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# SAMeCiPP Today

**Dr. María Gala Santini Araujo**
*SAMeCiPP President*

Dear Readers,

More than five decades after its founding, the *Sociedad Argentina de Medicina y Cirugía de Pie y Pierna* [Argentine Society of Foot and Leg Medicine and Surgery (SAMeCiPP)] continues to serve as a cornerstone in the development of this subspecialty within orthopedic practice in Argentina, maintaining its commitment to education, continuing professional development, and academic exchange.

Significant advances have been achieved in the diagnosis and treatment of foot and ankle disorders, driven by a better understanding of biomechanics and pathophysiology, the refinement of surgical techniques—both open and minimally invasive—and the development of new implants and reconstructive strategies. This increasingly dynamic and challenging landscape demands continuous updating and a strong scientific foundation.

In this context, research plays a central role. The integration of basic science with clinical research not only enhances our understanding of disease mechanisms but also improves therapeutic decision-making and the evaluation of treatment outcomes. This interplay between fundamental knowledge and clinical application is essential for the sustained growth of the specialty.

Through the articles presented in this issue—including original clinical research, case reports, and technical notes—we hope to reflect our colleagues' commitment to advancing knowledge and strengthening evidence-based practice. In this regard, scientific publication is an essential tool for fostering critical thinking, encouraging the exchange of ideas, and promoting continuous improvement.

We would like to express our sincere appreciation to the Editorial Board of the *Journal of the Asociación Argentina de Ortopedia y Traumatología* for its support and collaboration in the preparation of this issue, providing a high-quality forum for scientific communication.

Finally, we invite all members of our community to continue actively participating in the generation and dissemination of knowledge, thereby contributing to the advancement of our subspecialty and, ultimately, to improving patient care.

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# Case Presentation

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*Case Resolution on page 286.*

## Tumor of the Hallux

**ABSTRACT**

A 34-year-old man presented with a progressively enlarging mass in the right hallux, with a 2-year history. The lesion was painful due to mechanical compression against the adjacent toes, particularly when wearing shoes with a narrow toe box. There were no signs of local infection, nocturnal pain, or associated weight loss. Radiographs showed a lesion in the proximal metaphyseal-diaphyseal region of the distal phalanx. Magnetic resonance imaging demonstrated an eccentrically located lesion with low signal intensity on T1-weighted sequences and high signal intensity on T2-weighted sequences.

**Keywords:** Neoplasm; eccentric location; atypical; intramedullary; hallux.

**Level of Evidence:** IV

## Tumoración en el hallux

**RESUMEN**

Un hombre de 34 años consulta por una masa en el hallux derecho, de crecimiento progresivo y 2 años de evolución, dolorosa por la compresión mecánica con los dedos adyacentes, en especial, con el uso de calzado estrecho en su cámara anterior, sin signos de infección local, ni dolor nocturno o pérdida de peso asociada. La radiografía muestra una lesión en la falange distal metafiso-diafisaria proximal. La resonancia magnética permite visualizar una lesión de baja intensidad en secuencia T1 y de alta intensidad en secuencia T2, de localización excéntrica.

**Palabras clave:** Neoplasia; localización excéntrica; atípica; endomedular; hallux.

**Nivel de Evidencia:** IV

## INTRODUCTION

A 34-year-old man employed at a plastics manufacturing plant, with a medical history significant only for dysautonomia, presented with a 2-year history of a progressively enlarging mass on the lateral aspect of the right hallux. The lesion was initially painless but had become symptomatic over the previous weeks, causing mechanical discomfort due to rubbing against the second toe when wearing shoes. The patient denied any ulceration or sinus tract formation, lesions involving the lesser toes, or ipsilateral inguinal lesions. He also denied weight loss, nocturnal pain, and pain at rest.

Physical examination revealed a firm, immobile nodular lesion on the lateral aspect of the distal phalanx of the hallux. The lesion was nonulcerated and showed no evidence of increased vascularity. Nail dystrophy secondary to previous onychocryptosis was noted, without signs of active infection. No clinical extension of the lesion into the interphalangeal joint was evident, and joint motion was preserved.

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## FINDINGS AND INTERPRETATION OF IMAGING STUDIES

Anteroposterior and oblique radiographs of the foot demonstrated an abnormality involving the distal phalanx of the hallux (Figure 1).


**Figure 1.** Radiographs of the right foot. **A.** Anteroposterior view. Eccentric lesion involving the proximal metaphyseal-diaphyseal region of the distal phalanx of the hallux (long arrow). **B.** Oblique view. Thinning of the dorsolateral cortex (short arrow).

Further imaging evaluation included contrast-enhanced magnetic resonance imaging (MRI) (Figure 2).

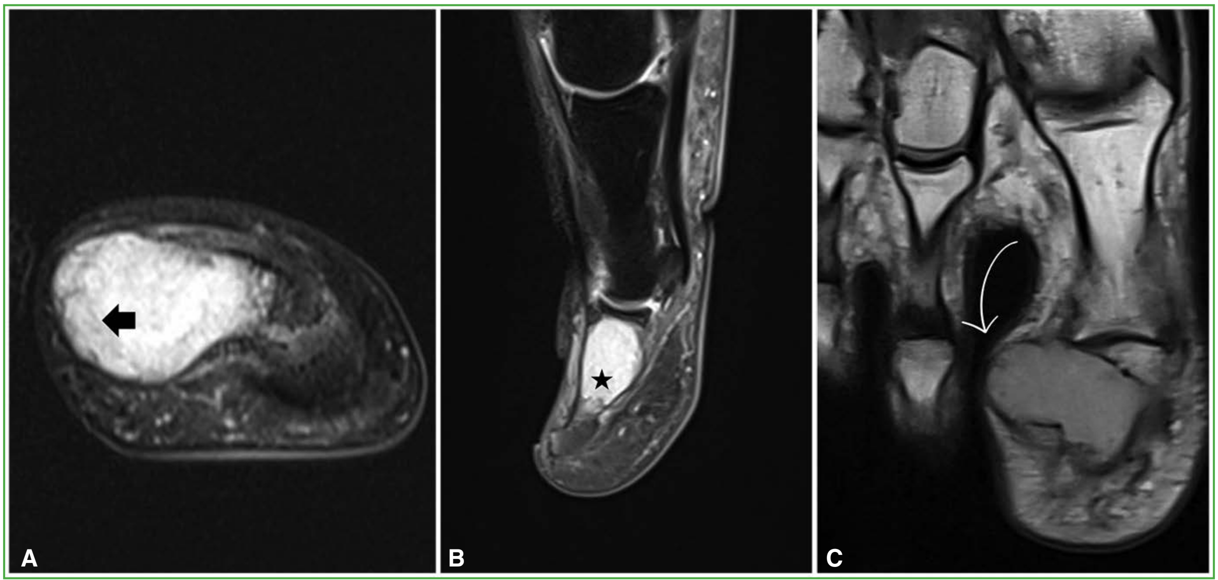


**Figure 2.** Contrast-enhanced magnetic resonance imaging of the right foot. **A.** Axial T2-weighted image showing a hyperintense lesion adjacent to the lateral cortex of the distal phalanx of the hallux (black arrowhead). **B.** Sagittal T2-weighted image demonstrating intramedullary extension within the distal phalanx of the hallux (black star). **C.** Coronal T1-weighted image showing lateral cortical destruction of the distal phalanx and a homogeneous, non-septated lesion (white curved arrow).

Based on the clinical presentation, physical examination findings, and imaging studies, surgical treatment was planned, consisting of complete tumor excision with tissue sampling for histopathological examination, placement of bone graft within the residual defect, and possible internal fixation if required.

Conflicts of interest: The authors declare no conflicts of interest.

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# Outcomes of Distraction Subtalar Arthrodesis for the Treatment of Calcaneal Fracture Malunion: A Case Series

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## ABSTRACT

**Objectives:** The objective of this study is to evaluate and analyze the outcomes of a series of patients diagnosed with calcaneal fracture malunion treated with distraction subtalar arthrodesis. **Materials and Methods:** Nine patients (five women and four men; mean age, 56.3 years) were retrospectively evaluated, with a mean follow-up of 31.28 months. Weight-bearing lateral radiographs were used to assess talocalcaneal height, talar declination angle, calcaneal declination angle, and Meary's angle. Clinical outcomes were evaluated using the Visual Analog Scale (VAS) for pain and the American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Score. Patient satisfaction was also assessed. **Results:** Talocalcaneal height increased by 0.7 cm, talar declination angle by 4.5°, CP by 1.3°, and Meary's Angle decreased by 4.8°. The VAS pain score decreased by 5.8 points, and the AOFAS score increased by 50 points. Eight patients reported being very satisfied and one patient was satisfied with the outcome. **Conclusions:** Distraction subtalar arthrodesis provides excellent clinical and radiographic outcomes in patients with calcaneal fracture malunion. It reduces pain and improves function while restoring hindfoot height and talar declination.

**Keywords:** Calcaneal fracture; malunion; subtalar arthrodesis.

**Level of Evidence:** IV

## Resultados de la artrodesis subastragalina distractiva en el tratamiento de secuelas de una fractura de calcáneo: serie de casos

## RESUMEN

**Objetivos:** Evaluar y analizar los resultados de una serie de pacientes con diagnóstico de secuela de una fractura de calcáneo tratados con artrodesis subastragalina distractiva. **Materiales y Métodos:** Se evaluó, en forma retrospectiva, a 9 pacientes (5 mujeres y 4 hombres; edad promedio 56.3 años), con un seguimiento de 31.28 meses. En las radiografías de perfil con carga, se evaluaron la altura astrágalo-calcánea, el ángulo de declinación del astrágalo, el ángulo de declinación del calcáneo y el ángulo de Meary. Se emplearon la escala analógica visual para dolor y la escala de la AOFAS de tobillo y retropié, y se determinó la satisfacción del paciente. **Resultados:** La altura astrágalo-calcánea aumentó 0,7 cm; el ángulo de declinación del astrágalo, 4,5°; el ángulo de declinación del calcáneo, 1,3° y el ángulo de Meary disminuyó 4,8°. La medición en la escala analógica visual disminuyó 5,8 puntos y la de la escala AOFAS aumentó 50 puntos. Ocho pacientes se manifestaron muy satisfechos y uno, satisfecho con el resultado. **Conclusiones:** La artrodesis subastragalina distractiva logra muy buenos resultados clínico-radiográficos en pacientes con diagnóstico de secuela de una fractura de calcáneo, disminuye el dolor y mejora la funcionalidad del paciente, al tiempo que restaura la altura del retropié y la declinación del astrágalo.

**Palabras clave:** Fractura de calcáneo; consolidación viciosa; artrodesis subastragalina.

**Nivel de Evidencia:** IV

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## INTRODUCTION

The sequelae of calcaneal fractures may be associated with a variety of structural and functional abnormalities of the hindfoot that result in pain and significant functional impairment, including peroneal tendon pathology, subtalar arthritis and stiffness, varus or valgus malalignment, and widening of the calcaneus.[1-3] Subtalar arthrodesis is the most commonly used salvage procedure because, when combined with other techniques such as osteotomies and lateral wall exostectomy, it has proven effective in relieving pain and correcting malunion deformities.[4-6]

Severe collapse of the posterior facet represents a more challenging scenario because it leads to secondary loss of talar declination and decreased hindfoot height, potentially resulting in anterior ankle pain, reduced ankle dorsiflexion, and diminished triceps surae function if not adequately corrected.[7–9] In 1988, Carr et al.[4] reported their results using distraction subtalar arthrodesis in these situations, and since then, several studies have demonstrated favorable outcomes with this technique.[1–9] Despite these encouraging results, there is still no consensus regarding certain aspects of the procedure, such as the optimal graft material or fixation method.

The aim of this study was to evaluate and analyze the outcomes of a series of patients with calcaneal fracture malunion treated with distraction subtalar arthrodesis.

## MATERIALS AND METHODS

A retrospective review was performed of a series of patients with calcaneal fracture malunion following an intra-articular calcaneal fracture who were treated with distraction subtalar arthrodesis and had a minimum follow-up of 6 months.

Patients treated with in situ subtalar arthrodesis, those with other ipsilateral leg, ankle, or foot injuries, and those with diabetes or neurological disease were excluded.

Eleven patients treated by the senior authors between May 2015 and December 2022 were identified. Four were excluded from the final analysis: one because follow-up was shorter than 6 months at the last evaluation, one because of an ipsilateral ankle fracture, and two because adequate preoperative clinical and radiographic assessments were unavailable. The final cohort consisted of 7 patients (5 women and 2 men) ranging in age from 36 to 74 years (mean age 61 years).

During the acute phase, four patients had been treated nonoperatively, one had undergone open reduction and internal fixation, and two had received no treatment because the initial injury had gone unrecognized.

Preoperative and postoperative clinical and functional evaluations were performed using the Visual Analog Scale (VAS) for pain[10] and the *American Orthopaedic Foot and Ankle Society* (AOFAS) Ankle-Hindfoot Scale (maximum possible postoperative score: 94/100, because the scale awards 6 points for normal or only mildly restricted subtalar motion).[11] Patient satisfaction was also assessed and categorized as dissatisfied, satisfied, or very satisfied.

For preoperative planning, weight-bearing anteroposterior and lateral radiographs of both feet and ankles, axial radiographs of both calcanei, and computed tomography scans were evaluated. The following parameters were measured on weight-bearing lateral foot radiographs: 1) Talocalcaneal height (TCH): distance from the talar dome to the plantar cortex of the calcaneal tuberosity measured along a line perpendicular to the ground, expressed in centimeters. 2) Talar declination angle (TDA): angle formed between a line perpendicular to the ground and a line perpendicular to the longitudinal axis of the talus. 3) Calcaneal declination angle (CDA): angle formed between a line tangent to the plantar cortex of the anterior process and calcaneal tuberosity and a line parallel to the ground. 4) Meary's angle (or Meary's line): angle formed by the longitudinal axes of the talus and the first metatarsal. If the talar inclination exceeds that of the first metatarsal, the resulting angle is considered negative (Figure 1). All measurements were performed by one of the authors using a goniometer.

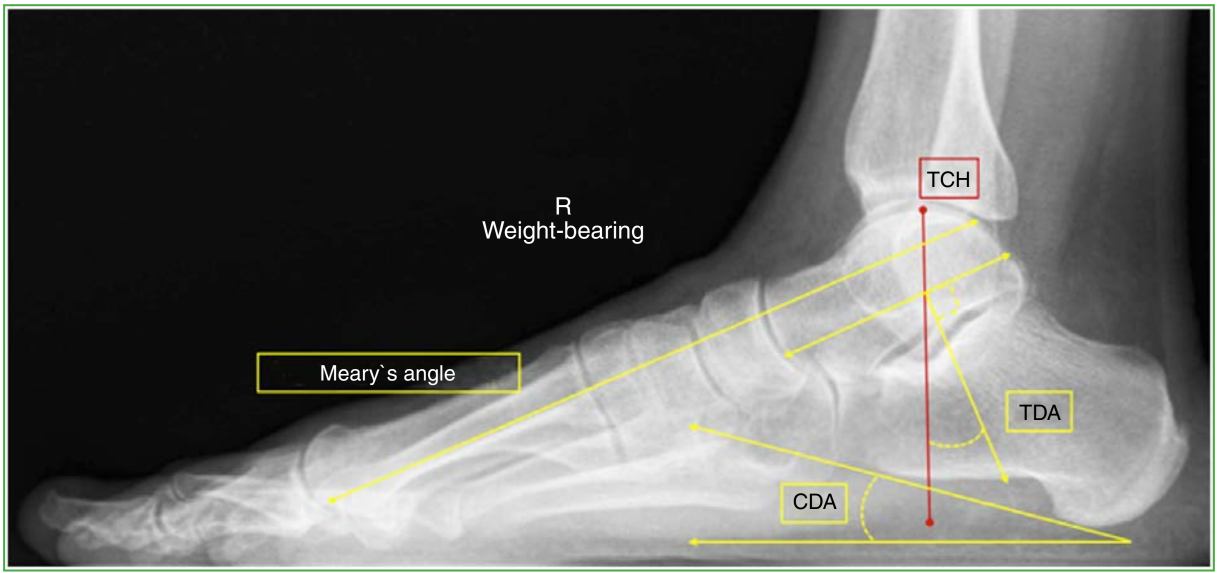


**Figure 1.** Measurements obtained on a weight-bearing lateral radiograph of an uninjured foot. TCH = talocalcaneal height; TDA = talar declination angle; CDA = calcaneal declination angle.

## Surgical Technique

In six patients, the extensile lateral approach described by Benirschke and Sangeorzan was used. Patients were positioned in the lateral decubitus position with pelvic straps, elevation of the operative limb, and a thigh tourniquet. The vertical limb of the incision was made longitudinally between the lateral border of the Achilles tendon and the posterior border of the fibula, with identification and protection of the sural nerve. The horizontal limb was made along the junction between the plantar and lateral skin. During dissection, care was taken to avoid injury to the peroneal tendons. The first step consisted of resection of the lateral wall of the calcaneus using a saw or osteotome when calcaneal widening was present, followed by removal of the subtalar articular cartilage. In cases of varus malalignment, a Dwyer-type osteotomy was performed using a saw or osteotome, whereas a medial sliding osteotomy was performed when valgus malalignment was present. The joint was distracted with a laminar spreader, and a PEEK spacer was inserted together with bone graft harvested from the previous bone cuts. Fixation was then achieved with two fully threaded 6.5- or 7.0-mm cannulated screws under fluoroscopic guidance.

In one patient, a posterolateral approach was used because substantial calcaneal widening was not present. The patient was positioned supine, and the incision included only the vertical limb of the extensile lateral approach.

# RESULTS

All patients reported hindfoot pain and stiffness and had failed conservative treatment, including oral analgesics, orthotics, and physical therapy. None reported anterior ankle pain.

Radiographs of all patients demonstrated subtalar osteoarthritis and collapse of the posterior calcaneal facet. Five patients had calcaneal widening associated with varus deformity >10°, whereas two had varus deformity without widening.

The mean postoperative follow-up was 32 months (range 6-98 months) (Table 1).

**Table 1.** Patient information

| | Age | Gender | Initial treatment | Follow-up (months) | Additional procedure | Bone graft | 6.5 mm cannulated screws | Complica-tions |
|---|---|---|---|---|---|---|---|---|
| 1 | 59 | F | None | 30 | None | Autologous - Iliac crest | Partial thread | Graft collapse |
| 2 | 36 | M | ORIF | 29 | RO + lateral wall resection + Dwyer | Autologous -Calcaneus | Partial thread | No |
| 3 | 57 | M | None | 18 | Lateral wall resection + osteo-tomy | Autologous -Calcaneus | Full thread | No |
| 4 | 21 | M | ORIF | 12 | RO + lateral wall resection + osteotomy | Autologous -Calcaneus | Full thread | No |
| 5 | 57 | F | None | 26 | Lateral wall resec-tion + Dwyer | Autologous -Calcaneus | Full thread + PEEK spacer | No |
| 6 | 74 | F | Conservative | 6 | Lateral wall re-section + Dwyer | Autologous -Calcaneus | Partial thread | Graft collapse |
| 7 | 70 | F | Conservative | 98 | Lateral wall resection | Autologous -Calcaneus | Partial thread + PEEK spacer | No |
| 8 | 73 | M | Conservative | 9 | Lateral wall resection + osteotomy | Autologous -Calcaneus | Partial thread | No |
| 9 | 60 | F | Conservative | 6 | Lateral wall resection | Autologous -Calcaneus | Full thread | No |

F = female; M = male; ORIF = open reduction and internal fixation; RO = removal of osteosynthesis.

## Clinical and Functional Assessments

According to the visual analog scale, the mean pain score was 7.5 (min. 6, max. 9) before surgery and 1.7 (min. 0, max. 5) at the postoperative evaluation.

The mean AOFAS score was 35.2 (min. 19, max. 61) before surgery and 87 (min. 74, max. 94) afterward (Figure 2). Six patients reported being "very satisfied" and one reported being "satisfied" with the treatment outcome.

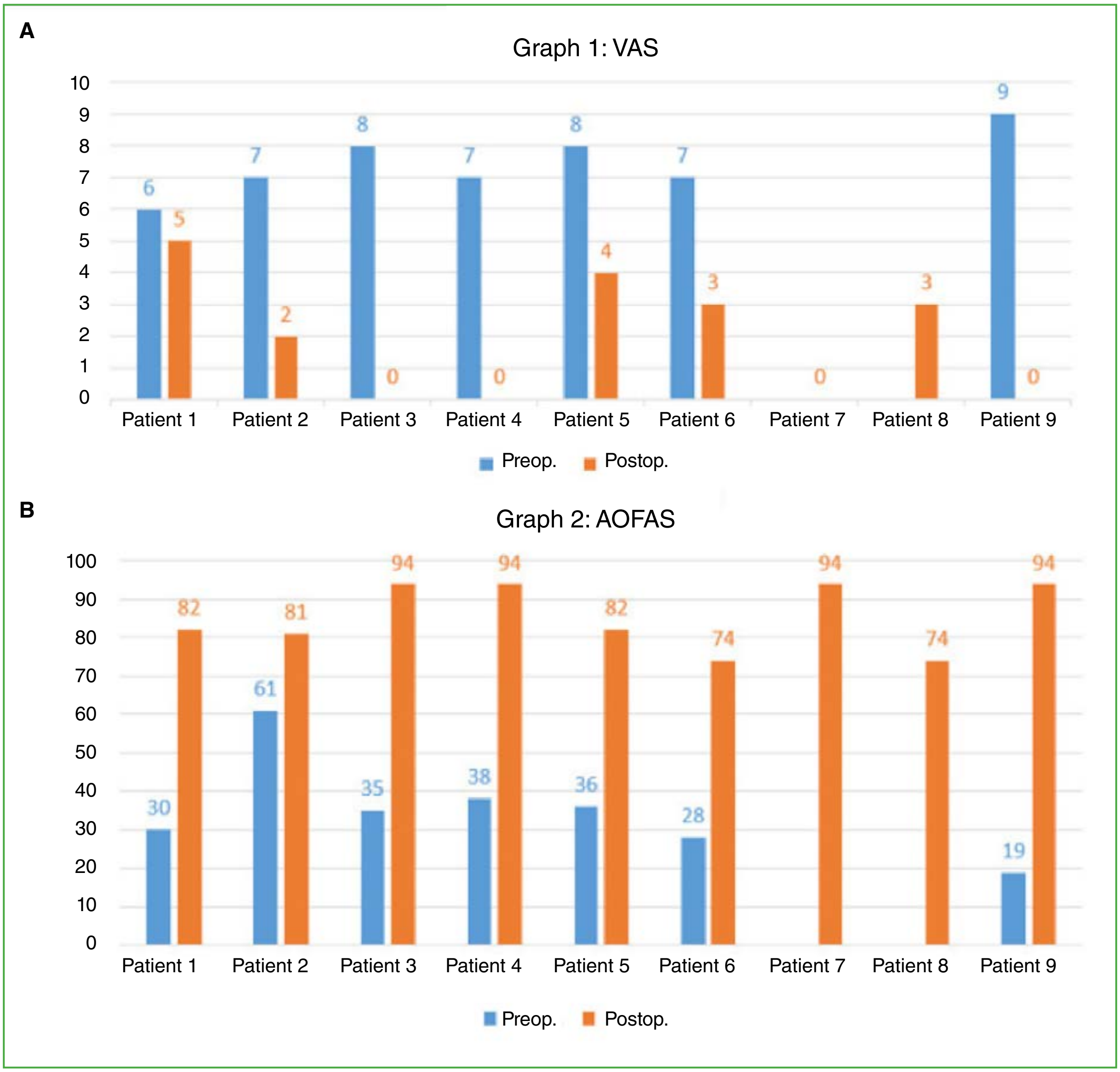


**Figure 2.** Comparison of preoperative and postoperative Visual Analog Scale (VAS) pain scores (**A**) and AOFAS Ankle-Hindfoot Scale scores (**B**).

## Radiographic Evaluation

The mean talocalcaneal height (TCH) in the uninjured feet was 7.1 cm (range 5.8-10.1 cm). The mean TCH in the affected feet was 7.1 cm (range 6.0-9.2 cm) preoperatively and 7.8 cm (range 5.6-10.7 cm) postoperatively. The mean talar declination angle (TDA) in the uninjured feet was 20° (range 14°-29°). The mean preoperative TDA in the affected feet was 12.5° (range 5°-23°), improving to 17° (range 5°-24°) postoperatively. The mean calcaneal declination angle (CDA) in the uninjured feet was 18° (range 15°-23°). The mean preoperative CDA in the affected feet was 13.7° (range 9°-25°), increasing to 15° (range 7°-22°) after surgery. The mean Meary's angle in the uninjured feet was –1.7° (range –7° to 3°). In the affected feet, the mean Meary's angle was 11.1° (range 0°-16°) preoperatively and 6.3° (range 0°-18°) postoperatively (Table 2).

**Table 2.** Radiographic measurement values.

| | TDA (°) | | | CDA (°) | | | Meary's angle (°) | | | TCH (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Preop. | Postop. | CF | Preop. | Postop. | CF | Preop. | Postop. | CF | Preop. | Postop. | CF |
| 1 | 5 | 5 | 14 | 9 | 9 | 15 | 16 | 18 | 0 | 6.5 | 5.6 | 7.2 |
| 2 | 15 | 16 | 20 | 9 | 8 | 15 | 14 | 0 | 0 | 8.1 | 10.7 | 9.3 |
| 3 | -- | 15 | 27 | -- | 13 | 16 | -- | 0 | -7 | -- | 8.5 | 9 |
| 4 | -- | 22 | 20 | -- | 22 | 21 | -- | 0 | 0 | -- | 8.2 | 8.4 |
| 5 | 23 | 24 | 23 | 9 | 7 | 15 | 0 | 0 | -2 | 6.7 | 8.2 | 6.1 |
| 6 | 5 | 12 | 29 | 14 | 15 | 20 | 16 | 13 | -6 | 6 | 6.5 | 6.7 |
| 7 | 10 | 16 | 20 | 25 | 22 | 24 | 16 | 13 | 3 | 6.8 | 7.5 | 7.1 |
| 8 | 18 | 20 | 25 | 11 | 15 | 20 | 10 | 0 | -5 | 6.6 | 6.8 | 7.6 |
| 9 | 12 | 16 | 20 | 19 | 15 | 19 | 6 | 3 | 0 | 9.2 | 9.5 | 10.1 |
| Mean | 12.5 | 16.2 | 22 | 13.7 | 14 | 18.3 | 11.1 | 5.2 | -1.9 | 7.1 | 7.9 | 7.9 |

TDA = talar declination angle; CDA = calcaneus declination angle; TCH = talocalcaneal height; Preop. = preoperative; Postop. = postoperative; CF = contralateral foot.

## DISCUSSION

Distraction subtalar arthrodesis is a well-established indication in patients with calcaneal fracture malunion associated with loss of hindfoot height and talar horizontalization, regardless of whether anterior ankle impingement is present.[12,13]

Our findings are consistent with those reported in the international literature highlighting the benefits of this procedure.[1,6,7,14-20] Since the initial descriptions by Gallie[14] and the popularization of the technique by Carr et al.,[4] restoration of hindfoot height has been one of the primary objectives. In this regard, Myerson and Quill[7] proposed a loss of talocalcaneal height (TCH) greater than 8 mm together with radiographic evidence of tibiotalar impingement as an indication for surgery. Similarly, Zwipp and Rammelt[13] incorporated this indication into their classification of type 3, 4, and 5 lesions, in which restoration of hindfoot height and talar declination are key treatment goals.[8,15,19,20]

In our series, the effectiveness of the procedure was reflected in substantial clinical improvement, with a mean reduction of 5.8 points on the Visual Analog Scale and a mean increase of 50 points on the AOFAS Ankle-Hindfoot Scale. Radiographically, mean TCH increased by 0.7 cm, TDA improved by 4.5°, and CDA improved by 1.3°, whereas Meary's angle decreased by 4.8°. These results translated into a high level of patient satisfaction, with 88.8% of patients reporting that they were "very satisfied," including one patient who experienced significant clinical improvement despite partial graft collapse.

Graft collapse is a recognized complication of this procedure.[21] In our series, it occurred in two cases (22.2%), highlighting the importance of fixation strategy and structural support (Figure 3). Although controversy remains regarding the use of fully threaded screws[1,3,4,22] versus partially threaded screws to achieve compression,[5–7] our experience suggests that maintaining correction with fully threaded screws may be advantageous in preventing loss of alignment.

With regard to grafting, although autologous iliac crest bone graft remains the gold standard because of its biological properties,[1-5,14,22,23] we have used alternative options to reduce donor-site morbidity. Structural grafts obtained from the Dwyer osteotomy or lateral wall resection, as well as the use of PEEK spacers,[24] appear to be effective alternatives (Figure 4). The latter provide excellent structural support and may reduce the risk of graft collapse.[25]

Regarding surgical exposure, the extensile lateral approach provided adequate visualization for removal of previous fixation hardware and performance of complex osteotomies. However, we agree with Pollard and Schuberth[21] that skin tension following distraction is a critical factor. Therefore, in severe deformities, we recommend making the vertical limb of the incision as vertical as possible to minimize the risk of wound-closure complications.


**Figure 3.** Representative case. Preoperative radiograph (**A**), intraoperative subtalar distraction (**B**), placement of the bone graft (**C**), and postoperative radiograph showing graft collapse (**D**).


**Figure 4.** Representative case. Preoperative radiograph (**A**), intraoperative image of the PEEK spacer (**B**), placement of the bone graft (**C**), and postoperative radiograph (**D**).

No infections or wound complications occurred, and the fusion rate in this series was 100%, comparable to that reported in other published studies.[21,25]

The main limitations of this study are the small sample size (7 patients) and the relatively short follow-up period. A major strength is the thorough clinical and radiographic evaluation of the patients.

Future studies with larger cohorts and longer follow-up are needed to further compare fixation methods and the types of bone graft used.

## CONCLUSIONS

Distraction subtalar arthrodesis is associated with excellent clinical and radiographic outcomes in patients with calcaneal fracture malunion. The procedure reduces pain, improves function, restores hindfoot height, and improves talar declination.

Conflicts of interest: The authors declare no conflicts of interest.

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# Direct Cannulated Screw Fixation of Bartoníček-Rammelt Type 2 and Type 3 Posterior Malleolar Fractures

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**ABSTRACT**
**Introduction:** The importance of the posterior malleolus in ankle stability has been demonstrated in numerous studies, and most authors agree that surgical fixation is indicated when the fragment involves more than 25-30% of the articular surface. However, the optimal fixation method remains controversial. **Objective:** To evaluate the mid-term outcomes of isolated fixation of posterior malleolar fractures using cannulated screws, with particular emphasis on functional recovery, joint stability, and complication rates. **Materials and Methods:** A retrospective study was conducted between January 2018 and December 2022. Inclusion criteria were age >18 years, posterior malleolar fractures treated exclusively with cannulated screws, and a minimum follow-up of 24 months. Clinical and radiographic evaluations were performed preoperatively and postoperatively. **Results:** Fifty-eight patients were included. The mean fragment size was 28.4% of the articular surface. Anatomic reduction was achieved in 82.7% of cases, with a union rate of 100%. At follow-up, ankle dorsiflexion was reduced by 25% and plantar flexion by 20%. The *American Orthopaedic Foot & Ankle Society* (AOFAS) score improved from 58.4 to 88.6, while the Visual Analog Scale (VAS) pain score decreased from 7.1 to 2.8. The overall complication rate was 17.2%. **Conclusions:** Direct fixation of the posterior malleolus with cannulated screws is an effective strategy for the management of these fractures, achieving high rates of anatomic reduction and a complication profile comparable to that of other fixation methods.

