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SAMeCiPP: Past, Present and Future of a Pioneering Subspecialization Society

Dr. Florencio Pablo Segura
President of the Sociedad Argentina de Medicina y Cirugía de Pie y Pierna. Period 2023-2024

SAMeCiPP [*Argentine Society for Foot and Leg Medicine and Surgery*] was founded in 1969 by a group of notable national orthopedic figures, including Orlando B. Natiello, Pascual Amato, and Alfredo Kohn Tebner, among others. It was a pioneer among AAOT's guest societies by bringing together the first group of specialists with the goal of advancing the growth of leg, ankle, and foot surgery through teaching, discussion, and opinion exchange.

More than 50 years have passed, and the advancements in the diagnosis and treatment of diseases affecting this region are immense. Some examples include advances in anesthetic procedures thanks to peripheral blocks, improved understanding of the biomechanics and physiopathogenesis of numerous diseases, the description of more powerful and precise deformity correction techniques, and the development of new approaches and anatomical implants for fracture fixation. Similarly, the ongoing development of minimally invasive surgery, arthroplasty, and sports injury reconstructions, among other recent accomplishments, has revolutionized our subspecialty, making it dynamic, diverse, and stimulating.

In this scenario, which is becoming increasingly complex for the orthopedic surgeon's everyday practice, medical education promoted and sustained by SAMeCiPP is a fundamental pillar. For decades, it has continued to support the training of its 390 current active members through its annual Congress, which will be in its 25th edition next April, and by supporting activities of all types across the country. Similarly, it oversees the training programs of new subspecialists and promotes the work of experienced surgeons. The ultimate goal is not only to keep our country at the forefront of scientific and technical advances, but also to ensure that numerous patients continue to receive outstanding care for the treatment of their ailments.

Within these multiple actions, the promotion of scientific publications plays a key role. The opportunity to collaborate with the AAOT on this special issue of its journal, which includes clinical research contributions from our members, allows us to continue fostering the interchange of ideas, debate, and controversy, which are critical drivers of progress in our discipline.

On behalf of the SAMeCiPP board of directors, we wish to thank the Editorial Committee for their encouragement, collaboration, and support in reaching this goal, and we ask our members to continue contributing to future issues.

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Case Presentation

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Case Resolution on page 210.

A 50-year-old man came to the outpatient clinic for pain and functional impairment of the right ankle and hindfoot associated with regional global edema and restriction of subtalar mobility (Figure 1).

Figure 1. Clinical presentation of the patient 20 days after trauma. **A.** AP view. **B.** Lateral view.

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He had sustained a right ankle injury from a fall from an enduro motorcycle 20 days before. He was treated at an emergency department on the day of the accident, where radiographs were taken (Figure 2). Without a certain diagnosis, immobilization with a walker boot and weight-bearing restriction were indicated. He was re-examined seven days after the trauma, and an MRI of the ankle and foot was requested (Figure 3), after which physiotherapy and progressive weight offloading were indicated. The pain progressively increased, and the edema and functional impairment persisted, so the patient decided to seek a second opinion.

Figura 2. Radiographs taken on admission. **A.** Foot, AP view. **B.** Foot, oblique view. **C.** Ankle, AP view. **D.** Ankle, lateral view.

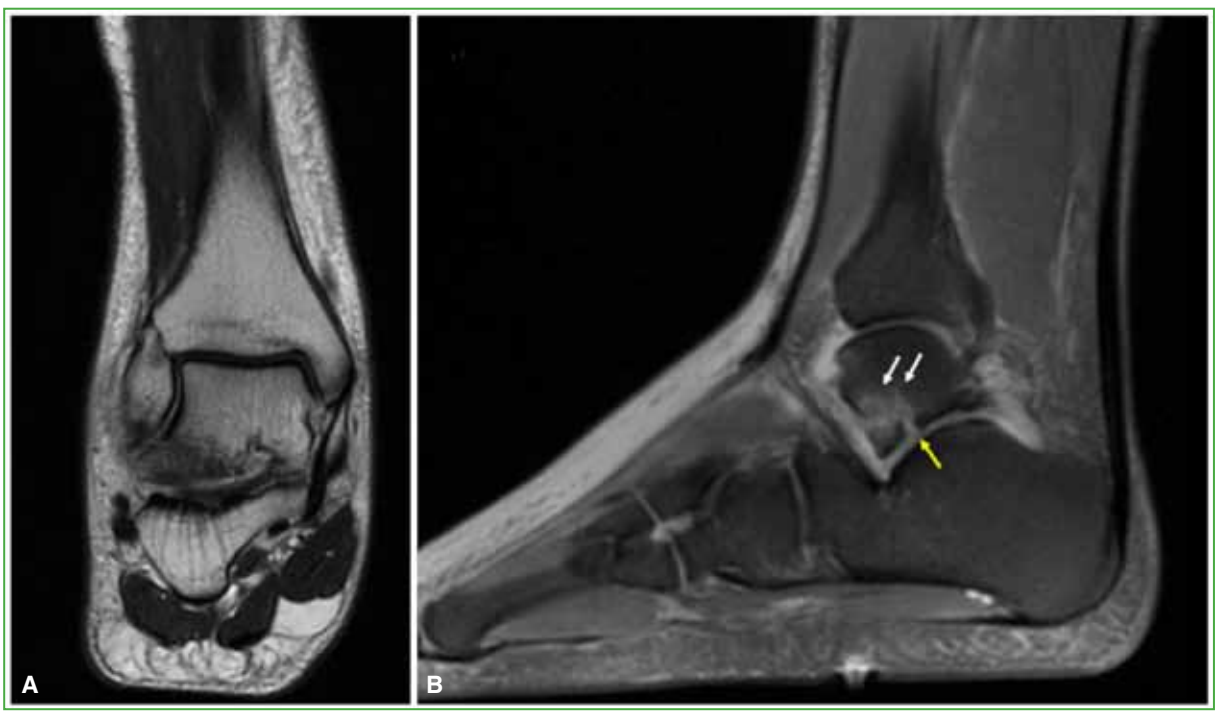

Figure 3. MRI of ankle and foot requested in the first control, 7 days after the accident. **A.** Coronal section. **B.** Sagittal section.

FINDINGS AND INTERPRETATION OF IMAGING STUDIES

The AP and oblique views of the foot revealed no images compatible with traumatic injuries. The AP ankle radiograph showed a solution of continuity in the distal lateral contour of the body of the talus (Figure 2C, yellow arrow). The lateral view of the ankle showed an incongruity in the anterior portion of the lateral process of the talus with loss of its symmetrical V-shaped contour (Figure 2D, yellow arrow).

MRI of the ankle and foot showed foci of post-traumatic bone edema in the plantar neck and talar body (Figure 3B, white arrows) and an oblique articular fracture with perifracture bone edema on the lateral process of the talus, involving the posterolateral subtalar joint without significant fragment displacement (Figure 3B, yellow arrow).

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Incidence of Floating Toe After Distal Minimally Invasive Metatarsal Osteotomy with Pin Osteosynthesis for the Treatment of Metatarsalgia and Rigid Hammertoe

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ABSTRACT

Introduction: Central metatarsalgia is a common cause of forefoot pain. The most common surgical treatment is Weil osteotomy and the most popular percutaneous technique is distal minimally invasive metatarsal osteotomy (DMMO). However, the main disadvantage of these techniques is the appearance of floating toes, which is even greater when associated with proximal interphalangeal arthrodesis. In this series of cases, DMMO was combined with a pin to elevate the center of rotation of the metatarsal head with the aim of reducing the presence of floating toes. Our main hypothesis was that this technique would result in a lower presence of floating toes in patients diagnosed with mechanical metatarsalgia and rigid hammertoe, compared to Weil osteotomies. **Materials and Methods:** A retrospective observational study was carried out on consecutive adult patients diagnosed with mechanical metatarsalgia and rigid hammertoe. DMMO was performed with pin fixation in combination with proximal interphalangeal (PIP) arthrodesis. Finally, the presence of floating toes was compared with a group of patients operated on with the Weil technique and PIP arthrodesis. **Results:** A total of 39 DMMOs with PIP arthrodesis were performed. The percentage of floating toes was 31% . There was no statistically significant difference compared to the Weil technique (36%, p = 0.634). **Conclusion:** DMMO for elevation of the center of rotation associated with PIP arthrodesis fixed with a pin did not provide a lower incidence of floating toes compared to Weil osteotomy.

Keywords: Metatarsalgia; hammertoe; distal metatarsal metaphyseal osteotomy; proximal interphalangeal arthrodesis; floating toe.
Level of Evidence: IV

Incidencia de dedo flotante en la osteotomía metatarsiana distal percutánea con osteosíntesis para el tratamiento de la metatarsalgia con dedo en martillo rígido

RESUMEN

Introducción: La metatarsalgia central es una causa frecuente de dolor de antepié. La osteotomía de Weil es el tratamiento quirúrgico más popular y la osteotomía metatarsiana distal percutánea (OMDP) es la técnica percutánea más utilizada. La principal desventaja de estas técnicas es la aparición de dedo flotante que es aún mayor cuando se la asocia a artrodesis interfalángica proximal (AIFP). En esta serie de casos, se combinó la OMDP y la osteosínetsis con clavija de Kirschner para elevar el centro de rotación de la cabeza del metatarsiano con el objetivo de disminuir la presencia de dedos flotantes. Nuestra principal hipótesis fue que esta técnica generará menos dedos flotantes en los pacientes con diagnóstico de metatarsalgia mecánica y dedo en martillo rígido, comparada con la osteotomía de Weil. **Materiales y Métodos:** Se realizó un estudio retrospectivo en pacientes adultos con diagnóstico de metatarsalgia mecánica y dedo en martillo rígido. Se los sometió a una OMDP más fijación con clavija de Kirschner en combinación con AIFP. Finalmente, se comparó la presencia de dedos flotantes con un grupo de pacientes operados con la técnica de Weil y AIFP. **Resultados:** Se realizaron 39 OMDP más AIFP. La tasa de dedos flotantes fue del 31%. No hubo una diferencia estadísticamente significativa comparada con la técnica de Weil (36%, p = 0,634). **Conclusión:** La ODMP con elevación del centro de rotación asociada con AIFP no proporcionó una menor incidencia de dedos flotantes en comparación con la osteotomía de Weil.

