



Original Article

Comparative study on three surgical techniques for intra-articular calcaneal fractures: open reduction with internal fixation using a plate, external fixation and minimally invasive surgery[☆]



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ABSTRACT

Objective: To evaluate, compare and identify the surgical technique with best results for treating intra-articular calcaneal fractures, taking into account postoperative outcomes, complications and scoring in the Aofas questionnaire.

Methods: This was a retrospective study on 54 patients with fractures of the calcaneus who underwent surgery between 2002 and 2012 by means of the following techniques: (1) open reduction with extended L-shaped lateral incision and fixation with double-H plate of 3.5 mm; (2) open reduction with minimal incision lateral approach and percutaneous fixation with wires and screws; and (3) open reduction with minimal incision lateral approach and fixation with adjustable monoplanar external fixator.

Results: Patients treated using a lateral approach, with fixation using a plate had a mean Aofas score of 76 points; those treated through a minimal incision lateral approach with screw and wire fixation had a mean score of 71 points; and those treated through a minimal incision lateral approach with an external fixator had a mean score of 75 points. The three surgical techniques were shown to be effective for treating intra-articular calcaneal fractures, without any evidence that any of the techniques being superior.

Conclusion: Intra-articular calcaneal fractures are complex and their treatment should be individualized based on patient characteristics, type of fracture and the surgeon's experience with the surgical technique chosen.

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Estudo comparativo entre três técnicas cirúrgicas para fraturas intra-articulares de calcâneo: redução aberta e fixação interna com placa, fixação externa e minimamente invasiva

R E S U M O

Palavras-chave:
Calcâneo/lesões
Calcâneo/cirurgia
Estudo comparativo

Objetivo: Avaliar, comparar e identificar a técnica cirúrgica com melhor resultado para o tratamento de fraturas intra-articulares do calcâneo, levando em consideração evolução pós-operatória, complicações e pontuação no questionário Aofas.

Métodos: Estudo retrospectivo de 54 pacientes com fraturas de calcâneo operados entre 2002 e 2012 com as técnicas 1) redução aberta com incisão lateral alargada em "L" e fixação com placa duplo "H" de 3,5 mm, 2) redução aberta por incisão lateral econômica e fixação percutânea com fios e parafusos e 3) redução aberta por incisão lateral econômica e fixação com fixador externo monoplanar regulável.

Resultados: Pacientes tratados pela via de acesso lateral e fixação com placa tiveram média de 76 pontos na escala Aofas, em pacientes tratados pela via de acesso lateral econômica e fixação com fios e parafuso a média foi de 71 e nos pacientes tratados com via de acesso lateral e fixador externo foi de 75 pontos. As três técnicas cirúrgicas demonstraram-se efetivas no tratamento da fratura intra-articular do calcâneo, sem evidência de superioridade de uma técnica sobre as demais.

Conclusão: : A fratura intra-articular do calcâneo é uma fratura complexa e seu tratamento deve ser individualizado, baseado nas características do paciente, no tipo de fratura e na experiência do cirurgião com a técnica operatória escolhida.

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Introduction

Calcaneal fractures correspond to approximately 1% to 2% of all the fractures of the human body and constitute nearly 60% of tarsal bones fractures. They generally follow high-energy axial traumas, such as fall from height or motor accidents.

According to the current literature, 60% to 75% of these fractures are considered to be displaced and intra-articular,¹⁻³ which evidences the difficulty of the treatment. They can cause great disability due to pain and chronic stiffness, in addition to hindfoot deformities. These fractures are characterized clinically by poor functional results due to their complexity.

Approximately 80% to 90% of the calcaneal fractures happen in males between 21 and 40 years, mostly in industrial workers. Several authors⁴⁻⁷ have reported that the rehabilitation of these fractures can take from nine months to several years, which implicates great economic burden on society.

Since the early 1980s, the treatment of choice for displaced and intra-articular calcaneal fractures was open reduction with internal fixation; however, soft tissue complications, such as surgical dehiscence and infection, can occur in up to 30% of the patients.⁸⁻¹⁰

In an attempt to reduce complication rates, new surgical techniques emerged, such as minimally invasive incision and percutaneous fixation, which cause less injury to the tissues and reduce the incidence of soft tissue complications.^{10,11}

Despite the modern surgical techniques and the considerable number of studies in the literature,¹¹⁻¹³ calcaneal fractures and their best treatment method remain an enigma for orthopedic surgeons.