**Keywords:** Fracture; posterior malleolus; ankle.
**Level of Evidence:** IV

## Fijación directa con tornillos canulados de las fracturas tipos 2 y 3 de Bartoníček y Rammelt

**RESUMEN**
**Introducción:** En numerosos estudios, se ha demostrado la importancia del maléolo posterior en la estabilidad del tobillo, y la mayoría concuerda en que es necesaria la fijación quirúrgica cuando el fragmento representa >25-30% de la superficie articular. Sin embargo, el método de fijación ideal sigue siendo controvertido. **Objetivo:** Evaluar los resultados a mediano plazo de la fijación exclusiva de fracturas del maléolo posterior con tornillos canulados, especialmente la recuperación funcional, la estabilidad articular y las tasas de complicaciones. **Materiales y Métodos:** Estudio retrospectivo realizado entre enero de 2018 y diciembre de 2022. Los criterios de inclusión fueron: edad >18 años, fracturas fijadas exclusivamente con tornillos canulados y un seguimiento mínimo de 24 meses. Se llevaron a cabo evaluaciones clínicas y radiológicas pre y posoperatorias. **Resultados:** Se incluyó a 58 pacientes. El tamaño promedio del fragmento fue del 28,4%. Se logró una reducción anatómica en el 82,7% de los casos, con una tasa de consolidación del 100%. En el seguimiento, la dorsiflexión disminuyó un 25% y la flexión plantar, un 20%. El puntaje de la escala de la AOFAS mejoró de 58,4 a 88,6, mientras que el puntaje de la escala analógica visual para dolor disminuyó de 7,1 a 2,8. La tasa global de complicaciones fue del 17,2%. **Conclusiones:** La fijación directa del maléolo posterior con tornillos canulados representa una estrategia efectiva para el manejo de estas fracturas, con altas tasas de reducción anatómica y un perfil de complicaciones comparable con el de otros métodos de fijación.

**Palabras clave:** Fractura; maléolo posterior; tobillo.
**Nivel de Evidencia:** IV

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## INTRODUCTION

Ankle fractures involving the posterior malleolus (PM) are associated with poorer clinical outcomes and a higher risk of osteoarthritis.[1-3] Numerous studies have demonstrated the importance of the PM in ankle stability, and most authors agree that surgical fixation is necessary when the fragment accounts for more than 25-30% of the articular surface.[4–8] Regardless of the size of the posterior malleolus, in recent years, greater attention has been paid to the anatomical restoration of the incisura and to the stability of the distal tibiofibular syndesmosis by directly reducing and fixing the posterior fragment.[9] There are various fixation options, such as anteroposterior or posteroanterior screws, buttress plates, or a combination of these techniques.[9–12] However, the ideal fixation method remains controversial.

Fixation of the PM with posterior screws allows for anatomical reduction and absolute stability, which are fundamental factors for adequate treatment.[13] Nevertheless, its effectiveness in terms of functional outcomes remains an active area of research.[14,15] The biomechanical stability of screw fixation has been questioned in comparison with other fixation methods, which motivated the present study.

The objective of this study was to evaluate the mid-term outcomes of treatment using cannulated screws alone for PM fractures. Through clinical and imaging evaluations, we sought to analyze key aspects, such as functional recovery, joint stability, and the occurrence of complications, as well as to identify predictors of therapeutic success. The analysis of these results may contribute to a better understanding of the indications and limitations of this treatment strategy for PM fractures.

## MATERIALS AND METHODS

After obtaining approval from our hospital's Ethics Committee (protocol number 9,273), we conducted a retrospective analysis of the department's database to identify all patients who underwent surgery for a trimalleolar ankle fracture between January 2018 and December 2022.

We included patients older than 18 years with acute unilateral ankle fractures (<15 days from injury) involving the PM, treated exclusively with screw fixation through a posterior approach, who underwent pre- and postoperative computed tomography (CT) and had a minimum follow-up of 24 months.

Patients were excluded if they had comorbidities that contraindicated surgery (poorly controlled diabetes mellitus, severe peripheral vascular disease), pre-existing pathology of the affected ankle, open fractures, avulsion fractures, or non-displaced fractures (<2 mm) in which the PM was not fixed.

### Variables Analyzed

After reviewing the medical records, the following variables were recorded: sex, age, affected side, and associated comorbidities (body mass index, diabetes mellitus, smoking, peripheral vascular disease, among others).

All patients had standard ankle radiographs and pre- and postoperative computed tomography (CT) scans available for evaluation.

Preoperative CT images were used to determine the size of the PM fragment (%) and the presence of a third fragment. The axial slice with the largest measurable diameter, on which the contour of the intact tibial articular surface could be assessed, was used as the reference.[16] The Bartoníček-Rammelt classification was used to define the different types of PM fractures.[17]

The time from injury to surgery, operative time, and the surgical approach used (posteromedial or posterolateral) were documented.

Based on the immediate postoperative radiographs, the fixation construct was classified as follows: one buttress screw plus one compression screw, one buttress screw plus two compression screws, or one buttress screw plus one positional screw (Figure 1). The fixation construct was selected intraoperatively according to fragment size and whether the intercalary fragment was resected. In addition, the need for supplementary syndesmotic stabilization with a transsyndesmotic screw was recorded.

All measurements were performed by a single examiner (the operating surgeon and study author). Synapse Radiology PACS® software (version 5.7.000 AI, FUJIFILM Healthcare Americas Corporation, USA) was used for all measurements.

The quality of PM reduction was assessed on immediate postoperative axial and sagittal CT images and classified as anatomical (<1 mm articular gap/step-off), satisfactory (1-2 mm), or unsatisfactory (>2 mm).[18–20]

The timing of weight-bearing initiation and the time to fracture union were recorded, with union defined as disappearance of the fracture line in the PM fragment.[21]


Figure 1. Fixation constructs used. **A.** One buttress screw plus two compression screws. **B.** One buttress screw plus one compression screw. **C.** One buttress screw plus one positional screw.

At the final follow-up, a clinical examination was performed to assess ankle range of motion in comparison with the contralateral side.[13] Outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score and the visual analog scale (VAS) for pain.

Finally, treatment-related complications were recorded, including the development of mid-term degenerative changes. The degree of post-traumatic osteoarthritis was graded at final follow-up according to the radiographic classification of Bargon.[22]

## Surgical Technique

All patients underwent surgery under spinal or general anesthesia in the prone position with a pneumatic thigh tourniquet. In 49 patients, a standard posterolateral approach was used between the flexor hallucis longus tendon and the peroneal tendons, with identification and protection of the sural nerve. In the remaining nine cases, a modified posteromedial approach was used to access displaced posteromedial fragments between the flexor hallucis longus tendon and the posterior tibial neurovascular bundle.

Once the fracture had been exposed, displaced intercalary fragments were resected when they impeded reduction (n = 12). Reduction was achieved under direct visualization using reduction forceps and confirmed by intraoperative fluoroscopy. A fully threaded cannulated screw with a washer was then placed at the proximal apex of the fragment to function as a buttress screw. Finally, depending on fragment size and morphology, one or two 4.0-mm cannulated screws were inserted to provide interfragmentary compression or, when the intercalary fragment had been resected, positional fixation (Figure 2). Syndesmotic stability was assessed intraoperatively using a fluoroscopic stress test, and a transsyndesmotic screw was inserted when instability persisted (43.1% of cases).

## Technical Considerations and Pitfalls

Fixation using cannulated screws alone is a reproducible technique; however, it requires careful attention to several critical points that, in our experience, make the difference between a satisfactory outcome and an inadequate reduction.

First, accurate identification of the fracture fragment may be challenging in the presence of metaphyseal comminution or intercalary fragments. Preoperative CT evaluation with axial and sagittal reconstructions is essential for planning the size and number of screws.

Second, the decision to resect an intercalary fragment should be individualized. When its presence prevents anatomical reduction of the main posterior fragment, we recommend fragment resection followed by PM fixation using a buttress screw and a positional screw.

Third, the buttress screw with a washer should be placed at the proximal apex of the fragment and oriented perpendicular to the fracture line. Improper orientation may result in axial migration of the fragment and loss of reduction. Compression screws should be checked on lateral fluoroscopic views to ensure that they do not penetrate the tibiotalar joint.

A common pitfall is underestimating residual syndesmotic instability. Even after anatomical fixation of the PM, intraoperative stress testing may reveal persistent syndesmotic instability, as occurred in 43.1% of our series. Failure to perform this assessment may compromise the functional outcome.

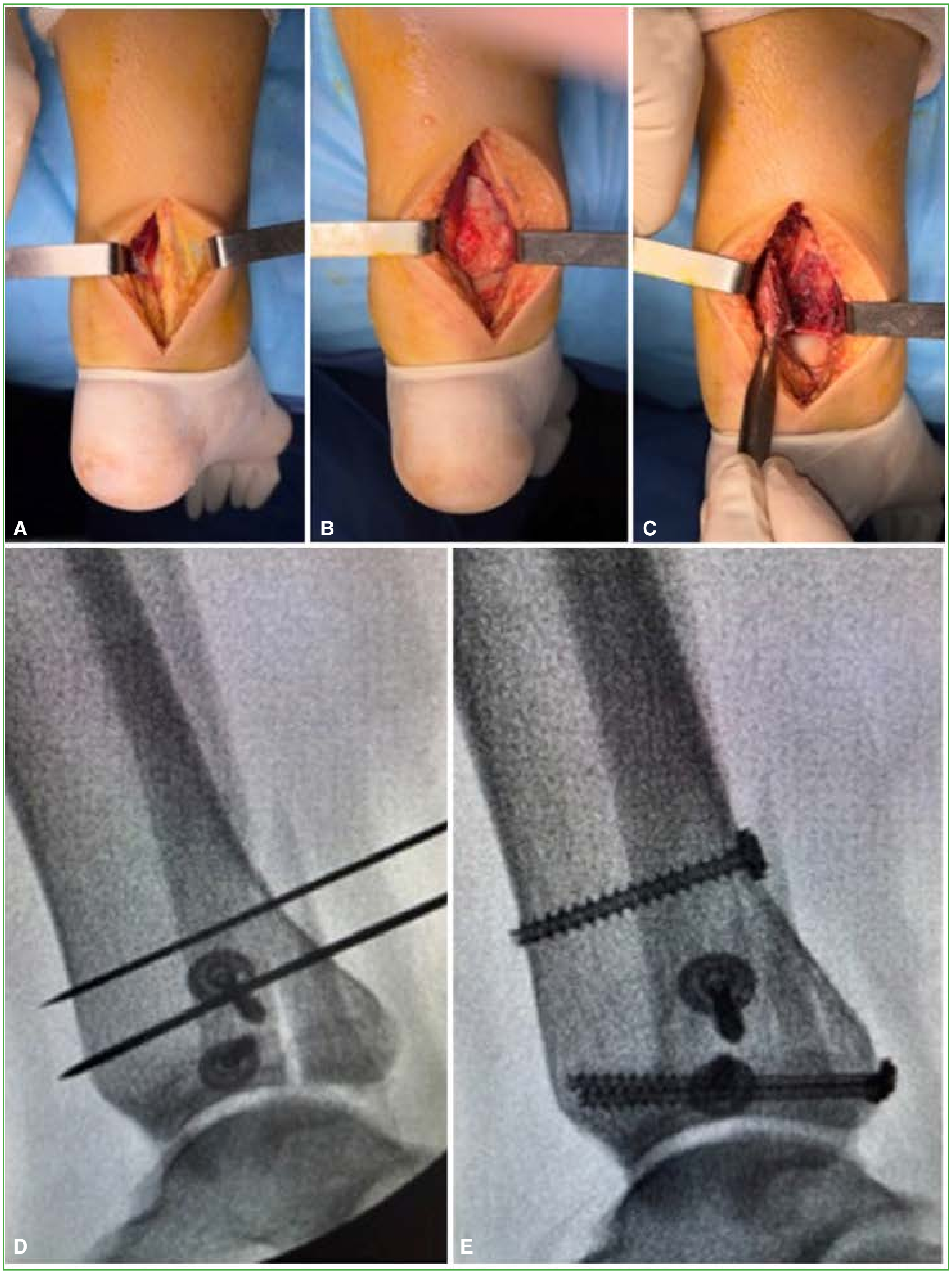


**Figure 2.** Surgical sequence for the posteromedial approach. **A.** Patient positioned prone with a posteromedial approach between the flexor hallucis longus tendon and the posterior tibial neurovascular bundle. **B.** Exposure and direct visualization of the posterior malleolus through the posteromedial approach. **C.** Mobilization of the posterior fragment under direct visualization to allow anatomical reduction. **D and E.** Intraoperative fluoroscopic images showing placement of the buttress screw with a washer at the proximal apex of the fragment to prevent shear displacement, followed by transfracture compression screws inserted through the posterior cortex to minimize tendon irritation.

Finally, posterior approaches allow the fixation construct to be tailored to the fracture pattern rather than forcing the fracture to conform to the fixation construct, as is often the case with posterior plating. The different screw configurations available, together with the possibility of countersinking the screws within the posterior cortex, facilitate anatomical reduction while minimizing the risk of irritation of the posterior tendons by the fixation hardware.

### Statistical Analysis

Continuous variables are presented as mean and standard deviation or median and interquartile range, according to their distribution, whereas categorical variables are expressed as frequencies and percentages.

Continuous and categorical variables were compared using Student's *t* test and the $\chi^2$ test (or Fisher's exact test, when appropriate), respectively. A p value $<0.05$ was considered statistically significant.

The collected data were entered into an Excel spreadsheet (Redmond, WA, USA), and statistical analyses were performed using GraphPad Prism version 8.0 (La Jolla, CA, USA).

## RESULTS

Between January 2018 and December 2022, 223 patients were treated for ankle fractures involving the posterior malleolus (PM).

Ninety-eight patients were excluded because the PM was not fixed for various reasons (most had nondisplaced Bartoníček-Rammelt type 1 or type 2 fractures), 27 because fixation was performed with a buttress plate, 21 because preoperative or postoperative CT scans were unavailable, 9 because of open fractures, and 10 because of insufficient follow-up.

The final series comprised 58 patients with PM fractures treated exclusively with cannulated screw fixation and a mean follow-up of 32.5 ± 7.7 months. Demographic characteristics are summarized in Table 1.

**Table 1.** Characteristics of the patients included in the series (n = 58).

| | |
|---|---|
| Gender, n (%) | |
| Female | 37 (63.8) |
| Male | 21 (36.2) |
| Age (mean, SD) | 44.6 ± 16.4 |
| Side, n (%) | |
| Right | 26 (44) |
| Left | 32 (56) |
| Comorbidities | |
| BMI (mean, SD) | 26.9 ± 4.2 |
| Diabetes, n (%) | 5 (8.6) |
| Smoking, n (%) | 4 (6.9) |
| Vascular, n (%) | 2 (3.5) |

SD = standard deviation; BMI = body mass index.

The mean PM fragment size was 28.4 ± 7.0% (range, 20–38%) of the tibiotalar articular surface. Twelve fractures (20.7%) were associated with an intercalary fragment.

Thirty-three of the 58 PM fractures (57%) were Bartoníček-Rammelt type 2 and 25 (43%) were type 3. No type 4 fractures were treated with screw fixation alone.

Surgery was performed at a mean of 8.9 ± 4.6 days after injury. Mean operative time was 93.3 ± 40.6 minutes. A posterolateral approach was used in 49 patients (84.5%) and a modified posteromedial approach in the remaining 9 (15.5%).

In 39 patients (67.3%), fixation consisted of a full-threaded cannulated buttress screw with a washer placed at the apex of the fracture, supplemented by two transfracture compression screws. In 12 patients (20.7%), fixation consisted of a buttress screw plus one compression screw, whereas in the remaining 7 (12%), a buttress screw plus one positional screw was used. In these latter cases, this construct was selected because displaced intercalary fragments had been resected to achieve anatomical reduction of the PM.

Despite direct fixation of the PM, additional syndesmotic stabilization with a transsyndesmotic screw was required in 25 cases (43.1%).

According to postoperative CT scans, 48 patients (82.7%) achieved an anatomical reduction of the PM, 9 (15.5%) a satisfactory reduction, and 1 (1.8%) an unsatisfactory reduction (Figures 3–5).

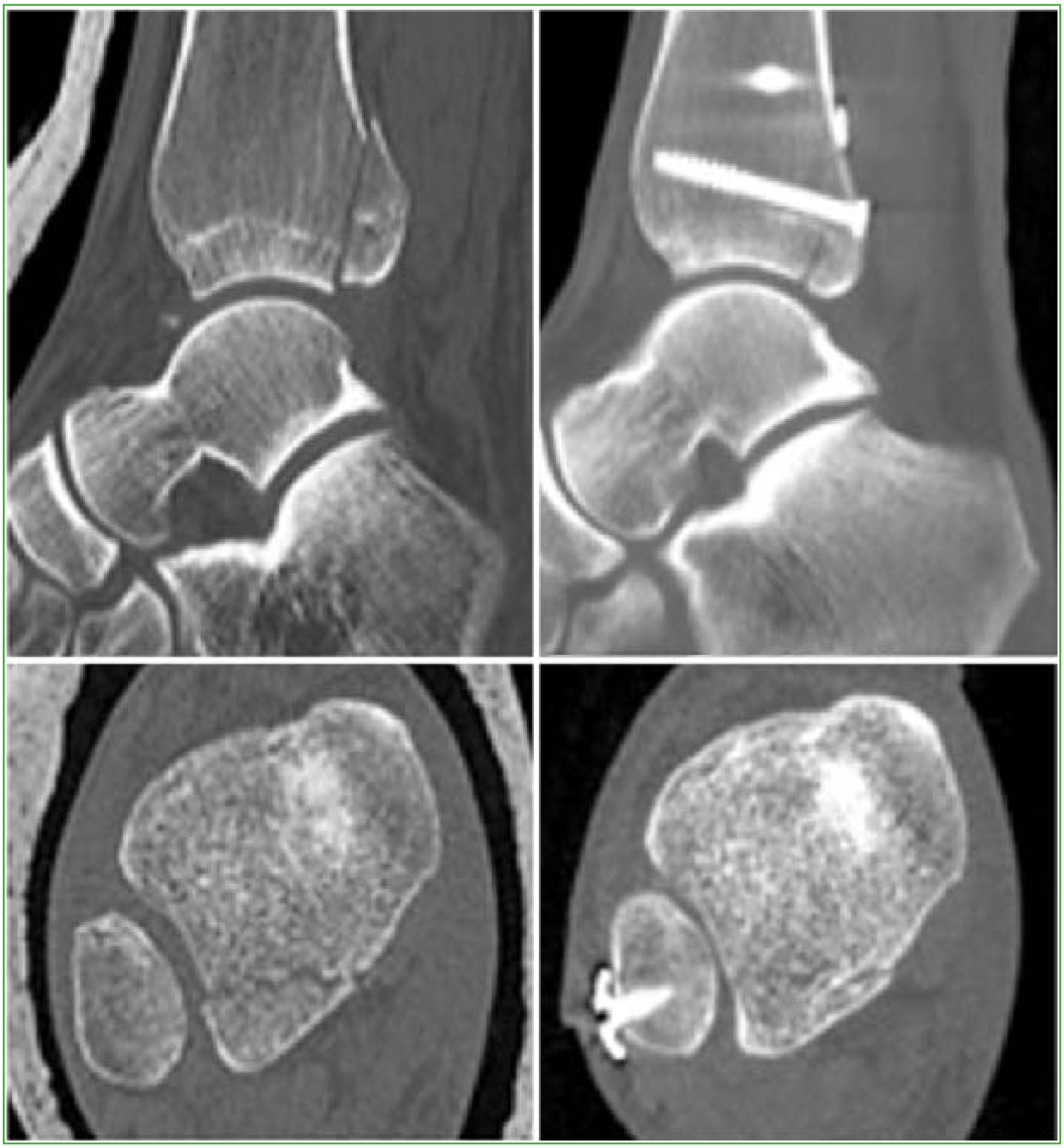

**Figure 3.** Quality of posterior malleolar reduction assessed by computed tomography in the immediate postoperative period: anatomical reduction. No displacement is observed.

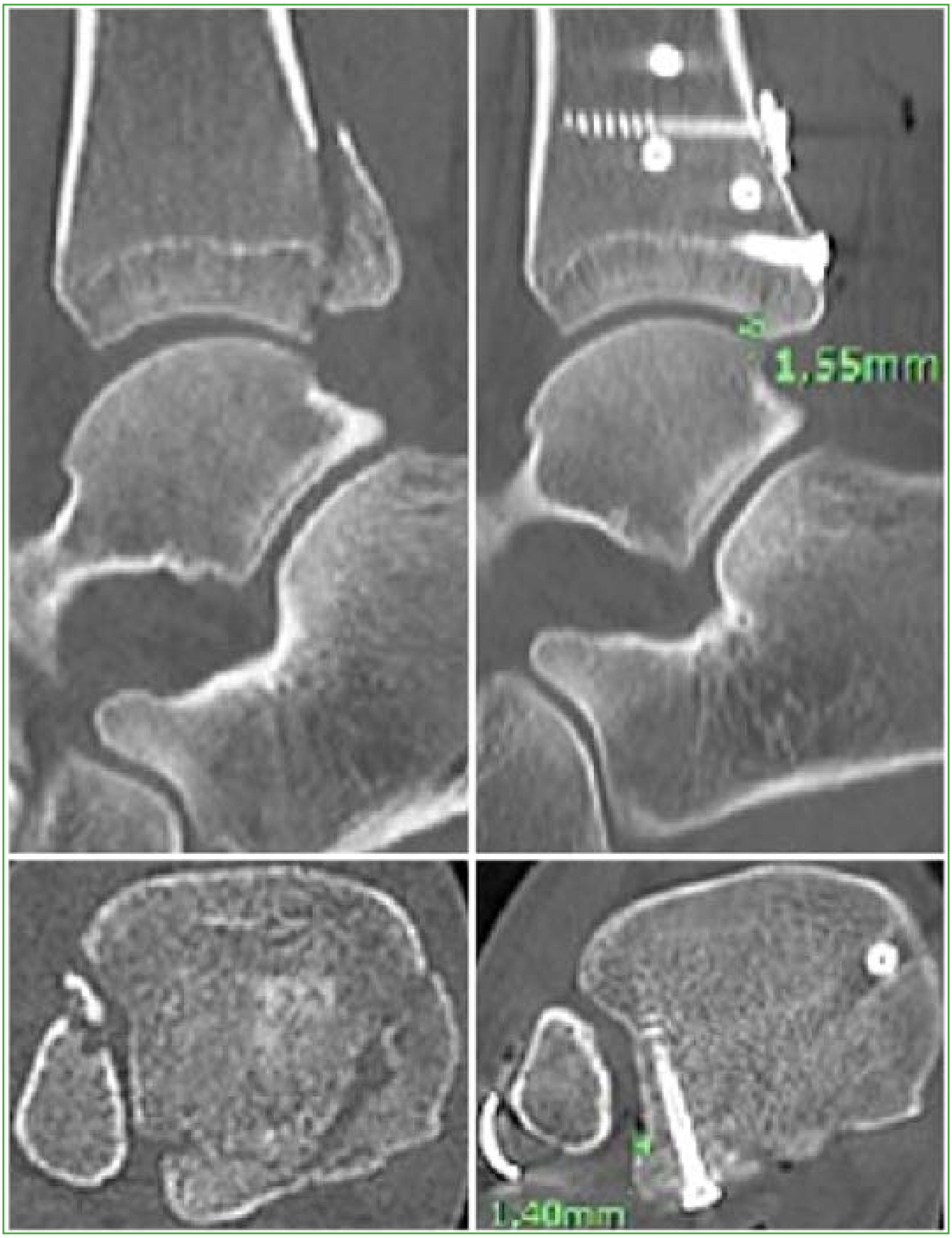


**Figure 4.** Quality of posterior malleolar reduction assessed by computed tomography in the immediate postoperative period: satisfactory reduction. Residual displacement between 1 and 2 mm is observed.


**Figure 5.** Quality of posterior malleolar reduction assessed by computed tomography in the immediate postoperative period: unsatisfactory reduction. Residual displacement >2 mm is observed.

Progressive weight-bearing was initiated at a mean of 5.3 ± 0.8 weeks, and PM union was achieved at a mean of 16.3 ± 3.8 weeks. The union rate at final follow-up was 100%.

Comparative assessment of ankle range of motion showed a 25% reduction in dorsiflexion and a 20% reduction in plantarflexion in the operated ankle (Table 2).

**Table 2.** Range of motion of the injured/uninjured ankle at the end of follow-up.

| Ankle range of motion | Operated | Uninjured | % |
|---|---|---|---|
| Dorsiflexion (°) | 13.7 | 18.3 | 75 |
| Plantar flexion (°) | 36.4 | 45.3 | 80 |

The percentages were obtained by dividing the range of motion of the operated ankle by the range of motion of the uninjured ankle.

The mean AOFAS score improved from 58.4 ± 5.1 preoperatively to 88.6 ± 5.6 at final follow-up. Mean pain scores on the visual analog scale improved from 7.1 ± 1.2 preoperatively to 2.8 ± 0.7 postoperatively.

The overall complication rate was 17.2% (n = 10). Two patients (3.45%) developed surgical site infections requiring surgical debridement and culture-directed antibiotic therapy. Three patients (5.17%) underwent implant removal one year after surgery because of implant-related pain. Finally, five patients (8.62%) developed grade 2 or grade 3 post-traumatic osteoarthritis according to the Bargon classification. None required revision surgery at the time of the study.

No cases of loss of reduction or implant failure were observed at final follow-up.

## DISCUSSION

Ankle fractures involving the posterior malleolus (PM) have consistently been associated with poorer clinical outcomes.[1,3,8] Appropriate treatment, surgical indications, and the optimal method of PM fixation remain subjects of debate.[7,10,11,13,23] Although buttress plating appears to be the preferred method for many authors, the findings of our study demonstrate that fixation with cannulated screws alone provides satisfactory mid-term clinical and radiographic outcomes comparable to those achieved with buttress plates.

Fractures involving more than 25% of the articular surface should be treated surgically.[16,18,24,25] For smaller fragments, the decision depends on fragment displacement, involvement of the incisura, and the presence of displaced intercalary fragments. Recent studies have suggested that fixation of these smaller fragments may also improve joint stability.[4,21,24] In our series, the mean PM fragment size was 28.4 ± 7.0%, similar to that reported by Zhang et al.[13] in which the mean fragment size was 30.9% in the screw fixation group and 31.7% in the plate fixation group.

The choice of surgical approach is based on the Bartoníček-Rammelt fracture classification, as well as the surgeon's preference and experience.[26] Erdem et al.[15] treated all PM fractures through a posterolateral approach. Similarly, Forberger et al.[27] used the same approach with excellent results. In our series, a posterolateral approach was used in 49 patients (84.5%), whereas a modified posteromedial approach was selected in the remaining 9 cases (15.5%) to reduce and fix displaced posteromedial fragments.

The literature generally recommends buttress plates rather than screws for PM fixation.[28] This recommendation is based on the belief that plates better prevent axial fragment migration by maintaining reduction,[14] a factor considered critical for successful fixation of these fractures.

In contrast, several recent studies have demonstrated that direct screw fixation provides functional and radiographic outcomes equivalent to those obtained with buttress plating while offering three distinct advantages: (1) less soft-tissue dissection, because it does not require the extensive exposure of the posterior tibial surface needed for plate application; (2) shorter operative time (Zhang et al. reported 78.5 vs. 98.2 minutes) and reduced intraoperative blood loss;[13,15,21] and (3) greater versatility of the fixation construct, allowing adaptation to fragment size and the presence or absence of intercalary fragments by using two or three 4.0-mm screws (Figure 6).

**Figure 6.** A 56-year-old patient with a fracture involving a large portion of the posterior malleolus. **A and B.** Preoperative ankle computed tomography, axial and sagittal views. The large posterior fragment involves 40% of the posterior malleolus. **C and D.** Anteroposterior and lateral ankle radiographs obtained one year after surgery. The reduction achieved with a construct consisting of one buttress screw plus two compression screws inserted through the posterior cortex is demonstrated. Stable fixation with complete union and no sagittal displacement was achieved.

These advantages, together with the lower cost of screws compared with precontoured plates, make this technique particularly attractive for resource-limited centers and for surgeons experienced in posterior approaches.

In our series, three different cannulated screw constructs were used, all incorporating a buttress screw with a washer. Mean operative time was 93.3 ± 40.6 minutes, and fracture union was achieved in all patients without loss of reduction at a mean of 16.3 ± 3.8 weeks.

In ankle fractures associated with syndesmotic injury, rotational forces predominate, and disruption or avulsion of the posterior inferior tibiofibular ligament is frequently accompanied by injury to the anterior inferior tibiofibular and interosseous ligaments.[28] Therefore, fixation of the PM alone does not guarantee complete syndesmotic stability or accurate rotational reduction of the fibula within the incisura.

Accordingly, despite direct fixation of the PM, additional syndesmotic stabilization with a suprasyndesmotic screw was required in 25 cases (43.1%).

Failure to restore articular congruity is associated with poorer postoperative functional outcomes compared with anatomical reduction.[18–20] The incidence of osteoarthritis increases when the articular step-off exceeds 2 mm.[30] Both articular congruity and stability are independent prognostic factors that determine surgical success.[13,31,32] In our study, anatomical reduction was achieved in 48 patients (82.7%) and satisfactory reduction in 9 (15.5%). Kang et al.[22] reported similar findings, with 94% of screw-fixed PM fractures showing an articular step-off <2 mm. In a comparative study of 40 patients, Erdem et al.[15] reported one patient with a 3-mm step-off in the screw fixation group and one patient with a 2-mm step-off in the plate fixation group.

In our series, the mean AOFAS score improved from 58.4 to 88.6, while the mean visual analog scale pain score decreased from 7.1 to 2.8 at final follow-up. These findings are consistent with those reported in previous studies of PM fixation. In a retrospective study of 32 patients, Roukun et al. reported a mean AOFAS score of 92 points at final follow-up. Likewise, Forberger et al., in a series of 45 patients treated with buttress plate fixation, reported a mean postoperative AOFAS score of 93 points.

Conservative treatment of ankle fractures has been associated with a statistically significant reduction in ankle range of motion compared with surgical treatment.[20,31] Therefore, we consider anatomical reduction and stable internal fixation essential, as they allow early mobilization exercises, which are fundamental for rapid recovery.[31]

In our series, dorsiflexion of the operated ankle was reduced by 25% and plantarflexion by 20% compared with the contralateral ankle. These findings are consistent with previous reports. Zhang et al.[13] observed reductions of 22.5% in dorsiflexion and 15.1% in plantarflexion in the screw fixation group, compared with the uninjured ankle, whereas the corresponding values in the plate fixation group were 15.5% and 12.2%, respectively.

Despite the favorable mid-term outcomes, postoperative complications, particularly the development of osteoarthritis, remain an important concern. This underscores the importance of meticulous preoperative evaluation and appropriate surgical technique, as anatomical reduction and stable internal fixation are essential for minimizing these risks. The complication rate observed in our study is comparable to those reported in the literature. Five patients (8.6%) developed post-traumatic osteoarthritis by the end of follow-up. Similarly,

Zhang et al.[13] identified five cases (10.4%) of severe osteoarthritis.

## CONCLUSIONS

This study has limitations inherent to its retrospective design, including the lack of randomization and the relatively small sample size. Prospective studies with larger cohorts and longer follow-up are needed to validate our findings and further evaluate the effectiveness of different fixation techniques.

In our series, anatomical or satisfactory reduction of the PM was achieved in 98% of patients, with no loss of reduction during follow-up and a complication rate comparable to those reported for other fixation methods.

Direct fixation of posterior malleolar fractures with cannulated screws represents an effective strategy for the management of these injuries.

