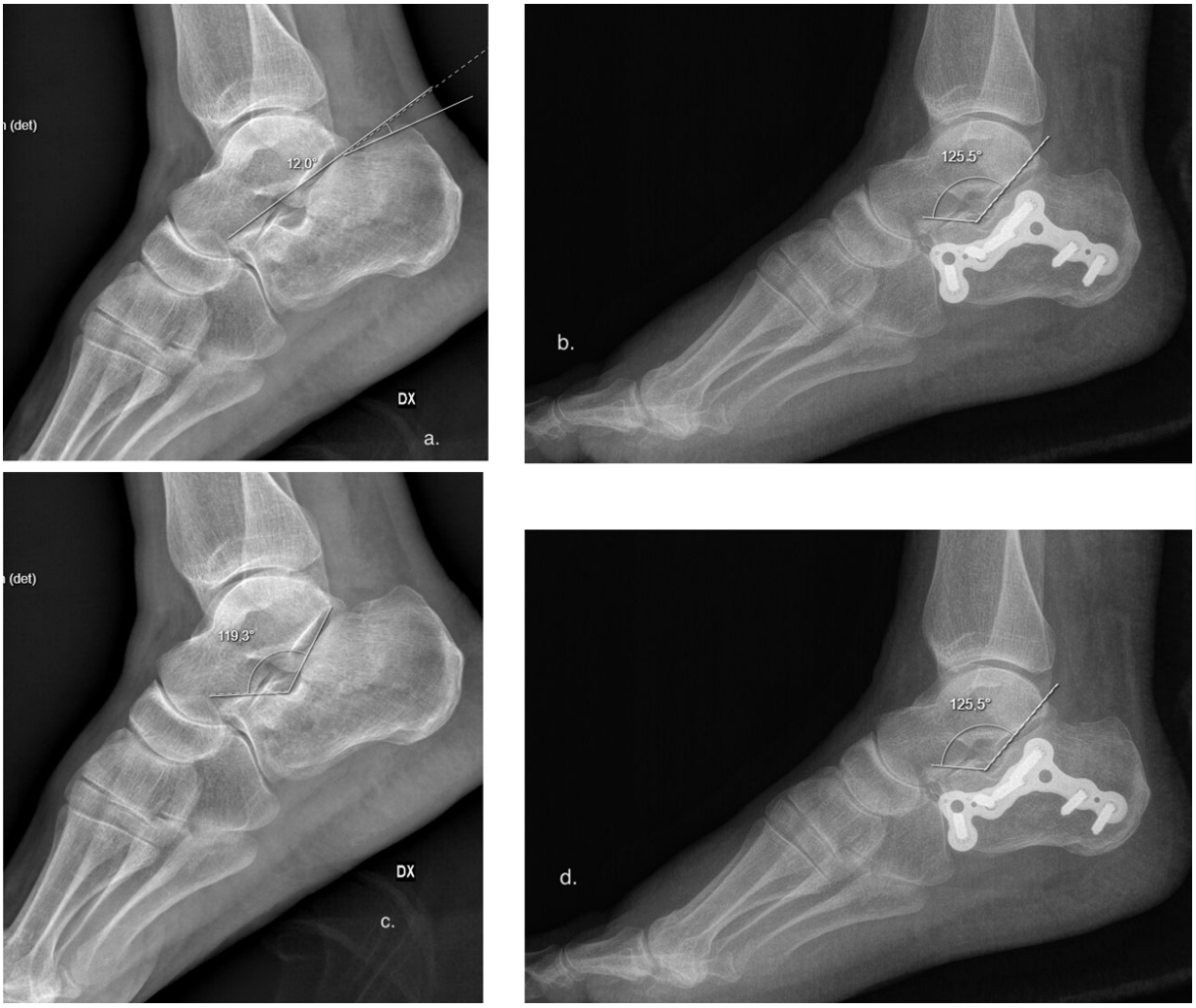

Figure 3. a, Preoperative and (**b**) postoperative X-ray with Böhler's angle measurement. **c**, Preoperative and (**d**) postoperative X-ray with Gissane's angle measurement.