Palabras clave: Metatarsalgia; dedo en martillo; osteotomía metatarsiana distal percutánea; artrodesis interfalángica proximal; dedo flotante.
Nivel de Evidencia: IV

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INTRODUCTION

Central metatarsalgia is a common cause of forefoot pain that is often associated with deformity of the hallux or lesser toes. This could be related to a variety of factors, including anatomical abnormalities of the foot, systemic diseases, iatrogenesis, etc.[1] Rocker[2] is a term used in gait cycle analysis to refer to the fulcrum used by the foot during gait progression. During gait, the foot functions as a *three-rocker* mechanism. Depending on the moment in the gait cycle at which the overload occurs, mechanical metatarsalgia can be classified as first-, second- or third-rocker metatarsalgia. The heel is the first rocker while resting on the ground during the first 10% of the gait cycle; in this case, metatarsalgia is caused by a congenital deformity, pes cavus, or calf shortening. The ankle is the second rocker, the entire foot is in contact with the ground. In this instance, metatarsalgia occurs with limited ankle motion or increased plantar flexion of the lesser metatarsals that overloads the forefoot. Mechanical metatarsalgia of the propulsive third rocker or forefoot develops when the heel is lifted and overload is transferred to the lesser metatarsal heads due to an insufficient first ray. Metatarsal head elevation is effective for second-rocker metatarsalgia, while metatarsal shortening is effective for third-rocker metatarsalgia.[2,3] When conservative treatment fails, surgical resolution is required. Radical techniques have been described, such as resection of the metatarsal head, as well as conservative techniques, such as open or percutaneous osteotomies, with preservation of the metatarsophalangeal joint.[1,4,5]

Among osteotomies, the one described by Weil[6] for the treatment of central metatarsalgia is the most popular. It is an open intra-articular technique for controlled metatarsal shortening. Its main disadvantage is the appearance of floating toe, that is, toes that do not make contact with the floor when standing.[7-9] The etiology of this complication has not yet been clarified.[10] In terms of percutaneous osteotomies, one of the most commonly used is the distal metatarsal minimally invasive osteotomy (DMMO). These minimally invasive techniques are on the rise because they cause less soft tissue damage, which has led to the use of this approach for mild to severe forefoot deformities.[11,12] However, floating toe also appears to be a common complication following this osteotomy. The presence of floating toe is even greater when associated with proximal interphalangeal joint (PIPJ) arthrodesis.[6] Some authors suggest that this is due to a lowering of the center of rotation that leads the intrinsic flexor muscles to pass over it, leading to extension of the metatarsophalangeal joint.[13]

Considering the latter, DMMO and Kirschner pin osteosynthesis were combined to elevate the metatarsal head in order to reduce the presence of floating toes. Our main hypothesis was that DMMO with a pin will cause fewer floating toes in those patients diagnosed with mechanical metatarsalgia and rigid hammertoe compared to Weil osteotomy.

MATERIALS AND METHODS

A retrospective observational study was performed on consecutive adult patients with a diagnosis of mechanical metatarsalgia and rigid hammertoe who underwent DMMO plus Kirschner pin fixation in combination with PIPJ arthrodesis at our institution, between August 2012 and February 2015.

Inclusion criteria were: adults who underwent surgery using the technique described below for mechanical metatarsalgia of the third rocker with metatarsophalangeal dislocation or subluxation with rigid hammertoes.

Exclusion criteria included neurological disease, post-traumatic sequelae, previous metatarsal surgeries, osteoarthritis of the involved metatarsophalangeal joint, Freiberg's disease, pes cavus, and incomplete medical records.

Surgical technique

The patient is placed in the dorsal decubitus position, with regional anesthetic block and hemostatic cuff at ankle level. Extensor tenotomy and proximal interphalangeal capsulotomy are performed via a dorsal longitudinal approach to the toe, followed by peg-and-socket arthrodesis of this joint with a 1.5 mm diameter Kirschner pin under image intensification.

We proceed with a minimally invasive approach to the metatarsal neck, followed by a percutaneous tenotomy of the extensor digitorum longus and extensor digitorum brevis, a dorsal capsulotomy, and percutaneous excision of both collateral ligaments. Once the metatarsophalangeal joint is reduced, the Kirschner pin is advanced towards the distal metatarsal metaphysis maintaining the reduction, all under fluoroscopic control.

DMMO is then performed on the distal metaphysis at an angle of approximately 45° to the floor. This is performed from distal dorsal to proximal plantar to achieve the ascent and shortening of the metatarsal head, finally the pin is advanced towards the diaphysis of the metatarsal (Figure 1). Thus, the aim is to reduce the pressure exerted by the metatarsal heads against the floor (Figure 2). On the other hand, the center of rotation is raised so that the intrinsic muscles act again as flexors of the metatarsophalangeal joint, trying to reduce the incidence of floating toe. Finally, percutaneous tenotomy of the flexor digitorum longus of the treated toe is performed to prevent further progression to mallet toe.

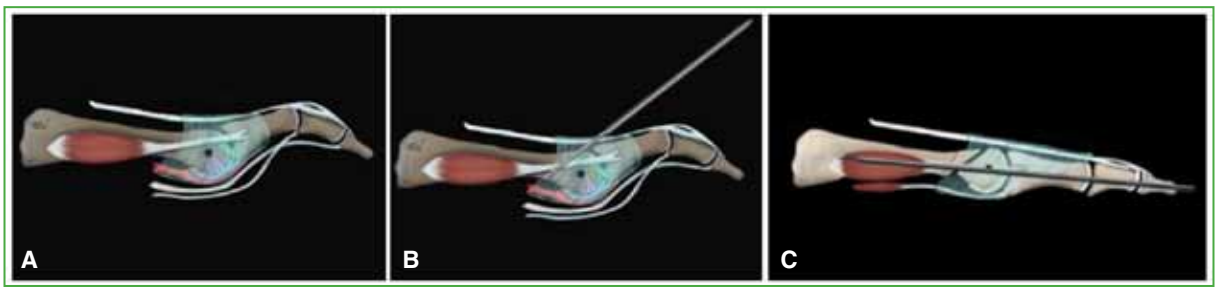

Figure 1. Percutaneous distal metatarsal osteotomy. **A.** Diagram of hammertoe with center of rotation of the metatarsal head. **B.** Percutaneous osteotomy with Shannon reamer. **C.** The Kirschner pin advances toward the diaphysis of the metatarsal, raising the center of rotation.

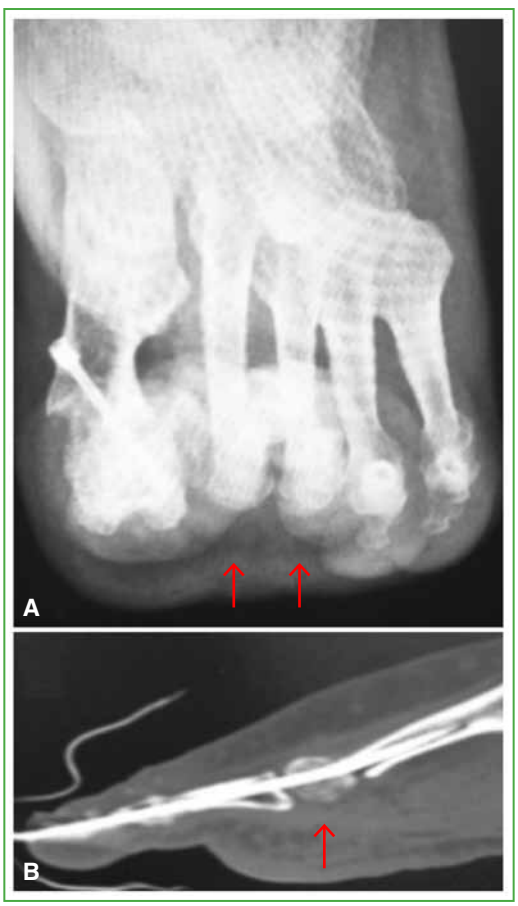

Figure 2. Elevation of the metatarsal heads. **A.** Sesamoid radiograph, axial view. **B.** Computed tomography of the forefoot, sagittal section. The red arrows indicate the elevation of the metatarsal heads.

Postoperative care

The first 24 hours are spent without weight-bearing until the anesthetic block effect fades. After 20 days, home ambulation is permitted with full weight bearing in the post-surgical neutral shoe, and the osteosynthesis is removed at 21 days.

Patients were evaluated clinically and radiologically before surgery, after 3 weeks, after 3 months, or until consolidation was established (Figures 3 and 4).

Radiographic evaluation

Anteroposterior and lateral weight-bearing radiographs were taken before surgery and at different subsequent instances. Preoperatively and postoperatively, metatarsophalangeal joint congruence was analyzed and recorded as reduced, subluxated or luxated. The osteotomy (DMMO) was also evaluated for the presence of malunion or pseudarthrosis. The variation of the metatarsal formula, especially the length of the first metatarsal (*Index Plus/ Index Plus Minus/Index Minus*), was recorded.[14,15]

Clinical evaluation

The main evaluation was the presence or absence of floating toes, defined as toes that do not make contact with the floor when the patient is standing.[7-9] At the end of the follow-up period, function was assessed with the *American Orthopaedic Foot and Ankle Society* (AOFAS) scale,[16] which takes into account the following variables: pain, functional impairment, footwear restriction, plantar callus, alignment, stability, and metatarsophalangeal joint stiffness. As all patients had proximal interphalangeal joint arthrodesis, the maximum score considered was 95.