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# Minimally Invasive Treatment of Chronic Exertional Compartment Syndrome: A Case Series

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## ABSTRACT

**Introduction:** Chronic exertional compartment syndrome causes exertion-induced limb pain. It predominantly affects young athletes and the diagnosis is confirmed by measuring intracompartmental pressure. Fasciotomy is the treatment of choice when symptoms do not respond to conservative management. Minimally invasive decompression has gained increasing attention because of its lower morbidity and faster patient recovery. **Objective:** To describe the surgical technique and its clinical, functional, and patient-reported outcomes. **Materials and Methods:** A retrospective descriptive study was conducted on three men with chronic exertional compartment syndrome who underwent surgery between 2021 and 2025. The following variables were analyzed: demographic characteristics, pain assessed using the Visual Analog Scale (VAS), function assessed using PROMIS®, quality of life assessed using the EuroQol-5D, sports activity level assessed using the Tegner Activity Scale, complications, and patient satisfaction. **Results:** The median age was 27 years. Pain decreased from 10 to 2. The PROMIS® T-score increased from 49.0 to 55.0, and the EuroQol-5D score increased from 0.85 to 1.0. Two patients exceeded their preinjury sports activity level, and one returned to the same level. One minor complication was recorded. **Conclusions:** Minimally invasive fasciotomy achieved satisfactory preliminary clinical and functional outcomes; however, larger comparative studies are needed to validate these findings.

**Keywords:** Chronic exertional compartment syndrome; fasciotomy; minimally invasive surgery; leg pain.
**Level of Evidence:** IV

## Tratamiento mínimamente invasivo para el síndrome compartimental crónico por ejercicio: serie de casos

## RESUMEN

**Introducción:** El síndrome compartimental crónico por ejercicio causa dolor en las extremidades inducido por el esfuerzo. Afecta predominantemente a atletas jóvenes y su diagnóstico se confirma midiendo la presión intracompartimental. La fasciotomía es la técnica de elección cuando el cuadro no responde al manejo conservador. La descompresión mínimamente invasiva ha ganado relevancia, debido a la menor morbilidad y la rápida recuperación del paciente. **Objetivo:** Describir la técnica quirúrgica y los resultados clínicos, funcionales y subjetivos. **Materiales y Métodos:** Estudio descriptivo retrospectivo de 3 hombres con síndrome compartimental crónico por ejercicio operados entre 2021 y 2025. Se analizaron las siguientes variables: demográficas, dolor (escala analógica visual), función (PROMIS®), calidad de vida (EuroQol-5D), nivel deportivo (clasificación de Tegner), complicaciones y satisfacción. **Resultados:** La mediana de edad fue de 27 años. El dolor disminuyó de 10 a 2. El puntaje T aumentó de 49,0 a 55,0 y el puntaje del EuroQol-5D, de 0,85 a 1,0. Dos pacientes superaron su nivel deportivo previo y uno lo igualó. Se registró una complicación menor. **Conclusiones:** La fasciotomía mínimamente invasiva logró resultados clínicos y funcionales preliminares satisfactorios; sin embargo, se requieren estudios comparativos más amplios para validar estos hallazgos.

**Palabras clave:** Síndrome compartimental crónico por ejercicio; fasciotomía; cirugía mínimamente invasiva; dolor de pierna.
**Nivel de Evidencia:** IV

## INTRODUCTION

Chronic exertional compartment syndrome (CECS) is a condition characterized by pain caused by increased intracompartmental pressure (ICP) within fascial compartments. It occurs primarily in individuals who engage in intense physical activity and can affect both the lower and upper extremities.[1] The classic symptoms include

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pain, muscle tightness, weakness, cramps, and paresthesias, which are relieved by cessation of exercise and rest.[2,3] However, diagnosis remains challenging because of the nonspecific and variable clinical presentation. It is established based on clinical findings and the measurement of ICP before and after exercise, which is considered the gold standard.[4]

CECS predominantly affects young athletes, particularly runners and soccer players (more commonly involving the lower extremities), as well as weightlifters and motorcyclists (more commonly involving the upper extremities).[1] According to military studies, Velasco et al.[3] reported an annual incidence of approximately 1 case per 2,000 individuals. The exact etiology remains unknown, although factors such as repetitive microtrauma, myopathies, vascular compromise, decreased fascial compliance, and muscle hypertrophy have been proposed.[5]

Conservative treatment includes physical therapy, massage therapy, nonsteroidal anti-inflammatory drugs, and foot orthoses.[1] However, fasciotomy is currently the surgical treatment of choice for refractory cases.[2] Available techniques include traditional open, endoscopic, and minimally invasive fasciotomy.[1] Minimally invasive fasciotomy has shown encouraging results, with return to activity at approximately three weeks and high patient satisfaction rates,[6–8] although some authors have reported potentially higher rates of complications or recurrence.[9]

To mitigate the risks of blind dissection and incomplete decompression commonly associated with single-incision techniques,[8,10] we adopted a dual-incision approach.[11] This method allows direct visualization and protection of the superficial peroneal nerve, thereby ensuring adequate fascial release.[11]

The objective of this study was to evaluate whether this dual-incision approach combines the safety of the open technique with the accelerated functional recovery associated with minimally invasive surgery. We describe a minimally invasive fascial decompression technique used in three patients with CECS and evaluate the clinical and functional outcomes, patient satisfaction, and return to sports activity.

## MATERIALS AND METHODS

A descriptive, retrospective, observational study was conducted in three patients diagnosed with CECS who underwent minimally invasive fascial decompression between 2021 and 2025. The diagnosis was established based on clinical evaluation, imaging studies, and post-exercise ICP measurements according to the criteria proposed by Pedowitz et al.[4] All patients had symptoms refractory to conservative treatment and were therefore indicated for surgical management.

Conservative treatment consisted of a nonoperative approach aimed at correcting extrinsic and intrinsic factors potentially associated with the development of the condition. All patients completed a physical therapy program focused on stretching and muscle-strengthening exercises, together with a gradual reduction in training volume and modifications to the training surface and athletic footwear. In addition, they used custom foot orthoses to improve alignment and reduce repetitive impact forces on the affected compartments.[12] Conservative treatment was maintained for a minimum of six months before surgery was indicated because of persistent symptoms and functional impairment.

Patients older than 16 years with confirmed CECS, established by clinical examination and ICP measurement, who underwent minimally invasive surgery and had a minimum follow-up of six months were included. Patients with acute compartment syndrome, concomitant musculoskeletal disorders, or incomplete medical records were excluded.

### Surgical Technique

The patient is placed in the supine position under spinal anesthesia with a thigh tourniquet. A minimally invasive dual-incision technique is used for decompression of the anterior and lateral compartments.[11] Two longitudinal incisions approximately 2.5-4 cm in length are made along the lateral aspect of the leg. The proximal incision is located approximately three fingerbreadths distal to the fibular head, whereas the distal incision is placed three fingerbreadths proximal to the lateral malleolus. Both incisions are centered over the intermuscular septum, identified using the leg compression test.[7] It is essential to identify and protect the superficial peroneal nerve before performing the distal fasciotomy. Its course should be identified during the preoperative physical examination, as the nerve typically emerges through the deep fascia at the junction of the middle and distal thirds of the leg.[8]

The fasciotomy is performed in a minimally invasive manner using Metzenbaum scissors. The fascia is identified, and adequate release is confirmed both visually and by digital palpation. At least 90% of the total fascial length should be released to prevent recurrence due to incomplete decompression.[5] For the posterior compartments (superficial and deep posterior compartments), a single longitudinal incision approximately 5 cm in length is made 2.5 cm medial to the tibial crest at the mid-leg level.[11] The great saphenous vein and saphenous nerve are identified and protected. Before wound closure, the tourniquet is released and meticulous hemostasis is achieved. The procedure is performed unilaterally or bilaterally, depending on the case. An elastic compression bandage is applied, and weight-bearing as tolerated with crutch assistance is allowed immediately after surgery. The surgical technique is shown in the Figure.


**Figure.** Surgical technique.

The analyzed variables were obtained from the medical records, postoperative follow-up, and a structured telephone survey. All patients provided written informed consent. Demographic, clinical, imaging, and functional data were collected. The recorded variables included age, sex, affected side, comorbidities, type of sport practiced, preoperative and postoperative functional level according to the Tegner Activity Scale,[13] clinical characteristics (symptoms, time from symptom onset to surgery expressed in months, time to pain onset during sports activity expressed in minutes, and preoperative and postoperative visual analog scale [VAS] scores),[14] preoperative imaging studies (pre- and post-exercise magnetic resonance imaging, ultrasonography, and plain radiographs), post-exercise ICP measurements in the anterior, lateral, and posterior compartments of both legs, postoperative complications, return to work and sports activity measured in weeks, and qualitative return-to-sport level based on the patient's perception.

ICP was measured using a multiparameter monitor connected to a mean arterial pressure measurement system through a three-way stopcock. The system was flushed with saline solution, and a 14-gauge Abbocath catheter was used for pressure measurements. After calibration and zeroing, the transducer was positioned at the same level as the lower extremities, and measurements were obtained from the different compartments. To ensure reproducibility and minimize interobserver variability, all measurements were performed by the same senior surgeon. The provocation protocol consisted of continuous running until the patient reported symptom limitation. Measurements were obtained immediately after cessation of exercise, always within 5 minutes of symptom reproduction.

All postoperative complications were recorded and classified throughout follow-up, including infections, neurological injuries, seromas, hematomas, symptom recurrence, and the need for reoperation.

Return to activity was evaluated by recording the time elapsed, in weeks, from surgery to resumption of sports participation, as well as the level achieved compared with the preoperative level, according to the patient's perception, and categorized as: same level, lower level, higher level, change of sport, or no return.

Patient satisfaction was assessed using a structured telephone survey based on a five-point Likert scale.[15] Patients were classified as very satisfied if they reported no or mild pain and no difficulty walking; satisfied if they reported mild pain, walking with or without slight difficulty, and willingness to undergo the same procedure again under similar circumstances; neither satisfied nor dissatisfied if they expressed no clear opinion; dissatisfied if they reported moderate pain, difficulty walking, and doubts regarding the success of the procedure; and very dissatisfied if they experienced greater pain and greater difficulty walking than before surgery. In addition, patients were asked: *"Knowing the outcome now, would you choose to undergo the same surgery again?"*, with a dichotomous (Yes/No) response.

The Spanish version of the PROMIS® Physical Function Short Form 10a (PROMIS® PF-10a)[16,17] was used as a standardized instrument for assessing self-reported physical function. This questionnaire consists of 10 items developed using item response theory and measures functional capacity in adults across activities ranging from basic daily tasks to more demanding physical activities. The Spanish version has been validated, ensuring conceptual and linguistic equivalence. PROMIS® PF-10a provides a precise, efficient, and responsive assessment with high reliability. Results are expressed as T-scores (mean = 50; standard deviation = 10), allowing direct comparison with the general population and across different clinical groups. The instrument evaluates the patient's ability to perform activities ranging from dressing and personal hygiene to running and lifting weights. Each item is scored from 1 to 5, with higher scores indicating better physical function. Raw scores range from 10 to 50 and are subsequently converted into T-scores. Values above 60 indicate excellent physical function or absence of limitations; values around 50 ± 10 represent average function in the general population; and values below 40 indicate significant functional impairment. An increase of ≥4–6 T-score points is considered a clinically meaningful improvement in physical function.

Health-related quality of life was assessed using the EuroQol-5D (EQ-5D) questionnaire,[18,] which allows patients to rate their health status across five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension is classified into three severity levels (no problems, some problems, or severe problems), generating a five-digit profile that describes the individual's health status. These profiles are converted into a utility index based on population preference values, ranging from 1 (best possible health state) to 0 (equivalent to death), with negative values possible for health states considered worse than death. For this study, the Spanish social value set proposed by Herdman et al. (2001)[18] was used, assigning specific coefficients to each dimension and severity level.

### Statistical Analysis

The results are presented descriptively using measures of central tendency (mean and median) and dispersion (standard deviation and interquartile range [IQR]), together with absolute and relative frequencies, owing to the small sample size.

## RESULTS

Three male patients were included, with a median age of 27 years (IQR 22-28). Two had bilateral involvement and one had unilateral right-sided involvement. Two were active smokers. All three participated in sports: one played competitive field hockey (Tegner level 8), one played competitive padel (level 6), and the third participated in recreational soccer combined with weight training (level 6). The median follow-up was 25.3 months (IQR 7-55.6).

The median time from symptom onset to surgery was 18 months (IQR 12-72), and the median time from the start of exercise to pain onset was 5 minutes (IQR 3-10).

Intracompartmental pressure measurements were obtained after exercise, within 5 minutes of symptom onset, and all values were elevated, consistent with CECS. In Patient 1, pressures were 35 mmHg in the anterior compartment, 39 mmHg in the lateral compartment, and 42 mmHg in the posterior compartment of the right leg, and 32, 41, and 40 mmHg, respectively, in the left leg. In Patient 2, pressures were 38 mmHg in the anterior compartment and 40 mmHg in the lateral compartment of the right leg, and 36 and 37 mmHg, respectively, in the corresponding compartments of the left leg, confirming bilateral chronic involvement. Patient 3 had pressures of 42 mmHg in the lateral compartment and 30 mmHg in the posterior compartment of the right leg, and 19 and 13 mmHg, respectively, in the corresponding compartments of the left leg. These values exceeded the commonly accepted diagnostic thresholds, defined as pressures >30 mmHg immediately after exercise or >20 mmHg at 5 minutes, according to the criteria proposed by Pedowitz et al.[4] The ICP measurements are summarized in Table 1.

**Table 1.** Measurement of intracompartmental pressure.

| Measurement of intracompartmental pressure (mmHg) | Right leg | | | Left leg | | |
|---|---|---|---|---|---|---|
| | Anterior | Lateral | Posterior | Anterior | Lateral | Posterior |
| Patient 1 | 35 | 39 | 42 | 32 | 41 | 40 |
| Patient 2 | 38 | 40 | | 36 | 37 | |
| Patient 3 | | 42 | 30 | | 19 | 13 |

All patients underwent imaging studies that showed no structural abnormalities. Two patients underwent post-exercise magnetic resonance imaging, which revealed no muscle edema, fascial hernias, or signs of neurovascular entrapment.

The median time to return to work was 3 weeks (IQR 1-6), whereas return to sports occurred after a median of 8 weeks (IQR 4-32). Two patients returned to a higher level of sports participation than before surgery, and one returned to the same level. None changed sports or discontinued athletic activity.

The Tegner Activity Scale remained unchanged, with a median score of 6 (IQR 6-8) both preoperatively and postoperatively. In contrast, pain measured with the visual analog scale (VAS) decreased substantially, from a median of 10 (IQR 8-10) preoperatively to 2 (IQR 0-4) after surgery.

The PROMIS® PF-10a T-score increased from a median of 49.0 (IQR 47.0-49.4) to 55.0 (IQR 49.4-61.0), reflecting an overall improvement in physical function. Similarly, the EuroQol-5D index increased from 0.85 (IQR 0.85-1.0) to 1.0 (IQR 1.0-1.0), indicating improved postoperative health-related quality of life.

Only one patient experienced minor complications: a superficial hematoma that resolved with compressive bandaging and mild dysesthesia at the lateral incision site of the left leg, which improved during follow-up. The dysesthesia resolved spontaneously without permanent motor or sensory sequelae. No infections, symptomatic recurrences, or reoperations were recorded.

In the satisfaction survey, two patients reported being very satisfied and one reported being neither satisfied nor dissatisfied. Two patients answered "Yes" to the question, *"Would you choose to undergo the same surgery again?"* The remaining patient answered "No," stating that the postoperative recovery period had been prolonged and demanding. The clinical and demographic characteristics of the patients are summarized in Table 2.

**Table 2.** Clinical and demographic characteristics of the patients.

| Variables | |
|---|---|
| Patients | 3 |
| Age, median (IQR) | 27 (22-28) |
| Male sex | 3 |
| Side | |
| Right | 1 |
| Left | 0 |
| Bilateral | 2 |
| Comorbidities | |
| Smoking | 2 |
| Sports played | |
| Field hockey | 1 |
| Padel | 1 |
| Soccer | 1 |
| Time from symptom onset to surgery (months), median (IQR) | 18 (12-72) |
| Time to symptom onset during exercise (min), median (IQR) | 5 (3-10) |
| Return to work (weeks), median (IQR) | 3 (1-6) |
| Return to sports (weeks), mean (SD) | 8 (4-32) |
| Level of return to sports | |
| Better level | 2 |
| Same level | 1 |
| Lower level | 0 |
| Changed sports | 0 |
| Did not return | 0 |
| Tegner classification, median (IQR) | |
| Preoperative | 6 (6-8) |
| Postoperative | 6 (6-8) |
| Would you undergo the surgery again? | |
| Yes | 2 |
| No | 1 |
| Likert satisfaction level | |
| Very satisfied | 2 |
| Satisfied | 0 |
| Neither satisfied nor dissatisfied | 1 |
| Dissatisfied | 0 |
| Very dissatisfied | 0 |
| Visual Analog Scale for pain, median (IQR) | |
| Preoperative score | 10 (8-10) |
| Postoperative score | 2 (0-4) |
| T score, PROMIS® PF-10a, median (IQR) | |
| Preoperative | 49.0 (47.0-49.4) |
| Postoperative | 55.0 (49.4-61.0) |
| EuroQoL-5D Index, median (IQR) | |
| Preoperative | 0.85 (0,85-1.0) |
| Postoperative | 1.0 (1,0-1.0) |
| Follow-up (months), median (IQR) | 25.29 (7-55.59) |

IQR = interquartile range.

## DISCUSSION

In this series of three patients who underwent minimally invasive fascial decompression, overall clinical and functional improvement was observed, with a marked reduction in pain, full return to sports participation, and high levels of patient satisfaction. Only one minor complication was recorded: a superficial hematoma and transient dysesthesia that resolved spontaneously. These findings are consistent with those reported in the literature, which demonstrates satisfactory functional recovery, low morbidity, and rapid return to sports following minimally invasive techniques.[1,5]

The main contribution of this study is the use of a dual-window approach to overcome the limitations of single-incision techniques, as it allows direct visualization of the superficial peroneal nerve while ensuring complete fascial release. This modification successfully combines the safety of the traditional open approach with the advantages of accelerated functional recovery associated with minimally invasive surgery.

Broderick et al.[8] described a minimally invasive technique assisted by an illuminated retractor that allows fascial release under direct visualization through a single 3-4 cm lateral incision. They highlighted the ability to visualize the superficial peroneal nerve and avoid blind dissection as a major advantage. All five patients in their series returned to sports at 12 weeks without complications, yielding results comparable to those observed in our study. Oliver et al.[7] reported the use of the mini-open lower limb fasciotomy (MLLF) technique in a cohort of 38 patients. They found a complication rate of 16% and a reoperation rate of 8%. Pain improved significantly, 64% of patients returned to sports, and overall satisfaction reached 74%, although a considerable proportion experienced partial recurrence of symptoms.

Similarly, Thein et al.[19] compared conservative treatment with minimally invasive anterior compartment fasciotomy in 43 patients and observed significantly greater improvements in pain and Tegner Activity Scale scores in the surgical group, with 77.4% of patients returning to their preinjury level of sports participation compared with 25% in the conservatively treated group. These findings support the role of surgical treatment in refractory cases, particularly among young athletes with high functional demands.

Grechenig et al.[20] evaluated the safety of minimally invasive fasciotomy of the anterior, lateral, and deep posterior compartments in 60 cadaveric lower extremities. Complete fascial release was achieved in 97%-100% of specimens without significant neurovascular injury, confirming the anatomical feasibility and safety of the technique. Nevertheless, in the literature, the overall complication rate of minimally invasive techniques is approximately 13%.[5] In this regard, the minor complication observed in our series (a superficial hematoma associated with transient dysesthesia that resolved spontaneously) is consistent with published reports. Likewise, Maffulli et al.[21] evaluated 18 athletes treated through a single minimal incision and reported that 94% returned to their previous or a higher level of sports participation, together with significant improvements in SF-36 and EQ-5D scores, without major complications or recurrences.

Baumfeld et al.[22] published a prospective series of 13 patients with chronic exertional compartment syndrome treated using a minimally invasive technique and reported a significant improvement in Tegner scores (from 3.9 to 7.1; $p = 0.01$), enhanced athletic performance, an increase in weekly running distance from 14 to 38 km, and 92% of patients reporting satisfaction or high satisfaction after a minimum follow-up of 12 months. These findings provide contemporary evidence that minimally invasive fasciotomy improves athletic performance and quality of life while maintaining a low complication rate, in agreement with our results.

More recently, endoscopic and ultrasound-guided techniques have also been described, offering the theoretical advantages of less soft-tissue trauma and improved cosmetic outcomes. However, their use remains limited by technical complexity, the risk of iatrogenic injury, and the lack of robust comparative evidence.[23,24]

Overall, the available evidence supports minimally invasive fasciotomy as a safe and effective alternative to the open approach, providing equivalent functional outcomes while reducing morbidity and improving cosmetic recovery. The minimally invasive technique shortens incision length, preserves soft tissues, and facilitates earlier rehabilitation, although an adequate learning curve is required to ensure complete fascial release.[20]

The diagnosis of CECS remains challenging because its symptoms may mimic medial tibial stress syndrome, nerve entrapment syndromes, or exertional claudication.[12,25,26] Post-exercise ICP measurement remains the diagnostic gold standard, although its availability is limited.[4,27] Post-exercise magnetic resonance imaging may provide complementary information, particularly in atypical cases or when findings are inconclusive.[28-30] Clinical suspicion therefore remains essential to avoid delayed diagnosis and treatment.

Regarding functional assessment, no disease-specific scales or return-to-sport criteria have been developed for patients with CECS. Consequently, validated instruments such as the PROMIS® PF-10a and EuroQol-5D were used to objectively quantify physical function and health-related quality of life.[16-18] Although these instruments were not specifically designed for CECS, they provide a standardized framework that facilitates interinstitutional comparisons and longitudinal follow-up.

The limitations of this study include its small sample size, retrospective design, and the selection bias inherent to this type of analysis. Nevertheless, CECS is a rare and frequently underdiagnosed condition, making even small case series valuable for describing the application and outcomes of emerging surgical techniques. A methodological strength of this study is that all procedures were performed by the same surgeon, thereby reducing technical variability.

In summary, our findings demonstrate a favorable trend regarding symptom relief, return to sports participation, and postoperative satisfaction following minimally invasive fascial decompression. However, prospective multicenter studies with larger cohorts and longer follow-up are required to confirm its effectiveness and establish definitive comparisons with conventional approaches.

## CONCLUSIONS

Minimally invasive fasciotomy for the treatment of chronic exertional compartment syndrome yielded satisfactory preliminary clinical and functional outcomes, including substantial pain relief, early return to sports, high patient satisfaction, and minimal postoperative morbidity. Although these findings suggest that this technique represents a viable therapeutic option for young, active patients, the descriptive nature of the study and the small sample size require that the results be interpreted as preliminary. Larger multicenter studies with longer follow-up are needed to definitively establish its benefits.

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# Tenosynovial Giant Cell Tumor of the Hindfoot: Arthroscopic Treatment and Clinical Outcomes

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## ABSTRACT

**Introduction:** Tenosynovial giant cell tumor is a benign synovial proliferation with locally aggressive behavior. Its occurrence in the hindfoot is uncommon and challenging. **Objective:** To evaluate the clinical outcomes and recurrence rate in patients with tenosynovial giant cell tumor of the ankle or subtalar joint treated with arthroscopic synovectomy without adjuvant radiotherapy. **Materials and Methods:** An observational study was conducted on seven patients treated exclusively by arthroscopy between 2014 and 2023, with a minimum follow-up of 24 months. The *American Orthopaedic Foot & Ankle Society* (AOFAS) score and the Visual Analog Scale (VAS) for pain were analyzed, and recurrence was monitored by magnetic resonance imaging. **Results:** Four diffuse and three localized forms were treated. Complete resection was achieved in all cases. The AOFAS score improved significantly from 63.43 to 94.57 ($p < 0.001$), and the VAS pain score decreased from 5.71 to 0.43 ($p < 0.001$). No complications or recurrences were observed after a mean follow-up of 57.4 months. **Conclusions:** In our series, arthroscopic synovectomy yielded satisfactory clinical outcomes, with no recurrences observed during follow-up. This technique may be considered an effective alternative in selected cases where complete resection of the pathological tissue is technically feasible, potentially avoiding the need for adjuvant radiotherapy.

**Keywords:** Tenosynovial giant cell tumor; pigmented villonodular synovitis; arthroscopy; ankle; subtalar joint; synovectomy.

**Level of Evidence:** IV

## Tumor tenosinovial de células gigantes en el retropié. Tratamiento artroscópico y resultados clínicos

## RESUMEN

**Introducción:** El tumor tenosinovial de células gigantes es una proliferación sinovial benigna, pero de comportamiento agresivo local, cuya presentación en el retropié es infrecuente y desafiante. **Objetivo:** Evaluar los resultados clínicos y la tasa de recidiva en pacientes con un tumor tenosinovial de células gigantes del tobillo o la articulación subastragalina tratados con una sinovectomía artroscópica, sin radioterapia adyuvante. **Materiales y Métodos:** Estudio observacional de 7 pacientes tratado exclusivamente mediante artroscopia, entre 2014 y 2023, con un seguimiento mínimo de 24 meses. Se analizaron los puntajes de la escalas de la AOFAS y la escala analógica visual, y se monitoreó la recidiva con resonancia magnética. **Resultados:** Se trataron 4 formas difusas y 3 localizadas. Se logró la resección completa en todos los casos. El puntaje de la escala de la AOFAS mejoró significativamente de 63,43 a 94,57 ($p <0,001$) y el dolor se redujo de 5,71 a 0,43 ($p <0,001$). No se registraron complicaciones ni recidivas tras un seguimiento promedio de 57.4 meses. **Conclusiones:** En nuestra serie, con la sinovectomía artroscópica, los resultados clínicos fueron satisfactorios y no hubo recidiva durante el seguimiento. La técnica podría considerarse una alternativa eficaz en casos seleccionados donde sea técnicamente factible lograr una resección completa del tejido patológico, evitando potencialmente la necesidad de radioterapia adyuvante.

**Palabras clave:** Tumor tenosinovial de células gigantes; sinovitis vellonodular pigmentada; artroscopia; tobillo; articulación subastragalina; sinovectomía.

**Nivel de Evidencia:** IV

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## INTRODUCTION

Tenosynovial giant cell tumor (TGCT), formerly known as pigmented villonodular synovitis, is a benign proliferation of the synovial membrane with locally aggressive behavior. Clinically, it presents with persistent pain, joint swelling, progressive stiffness, and even joint effusion, making the differential diagnosis with common inflammatory or traumatic conditions, such as sprains or mechanical or inflammatory synovitis, particularly challenging.[1] Early diagnosis and timely treatment are essential to prevent progression to joint degeneration or structural deformity.[2]

TGCT occurs in two forms: localized (L-TGCT) and diffuse (D-TGCT). The localized form presents as well-defined nodules, is less aggressive, has a low recurrence rate, and is more common in the hands and feet. In contrast, the diffuse form extensively involves the synovial membrane, may extend to bursae and tendon sheaths, and is associated with greater joint damage and a higher recurrence rate when complete synovectomy is not achieved (Figures 1 and 2).[2,3]

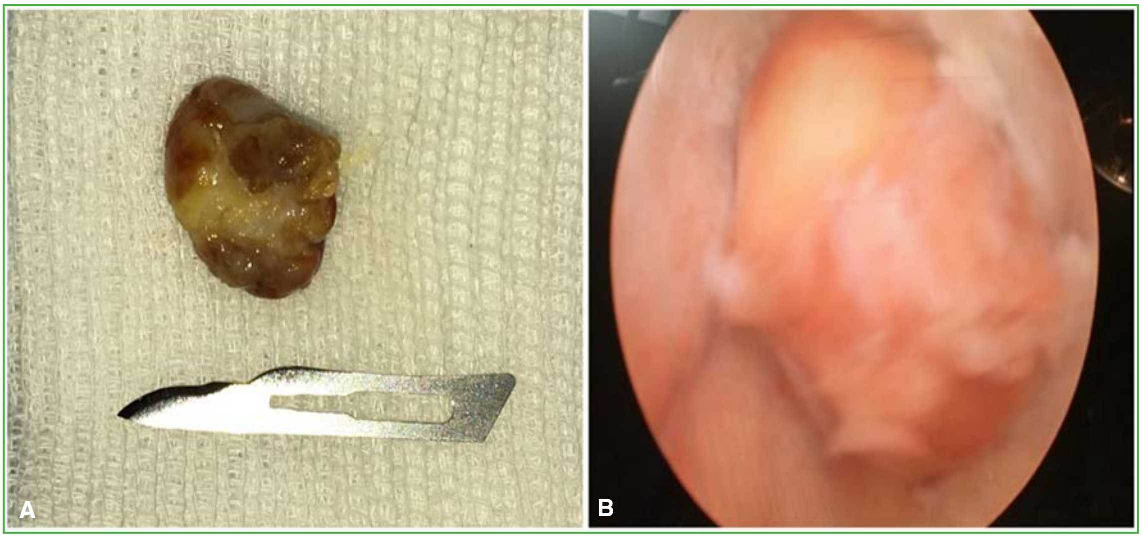


**Figure 1. A.** Macroscopic image of a resected localized tenosynovial giant cell tumor nodule. **B.** Arthroscopic image of an intra-articular localized tenosynovial giant cell tumor nodule.

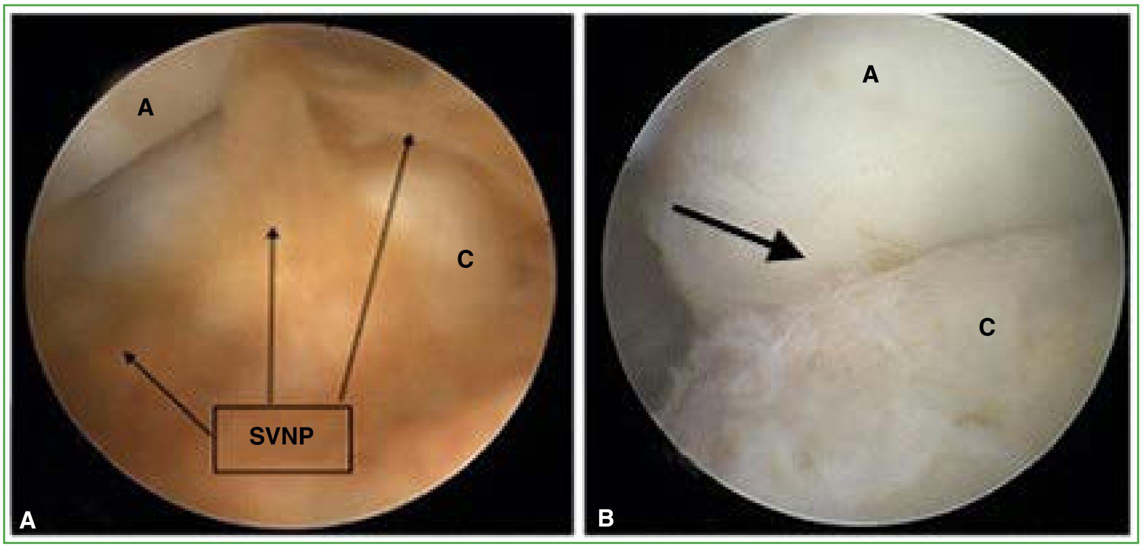


**Figure 2. A.** Intra-articular image of a diffuse tenosynovial giant cell tumor before synovectomy; black arrows indicate pathological synovial tissue. **B.** After synovectomy. The arrow points to the subtalar joint. C = calcaneus; T = talus.

The knee is the most commonly affected joint (70-80%), followed by the hip (10-20%). Ankle involvement accounts for only 2-4% of cases and is even less common in joints such as the subtalar, tarsometatarsal, or interphalangeal joints. The low prevalence of this condition in the ankle and foot poses a considerable diagnostic challenge. Its clinical presentation is often insidious and may be mistaken for other joint disorders.[1–3]

From an imaging standpoint, plain radiographs and computed tomography (CT) may initially reveal subchondral erosions with preservation of the joint space. Magnetic resonance imaging (MRI) is the imaging modality of choice, as it allows visualization of synovial proliferations and hemosiderin deposits, which are characteristic of this disease. In more advanced cases, multiple osseous erosions or extra-articular extension may be observed, further complicating therapeutic management (Figure 3).[3,4]


**Figure 3. A.** Anteroposterior ankle radiograph. The arrows indicate osteochondral lesions of the talar dome. **B.** Lateral ankle radiograph. The arrow indicates anterior bony impingement. **C and D.** Sagittal and coronal computed tomography (CT) images of the ankle. The arrows indicate osteochondral lesions.