This study aimed to assess, compare, and identify the surgical technique with the best clinical functional result in the treatment of displaced and intra-articular calcaneous fracture, including (1) open reduction with extended L-shaped lateral incision and fixation with 3.5-mm double-H plate; (2) open reduction with minimal incision lateral approach and percutaneous fixation with wires and screws; and (3) open reduction with minimal incision lateral approach and fixation with adjustable monoplanar external fixator.

Material and methods

The study protocol was approved by the Research Ethics Committee under No. 064/11.

This was a retrospective study that analyzed the medical charts of 54 patients with 60 calcaneal fractures, operated on between 2002 and 2012, in an university hospital in Campinas, SP, Brazil, by a single orthopedic surgeon (foot-and-ankle specialist). The inclusion criteria comprised skeletally mature individuals with deviated intra-articular calcaneal fractures classified as Sanders type II and III, who were operated on with one of the following surgical techniques:

1. Conventional lateral surgical access plus fixation with a 3.5-mm implant: incision between the fibula and calcaneus tendon beginning above the lateral malleolus, extended around and posterior to the malleolus toward the base of the V metatarsal. The sural nerve is identified and protected. The calcaneofibular ligament is detached from its calcaneous insertion and, along with the dislocated

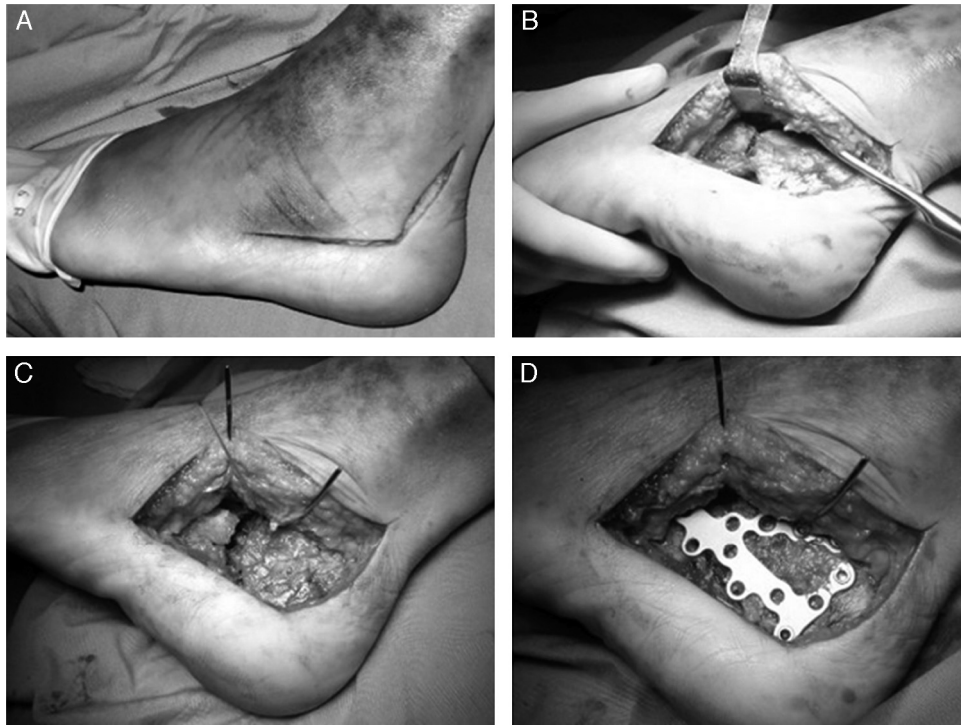


Fig. 1 – Wide lateral approach as described by Seligson (A); reduction of the fracture by direct visualization with periosteum elevator (B); temporary fixation of the reduction with Kirschner 1.6 wire (C); internal fixation with 3.5-mm calcaneus plate (D).