Finally, these variables were compared to those of the first 26 consecutive patients with metatarsalgia and rigid hammertoes who underwent Weil and PIPJ arthrodesis at our Center. This approach involves conducting an open osteotomy parallel to the floor surface, from the dorsal region of the metatarsal head to the proximal, to accomplish shortening, which is then fixated with a 2.7 mm screw.

Figure 3. Preoperative weight-bearing foot radiographs. **A.** Anteroposterior **B.** Lateral.

Figure 4. Anteroposterior and lateral radiographs of the foot. **A and B.** Two weeks later. **C and D.** Three months later. **E and F.** Six months later.

RESULTS

Between August 2012 and February 2015, 28 patients diagnosed with metatarsalgia with rigid hammertoe underwent surgery with the previously described surgical technique. Five of them were excluded because they failed to attend the indicated clinical controls. Seven of the remaining 23 patients underwent bilateral surgeries (30 feet, 39 osteotomies).

The rate of floating toes was 31% (12 of 39 osteotomies). In the postoperative radiographic evaluation of the metatarsal formula, although 28 of the 30 feet had undergone hallux surgery, only four showed postoperative index minus.

There were no cases of pseudarthrosis or transfer metatarsalgia. Metatarsophalangeal reduction was achieved in 34 cases (88%) and dislocation recurrence occurred in five joints (12.8%). In most cases, recurrence was asymptomatic. The only symptomatic case, a patient with varus deviation of the second toe, was resolved with a percutaneous osteotomy of the first phalanx (Figures 5 and 6).

Figure 5. Postoperative complication. Weight-bearing foot radiographs, AP view. **A. B.** Immediate postoperative period. **C.** Varus misalignment of the second toe. **D.** Percutaneous osteotomy of the first phalanx. **E.** Radiographic control with consolidated osteotomy.

Figure 6. Clinical images of postoperative complication. **A.** Preoperative image. **B.** Advanced postoperative period after percutaneous distal metatarsal osteotomy plus osteosynthesis. **C.** Postoperative period after percutaneous osteotomy of the first phalanx for correction of varus deviation of the second toe.

Tables 1 and 2 show the demographic characteristics and postoperative outcomes of the patients treated with the surgical technique described in this case series, compared with those of the first 26 consecutive patients in the series treated with Weil osteotomy plus PIPJ arthrodesis at our institution.

There was no statistically significant difference in the presence of floating toes comparing both techniques ($p = 0.634$); however, the postoperative reduction of the metatarsophalangeal joint was significant and was more successful with the Weil technique ($p < 0.001$). Functional outcomes were satisfactory in both groups, with a mean AOFAS scale score of 86 (range 63-90) for the DMMO with Kirschner pin group and 81.2 (range 19-95) for the Weil osteotomy plus PIPJ arthrodesis group.

Table 1. Demographic characteristics of patients treated with percutaneous distal metatarsal osteotomy (DMMO) plus Kirschner pin and Weil osteotomies.

	DMMO + pin	Weil Osteotomy
Number of patients	23	26
Age (years)	72 (69-85)	62 (23-78)
Gender (Female/Male)	23/0	24/2
Follow-up (months)	22 (18-30)	18 (6-36)
Distribution		
Second metatarsal	30	31
Third metatarsal	7	6
Fourth metatarsal	2	1

Table 2. Clinical and radiographic outcomes of patients treated with percutaneous distal metatarsal osteotomy (DMMO) plus Kirschner pin and Weil osteotomies.

	DMMO + pin	Weil Osteotomy	p
Number of osteotomies	39	38	
Floating toes, n (%)	12 (31)	14 (36)	0.634
Dislocated/subluxated joint, preoperative, n (%)	39 (100)	19 (50)	0.5
Reduced joint, postoperative, n (%)	34 (87)	38 (100)	**<0.001**

DISCUSSION

Central metatarsalgia is a common cause of forefoot pain that is often associated with toe deformities.[2] Different surgical techniques have been proposed, but none have yielded optimal results.[8] Weil's osteotomy is an effective and safe procedure for the treatment of central metatarsalgia, although it may be associated with some complications, such as floating toe deformity.[8] As published by Trnka et al.,[13] this is due to the lowering of the center of rotation leading to extension of the metatarsophalangeal joint, because the interosseous muscles become dorsiflexors. However, in this series, the metatarsal head elevation achieved with DMMO plus Kirschner pin fixation failed to reduce the rate of postoperative floating toes compared with Weil osteotomy.

The rate of floating toes in our series is 31%, considering that 30 of the 39 osteotomies were performed on the second metatarsal, 10 of the floating toes were on the second toe. This may be because the second metatarsophalangeal joint has only dorsal interossei, which would explain a less effective active plantar flexion compared to the other lesser toes.[17]

In a recent review of 1131 Weil osteotomies, Highlander et al.[10] reported an overall incidence of floating toes of 36%. O'Kane and Kilmartin[1] published a 20% incidence of floating toe in 40 open Weil osteotomies without PIPJ arthrodesis, in a relatively short follow-up period of 8.6 months.[1] On the other hand, Migues et al.[8] reported an overall incidence of floating toe of 28.5% in 70 Weil osteotomies, 14 of the 20 floating toes had undergone PIPJ arthrodesis. The authors attribute this difference to PIPJ arthrodesis making the metatarsophalangeal contracture more evident in dorsiflexion. The reduction of the tension of the plantar flexor mechanism associated with the retraction of the dorsal structures during healing would be responsible for this evolution.[17]

Modifications of the Weil osteotomy, such as the Maceira osteotomy,[2,18] have been proposed to avoid the descent of the head and the incidence of floating toe. It consists of a triple cut adapted from the Weil osteotomy that allows shortening the diaphysis without head descent, however studies are still needed to confirm its advantages over the Weil osteotomy.[17]

Weil osteotomy has also been described along with suturing of the plantar plate and lengthening of the extensor tendon, in order to realign and decompress an unstable metatarsophalangeal joint.[19] Repair of the plantar plate restores the end part of the windlass mechanism favoring plantar flexion over dorsiflexion.[18,19] Gregg et al.[19] reported good functional outcomes and the lowest incidence (6%) of floating toe, with only two patients.

We can say that the incidence of floating toe in our patients (31%) is similar to that published in other articles.[8,10] The incidence of postoperative dislocation in this series was 13%. This figure is comparable with other published series (12-15%).[7,20] In most cases, the dislocations were asymptomatic. The only symptomatic case was resolved with a percutaneous osteotomy of the first phalanx (Figures 4 and 5). Postoperative functional outcomes were satisfactory with a mean AOFAS scale score of 86 points (range 63-90).

One of the limitations of this study was that the AOFAS scale was not used before surgery, but it should be taken into account that none of the patients included had responded to conservative treatment. On the other hand, this is a retrospective study and the number of patients is small. In addition, other associated surgical procedures were performed on the lesser toes and hallux.

It is important to note that all were treated by the same surgeon and under the same surgical protocol. This procedure would cause less soft-tissue damage because it is percutaneous and, in addition, it would have a lower cost in osteosynthesis material since only one Kirschner pin would be used.

Although several studies have compared the results of the Weil technique with DMMO without differences in range of motion and satisfaction,[21-23] we found no articles comparing the two techniques for the treatment of metatarsalgia associated with rigid hammertoe. Studies should be carried out with the same technique and in a randomized comparative fashion to obtain better evidence compared to open Weil osteotomy.

CONCLUSIONS

DMMO with elevation of the center of rotation associated with PIPJ arthrodesis fixed with a Kirschner pin did not provide a lower incidence of floating toes compared to Weil osteotomy. However, it is a valid alternative for the treatment of mechanical metatarsalgia associated with rigid hammertoes.

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

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Avulsion Fractures of the Posterior Calcaneal Tuberosity (Beak Fracture). Functional and Radiographic Evaluation

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ABSTRACT
Objectives: To present the functional and radiographic outcomes of six patients with beak fractures and to carry out a literature review. **Materials and Methods:** The functional (AOFAS Score) and radiological outcomes of six patients were evaluated. Three patients were male and three were female (mean age: 35.6 years). The mean time interval between injury and admission to the operating room was 2.83 hours. The extensile lateral approach was used. The fracture was fixed with 3.5, 4.0, or 4.5mm cannulated and solid screws alone or in combination with 3.5 and 2.7mm locking plates. **Results:** After a follow-up period of between 8 and 24 months, all the patients had clear signs of consolidation. On admission, all presented signs of soft tissue pain without signs of necrosis. The AOFAS score was 82.4 (5 good and 1 fair). The complications observed were a deep infection and loss of reduction in the same patient. **Conclusions:** Beak fractures can generate soft tissue complications if they are not treated urgently due to initial soft tissue involvement. Open reduction and fixation with screws and plates is the most stable fixation system.
Keywords: Calcaneal tuberosity; avulsion fracture.
Level of Evidence: IV

Fracturas por avulsión de la tuberosidad posterior del calcáneo "en pico de pato". Evaluación funcional y radiográfica

RESUMEN
Objetivos: Comunicar los resultados funcionales y radiográficos en seis pacientes con fractura "en pico de pato" (*beak fracture)* y realizar una revisión de la bibliografía. **Materiales y Métodos**: Se evaluaron los resultados funcionales (escala de la AOFAS) y radiológicos en seis pacientes (3 hombres y 3 mujeres; edad promedio 35.6 años). El tiempo promedio transcurrido entre la lesión y el ingreso en el quirófano fue de 2.83 h. Se realizó la rama vertical del abordaje lateral extendido. Se fijó con tornillos canulados y macizos de 3,5; 4,0 o 4,5 mm solos o combinados con placas de 3,5 y 2,7 mm bloqueadas. **Resultados:** Después de un seguimiento de entre 8 y 24 meses, todos los pacientes tenían signos francos de consolidación. Al ingresar, todos presentaban signos de sufrimiento de partes blandas sin signos de necrosis. El puntaje de la escala de la AOFAS fue de 82,4 (5, buenos y 1, regular). Las complicaciones fueron: una infección profunda y pérdida de la reducción en el mismo paciente. **Conclusiones:** Las fracturas "en pico de pato" pueden generar complicaciones de partes blandas si no son tratadas de manera urgente, debido al compromiso inicial de partes blandas. La reducción abierta y la fijación con tornillos y placas es el sistema de fijación más estable.
Palabras clave: Tuberosidad del calcáneo; fractura avulsiva.
Nivel de Evidencia: IV

INTRODUCTION

Fractures of the posterior calcaneal tuberosity account for 1-3% of all calcaneal fractures.[1] The most common cause is violent contraction of the calcaneus-soleus complex with the foot in dorsiflexion. This injury is common in diabetic and osteoporotic patients due to low energy trauma.[2]

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Beak fractures can cause skin necrosis with catastrophic consequences if not treated promptly. In emergency care, the foot should be placed in maximum plantar flexion to try to reduce the displaced fragment and thus reduce pressure on the posterior region of the calcaneus.