Surgery is the mainstay of treatment, and arthroscopic or open synovectomy is the treatment of choice for resection of the affected synovial tissue. D-TGCT has a recurrence rate ranging from 10% to 50%, particularly when extra-articular involvement precludes complete resection. In a series of 76 patients with ankle TGCT, the recurrence rate was 11%, occurring exclusively in the diffuse variant.[1,4]

In cases of more aggressive disease or postoperative recurrence, some authors advocate adjuvant radiotherapy as a complementary treatment. However, its use remains controversial because of potential adverse effects and the lack of consensus regarding its long-term efficacy.

Although TGCT has been recognized for decades, its low prevalence in the ankle and foot may explain the limited published literature specifically addressing these locations. This highlights the importance of reporting clinical experience to improve our understanding of the diagnostic and therapeutic management of these lesions.

The objective of this study was to evaluate the clinical outcomes and recurrence rate in a series of patients with TGCT who underwent arthroscopic synovectomy of the ankle or subtalar joint without adjuvant radiotherapy.

## MATERIALS AND METHODS

An observational, descriptive, longitudinal study was conducted to analyze a series of patients diagnosed with tenosynovial giant cell tumor (TGCT) of the ankle or subtalar joint. All patients had been treated exclusively by arthroscopic surgery between July 2014 and June 2023 and had a minimum follow-up of 24 months.

The inclusion criteria were: histopathological confirmation of TGCT (Figure 4), involvement of the ankle or subtalar joint, treatment exclusively by arthroscopic synovectomy without adjuvant radiotherapy, and a minimum of 24 months of clinical and imaging follow-up. The diagnosis was based on clinical findings and, primarily, magnetic resonance imaging (MRI), which guided the indication for arthroscopic synovectomy and tissue sampling for histopathological examination.

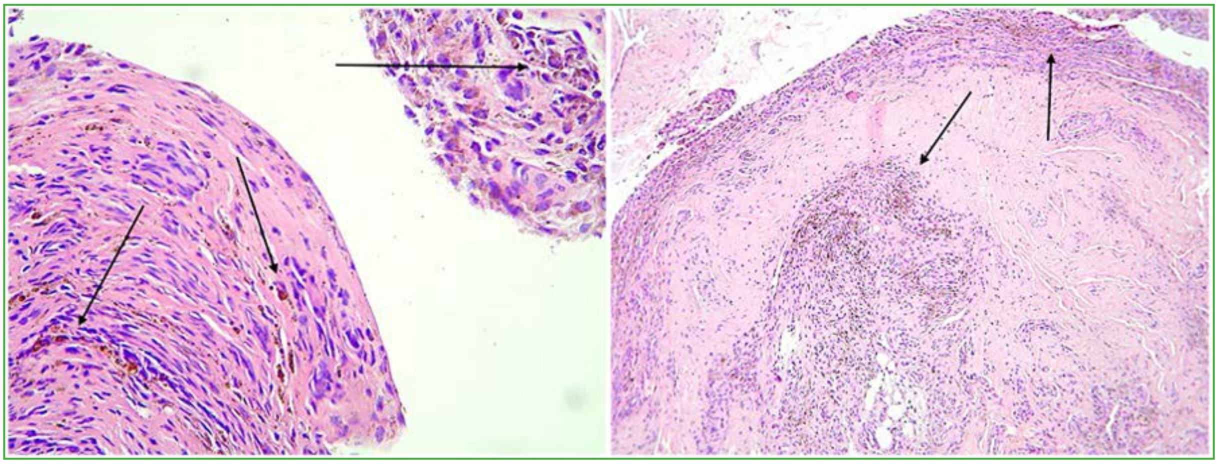

**Figure 4.** Histological findings from an arthroscopically obtained specimen. The arrows indicate hemosiderin deposits. Hematoxylin and eosin stain.

All patients underwent MRI during follow-up and at the final evaluation to assess for signs of recurrence.

The following variables were recorded: sex, age, affected side, involved joint (ankle, subtalar, or both), type of TGCT (localized or diffuse), presenting symptoms, and postoperative follow-up duration (months). The completeness of arthroscopic resection of the affected synovium (complete or incomplete) was also assessed. Preoperative imaging studies included anteroposterior, lateral, and oblique radiographs of the ankle and foot, as well as computed tomography (CT) and MRI of the ankle and foot. At the final follow-up visit, radiographs and MRI were repeated to rule out recurrence (Figures 5 and 6).

Preoperative and postoperative clinical outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score to assess pain, function, and foot and ankle alignment, as well as the visual analog scale (VAS) for pain. Patients were also asked whether they would choose to undergo the procedure again. Immediate and late postoperative complications (recorded at the final follow-up visit) were documented.

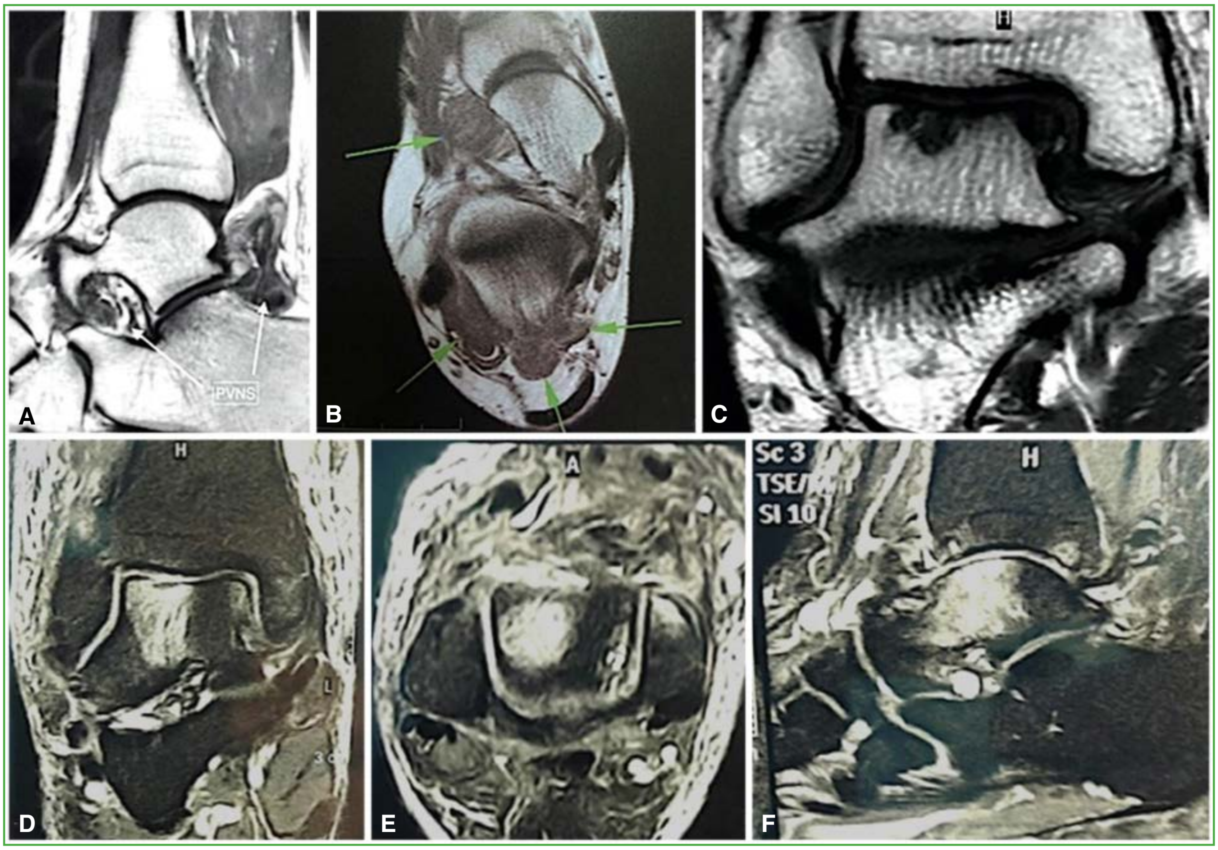


**Figure 5.** Magnetic resonance imaging of the ankle and hindfoot. The lesions are typically hypointense on both T1- and T2-weighted sequences because of the paramagnetic properties of hemosiderin. **A.** Sagittal T1-weighted image of the subtalar joint. Note the hypointense appearance of a tenosynovial giant cell tumor in the sinus tarsi and the posterior facet (white arrows). **B.** Axial image. Green arrows indicate the hypointense lesions of a tenosynovial giant cell tumor. **C.** Coronal image. Articular involvement of the talar cartilage and bone marrow. **D.** Coronal T2-weighted image of a tenosynovial giant cell tumor. **E.** Axial image. Extensive bone marrow edema involving the articular cartilage of the talar dome. **F.** Sagittal image. Kissing lesions involving the talar dome and the tibial plafond.

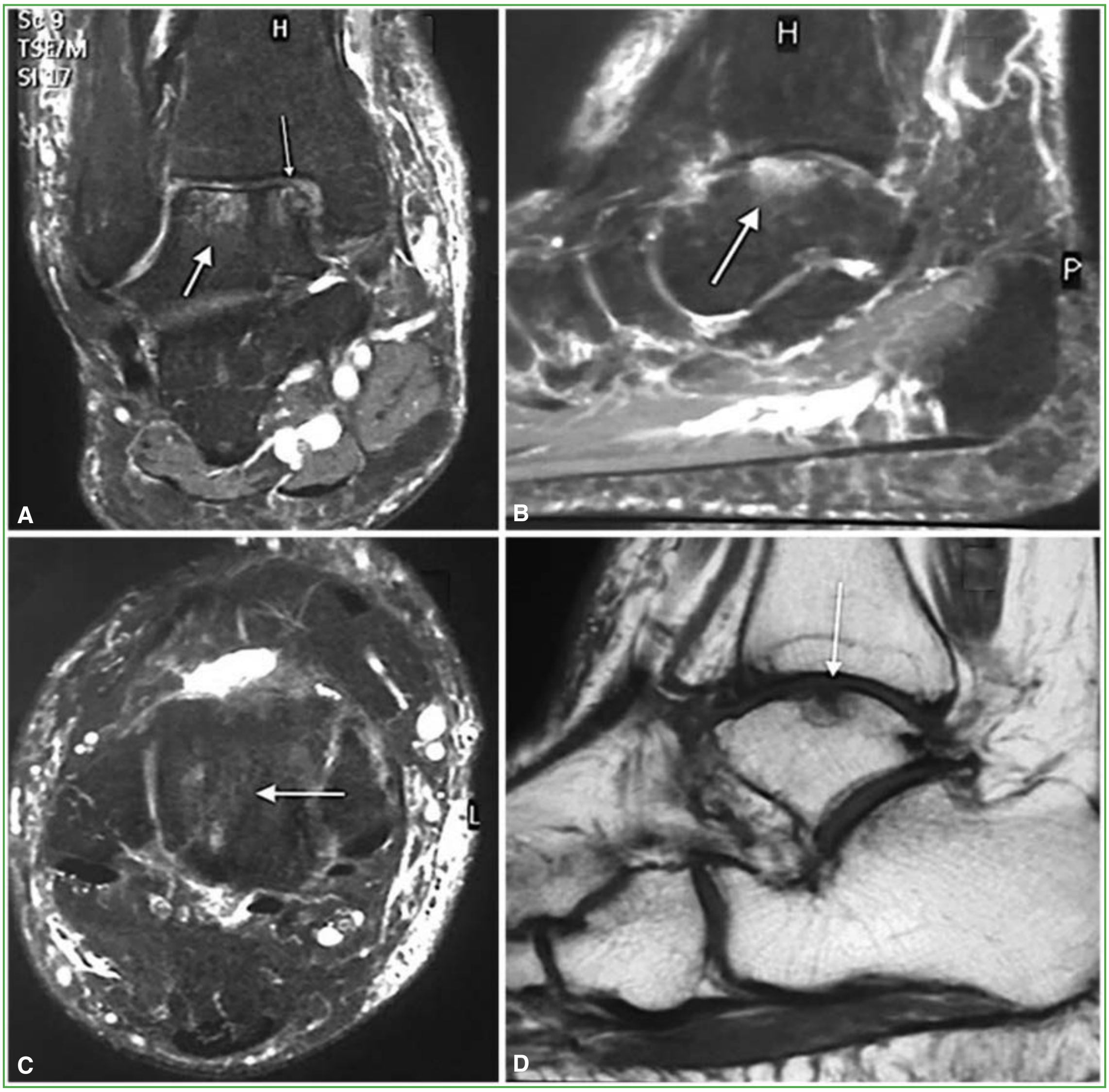


Figure 6. T2-weighted magnetic resonance images of the ankle and hindfoot obtained at the 36-month follow-up. **A.** Coronal image. **B.** Sagittal image. **C.** Axial image. The arrows indicate improvement of the bone marrow edema and osteochondral lesion. **D.** Sagittal T1-weighted image. Improvement of the articular surface of the talar dome is observed.

## Surgical Technique and Postoperative Management

The procedure was performed under popliteal nerve block and sedation. A thigh tourniquet was inflated to 250 mmHg after limb exsanguination.

Arthroscopy was performed using normal saline irrigation. In all cases, the objectives were complete resection of the affected synovium to prevent recurrence and procurement of tissue samples for histopathological examination.

The arthroscopic portals were planned according to the specific location of the lesion in each case. Anterior ankle arthroscopy was performed through the standard anteromedial and anterolateral portals, with the patient in the supine position, using a 4-mm arthroscope. For subtalar arthroscopy, 2.7-mm or 4.0-mm arthroscopes were used according to surgeon preference. Lateral, posterior, or combined lateral and posterior portals were used, with the patient positioned in the lateral decubitus or prone position, depending on the case. In one patient, lateral portals were used with a 2.7-mm, 30° arthroscope. In another patient with involvement of both the sinus tarsi and the posterior aspect of the subtalar joint, both lateral and posterior portals were required to achieve complete access to the subtalar joint. In this particular case, 2.7-mm and 4.0-mm arthroscopes were used, and the patient was placed in the prone position to allow knee flexion and external rotation of the leg, thereby facilitating access to the lateral aspect of the foot. In another patient, posterior arthroscopic portals were used with the patient in the prone position and a 4.0-mm arthroscope, applying gentle traction with a sling to reach the anterior portion of the posterolateral facet of the subtalar joint (Figure 7).


**Figure 7.** Arthroscopic approaches to the subtalar joint. **A and B.** Combined posterior and lateral arthroscopic approach with gentle distraction (**B**) to access difficult-to-reach areas. **C and D.** Lateral arthroscopic approach to the subtalar joint using an accessory lateral portal.

Arthroscopy allowed complete resection of the affected tissue and retrieval of at least one specimen of pathological synovium for histopathological examination in every case. Consequently, all patients underwent arthroscopic surgery with complete resection of the pathological tissue.

The portals were closed with 4-0 nylon sutures. A posterior below-knee plaster splint was applied, and patients were instructed to remain non-weight-bearing with crutches until the first postoperative visit, which took place 3 days after the procedure. At that time, the splint was removed, progressive weight-bearing was allowed as tolerated, and range-of-motion exercises were encouraged. Sutures were removed at 3 weeks.

## Statistical Analysis

Data were entered into Microsoft Excel® and analyzed using SPSS version 23. Descriptive statistics (mean and standard deviation) and the paired Student's *t* test were used to compare preoperative and postoperative AOFAS and VAS scores. A $p$ value <0.05 was considered statistically significant.

# RESULTS

The study included 7 patients with a mean age of 44.86 ± 11.60 years (range, 29–62 years). Five patients (71.43%) were male and two (28.57%) were female. Five patients (71.43%) had right-sided involvement and two (28.57%) had left-sided involvement. Four patients (57.14%) had D-TGCT, and three (42.86%) had L-TGCT. Joint involvement was distributed as follows: two cases (28.57%) with isolated subtalar involvement, two (28.57%) with isolated ankle involvement, and three (42.86%) with simultaneous involvement of both the ankle and subtalar joints. The patients' presenting symptoms are summarized in Table 1. The mean follow-up was 57.42 months (range, 24–132 months).

**Table 1.** Characteristics of the study patients.

| | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 |
|---|---|---|---|---|---|---|---|
| Age (years) | 54 | 45 | 37 | 62 | 36 | 29 | 51 |
| Gender | Male | Female | Male | Male | Male | Male | Female |
| Side | Right | Right | Left | Right | Left | Right | Right |
| Shape | Diffuse | Localized | Diffuse | Diffuse | Localized | Diffuse | Localized |
| Location | Ankle and subtalar joint | Subtalar joint | Ankle and subtalar joint | Ankle | Ankle | Ankle and subtalar joint | Subtalar joint |
| Symptoms | Swelling and pain | Swelling and pain | Swelling and pain | Swelling and pain | Swelling, pain, stiffness | Swelling, pain, limited range of motion | Swelling and pain |
| Follow-up | 36 months | 30 months | 96 months | 132 months | 48 months | 36 months | 24 months |
| Recurrence | No | No | No | No | No | No | No |

No intraoperative or postoperative complications, either early or late, were observed. No recurrences were detected on MRI at the final follow-up.

A statistically significant and clinically meaningful improvement was observed in the clinical outcome scores after surgery. The mean AOFAS score improved from 63.43 ± 14.63 (range, 51–87) preoperatively to 94.57 ± 3.78 (range, 91–100) postoperatively (Table 2).

Similarly, the mean VAS pain score improved from 5.71 ± 1.50 (range, 3–7) preoperatively to 0.43 ± 0.53 (range, 0–1) postoperatively, indicating substantial pain relief (Table 3).

**Table 2.** Statistical analysis of preoperative and postoperative AOFAS scale scores.

| Descriptive statistics - AOFAS | | | |
|---|---|---|---|
| | | **Preoperative** | **Postoperative** |
| Mean | | 63.43 | 94.57 |
| Median | | 56.00 | 93.00 |
| Mode | | 51 | 93 |
| Standard deviation | | 14.63 | 3.78 |
| Percentiles | 25 | 51.00 | 92.00 |
| | 50 | 56.00 | 93.00 |
| | 75 | 79.00 | 100.00 |

*AOFAS = American Orthopaedic Foot and Ankle Society.*

**Table 3.** Statistical analysis of preoperative and postoperative visual analog scale scores.

| Descriptive statistics - VAS | | | |
|---|---|---|---|
| | | **Preoperative** | **Postoperative** |
| Mean | | 5.71 | 0.43 |
| Median | | 6.00 | 0.00 |
| Mode | | 5* | 0 |
| Standard deviation | | 1.60 | 0.53 |
| Percentiles | 25 | 5.00 | 0.00 |
| | 50 | 6.00 | 0.00 |
| | 75 | 7.00 | 1.00 |

*There are multiple modes. The smallest value is shown. VAS = visual analog scale.

Preoperative and postoperative scores were compared using the paired Student's *t* test. Both the AOFAS and VAS scores showed statistically significant improvements after surgery ($p$ <0.001), demonstrating a clinically relevant postoperative benefit (Table 4, Figures 8 and 9).

All patients stated that they would choose to undergo the procedure again, reflecting a high level of satisfaction with the surgical outcome.

**Table 4.** Statistical analysis of pre- and postoperative AOFAS and VAS scores.

| Comparison of the contralateral healthy side and the operated side | | | | | |
|---|---|---|---|---|---|
| **Scale** | **Preoperative** | **Postoperative** | | | |
| | M (SD) | M (SD) | t | p | d |
| AOFAS | 63.43 (14.63) | 94.57 (3.78) | 7.30 | <0.001 | 2.76 |
| VAS | 5.71 (1.60) | 0.43 (0.53) | -8.21 | <0.001 | -3.10 |

AOFAS = *American Orthopaedic Foot and Ankle Society*; VAS = visual analog scale.

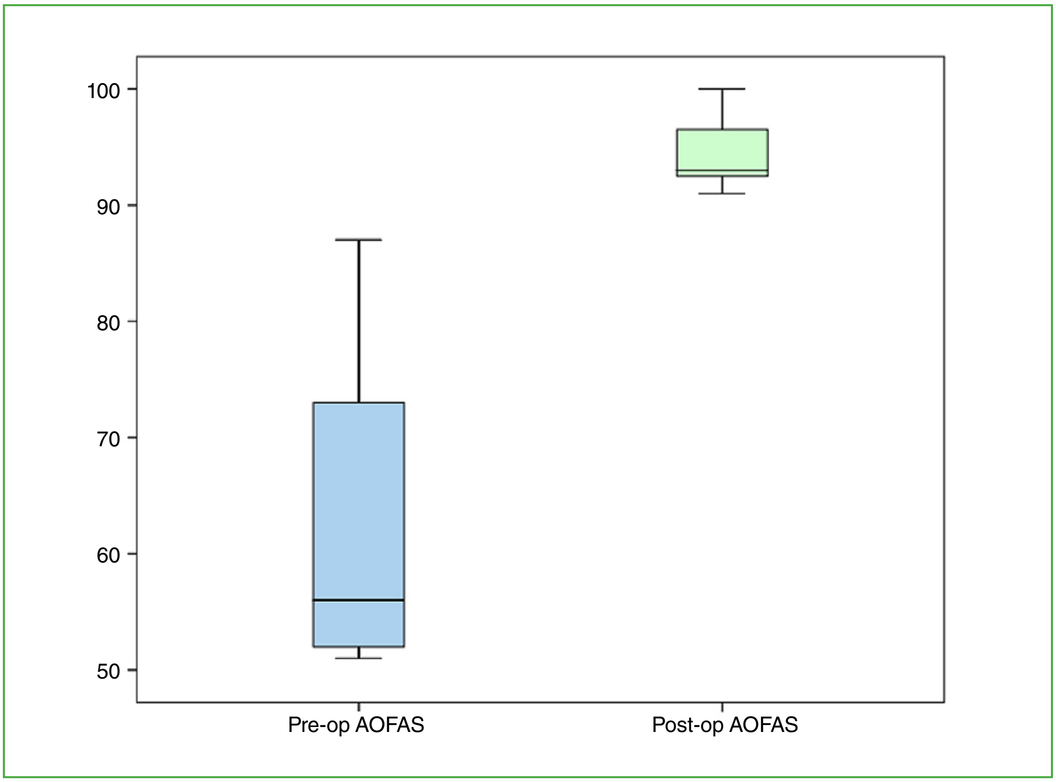


**Figure 8.** Pre- and postoperative changes in the *American Orthopaedic Foot and Ankle Society* (AOFAS) score.

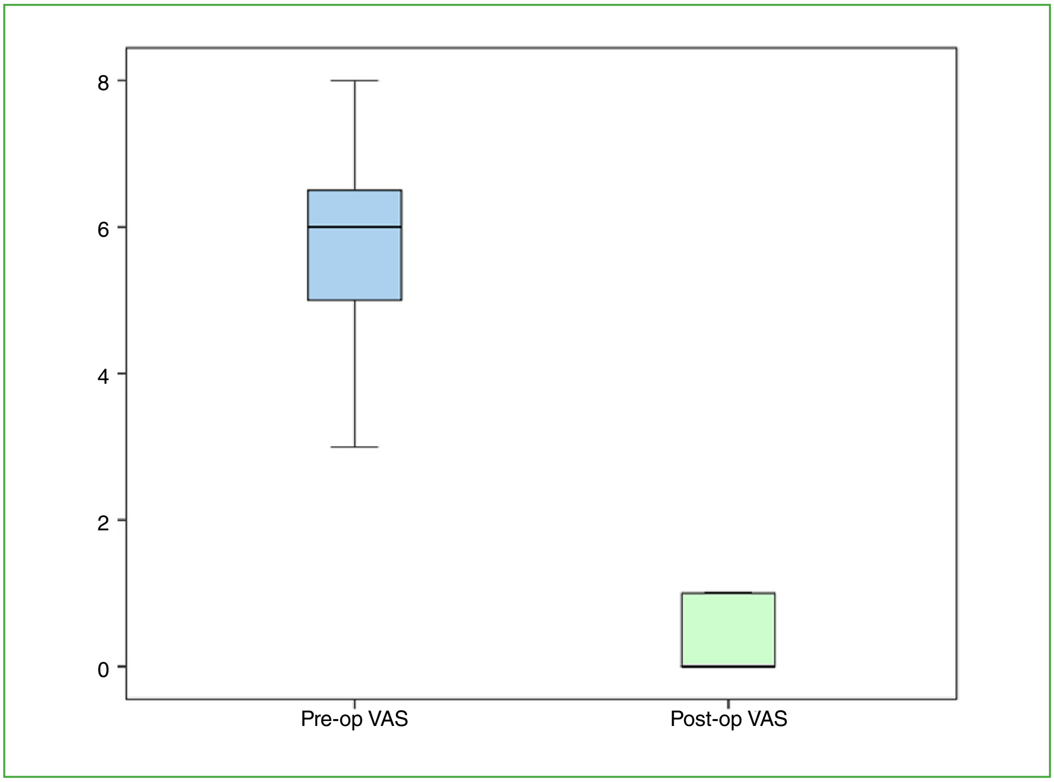


**Figure 9.** Preoperative and postoperative visual analog scale (VAS) scores.

## DISCUSSION

TGCT was first described by Chassaignac in 1852, who identified it as a condition affecting the flexor tendon sheaths, although he initially suggested that it might represent a malignant neoplastic process. Subsequently, in 1941, Jaffe described the clinical presentations of the disease, reported 20 cases involving both joints and tendons, and proposed a classification based on anatomical location and histopathological findings.[6] Granowitz et al. later conducted studies that contributed to the reevaluation and more precise classification of this disease as it is currently understood.[7]

Two main clinical forms have been described: localized TGCT (L-TGCT), characterized by the presence of small nodules with or without a pedicle, and diffuse TGCT (D-TGCT), in which the entire synovium and joint capsule are involved. Although both forms share similar macroscopic and histopathological features, including hemosiderin deposition within the synovial tissue, their biological behavior differs considerably. L-TGCT can usually be resected with adequate surgical margins and is associated with a lower recurrence rate. In contrast, surgical treatment of D-TGCT can be challenging because complete resection is often difficult to achieve. Consequently, this form may behave in a locally aggressive manner, with reported recurrence rates ranging from 9% to 49%, depending on factors such as duration of follow-up, the affected joint, completeness of resection, and the use of adjuvant radiotherapy.[7–10]

Historically, TGCT was considered a condition arising from chronic inflammatory processes of the synovium. However, more recent studies suggest that its origin may be neoplastic. Sciot et al. demonstrated a clear association between TGCT and clonal chromosomal abnormalities involving the 1p11–13 region. In subsequent studies, they identified colony-stimulating factor 1 (CSF-1), located at the 1p13 breakpoint, which encodes the CSF-1 cytokine responsible for the proliferation and differentiation of monocytes and macrophages. This evidence supports the hypothesis that TGCT is of neoplastic origin, representing a significant shift in the understanding of its pathogenesis.[11,12]

West et al. reported that 77% of patients with L-TGCT and 63% of those with D-TGCT exhibited CSF-1 overexpression, generating autocrine and paracrine signals that stimulate the proliferation of neoplastic macrophages. In addition, CSF-1 may induce other inflammatory cells, including histiocytes, lymphocytes, and osteoclasts, to express its receptor. These findings were confirmed by Nilsson et al., who reported that 92% of patients with TGCT had a breakpoint involving chromosome 1p11–13, frequently associated with a translocation involving 2q35–37. Both studies describe clonal abnormalities and trisomies involving chromosomes 5 and 7, further supporting the hypothesis of a neoplastic origin for this disease.[13,14]

According to Myers et al., the annual incidence of TGCT is 1.8 cases per million population. It affects men and women equally and occurs predominantly during the first three decades of life.[15]

With regard to foot and ankle involvement, few studies have been published, most consisting of small case series or isolated case reports. In 2006, Sharma et al. reported the largest series (14 cases), nine of which involved the ankle: six with extra-articular synovial tumor masses, two with intra-articular involvement, and one with isolated subtalar involvement. Rochwerger et al. published a series of eight cases: four involving the ankle and hindfoot joints, one involving the tarsometatarsal joints, and three involving the toes. Ghert et al. reported six cases: two involving the ankle and four involving multiple joints (subtalar, midfoot, and forefoot).[16–18]

In the early stages of the disease, radiographs may be normal. In more advanced stages, erosions, cysts with sclerotic margins, osteochondral lesions, mineralization, and involvement of the articular surfaces may be identified.

Diagnostic studies such as ultrasound, computed tomography, and bone scintigraphy are not definitive for establishing the diagnosis. MRI provides the most characteristic imaging findings, demonstrating hypointense signals on both T1- and T2-weighted sequences due to hemosiderin deposition. Although these findings are not pathognomonic, they are highly suggestive of the disease. MRI is also useful for assessing the extent of synovial involvement and detecting recurrences. It facilitates surgical planning aimed at achieving complete synovectomy and obtaining tissue samples for histopathological examination, thereby establishing the definitive diagnosis.[19]

Treatment of TGCT should be initiated early to prevent progression of joint damage and should be tailored according to variables such as patient age, lesion location, disease subtype, joint involvement, and the affected periarticular tissues. Complete resection may be performed through either an open or an arthroscopic approach. In D-TGCT, when complete resection cannot be achieved, adjuvant radiotherapy may be indicated. Blanco et al. reported favorable results with partial arthroscopic resection combined with low-dose radiotherapy (26 Gy); however, three patients (14%) required repeat arthroscopy because of recurrence.[20]

In a systematic review, Mollon et al. concluded that adjuvant radiotherapy significantly reduced recurrence in patients with D-TGCT and suggested that it should be considered when complete synovectomy cannot be achieved.[10] Reinhard et al. reported that radiotherapy is safe and effective both as an adjuvant treatment and for recurrent disease, with doses ranging from 30 to 50 Gy. In our series, adjuvant radiotherapy was not required because complete arthroscopic resection was achieved in all cases. The available studies agree that arthroscopic synovectomy is effective for localized intra-articular disease and is associated with a low recurrence rate. However, in diffuse ankle disease, TGCT extends through synovial recesses and tendon sheaths, making complete resection difficult and resulting in high recurrence rates following surgery alone (40–60%).[10,21-23]

Case series and cohort studies have shown that combining synovectomy with postoperative radiotherapy achieves local control rates exceeding 80–90% in patients with D-TGCT, whereas recurrence rates remain higher (40–60%) following surgery alone. In this context, adjuvant radiotherapy is primarily reserved for cases with incomplete synovial resection, extensive diffuse involvement, or postoperative recurrence. Baniel et al. reported recurrence rates below 10% after radiotherapy and observed no significant long-term adverse effects, further supporting its therapeutic role in the management of D-TGCT. In contrast, patients with L-TGCT have a favorable prognosis after complete surgical excision, with a low risk of recurrence in both the medium and long term.[23]

In all patients in our series, both those with L-TGCT and those with D-TGCT, complete resection of the pathological tissue was achieved. We believe that this may have contributed to the absence of recurrences during follow-up.

This study has several strengths, including the ability to achieve complete arthroscopic resection of the pathological tissue in every case. No recurrences were detected on MRI during follow-up, and clinical outcomes demonstrated significant improvements in both function and pain, as assessed by the AOFAS score and VAS. However, the study is limited by its retrospective observational design and small sample size, which preclude extrapolation of the results or the establishment of definitive conclusions. Nevertheless, given the rarity of this condition in the hindfoot and the limited literature available, we believe that our series provides clinically relevant information for the management of this uncommon entity.

## CONCLUSIONS

In our series, arthroscopic synovectomy achieved satisfactory clinical outcomes, and no recurrences were observed during follow-up. The technique may be considered an effective therapeutic option in selected cases in which complete resection of the pathological tissue is technically feasible. Although the results were favorable, studies including larger patient cohorts and longer follow-up are needed to establish definitive conclusions.