Postoperatively, patients treated with LP were immobilized in a short-leg cast for 4 weeks, followed by partial weight-bearing for another 3 weeks. EF-treated patients began passive and active ankle mobilization on day 1. The external fixator was kept for an average of 7 weeks (range 6-8), with full weight-bearing resuming after 8-12 weeks.

The final follow-up included clinical and radiographic examinations (anteroposterior and lateral ankle radiographs, axial calcaneus views) at 6 weeks, 12 weeks, 6 months, and 12 months, as well as final follow-up. American Orthopaedic Foot and Ankle Society (AOFAS) scores were recorded at each follow-up. CT scans were performed in all patients at the follow-up.

Statistical Analysis

Statistical analysis using Student's *t*-test was performed, and a value of $p \leq 0.05$ was considered statistically significant.

RESULTS

In the EF group, the mean AOFAS score at final follow-up was 74.1 (range 37-100). The data showed good or excellent outcomes in 50% (6 patients), while two (16.7%) expressed fair results, according to AOFAS scores. Six patients (50%) reported good satisfaction, while two (16.7%) expressed fair results.

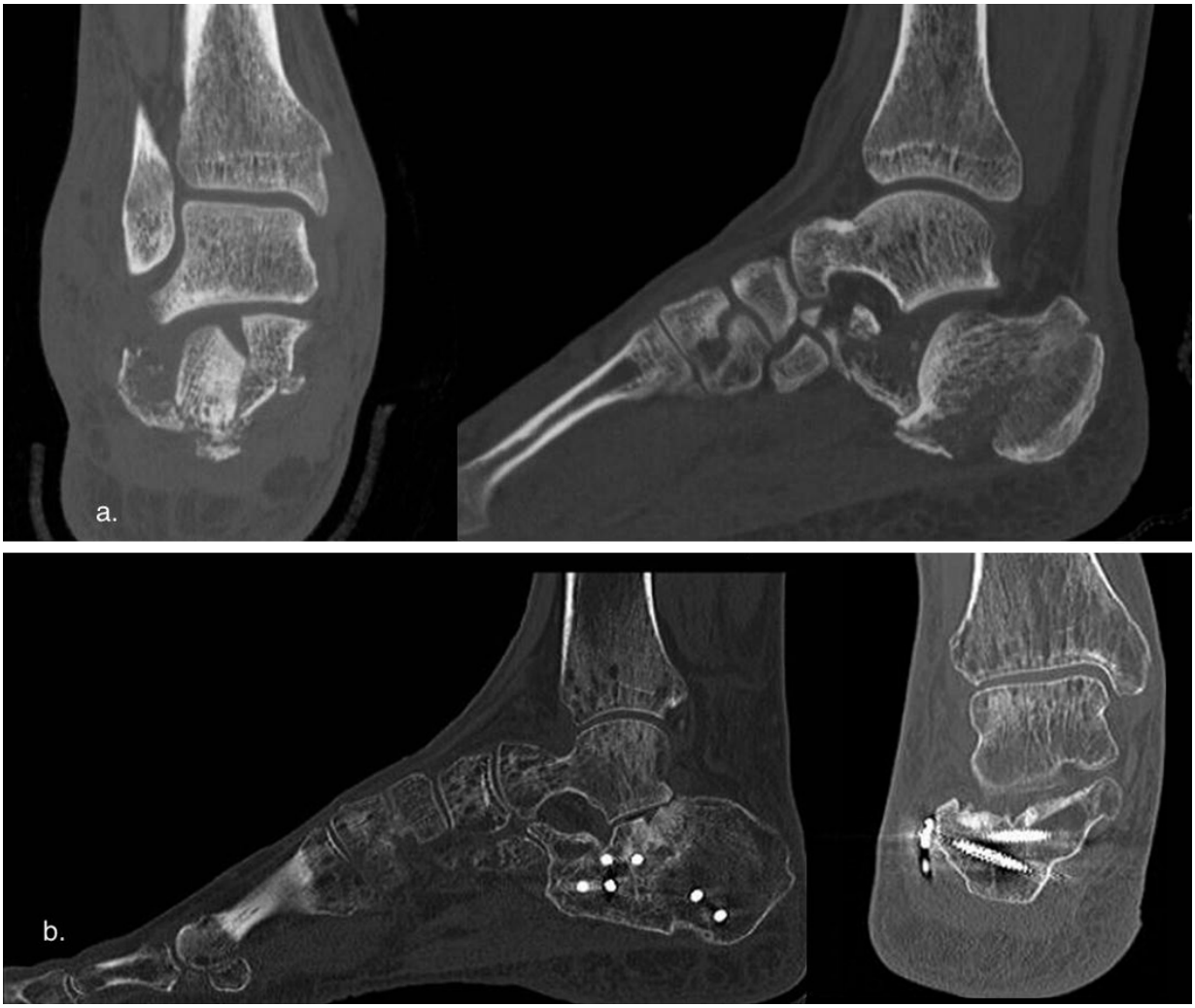

Figure 4. LP clinical case. **a**, Preoperative CT scan, man 46 y. **b**, CT scan at last follow-up (72 months).

In the LP group, the mean AOFAS score was 76 (range 55-88), with 75% reporting excellent or good results (Table 2). No significant differences in the AOFAS ankle hindfoot scale scores were observed between the two groups (p=0.65).

The median preoperative Böhler's angle was 14.2° (range 1°-32°) in the EF group, and 14.9° (range 9°-26°) in the LP group. Postoperative Böhler's angles were 32.6° (range 20°-58°) and 30.8° (range 20°-49°) in the EF and LP groups, respectively, with median increases of 18.9° and 15.9° (Figure 5, Table 3). In both groups, improvement of postoperative Böhler's angle was statistically significant (p<0.01)

Table 2. Patients' satisfaction at the follow-up time according to AOFAS scores.

	External fixation	MIS
Excellent	2 (16.7%)	4 (25%)
Good	6 <50<%)	8 (50%)
Fair	2 (16.7%)	4 (25%)
Poor	2 (16.7%)	

American Orthopaedic Foot and Ankle Society (AOFAS), minimally invasive surgery (MIS).