Although there is agreement on reducing this type of fracture in emergency care, there are no publications on definitive osteosynthesis at that time. The fixation method continues to generate debate. Treatments range from excision of the fragment in low-demand patients to open reduction and fixation with different types of osteosynthesis.[3]

Several authors have published on this subtype of tuberosity fracture in the last 70 years.[1-9] Most series include very few patients.

The purpose of this article is to present the functional and radiographic results of six patients with calcaneal tuberosity beak fractures and to carry out a literature review.

MATERIALS AND METHODS

We present the cases of three men and three women, aged 25 to 52 years (mean age 35.6 years). The average time elapsed between injury and admission to the operating room was 2.83 hours. In emergency care, we proceeded to perform the vertical limb of incision of the extensile lateral approach and an osteosynthesis. Lee's classification was used in all cases.[4]

Surgical technique

The patient was placed in the lateral decubitus position and the vertical limb of incision of the extensile lateral approach was performed. The fracture site was treated, and the posterosuperior fragment was reduced using a Schanz pin or reduction forceps. Fixation was performed with cannulated and solid 3.5, 4.0 or 4.5 mm screws alone or combined with 3.5 or 2.7 mm locking plates. Screws alone (3 cases) or screws combined with plates (3 cases) were used depending on the availability of the material in the emergency room. We consider a combination of plates and screws to be ideal. The limb was immobilized with a plaster cast in slight plantar flexion. One month after surgery, partial weight-bearing with a walker boot with a 1.5 cm heel enhancement was permitted until 45 days, followed by full weight-bearing with boot protection for 60 days. After 30 days, mobility of the ankle and foot was initiated.

CLINICAL CASE 1

A 30-year-old woman presented with a closed type II avulsion fracture of the posterior tuberosity on the left side of 4 hours of evolution, as a result of a motorcycle accident. She was admitted to the operating room in the Emergency Department. She had soft tissue involvement without skin necrosis. Reduction and fixation were performed with a 3.5 mm cortical screw and a 3.5 mm one-third tubular plate. In addition, the fracture presented a medial fragment of the tuberosity that was fixated with a 6.5 mm cancellous bone screw. Postoperative follow-up was 11 months. The *American Orthopaedic Foot and Ankle Society* (AOFAS) scale score was 83 (Figure 1).

CLINICAL CASE 2

A 52-year-old woman presented with a closed type II avulsion fracture of the posterior tuberosity on the right side of 4 h of evolution, associated with a fracture of the medial malleolus due to a bicycle-car accident. She had type 2 diabetes and good blood glucose controls. She was admitted to the operating room in the Emergency Department. She had soft tissue involvement without skin necrosis. Fixation was performed with two 4.5 mm cancellous bone screws. She developed a surgical wound infection immediately after surgery, which was treated with three procedures of surgical debridement and six weeks of intravenous antibiotics based on culture results. Loosening of the osteosynthesis material was detected, so she underwent a new surgery with removal of the osteosynthesis and the tuberosity fragment lost reduction. Postoperative follow-up was 13 months. The AOFAS scale score was 77.

Figure 1. **A.** Foot radiograph, AP view. **B.** Computed tomography of the foot, sagittal section. **C.** Computed tomography of the foot, axial section. **D.** Image of soft tissue before surgery. **E.** Vertical limb of incision of the extensile lateral approach. **F.** Foot radiograph, lateral view, with C-arm. **G.** Weight-bearing foot radiograph, AP view, one year after surgery. **H.** Foot radiograph, lateral view, one year after surgery. **I.** Clinical image, front. **J.** Clinical image, back.

CLINICAL CASE 3

A 25-year-old male presented with a closed type II posterior tuberosity avulsion fracture on the left side and a tibial plafond fracture that had evolved over 2 hours as a result of a motorcycle-car accident. He was admitted to the operating room in the Emergency Department. She had soft tissue involvement without skin necrosis. Three cannulated 4.0 mm cancellous screws were used to fixate the distal tibia, and a transarticular uniplanar external fixator, delta frame, was placed for two weeks followed by osteosynthesis of the tibial plafond. Postoperative follow-up was 8 months. The AOFAS scale score was 81.

CLINICAL CASE 4

A 35-year-old man presented with a closed type II avulsion fracture of the posterior tuberosity on the left side of 2 hours of evolution, with soft tissue involvement and no skin necrosis. He was admitted to the operating room in the Emergency Department. Fixation was performed with a 3.5 mm locking lambda plate and a 4.0 mm cannulated cancellous screw. Postoperative follow-up was 24 months. The AOFAS scale score was 83 (Figure 2).

Figure 2. A. Foot radiograph, AP view. **B.** Computed tomography of the foot, sagittal section. **C.** Computed tomography of the foot, axial section. **D.** Foot tomography with 3D reconstruction. **E.** Image of soft tissue before surgery. **F.** Foot radiographs, AP and lateral views, one year after surgery. **G.** Clinical image, front. **H.** Clinical image, back.

CLINICAL CASE 5

A 37-year-old man consulted for a closed type II avulsion fracture of the posterior tuberosity on the right side of 2 hours of evolution, with soft tissue involvement without skin necrosis. Fixation was performed in the operating room with three 4.0 mm cannulated cancellous screws. Postoperative follow-up was 18 months. The AOFAS scale score was 88.

CLINICAL CASE 6

A 29-year-old woman suffered a closed type II avulsion fracture of the posterior tuberosity on the left side of three hours of evolution, with soft tissue involvement but no skin necrosis. She was admitted to the operating room. Fixation was performed with two 4.0 mm cannulated screws and a 2.7 mm locking plate. Postoperative follow-up was 7 months. The AOFAS scale score was 88 (Figure 3).

RESULTS

After a follow-up of between 8 and 24 months (average 13.5 months), all fractures consolidated. All patients had soft tissue involvement on admission, but no signs of skin necrosis. The average AOFAS scale score was 82.4 (5, good and 1, fair). Complications were: deep infection and loss of reduction in the same patient. Asymptomatic thickening of the posterior region of the affected hindfoot was observed (Table).

Table. Results

	Age	Time of evolution	Follow-up	AOFAS score	Soft tissue involvement	Complications
Case 1	30 years	4 h	11 months	83	No skin necrosis	None
Case 2	52 years	4 h	13 months	77	No skin necrosis	Deep wound infection
Case 3	25 years	2 h	8 months	81	No skin necrosis	None
Case 4	35 years	2 h	24 months	83	No skin necrosis	None
Case 5	37 years	2 h	18 months	88	No skin necrosis	None
Case 6	35 years	3 h	7 months	83	No skin necrosis	None

AOFAS = *American Orthopaedic Foot and Ankle Society.*

Figure 3. **A.** Foot radiograph, AP view. **B.** Computed tomography of the foot, sagittal section. **C.** Image of soft tissue before surgery. **D.** Vertical limb of incision of the extensile lateral approach. **E.** Foot radiograph, lateral view, with C-arm. **F.** Foot radiograph, oblique view, with C-arm. **G.** Weight-bearing foot radiograph, AP view, one year after surgery. **H.** Weight-bearing foot radiograph, lateral view, one year after surgery. **I.** Clinical image, front. **J.** Clinical image, back.

DISCUSSION

The calcaneus is the largest bone in the foot and plays a fundamental role as a weight-bearing structure.[10]

Avulsion fractures of the calcaneal tuberosity are rare and usually occur in osteoporotic patients.[4-11]

Beavis et al.[1] classified calcaneal tuberosity avulsion fractures into three types: type I (sleeve) is a small posterior cortical avulsion of the tuberosity; type II is the beak fracture, and type III is an infrabursal avulsion fracture involving the superficial fibers of the Achilles tendon. Lee et al.[4] modified this classification and added type IV which is defined as *beak*, but with a small triangular fragment, where the deep fibers of the tendon are involved.

Lee et al.[4] assigned a mechanism for each type of fracture. Type I fractures occur due to low energy trauma, types III and IV are generated by higher energy trauma where there is a strong contraction of the gastrocnemius-soleus in young patients.[4-10] Type II fractures occur from a combination of contraction of the gastrocnemius-soleus complex and direct impact.[4-10]

Different authors have described conservative and surgical treatments.[12-17] Conservative treatment with immobilization in equinus is indicated in patients with fractures with displacement <1 cm or with impaired function prior to injury.[12-14]

This treatment should be the exception, because the immobilization time is prolonged (≥ 6-8 weeks) with a risk of displacement, possible skin necrosis and loss of plantar flexion strength.[1-15]

The beak subtype or Lee's type II has been described by several authors.[1,4,9] Our series contains six patients and is one of the largest in terms of case count among published series.[4-9] Lee et al. reported five cases of subtype II in a total of 20 tuberosity fractures.[4]

There is consensus among the different authors that this injury is a traumatic emergency and patients should be treated immediately due to the soft tissue involvement it generates. All our patients had soft tissue involvement in the posterior region of the calcaneus and underwent definitive reduction on admission: the average time between injury and surgery was 2.83 hours. No cases have been published with definitive osteosynthesis in the emergency.