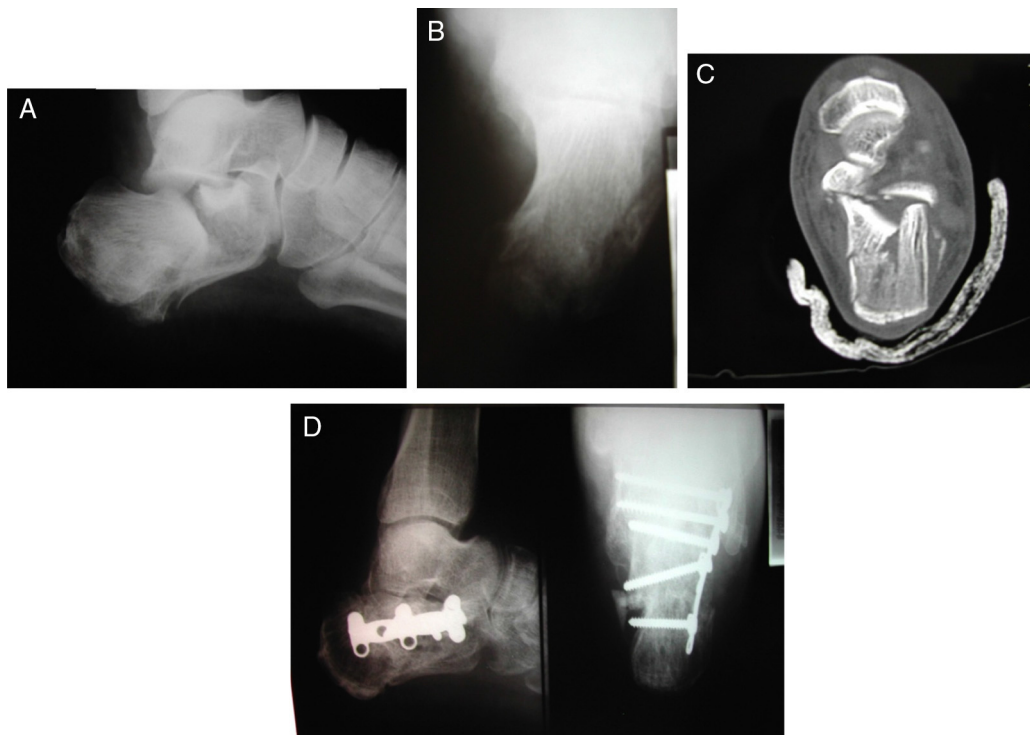


Fig. 2 – Example of displaced intra-articular calcaneal fracture, classified as Sanders II and treated with open reduction and internal fixation. (A) Anteroposterior X-ray of the calcaneus; (B) axial X-ray of the calcaneus; (C) coronal plane CT-scan; (D) post-operative result.

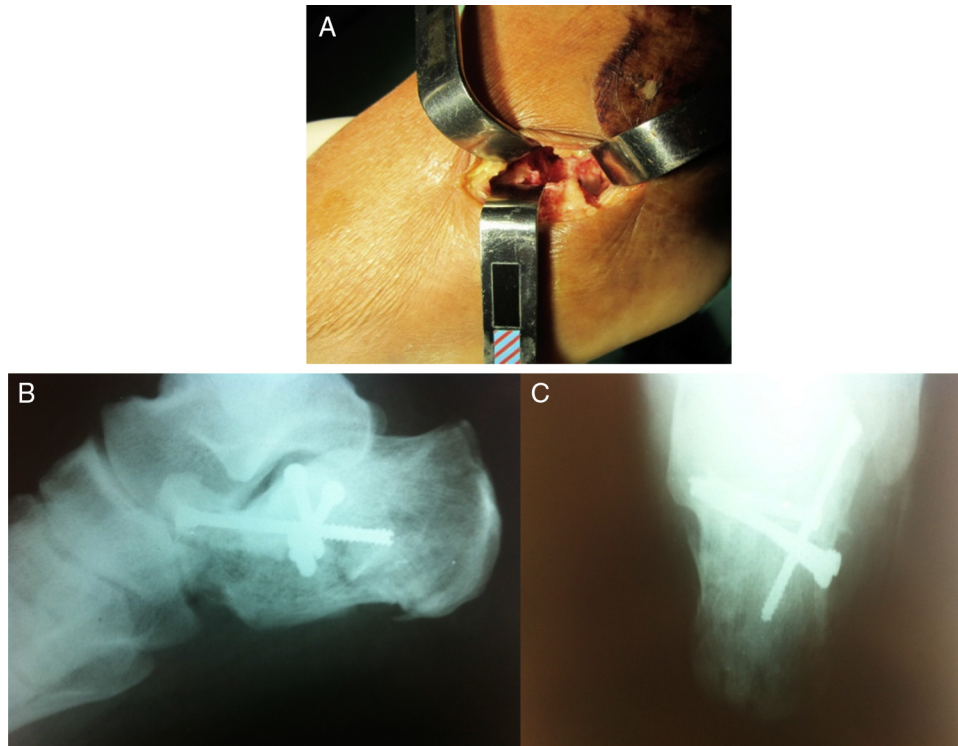


Fig. 3 – Example of calcaneal fracture treated with minimal incision lateral approach and fixation with pins and screws. (A) Minimal incision lateral approach; (B and C) post-operative result.

fibularis tendons, it is pushed out anteriorly to exhibit the lateral aspect of the calcaneus and the calcaneocuboid and subtalar joints. The fracture is then reduced and fixed with a 3.5-mm calcaneus implant (Figs. 1 and 2).