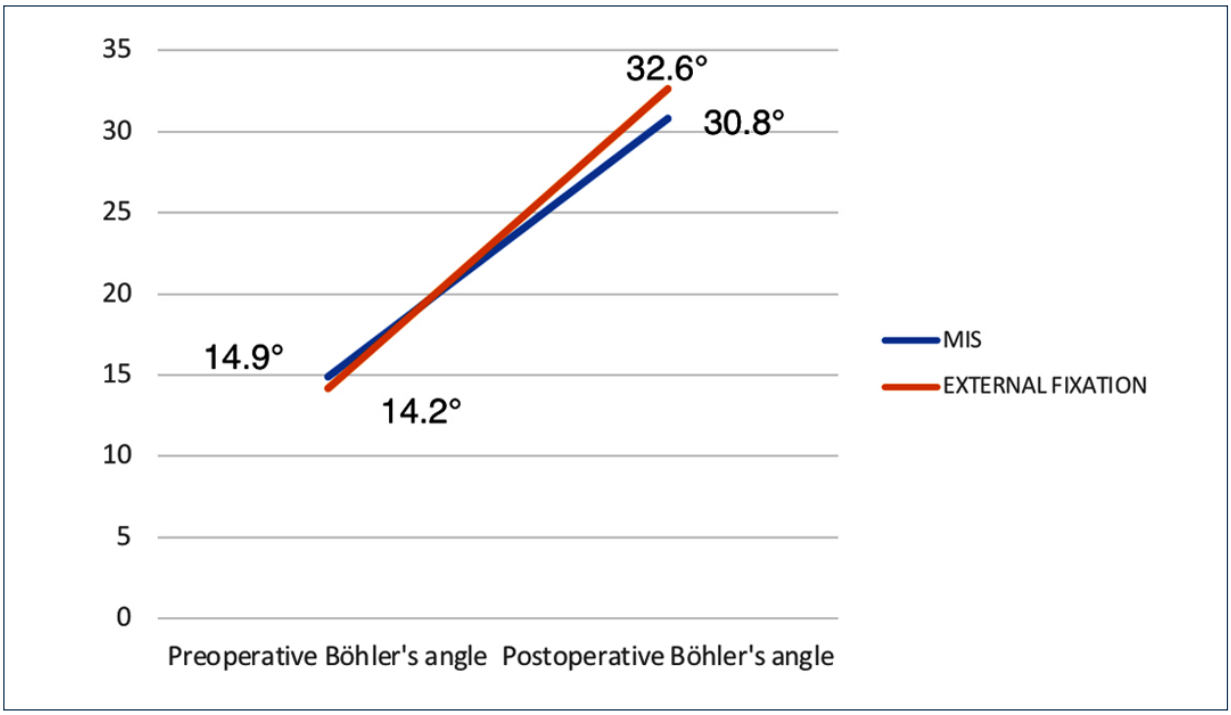

Figure 5. Increasing in Böhler's angle.

The median preoperative Gissane's angle was 130.2° (range 107°-180°) in the EF group, and 129.2° (range 104°-180°) in the LP group. Postoperative Gissane's angles were 115.8° (range 82°-138°) and 116.9° (range 90°-130°) in the EF and LP groups, respectively (Table 3). In both groups, improvement of postoperative Böhler's angle was statistically significant (p<0.01).

Postoperative complications included one case of algodystrophy in the LP group, resolved with clodronic acid and pulsed magnetic field therapy. Three cases of chronic peroneal tendinitis were resolved by removing the plate and screws after bone healing, and one patient underwent secondary subtalar arthrodesis due to osteoarthritis 3 years after the injury (Figure 6a-c). Only four patients resumed sports activity (two from each treatment group).

DISCUSSION

In 1916, Cotton and Henderson[18] emphasized the need for improved outcomes in treating calcaneus fractures. Since then, significant advances have been made in the management of intra-articular calcaneus fractures[19]. Despite the introduction of antibiotic therapy, which has helped reduce soft tissue complications, wound healing delays are still observed in 25% of patients treated for intra-articular calcaneal fractures *via* the standard lateral approach[20].

Table 3. Preoperative and postoperative angles.

	External fixation		MIS	
	Preoperative	**Postoperative**	**Preoperative**	**Postoperative**
Median Bohler's angle (range)	14.2° (1°to 32°)	32.6° (20° to 58°)	14.9° (9° to 26°)	30.75° (20° to 49°)
Median Gissane's angle (range)	130.2° (107° to 180°)	115.8° (82° to 138°)	129.2° (104° to 180°)	116.9° (90° to 130°)

Minimally invasive surgery (MIS).