Open reduction and internal fixation restore the gastrocnemius-soleus unit and avoid soft tissue complications.[12,16,17]

Numerous fixation systems have been described, such as Kirschner pins, cerclage wire,[18] tension bands,[19] lag screws alone, screws with plates,[19] and various harpoon systems.[12,17] The most widely accepted treatment has been the use of screws;[4,16] however, some studies have found that screw fixation alone may not be the best therapeutic option, even with a sufficiently large fragment, and this could result in treatment failure, particularly in patients with lower bone quality. In a cadaveric study, Khasen et al.[16] reported that lag screws alone failed to neutralize Achilles tendon traction force and considered supplementation with anchors to increase fixation.

Problems that can arise postoperatively include delayed wound healing when reduction and fixation are delayed, infection, fixation failure, and malunion.[4-14] In our series, one patient suffered a deep wound infection and subsequent loss of reduction due to early material removal.

The limitations of our presentation were the low number of patients, the short follow-up time, and the absence of a control group.

CONCLUSIONS

Beak fractures can lead to soft tissue complications if not treated urgently, due to the initial soft tissue involvement. Open reduction and osteosynthesis in the emergency room allowed us to achieve rapid soft tissue recovery and good outcomes in most patients.

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

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Compromise of Adjacent Joints in Long-Term Evolution of Ankle Arthrodesis

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ABSTRACT

Introduction: Tibiotalar arthrodesis is an option in the treatment of ankle osteoarthritis in patients who do not respond to conservative measures. Its main disadvantage is the compromise of adjacent joints in the medium and long term. **Objective:** To determine the involvement of adjacent joints in the medium and long term and its impact on functional outcomes in patients with ankle arthrodesis. **Materials and Methods:** We evaluated a series of 11 patients, 6 females and 5 males. The initial diagnosis was post-traumatic osteoarthritis (9 cases), septic arthritis (1 case), and osteochondral lesion of the talus (1 case). The mean age at the time of surgery was 50 years. The mean follow-up was 9 years. The radiographic compromise of the adjacent joints was evaluated. The patients were functionally evaluated using the Visual Analog Pain Scale (VAS), the AOFAS scale (American Orthopedic Foot and Ankle Score), and a simple satisfaction questionnaire. **Results:** 10 patients (91%) presented with osteoarthritis of one of the adjacent joints. The average score on the VAS was 2.6, while on the AOFAS scale, it was 71. Nine patients reported being very satisfied, one was moderately satisfied, and one was dissatisfied. **Conclusion:** The involvement of adjacent joints is very frequent in the long term, but this does not have a direct impact on the patient's functional outcomes.

Keywords: Ankle osteoarthritis; ankle arthrodesis; adjacent joints.
Level of Evidence: IV

Compromiso de las articulaciones vecinas en la evolución alejada de la artrodesis de tobillo

RESUMEN

Introducción: La artrodesis tibioastragalina es una opción para tratar la artrosis de tobillo en pacientes que no responden a las medidas conservadoras. Su principal desventaja es el compromiso a mediano y largo plazo de las articulaciones vecinas. **Objetivo:** Determinar el compromiso de las articulaciones vecinas a mediano y largo plazo, y su impacto sobre los resultados funcionales en los pacientes con artrodesis de tobillo. **Materiales y Métodos:** Se evaluó a una serie de 11 pacientes (6 mujeres y 5 hombres). El diagnóstico inicial era artrosis postraumática (9 casos), artritis séptica (1 caso) y lesión osteocondral de astrágalo (1 caso). El promedio de edad al operarse era de 50 años. La media de seguimiento fue de 9 años. Se evaluó el compromiso radiográfico de las articulaciones vecinas. La función se valoró mediante la escala analógica visual para dolor, la escala de la AOFAS y un cuestionario simple de satisfacción. **Resultados**: Diez pacientes (91%) tenían artrosis en alguna de las articulaciones vecinas. El puntaje medio en la escala analógica visual fue de 2,6 y el de la escala de la AOFAS, de 71. Nueve refirieron estar muy satisfechos; uno, medianamente satisfecho y otro se manifestó insatisfecho. **Conclusión**: El compromiso de las articulaciones vecinas es muy frecuente a largo plazo, pero esto no repercute directamente en los resultados funcionales.

Palabras clave: Artrosis de tobillo; artrodesis de tobillo; articulaciones vecinas.
Nivel de Evidencia: IV

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INTRODUCTION

Degenerative involvement of the ankle joint usually manifests with pain, stiffness and functional impairment. The most frequent cause of this condition is post-traumatic osteoarthritis secondary to fractures of the ankle, tibial plafond, or talus. The average age of these patients is lower than that of those with osteoarthritis of other joints, such as the hip or knee.[1]

In patients with isolated ankle osteoarthritis who no longer respond to conservative measures, the first challenge is the choice of the most appropriate surgical procedure for each patient.

Joint preservation surgeries, such as supramalleolar osteotomies and hindfoot osteotomies with or without soft-tissue procedures, have achieved good outcomes, but only in patients with partial joint damage and some alteration in the loading axis through the ankle.[1-4]

When osteoarthritis is advanced, the prosthesis is presented as a good alternative and has the advantage of preserving much of the functionality of the ankle and affecting, to a lesser extent, the adjacent joints, mainly the subtalar and Chopart joints (talonavicular and calcaneocuboid).[5,6] Despite this, it is not always the best option for our patients. Previous infection, poor soft tissue condition, major bone defects, and major dysfunction and instabilities are at least relative contraindications to ankle arthroplasty.[7]

For this reason, tibiotalar arthrodesis remains a very good therapeutic choice in these cases. Numerous studies have reported favorable outcomes, including pain reduction, an improved gait pattern, and a high level of patient satisfaction.[8,9] Its main disadvantage is the overloading of adjacent joints that could compromise these outcomes in the medium to long term.

In a study with 22 years of follow-up, Coester et al. observed that ankle arthrodesis is associated with premature osteoarthritis of the foot joints, although it decreases pain and improves function.[10] Hendrickx et al. described that osteoarthritic involvement of adjacent joints is evident, but its clinical and functional impact is not.[11]

Our hypothesis is that, while it is frequent in the distant progression of ankle arthrodesis to see involvement of adjacent joints in imaging assessments, this has no direct impact on the patients' clinical status.

The aim of this study was to determine the involvement of adjacent joints in the medium and long term, and its impact on functional outcomes in patients with ankle arthrodesis.

MATERIALS AND METHODS

A retrospective, observational study was carried out to evaluate a series of follow-up patients treated by our team. The senior surgeon's medical records file was examined for patients who had undergone tibiotalar arthrodesis between 2000 and 2022. Those with isolated ankle arthrodesis and a minimum follow-up of three years were included. Exclusion criteria were: arthrodesis of another joint or other lesion in the homolateral midfoot and hindfoot, follow-up <3 years, lack of presurgical radiographic imaging, and any congenital deformity, neuropathy or arthropathy.

Involvement of adjacent joints was assessed with anteroposterior and lateral radiographs of the homolateral midfoot and hindfoot. Neither the knee nor the contralateral foot were evaluated. All had preoperative and postoperative radiographs of the last control. Involvement was assessed with the Kellgren and Moore scale, which consists of five grades: grade 1, normal, no signs of osteoarthritis; grade 2, doubtful, minimal osteophytes; grade 3, minimal, osteophytes with normal joint space; grade 4, moderate, moderate narrowing of joint space; grade 5, severe, marked narrowing of joint space with subchondral sclerosis.[12] In the last control, function was assessed by questioning and a thorough physical examination, also using the visual analog scale (VAS), the *American Orthopaedic Foot and Ankle Society* (AOFAS) scale and a simple satisfaction questionnaire (they were asked how they felt about the treatment performed: dissatisfied, moderately satisfied or very satisfied).

RESULTS

Sixty-three ankle arthrodeses were analyzed in 63 patients; 29 could not be located or did not consent to be included in the study; nine had no pre-surgical radiographs; five had an associated lesion in the homolateral rearfoot or midfoot; two, poliomyelitis; six, less than three years of follow-up; and one died.

The sample consisted of 11 patients (6 women and 5 men). The initial diagnosis was post-traumatic osteoarthritis (9 cases), septic arthritis (1 case) and osteochondral injury of the talus (1 case). The mean age at surgery was 50 years (standard deviation [SD] = 15.47). The mean follow-up was 9 years (SD = 6.15).

Ten patients (91%) had osteoarthritis in one of the neighboring joints, whereas the remaining one did not (he had the shortest follow-up, 3 years). Ten (91%) had subtalar joint involvement and four (36%) had Chopart joint involvement (Figure 1).

Figure 1. Weight-bearing radiographs of the left ankle 6 months after ankle arthrodesis, AP view (**A**) and lateral view (**B**). Secondary osteoarthritis affecting the subtalar joint, but not the Chopart joint. Clinical images of the same patient from the front (**C**) and back (**D**).

Figure 2. Weight-bearing radiographs of the right ankle 12 years after ankle arthrodesis, lateral view (**A**) and AP view (**B**). Secondary osteoarthritis in the subtalar and Chopart joints. Clinical images of the same patient from the front (**C**) and back (**D**).

The mean AOFAS scale score was 71 (SD = 16.86), with a minimum of 26 and a maximum of 92. It should be noted that the maximum value for a patient with ankle arthrodesis is 92, as the scale gives 8 points for normal or slightly decreased ankle range of motion (>30°).