2. Mini-incision and fixation with threads and screws: lateral 3- to 5-cm incision directly above the tarsal sinus. Divulsion of the soft tissues, paying careful attention to the fibularis tendons. The joint fracture is reduced using delicate fine-tip chisels. A temporary fixation is performed using 1.6-mm Kirschner wires in the fragments, for maintenance of the reduction, and definite fixation is achieved with cannulated 3.5- or 4.5-mm screws (Fig. 3).
3. Mini-incision and monoplanar external fixator: lateral 3-5-cm incision directly above the tarsal sinus. Divulsion of the soft tissues, paying careful attention to the fibularis tendons and the sural nerve. The joint fracture is reduced using delicate fine-tip chisels. A temporary fixation is performed using 1.6-mm Kirschner wires in the fragments, for maintenance of the reduction. Two Schanz pins are inserted in the calcaneus below the joint surface of the subtalar region, two pins are inserted in the posterior region of the calcaneus and, finally, two pins are inserted in the anterior region. The external fixator is blocked. Then the main and vertical rails are distracted until proper reduction is visualized under fluoroscopy (Fig. 4).

Post-operatively, early mobilization of the ankle and subtalar joints is stimulated in the first post-operative week. The sutures are removed two weeks after the surgery. For patients operated with the external fixation technique, partial load is initiated after four weeks; total load starts at eight weeks,

Table 1 – Patients operated with each surgical technique.

Surgical technique	Number of patients	Number of fractures
L-shaped incision and plate fixation	20	23
Lateral mini-incision and fixation with threads and screws	27	27
Adjustable monoplanar fixator	7	10

together with the removal of the fixator. In other techniques, partial load is initiated in the eighth post-operative week. All patients undergo post-operative outpatient follow-up for at least two years.

Skeletally immature patients, those with calcaneal fractures classified as Sanders types I and IV, and those who had undergone prior foot surgery were not included.

Procedures

From 2002 to 2012, 54 patients (60 fractures) underwent surgery, and one of the three surgical techniques was randomly chosen: (1) open reduction with extended L-shaped lateral incision and fixation with double-H plate of 3.5mm, without bone graft, totaling 20 patients and 23 calcaneal fractures; (2) minimal incision lateral approach and minimal fixation focused in the subtalar joint, performed only with wires and screws (27 patients and 27 calcaneus fractures); and (3) minimal incision lateral approach and fixation with adjustable monoplanar external fixator, in seven patients and ten calcaneal fractures (Table 1).

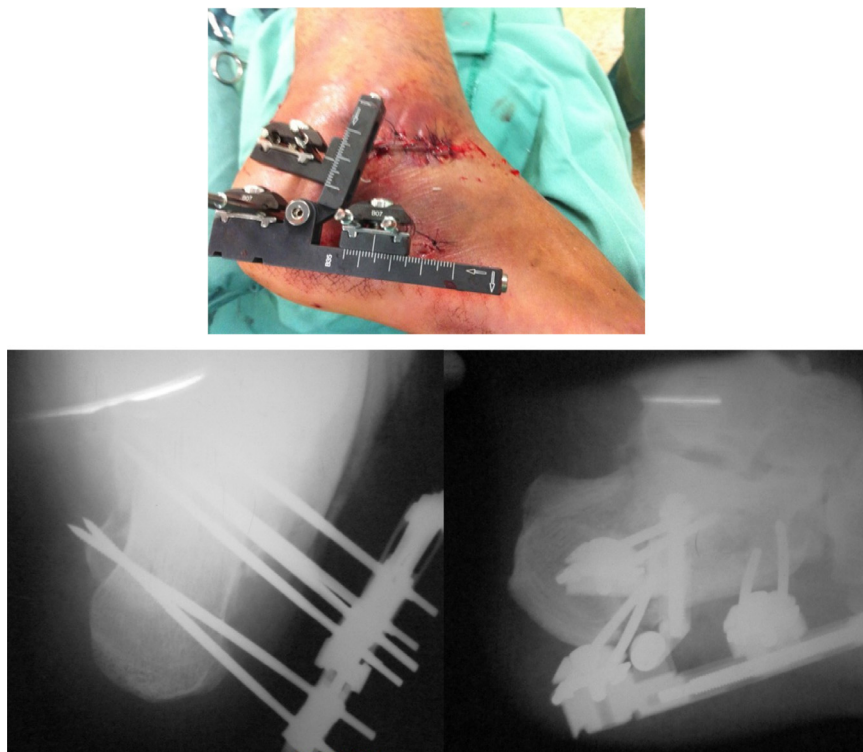


Fig. 4 – Example of fracture treated with minimal incision lateral approach and fixation with monoplanar external fixator.