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# Total Ankle Arthroplasty: Clinical and Radiographic Outcomes of a Case Series with 10-Year Follow-up

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**ABSTRACT**
**Introduction:** End-stage ankle osteoarthritis is a major cause of pain and disability. Total ankle arthroplasty (TAA) has emerged as an alternative to arthrodesis, aiming to preserve joint mobility and improve quality of life. However, long-term evidence remains limited. The objective of this study was to evaluate the clinical and radiographic outcomes of a series of patients who underwent TAA with a minimum follow-up of 10 years. **Materials and Methods:** A retrospective series of patients who underwent TAA between 2007 and 2015 was analyzed. Demographic data, pain assessed using the Visual Analog Scale (VAS), function assessed using the American Orthopaedic Foot & Ankle Society (AOFAS) score, quality of life assessed using the Short Form-36 (SF-36), radiographic findings, and implant survivorship were evaluated. **Results:** Out of 40 patients, 17 completed the 10-year follow-up. The median VAS score improved from 8 to 3 ($p < 0.001$). The AOFAS score increased from 36 to 79 points, reaching a maximum of 80 points at 5 years ($p < 0.001$). The SF-36 demonstrated good to very good results across most domains. Implant survivorship at 10 years was 82%. **Conclusion:** Total ankle arthroplasty provides sustained pain relief and improves function and quality of life at 10 years, supporting its role as a valid alternative to arthrodesis in patients with end-stage ankle osteoarthritis.
**Keywords:** Total ankle arthroplasty; survivorship; revision; quality of life.
**Level of Evidence:** IV

### Artroplastia de tobillo: evaluación clínica y radiológica de una serie de casos con un seguimiento de 10 años

**RESUMEN**
**Introducción:** La artrosis de tobillo en estadios avanzados es una causa importante de dolor y discapacidad. La artroplastia total de tobillo ha surgido como una alternativa a la artrodesis, con el objetivo de preservar la movilidad y mejorar la calidad de vida. La evidencia a largo plazo es limitada. El objetivo de este estudio fue evaluar los resultados clínicos y radiológicos de una serie de pacientes sometidos a una artroplastia total de tobillo con un seguimiento mínimo de 10 años. **Materiales y Métodos:** Se estudió a una serie de pacientes operados entre 2007 y 2015. Se evaluaron los datos demográficos, el dolor mediante la escala analógica visual (EVA), la función con el puntaje de la AOFAS, la calidad de vida con el SF-36, los hallazgos radiológicos y la supervivencia de la prótesis. **Resultados:** Diecisiete pacientes completaron el seguimiento de 10 años. El dolor mejoró de una mediana de 8 a 3 ($p <0{,}001$). El puntaje de la AOFAS aumentó de 36 a 79, con un máximo de 80 a los 5 años ($p <0{,}001$). El SF-36 arrojó resultados buenos a muy buenos en la mayoría de los dominios. La supervivencia de la prótesis a los 10 años fue del 82%. **Conclusión:** La artroplastia total de tobillo alivia el dolor y mejora la función y la calidad de vida a 10 años, esto la consolida como una alternativa válida frente a la artrodesis en pacientes con artrosis avanzada de tobillo.
**Palabras clave:** Artroplastia total de tobillo; supervivencia; revisión; calidad de vida.
**Nivel de Evidencia:** IV

## INTRODUCTION

Advanced ankle osteoarthritis is a disabling condition that causes pain, loss of motion, and functional impairment, significantly affecting patients' quality of life.[1-3]

Received on January 27th, 2026. Accepted after evaluation on April 27th, 2026 • Dr. DANIEL S. VILLENA • daniel.villena@hospitalitaliano.org.ar https://orcid.org/0000-0001-5742-1226
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Unlike hip and knee osteoarthritis, which is primary in origin and affects older individuals, ankle osteoarthritis is most commonly post-traumatic and usually affects young, active adults.[4]

For many years, ankle arthrodesis was considered the standard treatment for end-stage ankle osteoarthritis.[5,6] However, although it effectively relieves pain, it is associated in the medium and long term with the development of degenerative changes in adjacent joints, accompanied by relatively low levels of patient satisfaction and quality of life.[7]

Total ankle arthroplasty (TAA) emerged as a therapeutic alternative aimed at preserving joint motion, improving function, and reducing overload of adjacent joints.[8,9] Early TAA results in the 1970s were unsatisfactory, with high complication and revision rates.[5] Third-generation implants, such as the STAR® prosthesis in Europe and the Buechel-Pappas prosthesis in the United States, incorporate a three-component anatomic design with reduced constraint and minimal bone resection, allowing expansion of the surgical indications and improving short- and mid-term clinical outcomes.[10]

Implant designs continue to evolve, and long-term outcomes have become increasingly consistent, although they remain inferior to those reported for total hip and knee arthroplasty. This underscores the need for long-term follow-up studies evaluating not only implant survivorship but also patient-reported function and quality of life.

The primary objective of this study was to evaluate the clinical and radiographic outcomes of patients who underwent TAA with a minimum follow-up of 10 years. The secondary objective was to analyze long-term implant survivorship.

## MATERIALS AND METHODS

An observational, descriptive study was conducted on a series of patients who underwent TAA with a cementless, unconstrained prosthesis (Hintegra®, Integra LifeSciences, Plainsboro, NJ, USA) between January 2007 and December 2015, with a minimum follow-up of 10 years.

The inclusion criteria were age >18 years, TAA, and a minimum clinical and radiographic follow-up of 10 years. The exclusion criteria were incomplete medical records and inability to complete the quality-of-life questionnaires (e.g., cognitive impairment).

For the clinical, functional, and quality-of-life assessments, only patients with available follow-up and a retained implant at the time of the final evaluation were included. Patients who required revision surgery were included in the survivorship analysis as events but were excluded from the functional and quality-of-life analyses.

Of the initial 40 patients, only 17 underwent clinical evaluation at 10 years and constituted the study cohort selected from the original population.

Data collection was performed by two foot and ankle fellows who were not involved in the preoperative decision-making process.

### Surgical Technique

The procedure was performed on an inpatient basis. Through a standard anterior approach, the cementless tibial and talar components were implanted according to the manufacturer’s cutting guides.

The postoperative protocol consisted of immobilization in a short-leg cast for 3 weeks, followed by a removable walking boot, with progressive weight-bearing and functional rehabilitation.

Patients were followed monthly during the first 3 months. Thereafter, follow-up visits were scheduled at 6, 9, and 12 months after surgery and annually thereafter.

### Clinical and Surgical Evaluation

Demographic data, preoperative diagnosis, the need for concomitant procedures during TAA, intraoperative complications, reoperations, and revision surgeries were recorded.

Function was assessed using the *American Orthopaedic Foot and Ankle Society* (AOFAS) Ankle-Hindfoot Score, administered preoperatively and at 5 and 10 years postoperatively.[11] In addition, preoperative pain and pain at the 10-year follow-up were assessed using a visual analog scale (VAS; range, 0-10).

Quality of life was evaluated using the Spanish-validated version of the Short Form-36 (SF-36) questionnaire, administered only at the 10-year follow-up.[12]

## Definitions of Reoperation and Revision

Reoperation was defined as any surgical procedure intended to prolong implant survivorship without replacement of the metallic components (e.g., cyst curettage and grafting, polyethylene insert exchange, osteophyte excision, or osteotomies), whereas revision was defined as any procedure involving removal of the metallic components and implantation of a new TAA or conversion to arthrodesis.[13,14]

## Radiological Evaluation

Ankle CT scans and weight-bearing anteroposterior and lateral ankle radiographs obtained at the 10-year follow-up were analyzed. The presence of cysts, heterotopic ossification, and radiolucent lines was recorded.

## Statistical Analysis

Continuous variables were expressed as mean and standard deviation or median and interquartile range, as appropriate. Data normality was assessed using the Shapiro-Wilk test. Categorical variables were presented as absolute frequencies and percentages. Within-group comparisons were performed using the paired Student's *t* test or, in the case of non-normal distribution, the Wilcoxon signed-rank test. The $\chi^2$ test or Fisher›s exact test was used for categorical variables, as appropriate.

TAA survivorship was analyzed using a cumulative incidence function, considering revision as the event of interest and death as a competing event, up to 120 months (10 years), with a 95% confidence interval.

Descriptive and inferential statistical analyses were performed using JASP software, version 0.95.3 (JASP Team, Amsterdam, the Netherlands). Statistical significance was set at $p < 0.05$.

# RESULTS

## Demographic Data

Between January 2007 and December 2015, 40 patients underwent TAA. Twenty-three were excluded from the clinical and functional analysis at 10 years: 6 died from causes unrelated to the procedure, 7 underwent revision surgery, 1 had dementia, and 9 were lost to follow-up. It should be noted that patients who underwent revision surgery, either before or after the 10-year follow-up, were excluded from the clinical and quality-of-life assessments but were counted as events in the implant survivorship analysis. The demographic characteristics of the series are summarized in Table 1.

**Table 1.** Demographic data of the series.

| Variable | Measures of central tendency and dispersion |
|---|---|
| Age (years), mean (SD) | 68.25 (14.33) |
| Female | 10 (58.8%) |
| Right side | 9 (52.9%) |
| Preoperative alignment | |
| Neutral | 7 (41.2%) |
| Valgus | 4 (23.5%) |
| Varus | 6 (35.3%) |
| Preoperative diagnosis | |
| Post-traumatic osteoarthritis | 11 (64.7%) |
| Rheumatoid arthritis | 4 (23.5%) |
| Primary osteoarthritis | 2 (11.8%) |

Several of the 17 patients with a retained TAA and complete clinical, functional, and radiographic follow-up underwent concomitant procedures at the time of the index surgery: 5 underwent subtalar arthrodesis, 1 underwent double arthrodesis, 1 underwent an isolated valgus-producing calcaneal osteotomy, and 2 underwent valgus-producing calcaneal osteotomies combined with lateral ligament reconstruction. Of these latter two patients, one also required peroneal retinaculum repair, whereas the other underwent percutaneous Achilles tendon lengthening.

## Clinical Outcomes

The median pain score on the visual analog scale (VAS) was 8 (interquartile range [IQR] 7-8) preoperatively and 3 (IQR 2-3) at 10 years after surgery.

Functional assessment using the AOFAS Ankle-Hindfoot Score yielded a preoperative median of 36 points, reflecting marked functional impairment. At the 5-year follow-up, the median increased to 80 points, and at the 10-year evaluation, the scores remained stable, with a median of 79 points. Although a slight decrease was observed between the 5- and 10-year assessments, this difference did not reach statistical significance. In contrast, both the 5-year and 10-year scores were significantly higher than the preoperative values (Table 2).

**Table 2.** Results of the AOFAS scale.

| Variable | Preoperative | 5 years | 10 years |
|---|---|---|---|
| AOFAS, median (IQR) | 36 (32-37) | 80 (79-84) | 79 (72-80) |
| Preoperative AOFAS vs. 5 years | $p < 0.001$ | | |
| Preoperative AOFAS vs. 10 years | $p < 0.001$ | | |
| AOFAS 5-year vs. 10-year | $p > 0.05$ | | |

IQR = interquartile range; AOFAS = *American Orthopaedic Foot and Ankle Society*.

Quality of life at 10 years, as assessed with the SF-36 questionnaire, showed favorable results across all domains of the instrument (Table 3).

**Table 3.** Results of the Short Form-36 questionnaire.

| Variable | Median (IQR) |
|---|---|
| Role limitations due to physical health | 75 (50-100) |
| Physical functioning | 70 (45-85) |
| General health | 65 (35-75) |
| Bodily pain | 77 (65-80) |
| Vitality | 70 (50-70) |
| Role limitations due to emotional problems | 100 (66-100) |
| Social functioning | 87 (62-100) |
| Mental health | 76 (64-80) |
| Health transition | 50 (50-50) |

IQR = interquartile range.

These functional outcomes (AOFAS and SF-36) correspond only to patients with available follow-up and a retained implant at the final evaluation and therefore reflect the outcomes of a selected subpopulation from the original cohort.

## Radiographic Outcomes

The most frequent periprosthetic findings on the 10-year CT scans were radiolucent lines in 8 ankles (47.1%), predominantly around the tibial component; periprosthetic cysts in 9 cases (52.9%); and heterotopic ossification in 16 cases (94.1%). No apparent clinical correlation was identified in this series.

## Implant Survivorship

For the survivorship analysis, revision was considered the event of interest and death a competing event up to 120 months (10 years). The cumulative incidence of revision at 10 years was 18% (95% confidence interval, 7%-34%) (Figure).

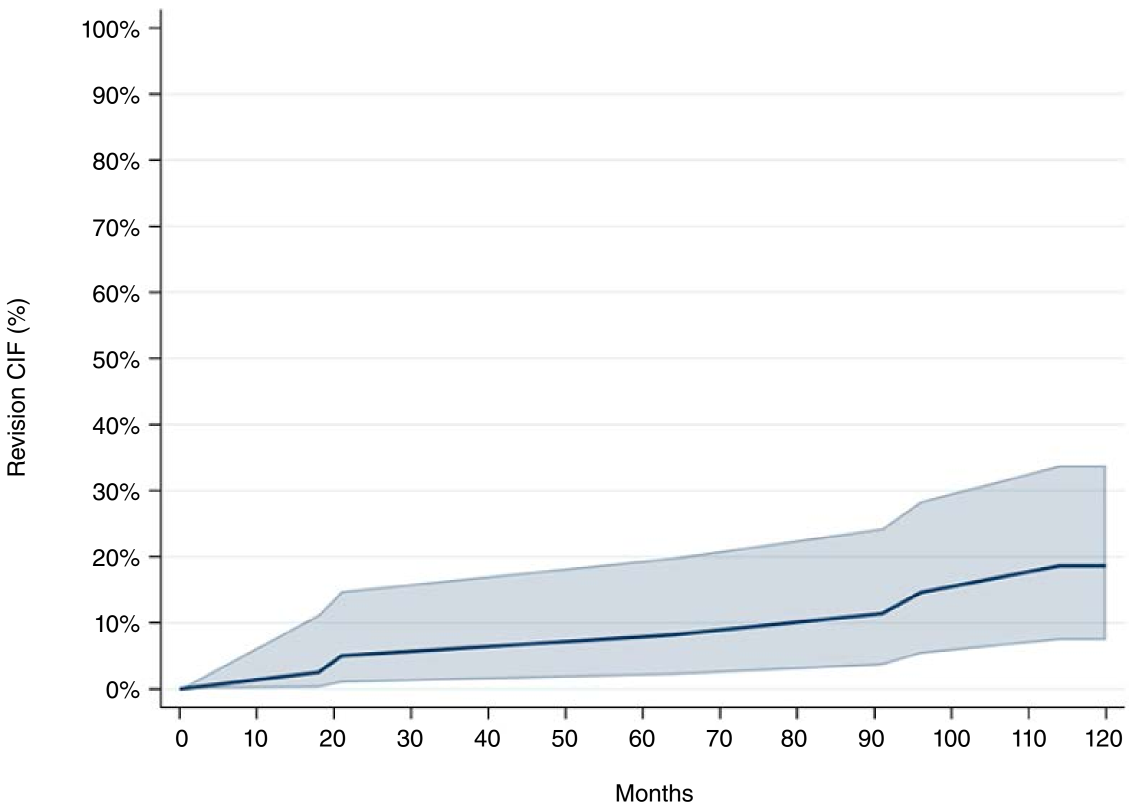


**Figure.** Cumulative incidence of revisions.

## Complications, Reoperations, and Revision Surgeries

Two intraoperative complications occurred: a fibular fracture and a medial malleolar fracture, both of which were treated with internal fixation during the same surgical procedure.

In addition, among the 17 patients included in the analysis, three required reoperation. One underwent excision of osteophytes and heterotopic ossification, another required liner exchange because of wear, and a third developed large bone cysts that required bone grafting.

In addition to the cases described above, Table 4 summarizes the 7 patients who underwent revision surgery during follow-up and were excluded from the final study cohort.

**Table 4.** Total ankle arthroplasty revisions.

| Patient | Reason for revision | Revision surgery |
|---|---|---|
| 1 | Medial malleolar fracture and liner dislocation | Tibio-talar arthrodesis |
| 2 | Liner breakage plus anterior bone impingement | Arthroplasty |
| 3 | Aseptic prosthetic loosening plus liner dislocation | Arthroplasty plus calcaneal valgus osteotomy |
| 4 | Prosthesis infection | 1st stage: cement spacer<br>2nd stage: tibiotalar arthrodesis |
| 5 | Tibial fracture | Osteosynthesis plus arthroplasty |
| 6 | Aseptic prosthetic loosening plus liner wear | Arthroplasty |
| 7 | Aseptic prosthetic loosening plus liner dislocation | Arthroplasty plus Evans and calcaneal valgus osteotomies |

## DISCUSSION

Tibiotalar arthrodesis remains the procedure of choice for treating patients with end-stage ankle osteoarthritis in many centers. However, over the past few decades, TAA has gained increasing prominence.[14] This trend is likely attributable to advances in implant design, the growing experience of surgeons, and, most importantly, the goal of reducing overload of adjacent joints.[15,16]

Our study yielded satisfactory results at 10 years after TAA for the treatment of ankle osteoarthritis. Functional scores improved significantly compared with preoperative values, and the cumulative incidence of revision at 10 years was 18% (95% confidence interval, 7%-34%).

Kofoed and Lundberg-Jensen reported that TAA is a safe and reliable treatment across different age groups after evaluating 52 ankles treated with this type of joint replacement and a mean follow-up of 9 years.[17]

TAA survivorship remains inferior to that observed after hip and knee arthroplasty, in which 10-year revision rates rarely exceed 6%[18,19]

With regard to implant survivorship and reintervention rates, the results should be interpreted with caution, as comparisons among studies depend on the definitions of reoperation and revision adopted in each case.[13,14]

This issue explains why survivorship rates reported in the literature range from 94.4% at 10 years, as described by Jastifer and Coughlin, to 66% in other publications.[20–22] Studies reporting lower survivorship rates excluded liner exchanges and reoperations for heterotopic ossification from the category of favorable surgical outcomes. It is noteworthy that a meta-analysis of 58 studies including 7,942 TAAs reported a 10-year survivorship of 89%; the most commonly used implants were the STAR® and Hintegra® prostheses.[23] In our series, implant survivorship at 10 years was 80%, consistent with the findings reported by Koivu et al. (78.5%) and Clough et al. (82.7%).[5] On the other hand, our reoperation rate was 7.5%, comparable to that reported by Lawton et al. (9.5%).[24]

In our cohort, AOFAS scores showed sustained improvement compared with preoperative values, with a non-significant trend toward deterioration between the 5- and 10-year follow-up evaluations. The median AOFAS score improved from 36 preoperatively to 79 at 10 years. These findings are consistent with those of Clough et al., who, in a series of 200 patients treated with STAR® prostheses, observed an increase in the mean AOFAS score from 28 to 61 points after nearly 16 years of follow-up.[5] Similarly, Bagheri et al., in a systematic review of more than 3,700 ankles with a minimum follow-up of 10 years, reported a mean improvement of 40 points in the AOFAS score, confirming the sustained long-term benefits of this intervention.[25]

Quality of life at 10 years, as assessed with the validated SF-36 questionnaire, also supports TAA as a valuable treatment alternative. These findings are consistent with those reported in other studies and further support the positive impact of TAA on functional outcomes and patients' overall perception of their health.[15,25]

On the other hand, the radiographic findings analyzed (radiolucencies, heterotopic ossification, and periprosthetic cysts) indicate that these are very common findings during the follow-up of this type of joint replacement. It is noteworthy that, in our series, they were not associated with a significant clinical or functional impact, nor did they affect patients' quality of life. Nevertheless, their clinical relevance remains a matter of debate in the literature. While some studies have associated these findings with an increased risk of failure, others have found no direct correlation with functional outcomes or the need for revision surgery.[21] This heterogeneity highlights the need for further investigation into these radiographic findings and their relationship with clinical and functional outcomes.

In 42.82% of the patients who underwent revision surgery, the indication was aseptic loosening, which is consistent with the literature identifying aseptic loosening as the leading cause of revision.[16,19]

The limitations of our study are those inherent to its retrospective design, its moderate sample size, and its single-site nature. Another limitation is the considerable rate of loss to follow-up, which we attribute primarily to the advanced age of the patients who underwent total ankle replacement during our early years of experience with this procedure. On the other hand, the strengths of this study include a series of patients treated with the same implant, in a relatively challenging setting for performing this type of procedure, and the limited local literature reporting clinical, functional, and radiographic outcomes of TAA with a minimum follow-up of 10 years.

Finally, future research should focus on multicenter studies with larger sample sizes and prospective designs that reduce selection bias and loss to follow-up.

## CONCLUSIONS

Total ankle arthroplasty is a valid therapeutic alternative to arthrodesis and provides sustained clinical and functional benefits over time. However, implant survivorship remains the main long-term challenge and should continue to be evaluated as newer prosthesis designs reach longer follow-up periods, surgical experience increases, and the population of candidates for this procedure expands.

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# Evaluation of Artificial Intelligence (ChatGPT-5.2) in the Classification and Indication for Fixation of Posterior Malleolar Fractures: A Multicenter External Validation Study

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## ABSTRACT

**Introduction:** Posterior malleolar fractures have a significant impact on ankle joint congruity. The indication for fixation no longer depends solely on fragment size but also on fracture morphology. Artificial intelligence (AI) has emerged as a tool to support clinical decision-making. The objective of this study was to evaluate the ability of AI to classify posterior malleolar fractures and determine the indication for fixation, compared with a reference standard based on expert consensus. **Materials and Methods:** A retrospective diagnostic accuracy study with external validation was conducted in accordance with the STARD-AI and GAMER guidelines. A protocol based on the Bartoníček and Rammelt classification was developed using 24 cases for calibration. Subsequently, 9 cases were evaluated using radiographs and computed tomography scans and analyzed by 12 experts and the ChatGPT-5.2 model. Agreement in fracture classification and sensitivity for the indication for fixation were assessed using Cohen's kappa coefficient. **Results:** ChatGPT-5.2 achieved 78% agreement in fracture classification, with a kappa coefficient of 0.56, indicating moderate agreement. Sensitivity for the indication for posterior malleolar fixation was 100%. **Conclusions:** Artificial intelligence demonstrated performance comparable to that of experts in the classification of posterior malleolar fractures and high sensitivity in determining the indication for fixation. It proved useful as a supportive tool in medical education settings. Studies with larger sample sizes are needed to validate these findings.

**Keywords:** Artificial intelligence; posterior malleolus; multicenter study.

**Level of Evidence:** III

## Evaluación de la capacidad de la inteligencia artificial (ChatGPT-5.2) para clasificar fracturas del maléolo posterior e indicar su fijación: estudio multicéntrico de validación externa

## RESUMEN

**Introducción:** Las fracturas del maléolo posterior del tobillo tienen un gran impacto en la congruencia articular del tobillo. La indicación de fijación ya no depende exclusivamente del tamaño del fragmento, sino también de su morfología. La inteligencia artificial surge como una herramienta para apoyar la toma de decisiones clínicas. El objetivo de este estudio fue evaluar la capacidad de la inteligencia artificial para clasificar fracturas del maléolo posterior e indicar su fijación, comparada con la de un estándar de referencia basado en el consenso de expertos. **Materiales y Métodos:** Se realizó un estudio retrospectivo de exactitud diagnóstica con validación externa, siguiendo las guías STARD-AI y GAMER. Se diseñó un protocolo basado en la clasificación de Bartoníček y Rammelt, utilizando 24 casos para calibración. Se evaluaron 9 casos mediante radiografías y tomografía computarizada, analizados por 12 expertos y por el modelo ChatGPT-5.2. Se determinó la concordancia en la clasificación y la sensibilidad para la indicación de fijación, utilizando el coeficiente kappa de Cohen. **Resultados:** El ChatGPT-5.2 alcanzó una concordancia del 78% en la clasificación de fracturas, con un coeficiente kappa de 0,56, que indica una concordancia moderada. La sensibilidad para la

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indicación de fijación del maléolo posterior fue del 100%. **Conclusiones:** La inteligencia artificial tuvo un desempeño comparable al de los expertos en la clasificación de fracturas del maléolo posterior y una alta sensibilidad en la indicación de fijación. Resultó útil como herramienta de apoyo en contextos de formación médica. Se requieren estudios con muestras más grandes para validar estos hallazgos.

**Palabras clave:** Inteligencia artificial; maléolo posterior; estudio multicéntrico.
**Nivel de Evidencia:** III

## INTRODUCTION

Posterior malleolar fractures have assumed a central role in the contemporary management of ankle fractures, not only because of their frequency but also because of their direct impact on syndesmotic stability and tibiotalar joint congruity. Current evidence has moved beyond the traditional paradigm based exclusively on fragment size and indicates that variables such as fracture morphology, involvement of the fibular incisura, and the degree of articular displacement are key determinants of the indication for fixation and the patient's functional outcome.[1,2]

In this context, the systematic use of computed tomography has enabled more accurate characterization of these injuries. The Bartoníček and Rammelt classification has been shown to be clinically useful because it integrates the morphology of the posterior fragment with its biomechanical relevance, thereby facilitating individualized surgical decision-making.[3] However, interpretation of these imaging studies continues to depend on the surgeon's experience, and interobserver variability persists, even among specialists.

At the same time, the development of artificial intelligence (AI) models has emerged as a promising tool in orthopedics, particularly for fracture detection and classification using imaging studies. Recent research has shown that these systems can achieve levels of accuracy comparable to those of expert clinicians in certain settings and may also improve diagnostic performance when used as decision-support tools.[4-6] Nevertheless, their application to specific surgical decision-making, such as determining the indication for posterior malleolar fixation, remains limited and has been scarcely validated in the current medical literature.

In this context, the aim of this study was to evaluate the ability of an AI model to classify posterior malleolar fractures according to the Bartoníček and Rammelt classification and to determine the indication for fixation, using an expert consensus reference standard for comparison.

## MATERIALS AND METHODS

A retrospective diagnostic accuracy study with external validation was conducted in accordance with the STARD-AI (Standards for Reporting Diagnostic Accuracy–Artificial Intelligence) and GAMER guidelines.

The study was carried out in two phases. In the first phase, a prompt was developed based on anatomical information and the Bartoníček and Rammelt classification to create a standardized evaluation protocol. Ninety-five ankle fracture cases were initially selected; 45 were reviewed, and 24 met the inclusion criteria and were used to calibrate the protocol before external validation. In addition, 9 cases were selected and sent to 12 independent volunteer experts, who were asked to classify each fracture according to the Bartoníček and Rammelt classification and determine whether posterior malleolar fixation was indicated. Each case included anteroposterior, mortise, and lateral ankle radiographs together with computed tomography (CT) images in the axial and sagittal planes (Figure). Data collection was performed using questionnaires created in Google Forms®.

In the second phase, the interpretations of the 12 experts and those generated by ChatGPT-5.2 acting as an expert evaluator were compared with the reference standard previously established from the patients' medical records.

The inclusion criteria were patients with ankle fractures involving the posterior malleolus, complete imaging studies (anteroposterior, mortise, and lateral radiographs together with CT scans), and complete medical records from admission through postoperative follow-up. The exclusion criteria were distal tibial fractures with secondary extension into the posterior malleolus and absence of postoperative follow-up. Fracture classification and the indication for posterior malleolar fixation were analyzed. Agreement was expressed as percentages and assessed using Cohen's kappa coefficient.


**Figure.** Sequence of images presented to ChatGPT-5.2 for interpretation. Ankle radiographs: anteroposterior (**A**), mortise (**B**), and lateral (**C**) views; and computed tomography images: axial and sagittal slices (**D and E**).

## RESULTS

ChatGPT-5.2 achieved 78% agreement with the expert consensus reference standard for the classification of posterior malleolar fractures. The estimated Cohen's kappa coefficient was approximately 0.56, indicating moderate agreement. Regarding the indication for posterior malleolar fixation, ChatGPT-5.2 achieved a sensitivity of 100%, correctly identifying all cases in which fixation was indicated; no false-negative results were observed in the study cohort. The analyzed parameters are summarized in the Table.

**Table.** Diagnostic performance of the ChatGPT-5.2 model.

| Parameter | Result |
|---|---|
| Total number of cases | 9 |
| Classification agreement | 78% |
| Kappa coefficient (estimated) | 0.56 |
| Sensitivity for fixation | 100% |
| False negatives | 0 |

It is noteworthy that ChatGPT-5.2 demonstrated higher accuracy in posterior malleolar fracture patterns with greater displacement, whereas discrepancies were observed in fracture patterns with minimal displacement.

## DISCUSSION

The results of this study demonstrate that AI can achieve levels of agreement comparable to those of experts in the evaluation of posterior malleolar fractures, particularly with respect to the indication for fixation.

The 100% sensitivity observed is clinically relevant, as failure to fix the posterior malleolus may be associated with persistent instability and poor functional outcomes.[1,2]

These findings are consistent with those of recent studies demonstrating the potential of AI for fracture diagnosis. Rivadeneira et al. reported perfect agreement between AI and expert evaluators in the classification of complex fractures.[7]

Similarly, Husarek et al., in a systematic review and meta-analysis, found that the use of AI as a decision-support tool increased diagnostic sensitivity, particularly among less experienced readers, compared with unassisted interpretation.[8]

Conversely, Mohammadi et al. reported that experts achieved higher diagnostic sensitivity than AI models, such as ChatGPT-4, when interpreting knee radiographs, suggesting that AI performance may still be inferior in certain clinical scenarios.[9]

Our study has important limitations. The small sample size limits the generalizability of the findings. In addition, the AI model was evaluated in a controlled environment, which may not fully reflect real-world clinical practice. Therefore, studies including larger samples and external validation are warranted.

Despite these limitations, the use of methodological guidelines such as STARD-AI and GAMER strengthens the validity of the study by enhancing transparency, standardization, and reproducibility in research on AI applications in orthopedic trauma.

## CONCLUSIONS

ChatGPT-5.2 achieved 78% agreement with the reference standard and a Cohen's kappa coefficient of 0.56, indicating moderate agreement, while demonstrating high sensitivity for identifying cases requiring posterior malleolar fixation. It may serve as a useful decision-support tool in training settings for inexperienced physicians.

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# Distal and Proximal Tibiofibular Dislocation: A Maisonneuve Equivalent. Case Report

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### ABSTRACT
We present a 32-year-old male patient with simultaneous dislocation of the proximal and distal tibiofibular joint without associated fibula fracture, an atypical injury and with very few cases described in the literature, presented after a sports trauma. By mechanism of trauma and analysis of the injury, it is set up parallel with a Maisonneuve injury. The diagnosis was made by radiographs which showed a diastasis in the proximal tibiofibular joint and an increase in the medial clear space in the ankle. Treatment included closed reduction of the proximal dislocation and an open reduction with internal fixation of the distal dislocation. After twelve months of follow-up, the patient showed a complete recovery, without pain or instability, and with a satisfactory American Orthopedic Foot and Ankle Society Score (AOFAS) score, which allowed him to resume his sports and work activity.
**Keywords:** Ankle injury; interosseous membrane; surgical treatment; syndesmosis lesion; tibiofibular diastasis; Maisonneuve fracture.
**Level of Evidence**: IV

### Luxación tibioperonea distal y proximal: equivalente de Maisonneuve. Reporte de un caso

### RESUMEN
Se presenta el caso de un hombre de 32 años con luxación simultánea de la articulación tibioperonea proximal y distal, sin fractura asociada del peroné, ocurrida luego de un trauma deportivo. Se trata de una lesión atípica y con muy pocos casos publicados. Por el mecanismo de trauma y el análisis de la lesión, se establece un paralelo con una lesión de Maisonneuve. Se llega al diagnóstico con radiografías que mostraron una diástasis en la articulación tibioperonea proximal y un aumento del espacio claro medial en el tobillo. El tratamiento incluyó la reducción cerrada de la luxación proximal y una reducción abierta con fijación interna de la luxación distal. Tras 12 meses de seguimiento, la recuperación del paciente era completa, no tenía dolor ni inestabilidad, el puntaje de la AOFAS era satisfactorio, y retomó su actividad deportiva y laboral.
**Palabras clave:** Lesión de tobillo; membrana interósea; tratamiento quirúrgico; lesión de sindesmosis; diástasis tibioperonea; fractura de Maisonneuve.
**Nivel de Evidencia:** IV

## INTRODUCTION

The proximal tibiofibular joint is formed by the lateral aspect of the lateral tibial plateau and the fibular head, with articular cartilage and synovium interposed between them. It is stabilized by a fibrous capsule and two ligaments: the anterosuperior tibiofibular ligament, composed of two or three flat bands that are thicker and stronger than its counterpart, and the posterosuperior tibiofibular ligament, which consists of a single band. This joint may be classified according to its configuration as either horizontal or oblique. The horizontal configuration provides a larger articular surface and greater rotational mobility, whereas the oblique configuration, because of its smaller articular surface and reduced rotational mobility, is more prone to dislocation.[1]

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The distal tibiofibular syndesmosis is a fibrous joint formed by the tibia and fibula, which are maintained together within the fibular notch of the tibia by four ligaments: the anteroinferior tibiofibular ligament, the posteroinferior tibiofibular ligament, the transverse ligament, and the interosseous ligament, the latter being a direct continuation of the interosseous membrane. This joint may be injured in approximately 50% of Weber type B fibular fractures and in all type C fractures. In ankle sprains, the reported incidence ranges from 1% to 11%.[2]

The high fibular fracture caused by a pronation-external rotation mechanism associated with injury to the distal tibiofibular syndesmosis was first described by the French surgeon Jules Germain Maisonneuve in 1840, although the eponym was later popularized by his compatriots Quenu, Chaput, and Destot. Currently, the most widely accepted definition of a Maisonneuve injury is a fracture of the proximal fourth of the fibula associated with injury to at least the anteroinferior tibiofibular ligament and the interosseous ligament, usually extending to involve the medial column of the ankle.[3]

The simultaneous occurrence of proximal and distal tibiofibular dislocation without an associated fibular fracture is an extremely rare injury, with only a few cases reported in the literature.