Nine patients reported being very satisfied with the treatment; one was moderately satisfied and another was dissatisfied. The latter evolved with pseudarthrosis that was not revised by the patient's own decision. Two presented metatarsalgia due to an exaggerated equinus in the arthrodesis and had to undergo a revision, the evolution was favorable. One patient presented with a 3 cm shortening of the operated lower limb that was mildly symptomatic and treated with a shoe enhancement. Osteosynthesis material was removed in one patient because of pain and their evolution was favorable (Figure 2, Table).

Table. Patient data.

n	Gender	Age (years)	Initial diagnosis	Osteoarthritis 1	Complications	Revision	Follow-up (years)	Osteoarthritis 2	AOFAS Scale	VAS	Satisfaction
1	F	76	Post-traumatic osteoarthritis	Grade 1	Metatarsalgia	Yes	12	Grade 4 (ST) and Grade 4 (Chopart)	71	4	Very satisfied
2	F	61	Post-traumatic osteoarthritis	Grade 1	Metatarsalgia	Yes	22	Grade 4 (ST) and Grade 1 (Chopart)	74	3	Very satisfied
3	M	71	Post-traumatic osteoarthritis	Grade 1	Pseudarthrosis	No	4	Grade 5 (ST) and Grade 1 (Chopart)	26	7	Dissatisfied
4	M	44	Post-traumatic osteoarthritis	Grade 1	Shortening 3 cm	No	18	Grade 5 (ST) and Grade 1 (Chopart)	66	2	Moderately satisfied
5	F	56	Post-traumatic osteoarthritis	Grade 1	No	No	15	Grade 4 (ST) and Grade 2 (Chopart)	66	5	Very satisfied
6	F	76	Post-traumatic osteoarthritis	Grade 1	No	No	3	Grade 1	92	0	Very satisfied
7	F	60	Post-traumatic osteoarthritis	Grade 1	No	No	6	Grade 4 (ST) and Grade 1 (Chopart)	79	2	Very satisfied
8	M	34	Post-traumatic osteoarthritis	Grade 1	No	No	8	Grade 4 (ST) and Grade 1 (Chopart)	74	3	Very satisfied
9	M	57	Septic arthritis	Grade 3 (ST) and Grade 1 (Chopart)	No	No	4	Grade 5 (ST) and Grade 2 (Chopart)	65	3	Very satisfied
10	F	57	OLT Complication	Grade 1	No	No	5	Grade 2 (ST) and Grade 1 (Chopart)	89	0	Very satisfied
11	M	64	Post-traumatic osteoarthritis	Grade 1 (ST) and Grade 1 (Chopart)	No	No	6	Grade 4 (ST) and Grade 2 (Chopart)	84	0	Very satisfied

References: F (Female), M (Male), OLT (Osteochondral Lesion of the Talus), ST (Subtalar), Osteoarthritis 1 (Osteoarthritis of adjacent joints prior to arthrodesis), Osteoarthritis 2 (Osteoarthritis of adjacent joints post arthrodesis).

DISCUSSION

In this series, 91% of patients had secondary osteoarthritis of the subtalar joint and 36% of patients had secondary osteoarthritis of the Chopart joint (talonavicular and calcaneocuboid joints).

Ankle arthrodesis continues to be a very good therapeutic alternative for patients with advanced osteoarthritis who do not respond to conservative measures. The advantages of this procedure are well known. It is a reproducible and reliable technique thanks to its extensive dissemination in the literature over several years.[13-15] It allows correction of alignment defects in the same procedure.[16,17] It can be indicated if there is a previous infection and the soft tissue condition is poor.[18] It has high consolidation rates.[8,19] The patient retains good gait biomechanics, with good functional outcomes and high rates of patient satisfaction.[20]

The main disadvantages observed are the involvement of the joints near the ankle, which would be overloaded, with the consequent risk of osteoarthritis in the medium or long term. The subtalar and Chopart joints would be the most affected by a lack of range of motion and load absorption in a healthy ankle.

But this does not appear to be directly related to functional outcomes. The mean VAS was 2.6 and the AOFAS scale score was 71. In addition, nine (82%) reported being very satisfied with the outcome of the treatment.

In a similar study, Said et al.[21] reported good to excellent outcomes at 7.5 years in 18 of 22 patients (82%), despite the fact that 17 of them (94%) had subtalar joint stiffness. These authors concluded that functional compromise is minimal.

In their series of 12 patients with 18 years of follow-up, Mazur et al.[13] found that all had radiographic signs of secondary osteoarthritis in the subtalar and midtarsal joints, but noted that these changes were not directly related to symptoms.

In their study of 37 patients with a 25-year follow-up, Jackson and Glasgow[22] observed radiographic signs of Chopart joint osteoarthritis in 22 patients (59%) and subtalar joint stiffness in all.

There is limited published data on the rate of arthrodesis of any adjacent joints following ankle arthrodesis for pain. In our series, it was not necessary for any patient. In a series of 185 patients with eight years of follow-up, Kerkhoff et al.[20] reported subtalar arthrodesis in four patients (2%) because of pain confirmed with previous infiltration.

The main strength of this study is the follow-up time that allows us to analyze the clinical and remote radiographic evolution of patients with ankle arthrodesis. Its weakness is that it includes a relatively small sample of 11 patients for an initial population of 63, which implies a bias due to the loss of patients (82%).

The results of this study are similar to those already published on the subject and we conclude that midfoot and hindfoot joint involvement (stiffness and osteoarthritis) is very frequent in the medium and long-term evolution of patients with ankle arthrodesis.[23,24] This incidence is close to 100%. Nonetheless, it has little direct bearing on the clinical progression of patients who, for the most part, have low-grade pain, acceptable function, and a high satisfaction rate.

CONCLUSION

Ankle arthrodesis can be considered a good treatment alternative for patients with severe and isolated tibiotalar osteoarthritis.

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Supramalleolar Osteotomies for Ankle Osteoarthritis: Clinical and Radiological Outcomes

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ABSTRACT

Introduction: Supramalleolar osteotomies are a treatment option for asymmetric ankle osteoarthritis. Our work aims to describe the clinical, radiographic, and subjective outcomes obtained in patients with ankle osteoarthritis who underwent a supramalleolar osteotomy (SMOT). **Materials and Methods:** Retrospective, observational, and descriptive study on patients who underwent SMOT for ankle osteoarthritis between January 2010 and July 2017. The patients' clinical records were analyzed. **Results:** We included 13 patients who underwent SMOT, 8 patients with valgus (61.5%) and 5 (38.5%) with varus rearfoot and ankle misalignment. The mean varus VAS score decreased from 9 ± 0.45 to 3 ± 1 postoperatively (p <0.05) and, in valgus deformities, from a mean 7.88 ± 0.35 to 2.15 ±1.64 postoperatively (p <0.05). The mean AOFAS score changed from 32.8 ± 16.2 to 82.1 ± 13.6 postoperatively in the varus deformity group (p <0.05) and from 31 ± 17.3 preoperatively to 93.1 ± 6.20 postoperatively in the valgus deformity group (p <0.05). Twelve patients (92.3%) achieved radiographic union in an average time of 10.4 weeks. **Conclusion:** Supramalleolar osteotomy as a treatment for asymmetric ankle osteoarthritis is a predictable technique with very good clinical and radiological outcomes in the short and medium term.

Keywords: Ankle osteoarthritis; supramalleolar osteotomy; joint preservation.

Level of Evidence: IV

Osteotomías supramaleolares en pacientes con artrosis de tobillo: resultados clínicos y radiográficos

RESUMEN

Introducción: Las osteotomías supramaleolares son una opción terapéutica para la artrosis asimétrica de tobillo. El objetivo de este artículo es describir los resultados clínicos, radiográficos y subjetivos obtenidos en pacientes con artrosis de tobillo sometidos a una osteotomía supramaleolar. **Materiales y Métodos:** Estudio observacional descriptivo retrospectivo de pacientes sometidos a una osteotomía supramaleolar por artrosis de tobillo entre enero de 2010 y julio de 2017. Se analizaron las historias clínicas para recabar datos clínicos y radiográficos preoperatorios y posoperatorios. **Resultados:** Se incluyó a 13 pacientes: 8 con una desalineación del tobillo y retropié en valgo (61,5%) y 5 (38,5%) en varo. El puntaje medio posoperatorio de la escala analógica visual del grupo con deformidad en varo disminuyó de 9 ± 0,45 a 3 ± 1 (p <0,05) y de una media de 7,88 ± 0,35 a 2,15 ± 1,64 (p <0,05) en aquellos con deformidad en valgo. El puntaje medio de la escala de la AOFAS se modificó de 32,8 ± 16,2 antes de la cirugía a 82,1 ± 13,6 en el posoperatorio, en el grupo con deformidad en varo (p <0,05) y de 31 ± 17,3 a 93,1 ± 6,20, respectivamente, en aquellos con deformidad en valgo (p <0,05). Se constató la consolidación radiográfica en 12 pacientes (92,3%), en un promedio de 10.4 semanas. **Conclusión:** La osteotomía supramaleolar como tratamiento de la artrosis asimétrica de tobillo es una técnica predecible, con muy buenos resultados clínicos y radiográficos a corto y mediano plazo.

Palabras clave: Artrosis de tobillo; osteotomía supramaleolar; preservación articular.