Bilateral X-rays in lateral and axial views were taken preoperatively, as well as in the immediate and late post-operative. The Böhler and Gissane angles were measured. The patients responded to the American Orthopedic Foot and Ankle Society (AOFAS)¹⁴ and Johnson¹⁵ questionnaires, and early and late surgical complications were also recorded. The AOFAS questionnaire measures the subjective scale of pain, foot function, and the alignment of the foot and ankle, with the following variables: level of activity (basic or recreational), walked distance, ability to walk in different surfaces, gait abnormality, foot and hindfoot motion (flexion-extension and inversion-eversion), and ankle hindfoot stability.

Johnson's questionnaire assesses complications and subjective satisfaction of the patient: completely satisfied, satisfied with minimal restrictions, satisfied with high restrictions, and dissatisfied.

The goal was to assess which of the following surgical techniques presented the best result in the treatment of displaced and intra-articular calcaneus fracture: L-shaped lateral incision and fixation with plate; mini-lateral incision and fixation with wires and screws; and adjustable monoplanar fixator. The Student's t-test for comparison of means, with unknown and different variances, was used for each pair of methods.

Thus, the following were compared: (1) if the L-shaped lateral incision and fixation with plate was equal to the mini-lateral incision and fixation with wires and screws; (2) if the L-shaped lateral incision and fixation with plate was equal to the adjustable monoplanar fixator; and (3) if the mini-lateral incision and fixation with wires and screws was equal to the adjustable monoplanar fixator. The answers for the AOFAS questionnaire from each patient comprised the collected data.

Results

Of 20 patients treated by lateral access route with plate fixation, 16 walked without restrictions (80%), two limped (10%), and two needed crutches (10%). The mean score of 76 (range: 62 to 94) was obtained in the AOFAS scale, in which excellent results range from 90 to 100 points. Good results range from 80 to 89; regular, from 70 to 79; and bad, below 69. The mean post-operative Böhler angle was 22° (range: 12 to 32°) and the mean Gissane angle was 129° (range: 100 to 132°); normal values range from 20° and 40° for the first angle, and are approximately 100° for the second.¹⁶

Of the 27 patients treated with minimal incision lateral approach and minimal fixation, 24 walked without limitations, two limped, and one needed crutches. All patients presented difficulty to walk in uneven terrain. The mean AOFAS score was 71 points (range: 60 to 90). The mean post-operative Böhler angle in these patients was 18° (range: 6 to 40°) and the mean Gissane angle was 88° (range: 76 to 102°).

Of the seven patients who were treated with minimal incision lateral approach and external fixation, six walked without limitations and one presented limping. The mean AOFAS score was 75 points (range: 63 to 87). The mean post-operative Böhler angle was 17.8° (range: 0 to 32°) and the mean Gissane angle was 103° (range: 100 to 126°).

At the significance level of 5%, it can be concluded that there was no difference among the three types of treatment, since the *p*-value for the three comparisons was always above 0.05. That indicates that there is no statistical difference among the treatments (Table 2).

Table 2 – Results from the statistical analysis.

	tobs	t-tab	p-value	v
Comparing				
L-shaped incision and plate fixation	0.77	-2.02	0.44	39.54
Lateral mini-incision and fixation with pins and screws				
Comparing				
Lateral mini-incision and fixation with pins and screws	-0.53	-2.19	0.61	11.41
Adjustable monoplanar fixator				
Comparing				
L-shaped incision and plate fixation	0.12	-2.14	0.90	14.07
Adjustable monoplanar fixator				

Discussion

The complex calcaneus anatomy, its spongy bone structure with thin cortical, articular and displaced fractures, high-energy trauma, and little soft tissue coverage contribute to the difficulty in handling its fractures.¹⁷⁻¹⁹

In developed countries, most of the displaced intra-articular calcaneal fractures are treated by means of open reduction via lateral approach and fixation with plate and 3.5-mm screw. This technique offers good visualization of the fracture, at the cost of greater damage to the soft tissues, which increases the risk of necrosis, surgical dehiscence, and infection. Thus, several surgeons have been searching for minimally invasive surgical techniques with less damage to the soft tissues.^{20,21}

In the group assessed, most patients were males at working age (mean of 40 years) and all cases had axial trauma due to fall from height as the trauma mechanism.