We present the case of a patient who sustained this injury following sports-related trauma, including its diagnosis, management, and clinical and radiographic outcomes.

## CLINICAL CASE

A 32-year-old man with no relevant medical history presented to the emergency department after sustaining an eversion and rotational injury to his left ankle while playing soccer 24 hours earlier. He reported severe pain, functional impairment, and inability to bear weight on the affected limb. Physical examination revealed bimalleolar swelling and tenderness, a positive squeeze test over the mid and distal thirds of the leg, and tenderness along the lateral aspect of the fibula at its proximal fourth. No wounds or distal neurovascular deficits were identified. Ankle trauma series radiographs were obtained. The images showed only widening of the medial clear space and findings suggestive of a posterior malleolar fracture (Figure 1).

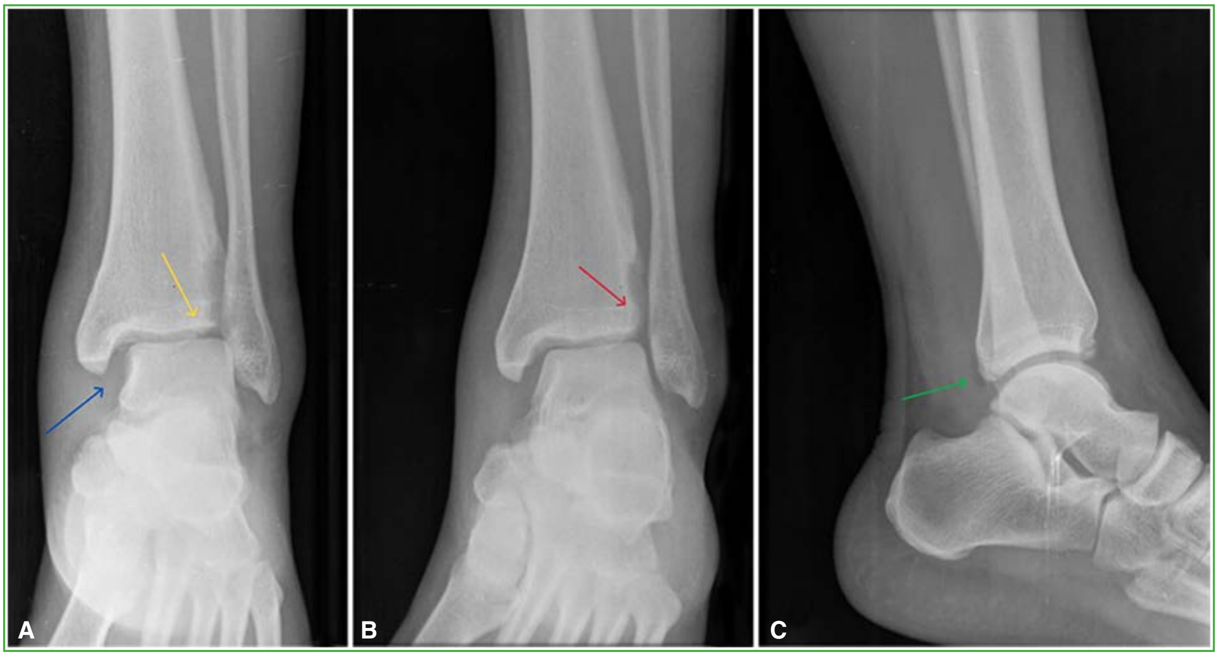


**Figure 1.** Radiographs of the left ankle. **A.** Anteroposterior view. Increased medial clear space, lateral displacement of the talus (blue arrow), and tibiotalar asymmetry (yellow arrow). **B.** Mortise view. Widening of the distal tibiofibular clear space (red arrow). **C.** Lateral view. Small posterior malleolar fracture (green arrow).

Radiographs of the leg demonstrated diastasis of the proximal tibiofibular joint without evidence of a fracture of the proximal fourth of the fibula (Figure 2). In addition, visualization of both the proximal and distal fibular articular facets was noted, an indirect sign of simultaneous tibiofibular dislocation, with the distal fibula in external rotation (Figure 3).[4]


**Figure 2.** Radiographs of the left leg. **A.** Anteroposterior view. No fibular fracture is observed. **B.** Lateral view. Anterior displacement of the proximal fibula (white arrow).

**Figure 3.** Radiograph of the left leg. The proximal and distal fibular articular facets are visible (double facet sign) (black circles). The distal fibula demonstrates a pointed appearance (black arrow).

A diagnosis of simultaneous proximal and distal tibiofibular dislocation associated with injury to the medial ankle complex and a posterior malleolar fracture, without an associated fibular fracture, was established. The patient was immobilized with a splint, and reduction and stabilization were scheduled for the day of admission.

## Surgical Technique

The patient was placed in the supine position and received spinal anesthesia and intravenous antibiotic prophylaxis. No tourniquet was used. Fluoroscopic guidance was employed throughout the procedure to assess the injury pattern (Figure 4).

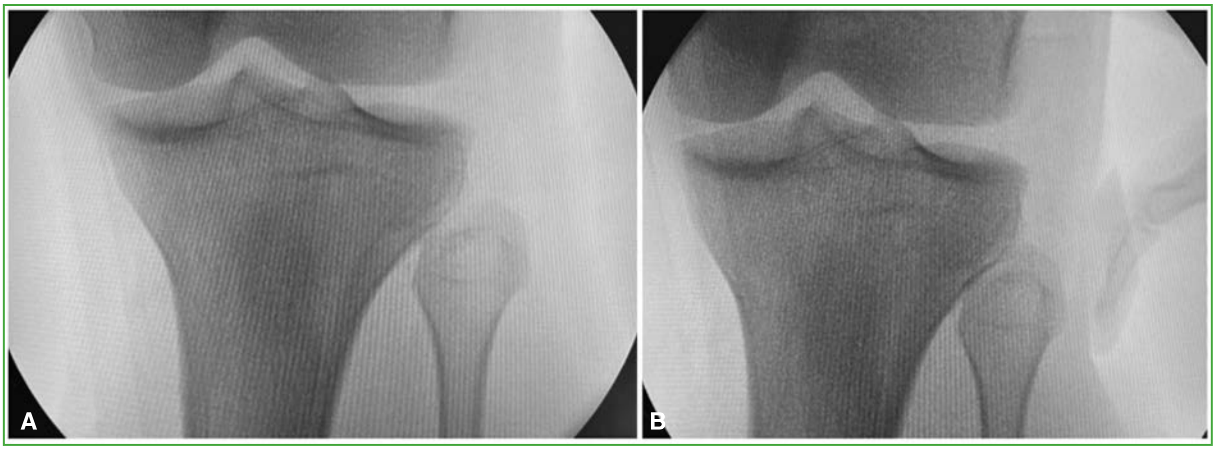


**Figure 4.** Left knee under fluoroscopic view. **A.** Note the proximal tibiofibular dislocation. **B.** Reduction achieved with manual compression.

With the knee flexed, the proximal tibiofibular dislocation was reduced by applying anteroposterior compression to the fibular head. A distal anterolateral approach to the ankle was then performed. After protecting the superficial peroneal nerve, syndesmotic diastasis was identified, with lateral displacement of the talus and external rotation of the fibula (Figure 5). Using a Steinmann pin as a joystick in the distal fibula, the external rotation deformity was corrected and the fibula was temporarily fixed to the tibia. Subsequently, through a lateral approach to the fibula, a pointed reduction clamp was applied, and a tibiofibular suture-button fixation device was inserted, along with a syndesmotic screw to enhance construct stability (Figures 6 and 7).

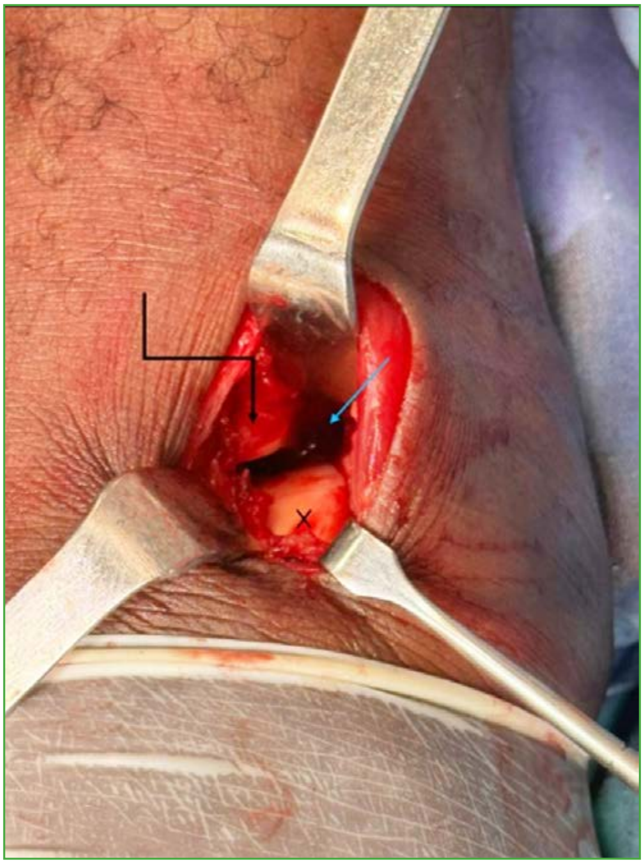

**Figure 5.** Intraoperative image of the left ankle. The distal tibia (angled black arrow), the talus (black cross), and the opening of the tibiofibular syndesmosis (blue arrow) are visible.

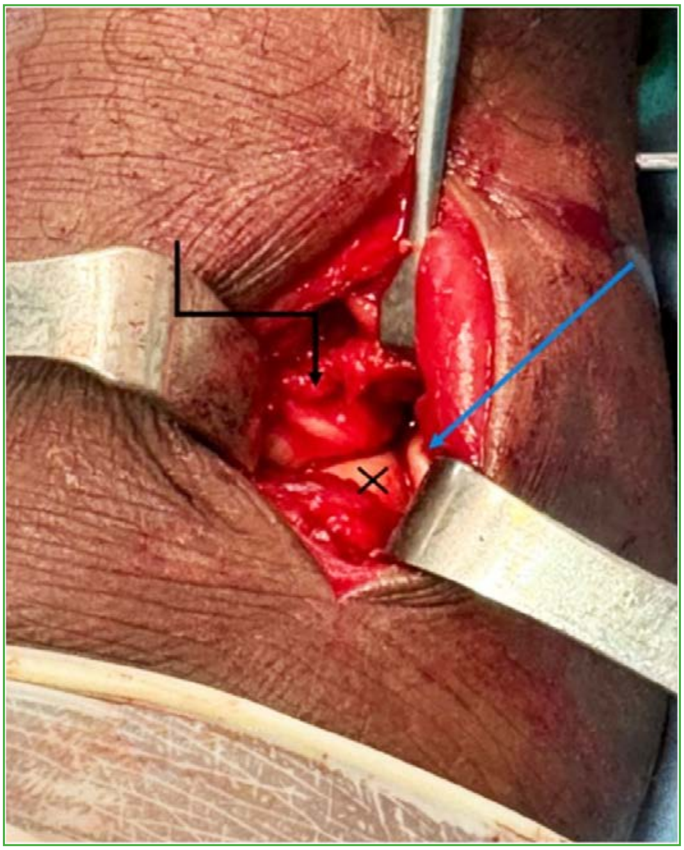

**Figure 6.** Intraoperative image of the left ankle. Correction of the tibiofibular diastasis. The distal tibia (angled black arrow), talus (black cross), and fibula (blue arrow) are visible.

**Figure 7.** Fluoroscopic image showing reduction and syndesmotic fixation using a pointed reduction clamp, a Steinmann pin, and a suture-button fixation device.

Intraoperative stability testing of both the proximal and distal tibiofibular joints demonstrated that reduction had been maintained and that both joints were stable. The posterior malleolar fracture was not considered amenable to surgical fixation because of its small size and minimal articular involvement.

The patient remained hospitalized for 24 hours. A postoperative computed tomography scan confirmed satisfactory reduction of both dislocations, appropriate positioning of the implants, and the absence of additional injuries (Figure 8).

The patient was discharged with an ankle orthosis and instructed to remain non-weight-bearing. Physical therapy was initiated during the third postoperative week. Protected weight-bearing was allowed at 6 weeks, progressing to full weight-bearing at 3 months.

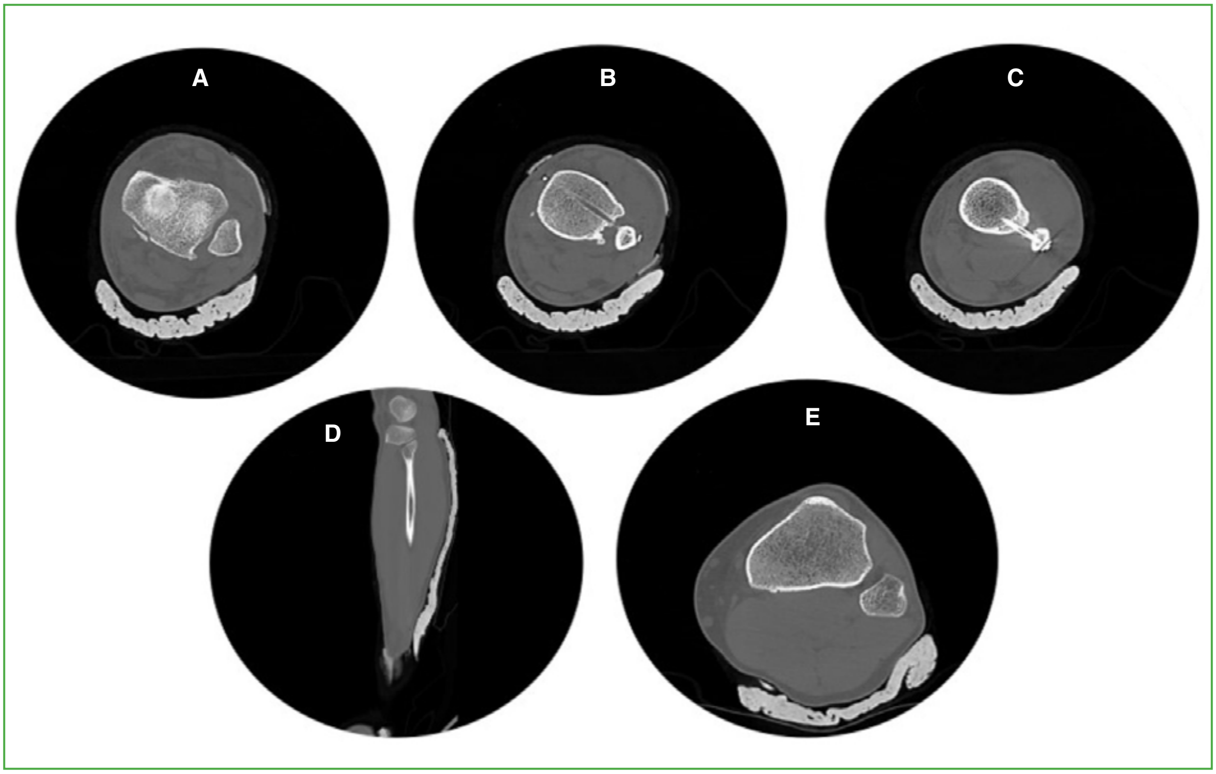


**Figure 8.** Postoperative computed tomography of the left leg. **A.** Axial image. Adequate fibular reduction within the incisura and an extra-articular posterior malleolar fragment. **B.** Axial image. Suture-button fixation in position. **C.** Axial image. Syndesmotic screw in position. **D.** Sagittal image. Reduced oblique proximal tibiofibular joint. **E.** Axial image. Congruent reduction of the proximal tibiofibular joint.

At 12 months of follow-up, the patient reported no pain and showed no clinical or radiographic evidence of instability of either the knee or the ankle (Figure 9). He had returned to both work and sports activities. His score on the *American Orthopaedic Foot & Ankle Society* (AOFAS) scale was 97/100.


**Figure 9.** Anteroposterior (**A**) and lateral (**B**) radiographs of the left leg obtained 12 months after surgery. Adequate reduction of the tibiofibular syndesmosis and maintenance of the combined fixation construct.

## DISCUSSION

Simultaneous injury to the proximal and distal tibiofibular joints is uncommon. Very few cases have been reported, and no standardized treatment protocol has been established because of the heterogeneity of the available studies. Reported follow-up ranges from 6 to 12 months, although outcomes have generally been satisfactory (Table).[5-9]

Proximal tibiofibular dislocation is estimated to account for approximately 1% of all knee injuries; however, the rate of missed diagnosis may be as high as 60%.[10] The injury mechanism typically involves either high-energy trauma or sports-related trauma causing knee flexion (which relaxes the dynamic stabilizers and renders the joint vulnerable) combined with rotational forces,[11] similar to the mechanism observed in our patient.

For radiographic diagnosis, the most commonly cited landmark is the Resnick line, a radiopaque line seen on the lateral knee radiograph that corresponds to the posterior aspect of the lateral tibial plateau and should intersect the midpoint of the fibular head. An anterior displacement of the fibular head relative to this line suggests anterior dislocation.[12]

Ogden classified this injury into four categories: atraumatic subluxation (3%), anterolateral dislocation (85%), posteromedial dislocation (10%), and superior dislocation (2%). This is a highly heterogeneous injury with limited representation in the current literature; consequently, there is no clear consensus regarding treatment. Management options range from nonoperative treatment to ligament repair or reconstruction, proximal tibiofibular arthrodesis, and proximal fibular head resection.[13,14]

In our case, once a stable closed reduction of the proximal tibiofibular dislocation had been achieved, we elected not to perform fixation or use external immobilization, such as a brace or splint, in order to avoid knee stiffness and facilitate earlier rehabilitation.

For the distal tibiofibular injury, open reduction and internal fixation was performed because closed reduction of the fibula into the fibular notch with percutaneous syndesmotic fixation is strongly contraindicated.[15] The patient underwent surgery on the day of admission to our institution, 24 hours after the injury. In this case, the patient had not one but two dislocations, and joint dislocations constitute an orthopedic emergency that should be reduced as soon as possible, particularly when multiple injuries affect the same limb segment.

**Table.** Review of previously reported cases.

| Published cases | Number of patients | Age | Mechanism of injury | Type of injury | Open/closed reduction | Follow-up | AOFAS score |
|---|---|---|---|---|---|---|---|
| Kumar et al.[5] 2003 | 1 | 36 | Pedestrian struck by a car | Closed PTFI and DTFI with deltoid ligament injury | Closed reduction of PTFI Repair of the deltoid ligament plus fixation screws (#2) | Non-weight-bearing brace for 8 weeks and removal of osteosynthesis hardware. 3 months, no symptoms. No radiographic follow-up. | N/A |
| Levy et al.[6] 2006 | 1 | 17 | Ankle sprain | Closed PTFI and DTFI with avulsion of the medial malleolus apex | Open reduction of PTFI (fixed with a 4.5 mm screw) and percutaneous reduction of DTFI (fixed with two 3.5 mm screws) | Non-weight-bearing brace for 12 weeks. Removal of osteosynthesis hardware at 6 months. At 8 months, pain-free for daily activities and sports. | N/A |
| Corrigan et al.[7] 2011 | 1 | 46 | Multiple trauma | Closed PTFI and DTFI | Open reduction of PTFI and DTFI, with 3.5- and 4.0-mm screws (proximal) and a 3.5-mm screw (distal) | 9 months with ankle-foot orthosis (bilateral foot drop due to aortic dissection). 15 months: stable knee and ankle. Distal screw fracture. | N/A |
| Bissuel et al.[8] 2017 | 1 | 31 | Fall from height (2 m) | Closed PTFI and DTFI with deltoid ligament injury | Closed reduction of PTFI, open reduction of DTFI, with plate and #2 3.5 mm screws and repair of the anterior tibiofibular ligament | No weight-bearing for 8 weeks and removal of osteosynthesis hardware. 18 months without symptoms. | 100 |
| Alencar et al.[9] 2019 | 1 | 34 | Sports (soccer) | Closed PTFI and DTFI | Open reduction of PTFI (fixation with a 3.5 mm screw) and percutaneous DTFI (fixation with two 3.5 mm #2 screws) | Immediate protected weight-bearing with crutches. Unrestricted walking after one month. 6 months without symptoms. No radiographic follow-up. | N/A |

AOFAS = *American Orthopaedic Foot and Ankle Society*; PTFI = proximal tibiofibular injury; DTFI = distal tibiofibular injury; N/A = not available.

The distal tibiofibular syndesmosis was stabilized using a combination of flexible fixation (suture-button fixation) and rigid fixation (a syndesmotic screw), based on current recommendations advocating augmentation in axially unstable fibular injuries, such as Maisonneuve injuries, and considering its similarity to our patient's injury (proximal dislocation).[16,17]

Current evidence does not support routine repair of the deltoid ligament in Maisonneuve injuries unless concentric reduction of the medial clear space cannot be achieved after fibular reduction because of deltoid ligament interposition, or unless gross valgus instability persists.[18] In our patient, restoration of the medial clear space was achieved following fixation and remained stable; therefore, neither exploration nor repair of the deltoid ligament was performed.

At the time of this report, the patient has experienced no symptoms related to either the flexible or rigid fixation constructs, thus implant removal has not been scheduled.

## CONCLUSIONS

This case report highlights the importance of carefully analyzing the injury sustained by the patient, understanding the trauma mechanism, and correctly interpreting diagnostic studies in order to ensure timely management of atypical injuries, such as simultaneous proximal and distal tibiofibular dislocation without an associated fibular fracture.

The treatment strategy consisted of closed reduction of the proximal dislocation and open reduction with internal fixation of the distal injury. This approach resulted in complete recovery without complications, supporting its effectiveness and suggesting that it may be considered in similar cases in the future.

To the best of our knowledge, this represents the sixth reported case of combined proximal and distal tibiofibular dislocation without an associated fibular fracture. Given the absence of large case series, it remains difficult to propose evidence-based treatment guidelines for this uncommon injury. At present, management must rely on the recommendations established for each component injury individually.

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# Anterior Tibial Artery Pseudoaneurysm as a Complication of Anterior Ankle Arthroscopy: A Case Report

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**ABSTRACT**
We present the case of an anterior tibial artery pseudoaneurysm as a complication following anterior ankle arthroscopy. This complication is extremely rare and represents a therapeutic challenge. A patient developed progressively worsening pain, limited dorsiflexion, local swelling, and gait claudication two weeks after undergoing anterior ankle arthroscopy for anterior impingement syndrome and an osteochondral lesion, without signs or symptoms of infection. Magnetic resonance imaging (MRI) and ultrasound established the diagnosis of an anterior tibial artery pseudoaneurysm. Treatment consisted of thrombin injection followed by microcoil embolization under angiographic guidance. The outcome was favorable, with resolution of pain, successful treatment of the pseudoaneurysm, and recovery of ankle mobility. **Conclusions:** Clinical suspicion is essential in patients presenting with disproportionate pain, swelling, or a pulsatile mass. Early diagnosis and treatment are associated with a better prognosis.
**Keywords:** Pseudoaneurysm; ankle; arthroscopy.
**Level of Evidence:** IV

**Seudoaneurisma de la arteria tibial anterior como complicación de una artroscopia anterior de tobillo. Presentación de un caso**

**RESUMEN**
Se presenta un caso clínico de un seudoaneurisma de la arteria tibial anterior como complicación luego de una artroscopia anterior de tobillo. Esta complicación es extremadamente infrecuente y supone un desafío terapéutico. Se trata de un paciente que, a las 2 semanas de la artroscopia anterior de tobillo por un síndrome friccional anterior y una lesión osteocondral, comienza con dolor creciente, limitación de la dorsiflexión, edema local y claudicación de la marcha, sin signos ni síntomas de infección. Con una resonancia magnética y una ecografía, se diagnosticó un seudoaneurisma de la arteria tibial anterior, que se trató con una inyección de trombina y la posterior embolización con un *microcoil* bajo guía angiográfica. La evolución fue favorable, el dolor desapareció, el seudoaneurisma fue tratado, con éxito, y el paciente recuperó la movilidad del tobillo. **Conclusiones:** Es imprescindible la sospecha clínica ante un paciente con dolor desproporcionado, edema o una masa pulsátil. El diagnóstico y el tratamiento tempranos permiten un mejor pronóstico.
**Palabras clave:** Seudoaneurisma; artroscopia; tobillo.
**Nivel de Evidencia:** IV

## INTRODUCTION

Pseudoaneurysms are generally caused by disruption of all three layers of the arterial wall. They are most commonly iatrogenic in origin, although they may also occur following trauma.[1] Unlike true aneurysms, their wall is composed of fibrous tissue rather than the normal arterial wall layers, making them more prone to rupture.

The reported complication rate following ankle arthroscopy ranges from 3.5% to 17%. Most complications are minor and transient, with dysesthesia or paresthesia involving the superficial peroneal nerve being the most frequently reported.[2-5]

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## CLINICAL CASE

A 36-year-old man with no relevant medical history presented with chronic pain in his left ankle. He reported sustaining an ankle sprain 3 years earlier, after which he continued to experience anterolateral ankle pain that prevented him from participating in recreational sports activities. He underwent multiple courses of physical therapy without significant improvement. At the preoperative evaluation, his main complaint was moderate anterolateral pain in the left ankle at rest, which worsened with activity and weight-bearing.

### Clinical Findings

On initial physical examination, ankle alignment and ligamentous stability were preserved. No obvious swelling was present. Tenderness was noted over the anterolateral aspect of the ankle joint, particularly in the region of the anterior talofibular ligament and the anterior inferior tibiofibular ligament (Bassett's ligament). Forced ankle dorsiflexion reproduced marked pain in the anterolateral region, suggesting anterior ankle impingement. The patient also reported intra-articular pain during axial loading.

### Diagnostic Evaluation

*Preoperative imaging studies*

*Computed tomography:* Osteochondral lesion of the lateral talar shoulder measuring 7.8 x 4.0 mm. Calcifications within the anterior talofibular ligament (Figure 1).


**Figure 1.** Computed tomography of the ankle, coronal and sagittal images. Osteochondral lesion measuring 7.8 x 4.0 mm (green arrow).

*Magnetic resonance imaging:* Osteochondral lesion of the lateral aspect of the talar dome measuring 11 x 4 mm. Calcification of the anterior talofibular ligament and synovitis of the anterior ankle compartment (Figure 2).

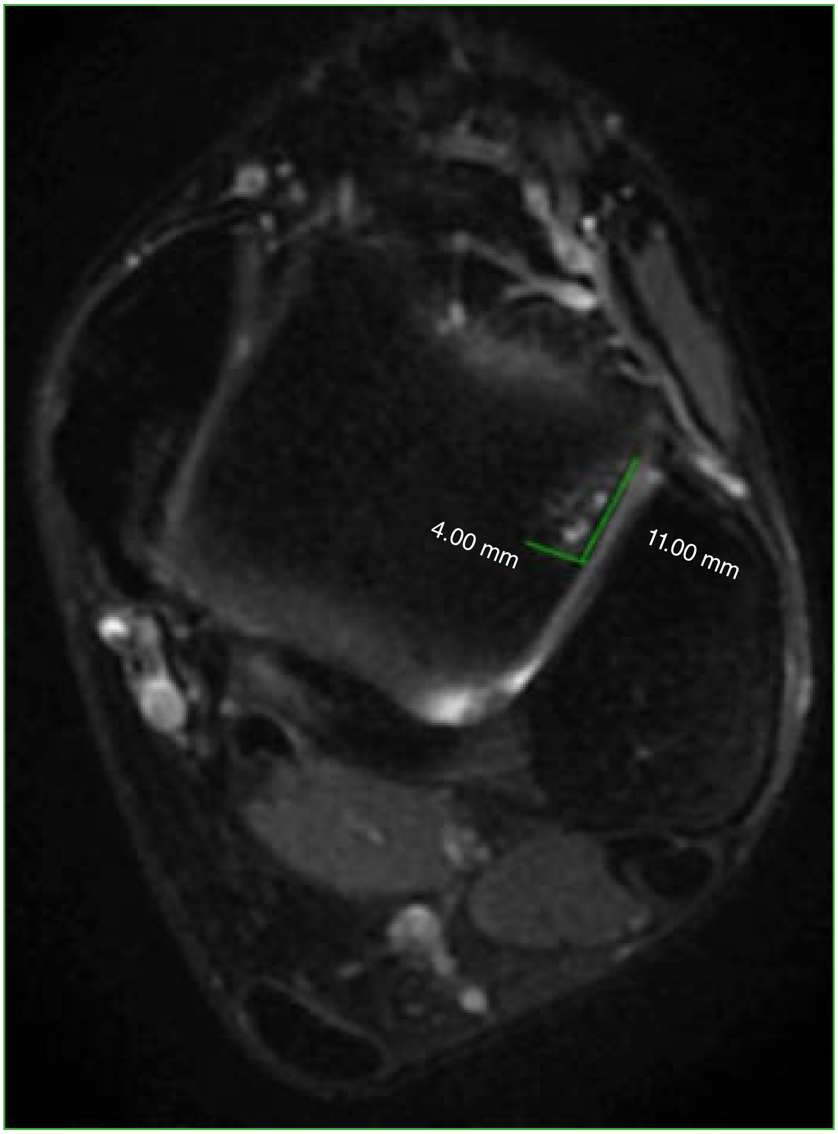


**Figure 2.** Magnetic resonance imaging of the ankle, axial image. Osteochondral lesion measuring 11.0 x 4.0 mm (green line).

## Initial Therapeutic Intervention

*Surgical plan:* anterior ankle arthroscopy for anterolateral soft-tissue impingement syndrome, synovitis, and an osteochondral lesion (Raikin zone 3-6).

Anterior ankle arthroscopy was performed through standard anteromedial and anterolateral portals. Synovitis, hypertrophy, and hyperemia of the anterior inferior tibiofibular ligament (Bassett's ligament) and the anterior talofibular ligament were observed. The osteochondral lesion was located in Raikin zone 3-6 and was classified as grade 3 according to the *International Cartilage Repair Society* (ICRS) classification (Figure 3).