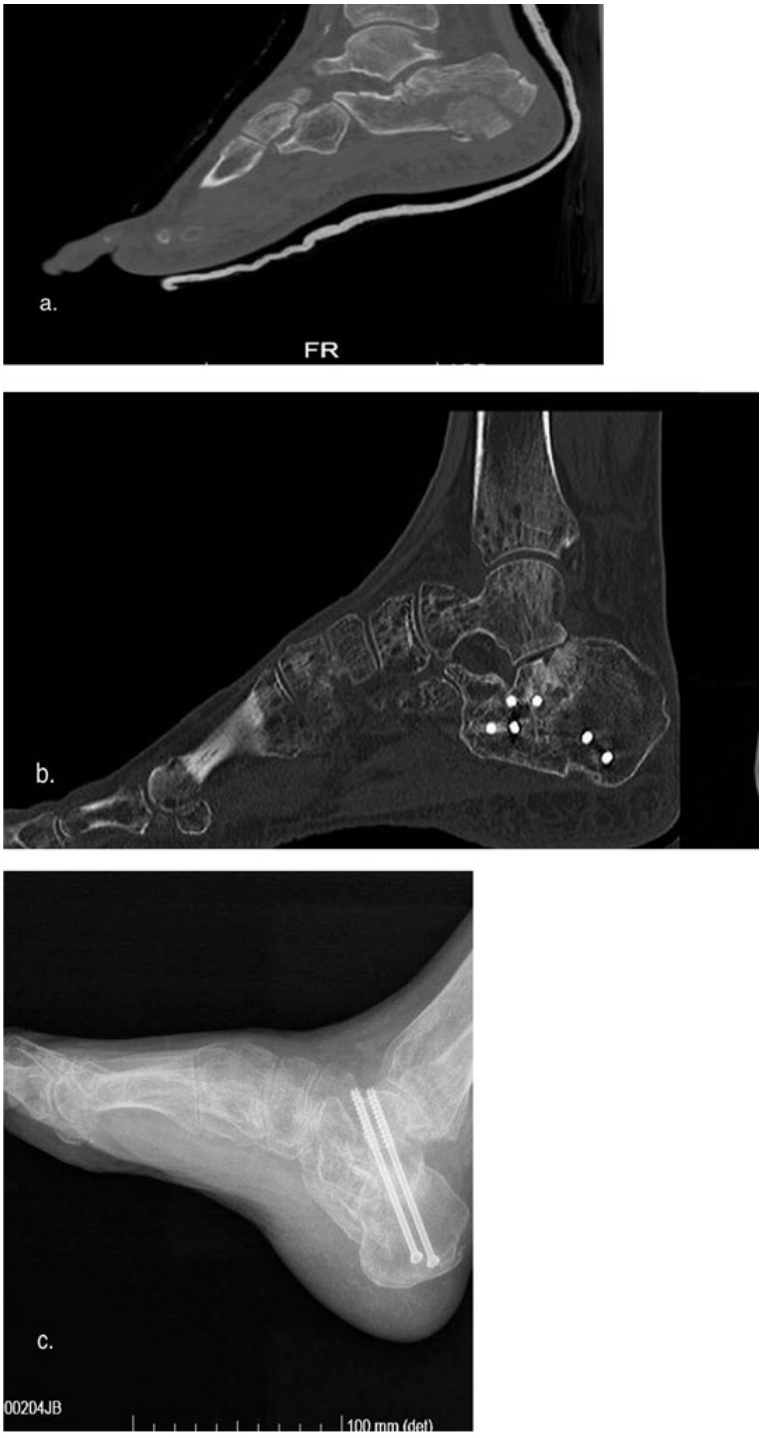

Figure 6. a, Preoperative CT scan, man 56 y, (**b**) CT scan after 30 months, (**c**) post-operative (secondary subtalar arthrodesis) X-ray.

The extensile lateral approach (ELA) is considered the gold standard for treating these fractures. It provides excellent visualization of the fracture site and facilitates accurate anatomic reduction of the articular surface. However, the ELA is associated with a high rate of complications, including fracture fragment devascularization, larger surgical exposure, wound edge necrosis or infection, and resection of the lateral calcaneal branch of the peroneal artery[21,22].

Minimally invasive techniques have been developed and promoted as alternatives to the traditional ELA to minimize soft tissue complications related to the L-shaped incision. These include percutaneous fixation (for example, in tongue-type fractures according to the Essex-Lopresti

classification), arthroscopically assisted fixation, and minimally invasive surgery (MIS)[11,23,24]. In recent years, several studies have evaluated the medium- and short-term outcomes of these approaches.

The use of MIS combined with rigid internal fixation using locking plates is now widely accepted for the treatment of most long-bone and periarticular fractures. This technique has been shown to facilitate early postoperative mobilization, accelerate rehabilitation, and promote better wound healing, thus reducing the incidence of local necrosis and infections[25].

However, there are few studies directly comparing the outcomes of ELA and MIS combined with rigid internal fixation, and most of these studies involve small sample sizes (15-35 patients). Additionally, many studies[26] are retrospective, with follow-up periods varying from several months to years. AOFAS scores are not included in all studies, and key factors such as time from injury to fixation, surgeon experience, incision length, and blood loss are often not reported[26,27]. Recent literature supports the use of MIS combined with rigid internal fixation for Sanders type II and III fractures, but fewer studies have examined its use in highly comminuted fractures (type IV in Sanders classification)[28].