Nivel de Evidencia: IV

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INTRODUCTION

Ankle osteoarthritis is a condition that affects 1% of the adult population worldwide.[1] In most cases, the origin is post-traumatic: due to a deformity as a consequence of a fracture or due to chronic ankle instability leading to abnormal joint loading that damages the cartilage, resulting in varus (most frequently) or valgus ankle and rearfoot misalignment.[1-3]

It is widely accepted that, for advanced osteoarthritis of the ankle, joint sacrifice surgeries (either joint fusion or arthroplasty) are the definitive treatment of choice.[1] However, in cases of partial or incomplete osteoarthritis (also called "asymmetric" osteoarthritis) in which there are areas of viable cartilage and some alteration of the loading axis of the ankle, supramalleolar ankle osteotomies (SMOT) are an option to consider as joint sparing procedures,[1,3] as they redistribute the load to areas with preserved cartilage and offload degenerated areas. Thus, they reduce pain, maintain range of motion, restore joint congruence[4] and delay the progression of osteoarthritis. Supramalleolar osteotomies can be considered as a definitive or intermediate treatment postponing an eventual arthroplasty or joint fusion which, if necessary, are performed on an already aligned limb.[5,6]

This is a technique described by Speed and Boyd[7] in 1936, but which gained popularity after the studies of Takakura in the 1990s[8] and, later, of Hintermann,[9] and has recently gained significant notoriety. Takakura et al. proposed this surgical technique in patients with a stage lower than IIIB, some authors reported good outcomes in patients with selected stage IIIB injuries.[10] Although the indications for supramalleolar osteotomy are still under discussion,[5] contraindications include patients with advanced osteoarthritis, unmanageable hindfoot instability, severe vascular or neurological disease, acute or chronic infection of the joint and, relatively speaking, patients >70 years old, with poor bone quality, and smokers.[11,12]

The aim of this study was to evaluate the functional, radiographic and subjective results obtained in patients with ankle osteoarthritis who underwent SMOT at our institution.

MATERIALS AND METHODS

This study had the prior approval of the institution's Ethics Committee.

Data were collected for patients treated with supramalleolar osteotomy between January 2010 and July 2017.

A retrospective descriptive observational study was carried out. During that period, 14 patients were operated on and 13 were included, since one did not complete the follow-up.

Inclusion criteria were: patients >18 years old with a diagnosis of asymmetric ankle osteoarthritis with <50% joint involvement, unresponsive to conservative treatment, undergoing SMOT. Patients with incomplete medical records and follow-up <2 years were excluded. Patients were evaluated clinically and radiographically before surgery, at 1 and 4 weeks postoperatively, then at 2, 3 and 12 months and, finally, with annual controls.

Clinical analysis

Comorbidities (smoking, diabetes mellitus, body mass index), habitual sports activity and etiology of ankle osteoarthritis were recorded. The sample was divided into two groups according to varus or valgus hindfoot deformity based on clinical assessment of the deformity and on weight-bearing radiographs. In addition, ankle instability was evaluated with clinical maneuvers in the office (stress tests) and with fluoroscopy in the operating room.

The clinical examination was performed using the visual analog scale (VAS), which assesses pain with images and numbers from 0 "no pain" to 10 "worst possible pain"; it allows pain to be located at all intermediate points between extremes;[13] and the *American Orthopaedic Foot and Ankle Society* (AOFAS)[14] hindfoot scale, which assesses hindfoot and ankle function, pain, limitation of daily living, gait, joint range of motion, and clinical alignment. Both scales were administered before surgery and at the end of follow-up; patients' subjective satisfaction was also determined by asking whether they would undergo surgery again.

Complications during follow-up, the need for removal of the osteosynthesis and the need for reconversion to arthrodesis or ankle arthroplasty during follow-up were evaluated.

Radiographic analysis

Anteroposterior and lateral weight-bearing radiographs of the ankle were taken before surgery and at the end of follow-up. In the anteroposterior projection, the following angles were evaluated: intermalleolar (IM) angle (angle between the longitudinal axis of the tibia and a line connecting the ends of the lateral and medial malleoli),[15] anterior distal tibial angle (ADTA) (angle between the tibial diaphysis and the articular surface of the tibial plafond in the anteroposterior view),[16] and talar inclination angle (TIA) (angle between the tibial plafond and the articular surface of the talar dome in the anteroposterior view).[16] In the lateral projection, the lateral distal tibial angle (LDTA) (anterior angle between the tibial diaphysis axis and the articular surface of the tibial diaphysis in the lateral view) was assessed.[17] These angles are used for both preoperative and postoperative planning to evaluate the radiographic surgical outcome (Figure 1).

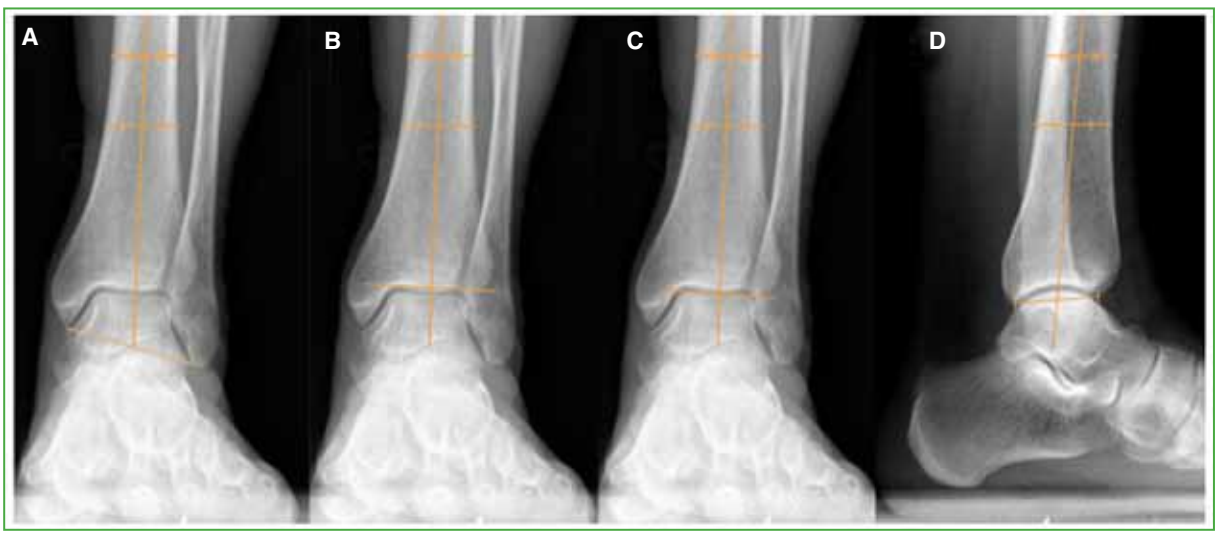

Figure 1. **A.** Intermalleolar angle (angle between the longitudinal axis of the tibia and a line connecting the ends of the lateral and medial malleoli). **B.** Anterior distal tibial angle (angle between the tibial diaphysis and the articular surface of the tibial plafond in the anteroposterior view). **C.** Talar tilt angle (angle between the tibial plafond and the articular surface of the talar dome in the anteroposterior view). **D.** Lateral distal tibial angle (anterior angle between the axis of the tibial diaphysis and the articular surface of the tibial diaphysis in the lateral view).

Osteoarthritis was classified according to the Takakura-Anaka classification on the anteroposterior weight-bearing radiograph. This classification includes four stages; I: no joint space narrowing, but there is subchondral sclerosis of the bone and osteophyte formation; II: narrowing of medial or lateral joint space; IIIa: obliteration of medial or lateral joint space; IIIb: obliteration of medial or lateral joint space extending over the roof of the talar dome; IV: complete obliteration of joint space.[18]

Preoperative CT scans were performed on all patients to assess the extent of joint involvement and, postoperatively, the tomographic time to consolidation was also recorded.

Preoperative planning

The patient is examined standing and walking, and the comparative stability and range of motion of the ankle and subtalar joint are assessed. The need for concomitant procedures is planned (ligament plastic surgery, calcaneal osteotomy, etc.), which will then be reevaluated during surgery to determine whether they are necessary.

The deformity in both the coronal and sagittal planes will be assessed on preoperative weight-bearing radiographs when planning the form and extent of the osteotomy. The required correction angle is marked on the preoperative radiographs and the size and orientation of the wedges to be used are calculated.[11] The normal angle of the distal tibial surface of the ankle is usually 93°. The LDTA is normally 80°. The height of the wedge to be resected or added is calculated by restoring the normal values and taking into account the values of the contralateral extremity.[19]

Surgical technique and postoperative management

The patient was placed in the dorsal decubitus position under regional anesthesia. Lateral and medial stress maneuvers were performed under fluoroscopy to evaluate for ankle instability. The type of osteotomy was defined taking into account the type of deformity and its magnitude. Varus deformities were treated with medial opening-wedge or lateral closing-wedge supramalleolar osteotomies. In minor deformities (<10º), medial opening-wedge osteotomies were performed, and in major deformities (>10º), lateral closing-wedge osteotomies were performed. Valgus deformities were treated with medial closing-wedge supramalleolar osteotomies. The osteosynthesis used was a 4.5 mm locking tibia plate. An allograft was placed if necessary.

In some cases, procedures were added in the same surgical stage. The fibula osteotomy was utilized to shorten in varus cases and lengthen in valgus patients, depending on the degree of joint realignment accomplished following tibial osteotomies. Ligament and tendon reconstruction was performed according to clinical and intraoperative radioscopic evaluation. Calcaneal osteotomies were performed when the hindfoot remained misaligned even after tibial osteotomy. Finally, the limb was immobilized with a short leg cast. All patients were discharged 24 h after surgery. The leg cast was removed four weeks after surgery. A walker boot was indicated for two weeks with no weight-bearing and for two weeks with partial weight-bearing. Patients began to wear their usual footwear two months after surgery. Kinesiotherapy began around the fourth week. The patients were authorized to resume sporting activities progressively according to tolerance, starting six months after the operation.

Statistical Analysis

Continuous variables are presented as means and standard deviation (SD) or median with their interquartile range (IQR) according to the distribution. Categorical variables are expressed as absolute value and percentage. To compare continuous preoperative and postoperative data, Student's t-test for dependent samples or Wilcoxon rank test were used as appropriate. Data were analyzed with STATA version 13 (Statacorp LP College Station Texas).