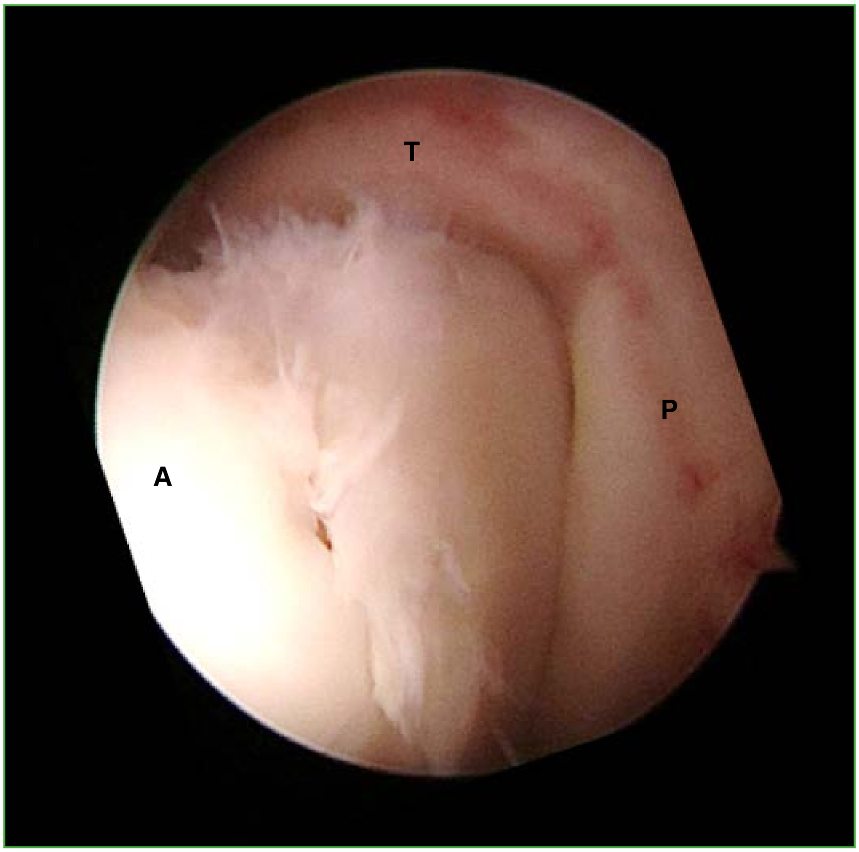


**Figure 3.** Arthroscopic image of the osteochondral lesion after synovectomy. T = tibia; P = fibula; A = talus.

Arthroscopic treatment consisted of synovectomy of the ankle joint and the affected ligaments, along with debridement of Bassett's ligament. The osteochondral lesion was treated with curettage of the lesion bed, excision of the delaminated cartilage, and smoothing of the lesion margins using a shaver. The procedure was completed with microfracture treatment. At the end of the procedure, an elastic compression bandage was applied. Ankle range of motion was allowed immediately, and weight-bearing was restricted for 1 month.

The patient progressed favorably during the first 2 weeks. Subsequently, he developed disproportionate pain over the anterior aspect of the ankle, which limited dorsiflexion and interfered with physical therapy. During weight-bearing, the pain caused an antalgic gait. There were no signs or symptoms of infection. Additional diagnostic studies were requested.

## Postoperative Diagnostic Evaluation

*Magnetic Resonance Imaging:* An extra-articular nodular lesion measuring 21 x 22 mm was identified in the anterior aspect of the ankle joint. The lesion had a cystic appearance and heterogeneous contents suggestive of blood products (Figure 4).

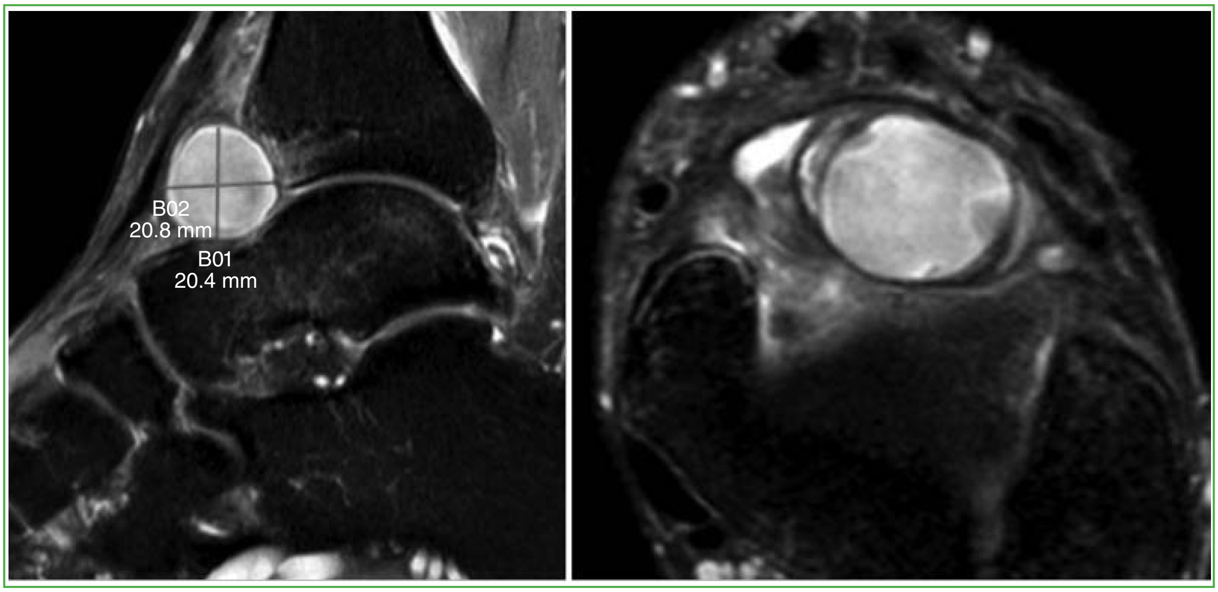


**Figure 4.** Magnetic resonance imaging of the ankle, sagittal and axial images. Pseudoaneurysm of the anterior tibial artery measuring 21 x 22 mm (green lines).

*Doppler ultrasound:* Pseudoaneurysm of the anterior tibial artery measuring 18 x 16 mm, with persistent flow within the lesion.

## Therapeutic Intervention for the Complication

In collaboration with the Interventional Radiology Department, a percutaneous thrombin injection was administered into the pseudoaneurysm under Doppler ultrasound guidance to induce thrombosis.[6] This procedure achieved thrombosis of most of the pseudoaneurysm; however, immediate follow-up studies demonstrated persistence of a small residual vascular sac with persistent flow. To complete treatment, selective angiography of the anterior tibial artery was performed a few days later. After identifying the pseudoaneurysm neck, embolization was performed through a microcatheter with placement of a microcoil within the pseudoaneurysm sac (Figure 5).

## Follow-up and Outcomes

No conventional open surgical procedure was required. Endovascular treatment allowed rapid recovery while avoiding major complications. No adverse events occurred during either intervention, and the patient tolerated both the thrombin injection and microcoil embolization without complications.

Following embolization of the pseudoaneurysm, symptoms improved progressively. Five months after surgery, the patient was pain-free and demonstrated marked improvement in ankle range of motion. At 8 months postoperatively, he had regained full ankle motion and reported only occasional discomfort with forced maximal dorsiflexion, which did not limit his physical activities.

**Figure 5.** Microcoil placement within the pseudoaneurysm.

# DISCUSSION

Pseudoaneurysms are a very rare complication following ankle arthroscopy, with a reported incidence of 0.008%.[5,7]

Anatomically, the anterior tibial artery and its terminal branch, the dorsalis pedis artery, are closely related to the anterior capsule of the ankle joint at the level of the talar neck and lie deep to the superior and inferior extensor retinacula. Anatomical variations have been described, including lateral deviation in 5.5% of cases and medial deviation in 3.5%. The artery may be injured during insertion or removal of arthroscopic instruments and, particularly, during synovectomy. The anterocentral portal has been associated with the highest incidence of vascular injury and has therefore largely fallen out of routine use.[8-10]

This complication is often diagnosed late. Patients typically present with disproportionate pain and swelling, followed by the development of a pulsatile mass. The condition is associated with considerable morbidity. Reported complications of pseudoaneurysms include hemarthrosis, vascular rupture, pain, swelling, and restricted range of motion.[11]

Doppler ultrasound and angiography can confirm the diagnosis of a pseudoaneurysm involving the anterior tibial artery or its terminal branch. Treatment options range from local compression and thrombin injection to coil embolization and open surgical resection.[12]

A major strength of this case is that it illustrates the effectiveness of minimally invasive endovascular treatment for a pseudoaneurysm in the distal leg, thereby avoiding open surgery. Furthermore, it highlights the importance of maintaining a high index of suspicion in patients who develop disproportionate pain following ankle arthroscopy. The coordinated multidisciplinary management provided by the orthopedic surgery and interventional radiology teams resulted in a favorable functional outcome.

The main limitation of this report is that it describes a single case, and therefore its findings cannot be generalized. Evidence regarding this complication is limited to isolated case reports and very small case series, making it difficult to establish precise risk factors or preventive measures beyond the general recommendations applicable to ankle arthroscopy. Furthermore, the exact timing of the arterial injury could not be determined because clinical manifestations appeared in a delayed fashion, which is a well-recognized characteristic of pseudoaneurysms.

## CONCLUSIONS

This complication is extremely uncommon and is frequently diagnosed late, resulting in increased morbidity. A high index of suspicion is essential in patients presenting with disproportionate pain, swelling, or a pulsatile mass. Early diagnosis and prompt treatment are crucial for achieving favorable outcomes. In this case, endovascular management enabled successful treatment of the pseudoaneurysm, facilitated rapid recovery, and avoided the need for a more morbid open surgical procedure.

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Conflicts of interest: The authors declare no conflicts of interest.

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# Osteoarticular Tuberculosis of the Foot and Ankle: Diagnosis and Treatment Based on Our Experience. Case Report

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**ABSTRACT**

Osteoarticular tuberculosis (TB) is the third most common form of extrapulmonary tuberculosis after pleural and lymph node involvement. It accounts for 1% of all tuberculosis cases, and only 3-12% of osteoarticular cases involve the foot and/or ankle. The objectives of this article are to present a clinical case and its treatment, compare it with similar cases reported in the literature, and raise awareness of this uncommon presentation. We report the case of a 50-year-old man with pulmonary tuberculosis who presented with pain in the malleolar region of the left ankle. Physical examination revealed a well-circumscribed soft-tissue mass without skin discoloration or increased local temperature, which subsequently progressed to ulceration. Radiographs and computed tomography scans showed cavitary osteolytic lesions with internal content and cortical disruption. A specimen was obtained for culture, which tested positive for *Mycobacterium tuberculosis*. The patient received antituberculous therapy for 9 months, and partial weight-bearing was initiated after 5 months. The outcome was favorable. **Conclusion:** Early diagnosis and appropriate multidisciplinary management are essential to prevent complications.

**Keywords:** Osteoarticular tuberculosis; foot and ankle; extrapulmonary tuberculosis; antibiotics; osteolytic lesions.

**Level of Evidence:** IV

## Tuberculosis ósea en el pie y el tobillo. Diagnóstico y tratamiento basados en nuestra experiencia. Reporte de caso

**RESUMEN**

La tuberculosis osteoarticular es la tercera forma de afectación extrapulmonar luego de la pleural y la ganglionar. El 1% de los enfermos con tuberculosis tiene este cuadro. Solo el 3-12% compromete el pie o el tobillo. Los objetivos de este artículo son comunicar un caso clínico y su tratamiento, compararlo con casos similares publicados y advertir sobre esta presentación infrecuente. Se trata de un hombre de 50 años con tuberculosis pulmonar que refiere dolor en la región maleolar del tobillo izquierdo. Tiene una tumoración blanda circunscrita, sin cambio de coloración ni aumento de la temperatura que evoluciona a una úlcera. La radiografía y la tomografía computarizada muestran imágenes osteolíticas cavitadas con contenido y disrupción cortical. Se toma una muestra para cultivo que resulta positiva para *Mycobacterium tuberculosis*. El paciente recibió un tratamiento antibiótico contra la tuberculosis durante 9 meses y continuó con carga parcial a los 5 meses; los resultados fueron favorables. **Conclusión:** Se deberá realizar un diagnóstico precoz e indicar un tratamiento multidisciplinario adecuado para evitar complicaciones.

**Palabra clave:** Tuberculosis osteoarticular; pie y tobillo; tuberculosis extrapulmonar; antibióticos; imágenes osteolíticas.

**Nivel de Evidencia:** IV

## INTRODUCTION

Tuberculosis is an infectious disease caused by *Mycobacterium tuberculosis*. It is transmitted through airborne droplets from a person with active tuberculosis to a susceptible individual and most commonly affects the lungs.[1] It is the second leading cause of death from infectious diseases after human immunodeficiency virus (HIV) infection, with 95% of cases and deaths occurring in developing countries.[2]

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Only 1% of patients with tuberculosis develop osteoarticular involvement. Approximately half of these cases affect the spine, whereas involvement of the foot and ankle accounts for 3%-12% of cases. Because of its nonspecific presentation and the difficulty of establishing an early diagnosis, this condition should always be considered, as delayed diagnosis may lead to extensive joint destruction, involvement of adjacent structures of the foot, and severe deformities.[2–4] Diagnosis is based on clinical suspicion, imaging studies, and microbiological confirmation.

Clinical manifestations often begin with pain in the affected region, functional impairment, and difficulty bearing weight. Patients may also present with fever, tachycardia, anorexia, weight loss, asthenia, and apathy, as well as swelling without erythema or increased local temperature, tenderness on palpation, and purulent discharge.[3]

Microbiological evaluation is essential. In addition to demonstrating the presence of bacilli, isolation of the causative organism allows *in vitro* susceptibility testing to antituberculous drugs.[4]

Early radiographic findings include increased bone density, soft-tissue swelling, and lamellar periosteal reaction, which may appear approximately 10 days after symptom onset. Characteristic findings are osteolytic lesions, while bone sequestra typically become evident during the second or third week.

Tuberculosis of the foot has four radiographic presentations. The most common is the periarticular granulomatous form, followed by the central granulomatous form, isolated hematogenous synovitis, and, finally, tuberculous tenosynovitis or bursitis.[5] Magnetic resonance imaging (MRI) allows early diagnosis and demonstrates early osseous and soft-tissue changes, including bone edema, trabecular fractures, synovial abnormalities, joint effusion, fluid collections, tenosynovitis, and inflammatory infectious changes. Bone scintigraphy has a sensitivity comparable to that of MRI. Definitive diagnosis is confirmed by biopsy or aspiration of the bone lesion.[6]

The objectives of this article are to present a clinical case, including its presentation, diagnosis, and treatment; to compare it with similar cases reported in the literature; to analyze the differences; and to discuss our experience.

## CLINICAL CASE

The patient was a 50-year-old man with a history of cutaneous pemphigus diagnosed in 2019, which had completely resolved, and pulmonary tuberculosis diagnosed in 2023. He was receiving treatment with rifampicin, isoniazid, and pyrazinamide. He reported a three-month history of sharp pain over the dorsum of the foot and the anterior aspect of the left ankle. He was taking corticosteroids, which worsened his symptoms. He presented in a wheelchair. Physical examination revealed a soft, fluctuant, well-circumscribed mass with well-defined borders, without skin discoloration or increased local temperature (Figure 1).

**Figure 1.** Medial malleolar region showing a soft, fluctuant, well-circumscribed mass with well-defined borders.

During subsequent follow-up, the lesion progressed to a sinus tract with abundant purulent discharge and, a few days later, to an ulcer in the medial malleolar region. The ulcer was approximately 4 cm in diameter, circular in shape, with elevated necrotic margins and a wound bed containing devitalized tissue and purulent discharge.

Anteroposterior and lateral radiographs of the foot and ankle obtained at presentation demonstrated multiple osteolytic lesions involving the talus, calcaneus, cuboid, medial and lateral malleoli, the lateral cuneiform, and the bases of the third, fourth, and fifth metatarsals, associated with cortical thinning (Figures 2-4).

Figure 2. Oblique radiograph of the foot. Multiple osteolytic lesions involving the talus, calcaneus, cuboid bone, and tibial and fibular malleoli.

Figure 3. Lateral radiograph of the foot and ankle. Multiple osteolytic lesions involving the talus and calcaneus.

**Figure 4.** Anteroposterior radiograph of the ankle. Multiple osteolytic lesions involving the talus and the tibial and fibular malleoli.

Computed tomography of the foot and ankle revealed generalized osteopenia, particularly in sections through the hindfoot involving the talar head and the anterior portion of the calcaneus (Figure 5).

This osteopenia resulted in marked cortical thinning and cortical disruption along the medial aspect of the calcaneus (Figure 6).

These findings were considered consistent with an inflammatory osseous process (osteomyelitis) associated with sequestrum and involucrum formation. Magnetic resonance imaging revealed marrow edema within the fifth metatarsal shaft, diffuse bone edema with trabecular fractures involving the talus and calcaneus, joint effusion within the anterior and posterior talar recesses and the sinus tarsi, synovial proliferation, and an approximately 35-mm fluid collection adjacent to the posterior tibial tendon. Additional findings included infectious-inflammatory changes and tenosynovitis of the flexor hallucis longus tendon. The joints otherwise appeared preserved. (Figures 7 and 8).

Samples were obtained for acid-fast bacilli culture, which yielded positive results.

The patient continued antituberculous therapy with pyrazinamide, isoniazid, and rifampicin for a total of 9 months. Progressive wound healing was observed. Partial weight-bearing was allowed after 3 months, progressing to full weight-bearing at 6 months (Figure 9).

The patient provided written informed consent for publication of the case and accompanying images.

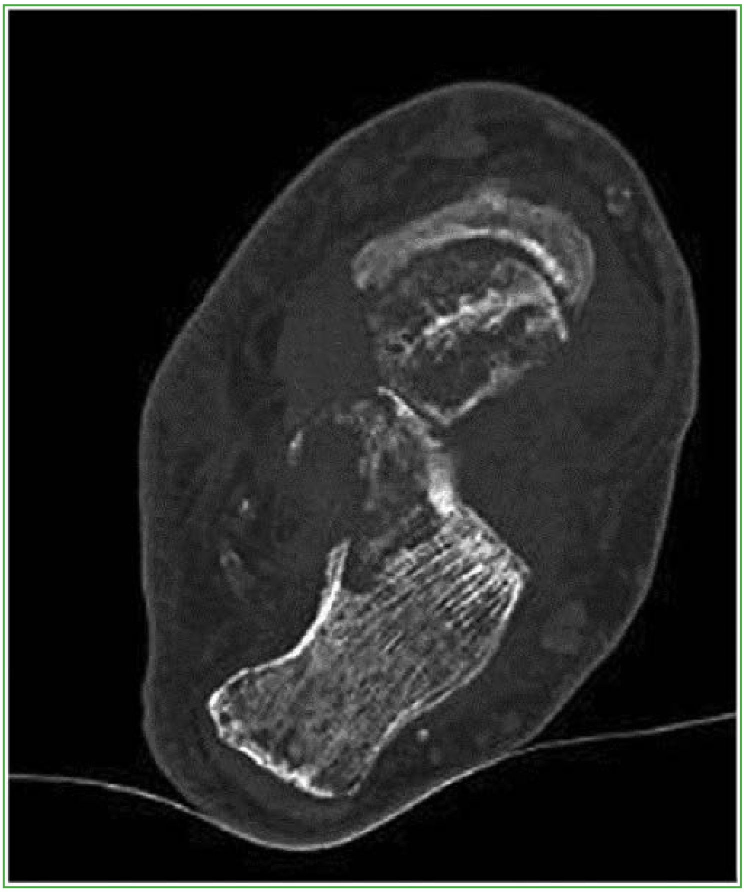

**Figure 5.** Computed tomography of the foot, axial image. Generalized osteopenia involving the talar head and the anterior portion of the calcaneus.

**Figure 6.** Computed tomography of the foot and ankle, sagittal image. Infectious involvement of the talus and calcaneus with sequestrum and involucrum formation.

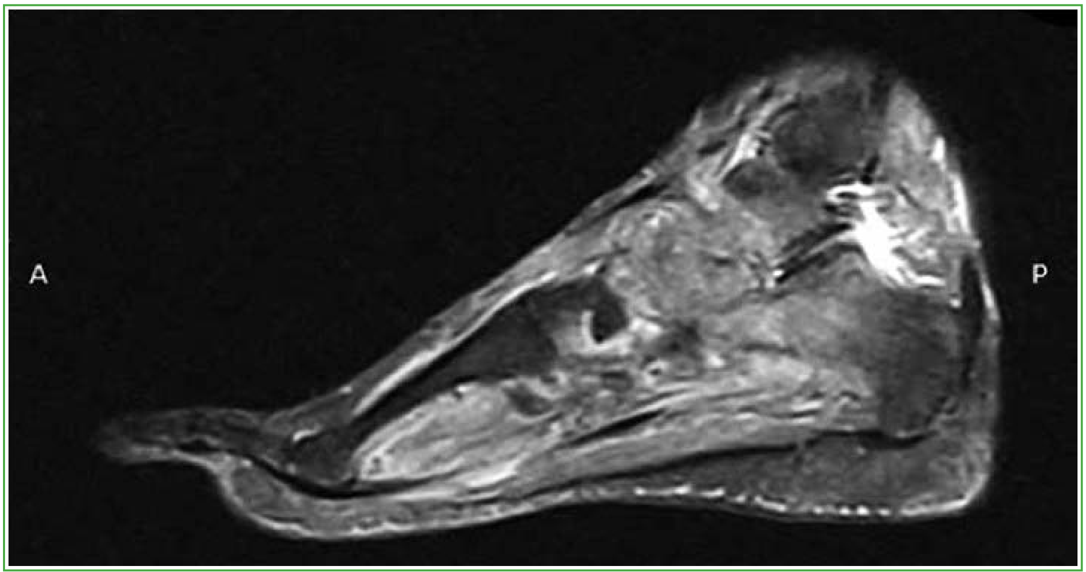


**Figure 7.** Magnetic resonance imaging of the foot and ankle, sagittal image. Trabecular fractures of the talus and calcaneus, an approximately 35-mm fluid collection adjacent to the posterior tibial tendon, and infectious-inflammatory changes are observed.

**Figure 8.** Magnetic resonance imaging of the foot and ankle, coronal image. Trabecular fractures of the talus and calcaneus and joint effusion within the anterior talar recess are observed.

**Figure 9.** Clinical improvement of the wound, with no drainage or fluctuance.

# DISCUSSION

The World Health Organization reported that 1.3 million people died from tuberculosis in 2022. During that year, an estimated 10.6 million people developed tuberculosis worldwide, including 5.8 million men, 3.5 million women, and 1.3 million children. Tuberculosis is present in all countries and affects all age groups.[1]

Isolated skeletal involvement is uncommon. The variable clinical and radiological manifestations may mimic osteomyelitis, bone tumors, or other inflammatory and neoplastic conditions.[7]

Studies by Lasalle Vignolo and by Navarrete et al. reported that osteoarticular tuberculosis accounts for only 1%-3% and 5%-10% of cases, respectively. Both authors emphasized that delays in diagnosis and treatment contribute substantially to disease progression.[8,9]

Conventional radiography remains the cornerstone of diagnosis, although radiographic changes may be absent during the early stages of the disease. For this reason, computed tomography and magnetic resonance imaging play an important role in the detection of calcifications and soft-tissue abnormalities, respectively.[2]

A high index of suspicion is essential in patients presenting with persistent pain, swelling, and chronic drainage. Delayed diagnosis results in more advanced disease and may also lead to financial burden and psychological distress. Biopsy of deep tissue specimens should be performed. Early diagnosis and antituberculous treatment for 9–18 months are essential to prevent joint involvement and other complications.[10]

It should be emphasized that diagnosis must be based on a combination of imaging findings and histopathological and microbiological analysis of biopsy specimens, as no single diagnostic gold standard has been established according to the literature reviewed.[11-13]

Casuriaga et al. stated that biopsy is the only method capable of definitively confirming the diagnosis. The absence of pathognomonic imaging findings further complicates diagnosis.[13]

The calcaneus is the most frequently affected bone in foot tuberculosis, possibly because it is the largest bone in the region and is particularly vulnerable to direct trauma. This finding is consistent with our case, although our patient also exhibited involvement of several other bones of the foot.[5,12,14]

Bains et al. reported an unusual case of a large cold abscess secondary to sternal tuberculosis. The patient was a 23-year-old immunocompetent Asian woman who presented with a painless, gradually enlarging swelling of the anterior chest wall that had been present for 5 months. The lesion measured 12.5 cm in diameter and was soft, non-tender, fluctuant, and without local warmth.[15]

The differential diagnosis includes rheumatoid arthritis, pyogenic osteomyelitis, tumors, sarcomas, and fungal osteomyelitis. Following imaging studies, we recommend confirmation of the diagnosis by bone biopsy, followed by appropriate treatment.[16] Tulli emphasized gradual ambulation with an appropriate orthosis beginning 3 months after initiation of treatment, with progressive discontinuation of the orthosis after 2 years.[17] Conde and Carvallo proposed surgical treatment consisting of debridement and placement of gentamicin-loaded cement because of the chronic nature of the disease. They also highlighted the lack of consensus regarding the treatment of calcaneal osteomyelitis.[18]

In our case, osseous tuberculosis did not present with the typical isolated calcaneal involvement commonly described in the foot, as multiple bones were affected. Considering the patient's clinical history and presenting manifestations, we obtained ankle and foot radiographs, computed tomography, and magnetic resonance imaging to exclude other possible diagnoses.

## CONCLUSIONS

Because tuberculosis of the foot and ankle is an uncommon condition, early diagnosis and prompt initiation of appropriate treatment are essential to prevent complications. Delayed diagnosis may result in joint involvement and unfavorable outcomes. Furthermore, the complexity of this disease requires a multidisciplinary approach.

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Conflicts of interest: The authors declare no conflicts of interest.

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# The Hindfoot in Orthopedics, History, and Mythology

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**ABSTRACT**
The hindfoot is an anatomical region whose significance extends beyond the strictly medical sphere and is linked to ancient Greek tradition and certain milestones in human history. The well-known stories of Oedipus, Achilles, and the history of the ordeal of crucifixion are analyzed, revisited, and reinterpreted from the perspective of our medical specialty. In all of them, fate emerges as an inescapable guiding principle.
**Keywords:** Hindfoot; mythology; history.
**Level of Evidence:** V

## El retropié entre la ortopedia, la historia y la mitología

**RESUMEN**
El retropié es una región anatómica cuyo interés trasciende lo estrictamente médico y se vincula con la tradición griega antigua y ciertos hitos de la historia de la humanidad. Los relatos célebres de Edipo, Aquiles y la historia del tormento de la crucifixión se analizan, actualizan y reinterpretan en relación con nuestra especialidad médica. En todos ellos, el destino aparece como un principio rector ineludible.
**Palabras clave:** Retropié; mitología; historia.
**Nivel de Evidencia:** V

The hindfoot is the anatomical region located posterior to the Chopart joint and comprises the talus, calcaneus, subtalar joint, capsuloligamentous structures, tendon insertions, the origins of the intrinsic foot muscles, and the surrounding soft tissues.[1] In addition to its medical significance, this structure is linked to traditions of ancient Greek mythology and significant milestones in human history.

I. The Pythia of the Oracle of Delphi in Greece—the *omphalos*, or navel of the world created by Zeus—had warned Laius, king of Thebes: “The son you have with Jocasta will be your murderer; he will sleep in your bed and shed your blood.” Parricide followed by incest with his mother. A curse hung over Laius for having raped and driven to suicide Chrysippus, son of the king of Pisa, thereby breaking the bond of brotherhood that united them. But on a Dionysian night, Jocasta conceived. According to Sophocles in *Oedipus Rex*, after the child was born, Laius ordered his servants to hang him by his feet from a tree on Mount Cithaeron, but not before piercing his ankles or heels with a fibula (an ancient brooch or clasp). The resulting swelling would give rise to the child’s name: *Oidema podós*, or Oedipus, meaning “swollen-footed,” and would leave him permanently lame.[2-5] Nevertheless, the Fates decreed that the child would survive and be adopted by the rulers of Corinth. As an adolescent, Oedipus began to question his origins and decided to consult the Oracle of Delphi. In response, he received an enigmatic message: “Return to your origin” (Corinth or Thebes?). The young man interpreted this as Thebes, and on his way there, during a chance altercation with a group of men, he unwittingly killed his father. On the outskirts of the city, atop a hill overlooking an abyss, he confronted the Sphinx, solved its riddle, and, as a result, the monster plunged to its death. With the people freed and Oedipus hailed as a hero, he was eventually crowned king and married the widowed queen, with whom he had children, unaware that she was his mother. The double prophecy had been fulfilled.

However, as a series of misfortunes and plagues befell Thebes, Tiresias—the blind seer—and the oracle revealed

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the truth. Jocasta hanged herself, and Oedipus used the brooches from the queen's dress to gouge out his eyes so as not to face reality. He then expiated his guilt until his death in a forest or in battle. Over the centuries, his story persisted in Western culture, giving rise to countless interpretations in theater, philosophy, the visual arts, and psychology.[2,3,5] The Oedipus and Jocasta complexes would emerge. [3,5,6] Homer refers to Oedipus in both the *Iliad* and the *Odyssey*; for Aristotle, *Oedipus Rex* was the most accomplished Greek tragedy, and its influence extended to Shakespeare's *Hamlet* and Melville's Captain Ahab in *Moby-Dick*. In painting and sculpture, depictions of Oedipus's feet can be seen in *The Rescue of the Infant Oedipus* (Salvator Rosa, 1663, The Royal Academy of Arts, London) and *The Infant Oedipus Revived by the Shepherd Phorbas* (Denis Antoine Chaudet, 1810–1818, Musée du Louvre, Paris).

II. According to various accounts, the sea nymph Thetis was destined to bear a son who would surpass his father in prowess. Consequently, no god wished to marry her. Instead, she wed Peleus, king of the Myrmidons of Phthia. From this union was born Achilles, known as the Pelides, the swift-footed one, or the fair-haired one. In an effort to make him invulnerable, his mother immersed him in the waters of the River Styx, the boundary between the world of the living and the Underworld. However, she failed to wet his heels, the only part of his body that remained human and therefore vulnerable. Achilles received from Chiron—the wise centaur—an outstanding education in both intellectual pursuits and the skills required for hunting wild animals. He later shared his military training with his inseparable friend and cousin Patroclus.[3] When the Trojan War began, Achilles commanded the Greek fleet and gained renown as the greatest warrior of all times. After Patroclus was killed by Hector, Achilles took revenge by slaying the Trojan prince in combat and dragging his corpse behind his chariot before the walls of Troy, to the horror of his family and fellow citizens.[7] He subsequently killed Penthesilea, queen of the Amazons, Memnon, the Ethiopian prince, and many other Trojans.[3] Yet an early death was the price imposed upon a life filled with passion and adventure. Deeply in love with Polyxena, one of the many daughters of the Trojan king and therefore sister of Hector, Paris, Troilus, Cassandra, Creusa, and others, Achilles, in a display of seduction and narcissism, revealed his story to her, including the vulnerability of his heel. The young woman, who profoundly despised Achilles, entrusted the secret to Paris. When hostilities resumed in the spring, Paris, aided by Apollo, drew his bow and released a poisoned arrow that pierced the right heel of the Pelides, causing his painful death. The ashes of Achilles, mixed with those of Patroclus, were placed in a golden urn buried on the promontory of Sigeum near the coast of the eastern Aegean Sea.[3] Centuries later, Alexander the Great would offer honors and libations after crossing the Dardanelles (Hellespont) on the eve of the Battle of the Granicus.[8] The *Iliad* concludes with the return of Hector's body to his father, Priam.[7] It does not recount the story of the Trojan Horse, the details of Achilles' death, or the flight of Aeneas.