In the analysis of the radiographic results of the Bohler and Gissane angle measurements, it was observed that in the open reduction with plate and fixation with plate and screws and in the open reduction (minimal incision) with percutaneous fixation groups, it was possible to restore the angles in 100% of the cases, whereas in the open reduction (minimal incision) with adjustable monoplanar external fixator group it was only possible to restore the Bohler angle in 40% of the cases. Meanwhile, all values for the Gissane angle were around the reference value. There can be a small variance in measuring these angles, as small rotations during the radiographic examination may influence the obtained values, and also due to the precision of the goniometer used. Nevertheless, these measurements were standardized and performed by an experienced professional.

According to the Johnson score, no patient was shown to be completely satisfied nor completely dissatisfied with any of the used techniques. This can be considered a positive fact, due to the typical clinical evolution of calcaneal fractures.

As for the AOFAS questionnaire, it was observed that regarding the minimally invasive technique with percutaneous fixation, 7.4% of the patients presented excellent results; 51.8%, good; 29.6%, fair; and only 11.1% of the results were considered poor. Regarding the minimally invasive technique with external fixation (monoplanar adjustable fixator), the questionnaire results appointed 20% good results; 60%, fair; and 20%, poor. In the literature, good and excellent results can vary between 42% and 62% with the conventional

Table 3 – Results from the AOFAS scale.

Surgical technique/AOFAS	Mean	Variation
L-shaped incision and plate fixation	76	62-94
Minimal incision lateral approach with pins and screws	71	60-90
Adjustable monoplanar fixator	75	63-87

technique of open reduction and fixation using plate and screws. This demonstrates an advantage of the mini-open reduction with percutaneous fixation comparing to the other techniques, as it presented 65.2% good and excellent results, which was above the observed mean (Table 3).

Regarding the complications, a topic of high relevance for the choice of the definite treatment, the present study demonstrated that in the group treated with mini-open reduction and percutaneous fixation, there were no soft tissue complications such as necrosis, dehiscence, tendinitis, or nervous injuries, which can reach from 27% to 33% of the cases in the literature. In the external fixation with adjustable monoplanar fixator group, one patient (14.2%) presented soft tissue infection. In the group treated with the conventional technique of open reduction and fixation with plate and screws, four patients (20%) presented the following complications: infection (25%), skin necrosis (50%), and sural nerve neuroma (25%).

The literature indicates that approximately 80% of the patients who undergo the conventional surgical technique return to work.^{22,23} The present study demonstrated that, with the minimally invasive technique and percutaneous fixation, all patients returned to their work activities. Of the patients treated with the conventional technique, 100% returned to their work activities; however, 50% of them resumed different activities.

The discrepancy found in the literature between the results obtained with the conventional technique of L-shaped access and the minimally invasive techniques may be explained by the fact that the latter causes less morbidity, since they are less aggressive causing less soft tissues damage.

There is no universal treatment or surgical approach to all displaced intra-articular calcaneal fractures. The choice of treatment must be based on the characteristics of the patient and on the type of fracture. The type of fracture, degree of displacement, and subtalar incongruence are important indicators, as well as the condition of the soft tissues,

the physical and mental state of the patient, and the presence of comorbidities, such as smoking and *diabetes mellitus*, which directly influence the healing process and can increase the risk of surgical complications. The literature shows that the learning curve for the treatment with open reduction and fixation for displaced intra-articular calcaneus fractures is around 35–50 surgeries.²⁴ Therefore, the surgeon's experience must also be considered when deciding the best surgical technique.

Conclusions

In the face of an international discussion about the effectiveness of minimally invasive technique, this study proved the efficiency of such techniques and demonstrated that, in addition to that, they are correlated with lower morbidity and better quality of life of the patients, findings that have already been observed in the literature. However, the present study did not demonstrate a statistical superiority of the minimally invasive technique with percutaneous fixation over the other techniques. Studies with a higher number of patients are needed, considering the small number of randomized studies comparing these techniques.

Conflicts of interest

The authors declare no conflicts of interest.

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