The sinus tarsi approach is the most frequently used limited lateral approach. In their meta-analysis, Zhang et al[29] demonstrated that the sinus tarsi approach outperforms the ELA with smaller incisions, a lower incidence of wound healing complications, and a reduced postoperative VAS score. Moreover, alignment on lateral radiographs and the excellent-to-good rates according to the AOFAS score were not negatively impacted.

In 2022, Wallace et al[27] described one hundred and five fractures in 100 patients treated with the sinus tarsi approach for intra-articular calcaneal fractures. The wound complication rate was 11.9%, with 1.9% requiring additional procedures.

According to many authors[30-32], external fixation is typically indicated for the emergency treatment of open calcaneal fractures or closed fractures with severe soft tissue compromise. A few studies[33,34] have explored percutaneous reduction and external fixation as definitive treatments for articular calcaneal fractures, irrespective of soft tissue concerns.

In 2006, Magnan et al[35] described the treatment of 54 intra-articular fractures with a mini-fixator, reporting good-to-excellent outcomes in 96.7% of patients. They observed three cases of thalamic displacement due to early weight bearing. In 2024, Checa-Betegon et al[33] treated 42 intra-articular calcaneus fractures with external fixator, reporting a mean postoperative AOFAS score of 79.1. Van Hoeve and Poeze[36] conducted a review in 2016 evaluating outcomes after treatment with percutaneous and minimally invasive open techniques for calcaneal fractures. They found that percutaneous reduction and screw osteosynthesis, along with minimally invasive open techniques, resulted in significantly better outcomes (based on AOFAS scores and improvements in Bohler's angle) compared to external fixation and other methods such as K-wire fixation. They also noted a higher infection rate in the external fixation group due to more frequent pin-tract infections[36].

The primary goals of treatment are to restore the calcaneus's three-dimensional structure (height, length, and width), reconstruct the subtalar joint, decompress the sub-peroneal area (avoiding peroneal conflict), reduce the calcaneocuboid surface, and align the calcaneal tuberosity in its physiological position.

In our experience, minimally invasive surgery has proven effective in achieving these objectives. Both external and internal fixation *via* the sinus tarsi approach have successfully restored the calcaneal height and increased the Bohler's angle (Figure 5). According to the literature, the wound complication rate is lower with both minimally invasive techniques[15,20,27,37,38].

Veltman et al[39] analyzed long-term outcomes (mean follow-up 4.6 years) for 1,730 intra-articular calcaneal fractures. The average AOFAS score was 73.7 (range: 63 to 92), consistent with the findings of our study. The authors considered external fixation a good alternative for definitive treatment of intra-articular calcaneal fractures, with functional outcomes comparable to internal fixation, excluding concerns related to nursing and patient compliance.

This study has several limitations: the small sample size and the lack of randomization are the most significant.

CONCLUSIONS

MIS techniques yield results comparable to those of open reduction and internal fixation (ORIF), with the advantages of shorter waiting times, better soft tissue preservation, and reduced complication

rates[23-25]. Both internal and external fixation provide excellent outcomes for the treatment of Sanders type II and III fractures. The choice between the two approaches should be guided by the surgeon's experience and the specific clinical scenario.

Conflict of Interest:

The authors declare that they have no conflict of interest to disclose.

Authors' Contributions:

M.B. and A.P. participated in the drafting and critical revision of the manuscript. L.P. contributed extensively to the study's methodology development and was instrumental in the acquisition of data. Additionally, M.B. played a key role in interpreting the data and provided substantial input in the writing and editing of the manuscript. L.P. was deeply involved in data analysis and interpretation. A.P. and G.Z. contributed significantly to the drafting of the manuscript, particularly in the discussion and conclusion sections.

Ethics Approval and Informed Consent:

The study protocol received approval from the local Ethics Committee (Val Padana 39/2018 - June 19, 2019). All patients signed an informed consent to allow the study and the publication of the results anonymously.

Availability of Data and Materials:

Data are available on reasonable request by the author L.P.

AI Disclosure:

No AI was used.

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