III. Crucifixion was a method of execution that the Romans adopted from Carthage. It was characterized by prolonged agony leading to death and by public humiliation. It was inflicted upon slaves, criminals, foreigners, and rebels, but not upon Roman citizens, except in cases involving military deserters. This form of execution was employed by various Mediterranean peoples, including the Assyrians, Chaldeans, Babylonians, Persians, Phoenicians, Arabs, and the Macedonian Greeks of Alexander the Great. It was also practiced in Japan, where it was known as *haritsuke*, particularly as a means of persecuting and punishing Christians during the Edo (Tokugawa) shogunate period (1603–1867).[9] Of particular interest here is the method employed by the Romans. During the slave revolt led by Spartacus (73 BC), approximately 6,472 rebels were crucified along the embanked Via Appia between Rome and Capua (189 km).[9,10] Roman cohorts carried all the necessary components in prefabricated form on wagons, allowing them to perform crucifixions regardless of local terrain conditions.

The procedure began by digging a hole to secure the vertical post, or *crux*. The condemned person's wrists were then fixed to the transverse beam, or *patibulum*, using iron nails driven through the space between the radius and ulna. On some occasions, the upper limbs were secured with ropes instead. Once the body had been raised and the beams firmly assembled, the T-shaped cross, or *Crux Commissa*, was complete.

The condemned individual was positioned with the hips and knees flexed and the lower limbs slightly displaced laterally to facilitate simultaneous transfixion of both calcanei with a single nail driven into the upright post.[10,11] These positions apparently reduced the victim's ability to resist. Death resulted from exhaustion, neurogenic or hypovolemic shock, or embolism.[12] Prior to nailing, the condemned individual was scourged with wooden rods or a short whip (*flagrum*).[12] In 1968, an anthropological specimen belonging to a man aged 24-28 years was discovered at Giv'at ha-Mivtar, Ras el-Masaref, Jerusalem. The findings corroborated the previously described method and also revealed fractures of the leg bones, a practice deliberately carried out by the executioner to hasten death (*crurifragium*). The specimen consisted of a right calcaneus and a left sustentaculum tali, both pierced by a nail. Beneath the head of the nail, a fragment of *Pistacia* or *Acacia* wood was identified, apparently intended to prevent slippage of the soft tissues; at the opposite end, olive wood corresponding to the vertical post was found.[13] Despite the widespread use of crucifixion throughout the Mediterranean world and the numerous historical, religious, and literary references to the practice, this represents the first anthropological and traumatological evidence dating to the first century CE, prior to the destruction of the Second Temple (70 CE). The scarcity of available specimens may be related to the common practice of reusing materials for other purposes, which limited the preservation of archaeological remains.[12] A subsequent osteological analysis of the Giv'at ha-Mivtar find demonstrated that both calcanei had been pierced independently by iron nails measuring 11.5 cm in length, entering through the lateral aspect of the bone, exiting medially, and ultimately penetrating the wooden post. The nail diameter was not reported. Computed tomography played a decisive role in resolving the questions raised by these approximately 2,000-year-old remains.[14] The second published case derives from an excavation conducted on the Po River plain at La Larda di Gavello, in the Veneto region of Italy, where the skeleton of a man approximately 30 years of age was discovered. A 9-mm perforation was identified in the right calcaneus, traversing the bone below the sustentaculum tali—a perimortem lesion highly suggestive of crucifixion.[12] The third and most recent discovery dates from 2017 and comes from Fenstanton, Cambridgeshire, England. It consists of a right calcaneus pierced by a corroded iron nail, with the specimen remarkably well preserved. The skeleton dates to the fourth century CE (Roman legions remained in Britain from AD 43 to AD 449).[15] In all the specimens described, the metal nail was oriented perpendicular to the anteroposterior axis of the calcaneus. In certain populations, hindfoot bones have also been used for sex estimation.[16] Crucifixion was abolished in Rome during the fourth century CE by order of Constantine and was definitively suppressed by Theodosius I. Thousands of people were crucified in antiquity; however, one of them is regarded—alongside Moses and Muhammad, central figures of the Abrahamic religions—as having had a profound impact on the history of the Western world: Jesus of Nazareth, or *Yeshu Ha-Notzri*, who was crucified by order of the Roman prefect Pontius Pilate under the rule of Tiberius and died at Golgotha, outside Jerusalem, around AD 30-33.[17–19] According to Saramago, a painful and, if possible, ignominious death is always fitting for a martyr.[11] In the vast and diverse repertoire of the visual arts, considerable variation can be observed in the depiction of the fixation of Jesus Christ's feet, in contrast to recently discovered anthropological evidence.

In Islam, crucifixion was regarded as an exceptional punishment reserved—following judicial proceedings—for crimes classified as *ḥirāba* (armed aggression or warfare against the community of believers) or for serious acts of corruption, in accordance with Sura 5:33.[20]

## CONCLUSIONS

The stories evoked in this article share essential features: the wounding of the hindfoot, persistence through time, reinterpretation in each era, and the inescapable and tragic nature of their protagonists' destinies. In *Tadeo Isidoro Cruz*, Jorge Luis Borges wrote: "Any destiny at all, however long and complicated, in reality consists of a single moment—the moment in which a man once and for all knows who he is."[21]

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# Refining Growth Modulation: A Simplified Approach to Tension Band Plate Application

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**ABSTRACT**
Growth modulation using tension band plates (TBPs) is a well-established technique for the gradual correction of pediatric limb deformities. This study presents a refined surgical technique for TBP application designed to simplify the procedure while maintaining accuracy and safety. Key technical modifications include precise placement of guidewires using defined anatomical landmarks as references, the use of a minimal incision, and the incorporation of self-tapping screws to eliminate the need for pre-drilling. Clinical application of this modified approach reduces operative time, intraoperative fluoroscopy exposure, and surgical incision length while ensuring accurate TBP placement.
**Keywords:** Children; angular deformities; limb length discrepancy; guided growth; tension band plate.
**Level of Evidence:** IV

**Perfeccionando el crecimiento guiado: un enfoque simplificado para la aplicación de placas de banda de tensión**

**RESUMEN**
El crecimiento guiado mediante placas de banda de tensión es una técnica bien establecida para la corrección gradual de deformidades angulares en los miembros de los niños. Se presenta una técnica quirúrgica refinada para la aplicación de placas de banda de tensión, diseñada para simplificar el procedimiento manteniendo la precisión y la seguridad. Las modificaciones técnicas clave incluyen la colocación precisa de clavijas guía referenciadas a puntos de referencia anatómicos definidos, la utilización de una incisión mínima y la incorporación de tornillos autorroscantes para evitar la necesidad de utilizar una broca. La aplicación clínica de este enfoque modificado disminuye el tiempo quirúrgico, la exposición a la radioscopia intraoperatoria y la longitud de la incisión quirúrgica, al tiempo que garantiza una colocación precisa del implante.
**Palabras clave:** Niños; deformidades angulares; discrepancia de longitud de miembros; crecimiento guiado; placa de banda de tensión.
**Nivel de Evidencia:** IV

## INTRODUCTION

Guided growth is a widely accepted method employing temporary hemiepiphysiodesis to correct pediatric angular limb deformities and address leg length discrepancies by leveraging the remaining growth potential of the immature skeleton. This approach is minimally invasive and reversible, offering distinct advantages over corrective osteotomies, including accelerated recovery, permission for immediate weight-bearing, and decreased overall morbidity. The fundamental principle is rooted in the observations of Hueter and Volkmann, who described the influence of mechanical forces on physeal growth.[1-3]

Historically, guided growth techniques evolved from early methods such as Phemister's open epiphysiodesis[4] and Blount physeal stapling[5]. These were subsequently refined with the introduction of percutaneous epiphysiodesis utilizing transphyseal screws (PETS) by Métaizeau.[6] A significant advancement occurred in the early 2000s when Stevens introduced the tension band plate (TBP).[7] This implant provided a more stable and predictable construct for temporary hemiepiphysiodesis, substantially reducing implant complications and the need for revi-

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sion surgery compared to physeal staples. Consequently, the TBP rapidly became the preferred device for guided growth procedures. Recognizing the potential for further optimization, Masquijo et al.[8] introduced initial refinements to the TBP application technique in 2015, improving procedural efficiency while maintaining accuracy and safety. These prior modifications were associated with reduced operative time, decreased fluoroscopy exposure, and smaller incisions while ensuring precise implant placement.

The purpose of this paper and the accompanying video is to provide a comprehensive, step-by-step description of the authors' preferred refined technique for TBP placement for the management of pediatric angular deformities and leg length discrepancies. This resource aims to serve as a valuable guide for orthopedic surgeons performing guided growth procedures in skeletally immature patients.

## SURGICAL TECHNIQUE

The patient is positioned supine on a radiolucent operating table under regional anesthesia. The affected limb is prepared and draped in a sterile fashion to maintain strict aseptic technique throughout the procedure. A pneumatic tourniquet is applied to the proximal thigh and inflated to the appropriate pressure to provide a bloodless surgical field, thereby enhancing visualization.

Under fluoroscopic guidance, the initial guidewire is carefully inserted into the epiphysis. The trajectory is directed at approximately a 40-degree angle relative to the longitudinal axis of the bone, aiming toward the anatomical landmark of the femoral notch when operating on the distal femur. The precise distance between the guidewire tip and the distal femoral physis is determined by the size of the tension band plate being used. For example, when using a 20 mm TBP, which is commonly selected for the distal femur in adolescents, the guidewire should be positioned 10 mm distal to the physis. This position aligns with the spacing between the central and distal screw holes of the plate. The TBP is then temporarily advanced over the guidewire, and its position relative to the physis and the mechanical axis is assessed fluoroscopically in the sagittal plane. Once the optimal position is confirmed, the skin is marked with a surgical pen along the edges of the plate to create an external reference for alignment. The guidewire should be positioned as close as possible to the proximal margin of the distal screw hole to facilitate seamless screw placement after the plate is inserted through the small skin incision.

A second guidewire is then inserted into the metaphysis. This wire is placed divergent to the epiphyseal wire and oriented perpendicular to the femoral diaphysis in the coronal plane. Initial clinical assessment is performed to ensure both guidewires lie in the same sagittal plane and exhibit appropriate divergence (Figure 1).

**Figure 1.** Percutaneous placement of epiphyseal and metaphyseal guidewires. Note that both guidewires are positioned within the same sagittal plane but are divergent, ensuring optimal placement for guided growth modulation.

Fluoroscopic confirmation is then obtained to verify the correct spatial relationship and positioning of both guidewires relative to the physis and bone anatomy before proceeding with the incision.

The temporary guide plate is removed, and a small skin incision, typically measuring 2 cm in length, is made midway between the two guidewires. Blunt dissection is carefully carried down through the subcutaneous tissue to expose the periosteum. Meticulous effort is made to preserve the periosteum and the perichondral ring to minimize soft tissue disruption and avoid potential growth disturbance. The joint capsule, if encountered, is delicately opened to expose the bone surface without compromising the epiphyseal vessels. A tension band plate of the selected size (this plate is not used over the skin but is the implant for insertion) is then carefully guided over the two previously placed guidewires and seated flush against the bone surface. Two fully threaded 4.5 mm self-tapping screws are then inserted sequentially through the plate holes, following the trajectories of the guidewires. The epiphyseal screw is inserted first to secure the distal aspect of the plate to the epiphysis. Subsequently, the metaphyseal screw is inserted to stabilize the proximal aspect of the construct. The use of self-tapping screws eliminates the need for pre-drilling the screw holes, further streamlining the procedure. Final implant positioning is meticulously confirmed using C-arm fluoroscopy in both the coronal and sagittal planes. This ensures accurate plate alignment relative to the physis and mechanical axis, verifies stable fixation, and confirms that the screws have not violated the physis. The five essential fluoroscopic views required to confirm proper TBP placement are illustrated in Figure 2.

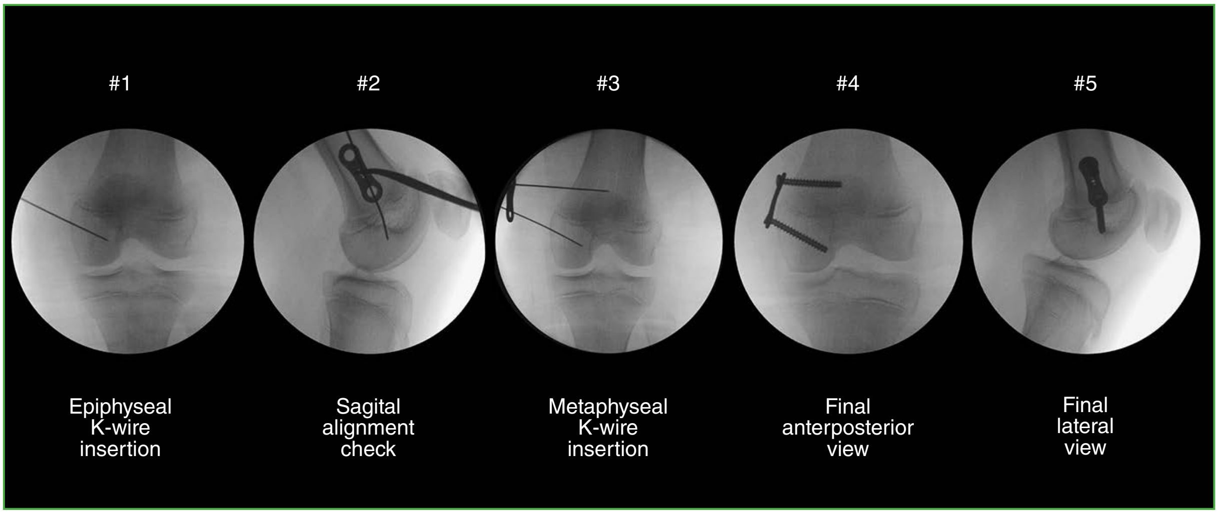


**Figure 2.** The five fluoroscopic views necessary for precise tension band plate placement, ensuring accurate positioning.

Following implant insertion and confirmation, the surgical site is thoroughly irrigated with sterile saline solution to remove any debris. Hemostasis is achieved, and the wound is closed in layers using absorbable sutures. A #2 Vicryl® suture is typically used for the subcutaneous tissue, and a #4.0 Vicryl® rapid suture is used for the skin closure. Sterile adhesive strips are applied over the incision, followed by a sterile dressing and a soft compressive bandage (Video).

Postoperatively, patients are permitted full weight-bearing and unrestricted range of motion of the affected limb as tolerated immediately following surgery. Follow-up clinical and radiographic evaluations are scheduled every three to four months to monitor the progression of deformity correction and to identify any signs of potential overcorrection, allowing for timely implant removal (Figure 3).

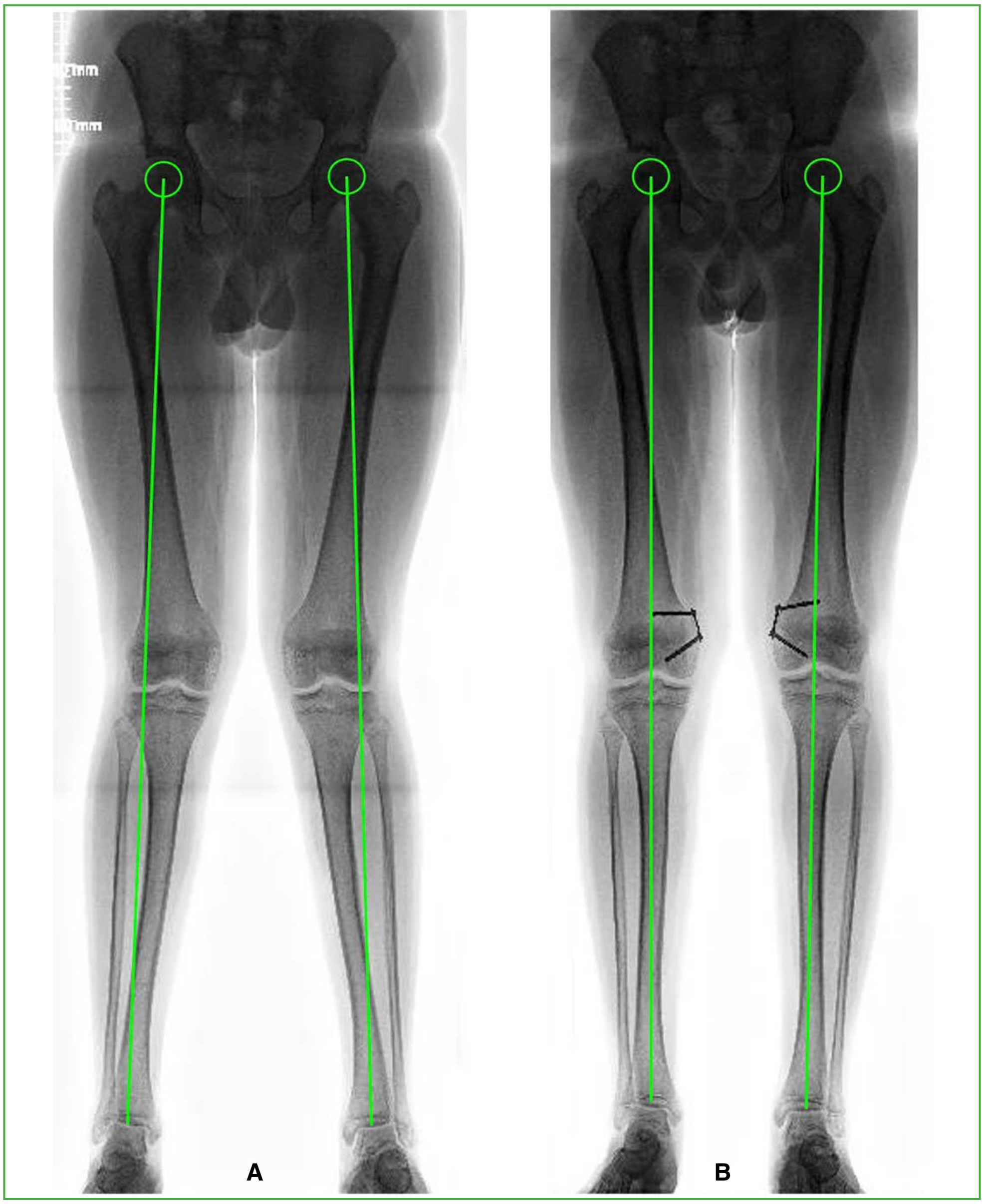


**Figura 3. A.** Preoperative clinical image of a 13-year-old boy with idiopathic genu valgum (zone 2), indicated for guided growth correction using tension band plates in the distal femur. **B.** Follow-up long-leg radiograph at 12 months demonstrating complete correction of the deformity.

# DISCUSSION

Growth modulation using tension band plates (TBPs) has significantly advanced the management of pediatric limb deformities, providing a minimally invasive, highly effective, and reversible treatment alternative to osteotomies.[9] While the original technique described by Stevens[7] remains the foundation, continuous refinements to the surgical approach are pursued to further enhance procedural efficiency, minimize invasiveness, and reduce associated morbidity. The modified TBP placement technique presented here builds upon our prior work[8] by introducing specific technical optimizations designed to streamline key surgical steps, resulting in demonstrated reductions in operative time, intraoperative radiation exposure, and incision size while preserving implant accuracy. Our refined approach enhances TBP placement through several key modifications. The use of precise guidewire positioning, referenced to anatomical landmarks and verified with a limited set of standardized fluoroscopic views, improves the accuracy of initial implant trajectory planning. Minimizing soft tissue dissection through a smaller incision potentially contributes to faster recovery and reduced post-operative discomfort. The incorporation of self-tapping screws eliminates the need for the pre-drilling step, simplifying the procedure and further reducing operative time. Collectively, these modifications result in a more reproducible and efficient technique that maintains the biomechanical effectiveness of the tension band principle for guided growth.

A particularly significant advantage of our modified technique is the substantial reduction in intraoperative fluoroscopy usage. Traditional TBP application often necessitates multiple fluoroscopic checks at various stages to ensure proper guidewire and plate positioning, leading to increased radiation exposure. By optimizing guidewire placement based on anatomical cues and using a defined set of only five standardized fluoroscopic views for final confirmation, our technique effectively minimizes radiation. This is paramount in pediatric orthopedics, where minimizing exposure to ionizing radiation is a critical priority. Children are more susceptible to the detrimental effects of radiation due to their actively dividing cells and longer remaining lifespan, increasing the lifetime risk of radiation-induced malignancies. Furthermore, cumulative intraoperative radiation exposure poses significant occupational hazards for the surgical team, particularly to less shielded areas such as the hands and thyroid. Our method aligns with the ALARA (As Low As Reasonably Achievable) principle, enhancing the safety profile of the guided growth procedure for both the patient and all operating room personnel without compromising the precision or effectiveness of implant placement. The use of an external guidewire reference and verifying wire divergence prior to incision further contributes to accurate initial positioning, reducing the need for subsequent radiographic adjustments.

## CONCLUSIONS

The refined technique for tension band plate application described herein represents an accessible, efficient, and reproducible alternative to standard TBP placement. The demonstrated advantages, including reduced operative time, decreased fluoroscopy exposure, smaller incisions, and maintained accuracy, offer benefits for both surgeons and patients while significantly enhancing surgical efficiency. As guided growth remains a cornerstone in the treatment of pediatric limb deformities, continued refinement of surgical techniques, such as the approach presented, will further optimize outcomes and improve the overall safety and efficacy of the procedure.

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Conflicts of interest: The authors declare no conflicts of interest.

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# Case Resolution

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*Case Presentation on page 189.*

## Lesión endomedular inusual en la falange distal del hallux

**RESUMEN**
Las lesiones óseas ocupantes de espacio de localización endomedular y excéntricas en huesos cortos del pie son infrecuentes, hay escasos reportes de caso y, hasta hoy, no se han descrito en la falange distal del hallux. Presentamos uno de estos casos, las evaluaciones clínica y radiológica, y el abordaje terapéutico.
**Palabras clave:** Neoplasia; localización excéntrica; atípica; endomedular; hallux.
**Nivel de Evidencia:** IV

## Unusual Intramedullary Lesion in the Distal Phalanx of the Hallux

**ABSTRACT**
Intramedullary, eccentrically located space-occupying bone lesions in the short bones of the foot are uncommon. Few cases have been reported in the literature, and to date, such lesions have not been described in the distal phalanx of the hallux. We present one such case, including its clinical and radiological evaluation and therapeutic management.
**Keywords:** Neoplasm; eccentric location; atypical; intramedullary; hallux.
**Level of Evidence:** IV

## DIAGNOSIS

Enchondroma of the distal phalanx of the hallux.

## DISCUSSION

The patient provided informed consent for surgery. In the operating room, prophylactic intravenous antibiotics were administered, and a toe tourniquet was applied for 45 minutes. Through an oblique incision in the lateral eponychium over the distal phalanx of the right hallux, the nail plate and nail bed were elevated, the lesion was identified in the central proximal metaphyseal-diaphyseal region of the phalanx, and curettage was performed with an osteotome, allowing removal of the lesion, which had a gritty, whitish, opaque appearance, with intramedullary involvement and lateral cortical destruction. The lesion was completely excised and submitted for histopathological examination. A residual bone defect involving less than 30% of the diameter of the distal phalanx remained. The bone cavity was irrigated with a 5% dextrose solution. A second incision was made over the lateral aspect of the ipsilateral heel to harvest a corticocancellous calcaneal bone graft, which was placed into the residual cavitary defect of the distal phalanx of the hallux. The wounds were closed in layers, and the limb was immobilized with a below-knee plaster splint.

The patient was discharged with analgesics and instructed to bear weight on the heel only. An outpatient follow-up visit was scheduled once the biopsy results became available.

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Histopathological examination revealed a lesion composed of hyaline cartilage, with no areas of necrosis, no chondrocyte atypia, and no myxoid change, forming well-defined cartilaginous nodules. Most importantly, no permeative growth pattern was identified (Figure 3).

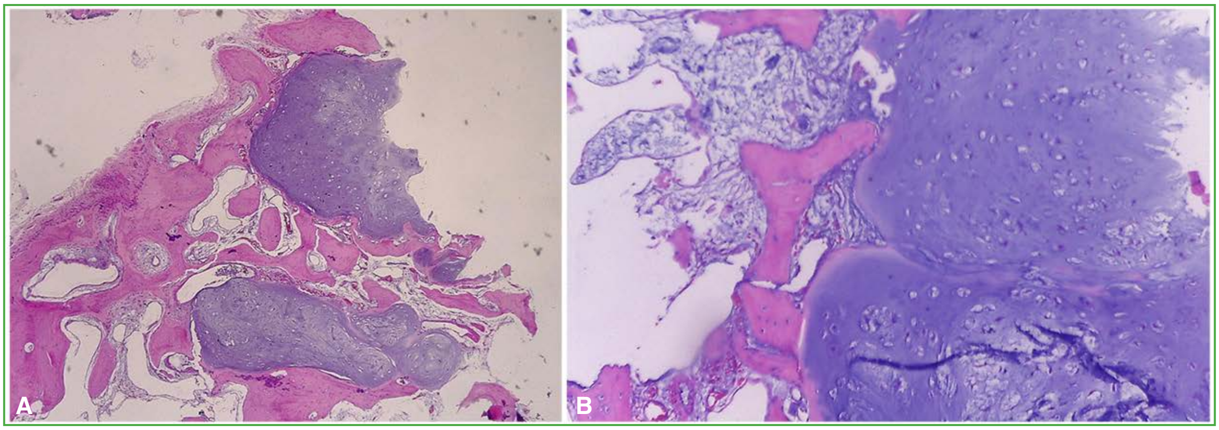


**Figure 3.** Well-defined nodules of hyaline cartilage, some eccentrically located, with no permeative growth pattern within the intertrabecular spaces. Hematoxylin and eosin stain; original magnification x4 (**A**) and x10 (**B**).

After 4 months of clinical follow-up, the patient reported no pain or mechanical discomfort while wearing shoes, with only residual nail discoloration. Radiographically, advanced bone healing was observed, with no evidence of recurrence (Figures 4 and 5).


**Figure 4.** Radiographs of the right foot. **A.** Anteroposterior view. Advanced bone healing (dotted white arrow). **B.** Oblique view. No evidence of tumor recurrence (curved white arrow).

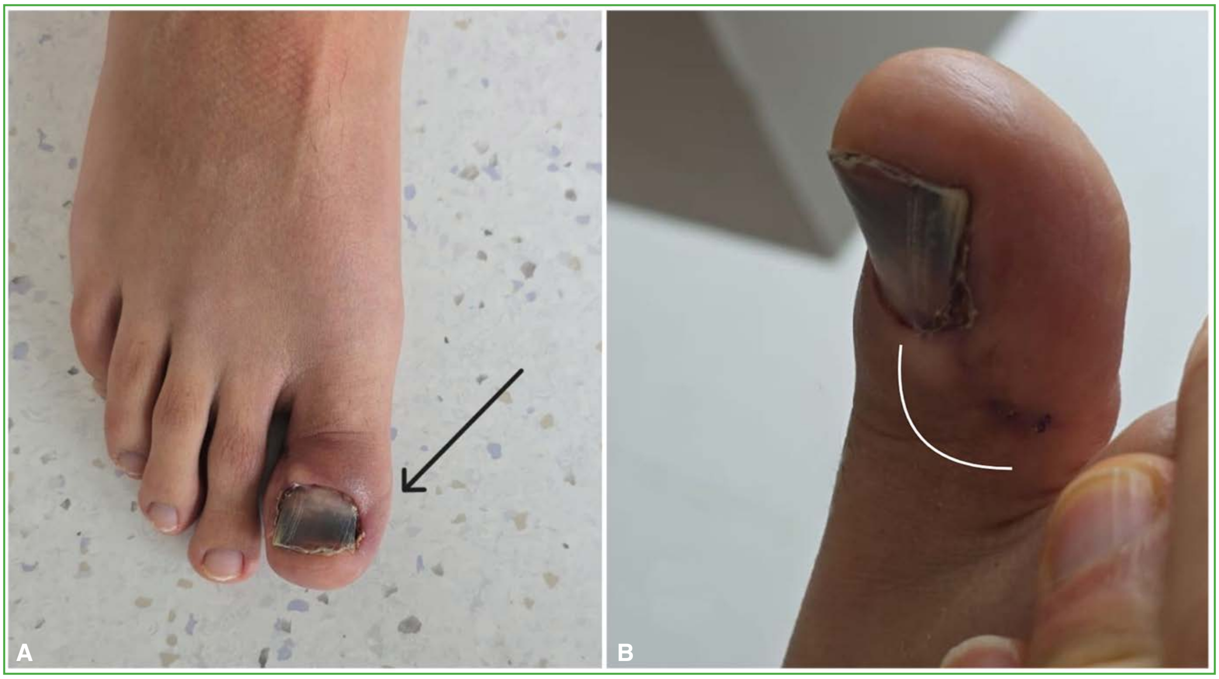


**Figure 5. A.** Clinical photograph of the right foot showing residual nail dystrophy of the hallux (black arrow). **B.** Healed surgical incision (curved white line).

Bone tumors of the foot and ankle are rare entities, accounting for only 5-10% of all musculoskeletal tumors.[1] Enchondroma is a benign neoplasm located within the medullary cavity that, when occurring in the foot, most commonly involves the metatarsals and phalanges; in 80% of cases, the proximal phalanx is the most frequent location. It is generally asymptomatic but may cause pain and swelling secondary to pressure from its intracavitary expansion or to a pathological fracture. Lesions range from 5 mm to 18.7 mm in size and are usually solitary; when multiple lesions are present, the condition is termed enchondromatosis or Ollier disease. When enchondromatosis is associated with soft-tissue hemangiomas, it is known as Maffucci syndrome.[2]

Histologically, enchondromas are composed of nodules of hyaline cartilage within the medullary cavity, often with peripheral endochondral ossification. The nuclei are round and hyperchromatic, and mitotic activity is absent. Enchondromas of the small bones of the hands and feet may exhibit increased cellularity and mild cytological atypia. Furthermore, when these cartilaginous nodules are eccentrically located, they may thin the cortex and even breach it, producing periosteal bulging. Although such findings may raise suspicion of malignancy, they are still considered features of benign lesions. Therefore, correlation of the clinical presentation, duration of symptoms, imaging findings, and histological features is essential, making the diagnosis frequently challenging.[3,4]

On radiographs, enchondroma appears as a well-defined, expansile, lytic lesion located centrally in the diaphysis or metaphyseal-diaphyseal region. Computed tomography may demonstrate characteristic intralesional calcification patterns and allows assessment of cortical integrity. Magnetic resonance imaging may reveal bone and soft-tissue edema, together with low-to-intermediate signal intensity on T1-weighted images, characteristic of cartilaginous tumors, and high signal intensity on T2-weighted images. Contrast-enhanced MRI readily demonstrates peripheral enhancement and internal septations.[5]

Malignant transformation of a solitary lesion in the foot and ankle is exceedingly rare. The risk may reach 5% in large lesions of the distal tibia and up to 20% in patients with Ollier disease or Maffucci syndrome. Conversely, secondary malignant lesions of the foot and ankle are extremely uncommon, accounting for only 1% of cases, and typically occur in advanced lung, breast, or endometrial cancer.[6]

Only isolated case reports have been published. One described a 16-year-old patient with a lesion of the proximal phalanx of the second toe that had been present for 10 years and became symptomatic 3 months before undergoing intralesional resection and bone grafting.[7] Similarly, a 27-year-old patient with a 4-month history of pain and a mass involving the proximal phalanx of the fourth toe underwent local resection, bone grafting, and Kirschner wire stabilization because of the size of the residual defect after resection.[8] In both cases, no recurrences were reported, and the patients remained asymptomatic throughout follow-up.

For solitary lesions, intralesional resection, bone grafting, and, in selected cases, temporary stabilization with a Kirschner wire are established as the most effective treatment for symptomatic lesions that fail conservative management or are associated with pathological fractures.[9]

In the present case, an open resection technique through a direct approach to the lesion is described. However, minimally invasive and endoscopic techniques have also been reported for resection of enchondromatous lesions and placement of a bone graft into the residual defect.[10] To date, no comparative studies have evaluated the outcomes of these techniques; therefore, both remain valid options for the management of these intraosseous lesions.

## CONCLUSIONS

Solitary lytic lesions of the toe phalanges are uncommon and generally benign, but they may cause pain, local deformity, and pathological fracture. Imaging evaluation is recommended, together with resection, biopsy, and, in selected cases, stabilization with a Kirschner wire.

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