RESULTS

The study included 13 patients undergoing SMOT: eight with valgus ankle and rearfoot misalignment (61.5%) and five (38.5%) with varus misalignment. The median follow-up was 27 months (IQR 24-48). Six were men (46%), the median age was 58 years (IQR 34-61). The mean body mass index was 24 kg/m2 (range 2 -2.64). Six patients (46%) practiced physical activity before surgery (Table 1).

Regarding associated foot and ankle pathologies, one (7.6%) had flat feet and two (15.3%) had subtalar osteoarthritis. The mean VAS score decreased from a mean of 9 (SD 0.45) before surgery to 3 (SD 1) postoperatively ($p < 0.05$), in the varus deformity group, and from a mean of 7.88 (SD 0.35) to 2.15 (SD 1.64) ($p < 0.05$), respectively, in the valgus deformity group. The median AOFAS scale score changed from 32.8 (SD 16.23) preoperatively to 82 (SD 13.65) after surgery ($p < 0.05$) in the varus deformity group and from 31 (SD 17.36) to 93.13 (SD 6.20) ($p < 0.05$), respectively, in the valgus deformity group.

When asked if they would undergo surgery again, 12 (92.3%) stated that they would indeed do it again, while only one said that they would not undergo surgery again.

Before surgery, six (46.1%) practiced recreational sports activities and all of them returned to sports. In 12 (92.3%), radiographic consolidation was achieved after surgery, in a median of 10.4 weeks (IQR 8-12) (Figures 2 and 3). Pseudarthrosis was observed in one patient, requiring revision surgery. Twenty-five aggregate procedures were performed (Table 2).

Table 1. Demographic characteristics of the study population.

	Varus (n = 5)	Valgus (n = 8)	Total (n = 13)
Male sex, n (%)	3 (60)	3 (37.5)	6 (46.1)
Body mass index, mean (SD), kg/m^2	27.3 (1.9)	23 (2.8)	24 (2.6)
Age, median (IQR 25-75), years	60 (52-61)	46 (29.5-60.7)	58 (34-61)
Right, n (%)	4 (80)	4 (50)	8 (61.5)
Etiology			
Post-traumatic (fracture), n (%)	2 (40)	6 (75)	8 (61,5)
Post-traumatic (instability), n (%)	2 (40)	2 (25)	4 (30.7)
Idiopathic, n (%)	1 (20)	0	1 (7.69)
Takakura Classification			
Stage I, n (%)	1 (20)	2 (25)	3 (23.1)
Stage II, n (%)	1 (20)	3 (37.5)	4 (30.7)
Stage IIIA, n (%)	0	3 (37.5)	3 (23.1)
Stage IIIB, n (%)	3 (60)	0	3 (23.1)

SD = standard deviation; IQR = interquartile range.

Figure 2. Takakura Stage IIIA. **A.** Preoperative ankle radiograph, AP view. **B.** Anteroposterior ankle radiograph, 6 years after internal supramalleolar closing-wedge varus osteotomy.

Figure 3. Takakura Stage IIIB. **A.** Preoperative ankle radiograph, AP view. **B.** Anteroposterior ankle radiograph, 2 years after internal supramalleolar opening-wedge valgus osteotomy.

Table 2. Associtated procedures

Associated procedures	Varus	Valgus	Total
Fibula osteotomy	4	3	7
External column lengthening	0	1	1
Calcaneal valgus osteotomy	3	1	4
Subtalar arthrodesis	0	2	2
Transfer of lateral peroneus longus tendon to lateral peroneus brevis tendon	1	1	2
Deltoid ligament repair	0	2	2
Bostrom-Gould surgery	2	2	4
Bone graft	2	1	3

Radiographic findings

In the group of patients with varus misalignment, the ADTA was modified from a median of 87.51 (IQR 78.18-89.5) preoperatively to a median of 91.47 (IQR 91.3-94.42) postoperatively (p <.0.05); the median LDTA changed from 84.17 (IQR 79.01-88) preoperatively to a median of 77.14 (IQR 76.73-82) postoperatively (p = 0.57); the IM angle changed from a median of 106.6 (IQR 102.25-110.65) preoperatively to a median of 96.74 (IQR 96-103.48) postoperatively (p = 0.06); and the TIA changed from a median of 5.6 (IQR 4.87-7.42) preoperatively to a median of 5.94 (IQR 1,.66-7.56) postoperatively (p = 0.74).

With respect to valgus misalignments, the ADTA changed from a median of 91.72 (IQR 85.72-98.32) to a median of 82.52 (IQR 78.24-87.18) (p<0.05); the LDTA, from a median of 87.68 (IQR 85.63-91.11) to a median of 90.6 (IQR 83.61-95.63) (p=0.72); the IM angle, from a median of 98.96 (IQR 90.96-102.35) to a median of 102.77 (IQR 99.52-106.45) (p <0.05); the TIA, from a median of 5.22 (IQR 1.80-7.1) to a median of 5.07 (IQR 1.84-5.13) (p <0.05) (Table 3).

In terms of osteoarthritic changes, Takakura stage II was the most frequent (Table 4).

Table 3. Radiographic outcomes

	Varus (n = 5)			Valgus (n = 8)		
Parameters	**Preoperative**	**Postoperative**	**p***	**Preoperative**	**Postoperative**	**p***
Talar tilt angle, median (IQR)	5.6 (4.87-7.42)	5.94 (1.66-7.56)	0.74	5.22 (1.80-7.1)	3.325 (1.83-5.13)	<0.05
Anterior distal tibial angle, median (IQR)	87.51 (78.18-89.5)	91.47 (91.3-94.42)	<0.05	91.72 (85.72-98.32)	82.52 (78.24-87.18)	<0.05
Intermalleolar angle, median (IQR)	106.6 (102.25-110.65)	96.74 (96-103.48)	0.06	98.96 (90.96-102.35)	102.77 (99.51-106.44)	<0.05
Lateral distal tibial angle, median (IQR)	84.17 (79.01-88)	77.14 (76.73-82)	0.57	87.68 (85.63-91.11)	90.60 (83.61-95.63)	0.72

*Statistical significance was established at p <0.05. IQR = interquartile range.

Table 4. Evolution of Takakura stages by patient

Patient	Takakura stage (Preoperative)	Takakura stage (Postoperative)	Stage variation
1	II	II	0
2	IIIA	IIIB	1+
3	II	II	0
4	IIIB	IIIB	0
5	IIIA	IIIA	0
6	I	I	0
7	IIIB	IV	1+
8	I	I	0
9	IIIB	IIIB	0
10	I	I	0
11	II	II	0
12	II	II	0
13	IIIA	IIIA	0

Regarding complications, osteosynthesis was removed in one patient due to implant intolerance. One patient required revision surgery due to lack of consolidation. Four months after the operation, the tibia osteosynthesis broke, so surgical correction was performed with two higher profile plates, PEEK cage and bone substitute.

No arthrodesis or arthroplasty conversion surgery was necessary in any case. One evolved with mild pain in the rearfoot at the level of the peroneal tendons, which disappeared with the use of plantar orthoses. There was one case of delayed healing of the wound that was resolved with advanced wound healing.

DISCUSSION

The results of SMOT for the surgical treatment of asymmetric ankle osteoarthritis have been published in multiple international series.[2,6,10,20-23] In our region, there are very few series published;[24] none in our country. It is a technique that, although it has been described and studied for some time, is still under discussion. In our series, the clinical outcomes were very good, with significant improvement in VAS and AOFAS scores, and a very good subjective perception of the procedure. Regarding the radiographic outcomes, most of the parameters improved in the anteroposterior evaluation of the ankle in both groups. In the valgus misalignment group, the variation of TIA, IM and ADTA angles was statistically significant. In the varus misalignment group, the ADTA showed statistical significance, while the TIA did not significantly improve. Statistical analysis of the results has to be considered in the context of a small sample. The median time to consolidation in our series was 10.4 weeks (IQR 8-12). One patient progressed to pseudarthrosis and required a revision procedure. Postoperative complications were rare. In no case was conversion to arthrodesis or arthroplasty necessary at the end of follow-up.

In the series of Kraähenbühl et al. on medial opening-wedge supramalleolar osteotomies for varus correction, the ADTA and TIA in the ankle mortise view changed significantly compared to the preoperative evaluation. They did not find statistically significant changes for the LDTA.[9] In their series to correct asymmetric osteoarthritis with varus deformity using a medial opening-wedge SMOT, Tanaka et al. reported correction in all angles preoperatively with respect to postoperatively, but did not mention statistical significance.[18] In the series published by Stamatis et al, varus deformities were corrected using a medial opening-wedge SMOT, while valgus deformities were corrected with a medial closing-wedge SMOT. The ADTA was corrected postoperatively with a statistically significant difference in both varus and valgus misaligned ankles. But, as in our cases with the postoperative LDTA, they found no statistically significant differences from preoperatively.[21] This seems reasonable given that SMOT corrects the deformity in the coronal plane.

While sagittal plane deformities can be modified, correcting such misalignments requires a correction in the dimension of the wedge in the anteroposterior direction or opting for dome-shaped osteotomies alignment of the ankle are important factors affecting clinical outcomes after SMOT. In agreement with the recommendations of Hintermann et al.,[25] we prefer to achieve a slight overcorrection of the osteotomy to change the loading axis and counteract the deforming effect of the soft tissues. On the other hand, although opening-wedge osteotomies can generate a slight loss of correction due to the collapse of the bone graft and the consequent closure of the osteotomy, fixation with a locking plate could add stability, preventing this phenomenon of under-correction from occurring. In our series of patients with varus deformity, we conducted medial opening-wedge osteotomies when the deformity was mild, and lateral closing-wedge osteotomies when the deformity was more severe. Valgus deformities were treated with medial closing-wedge osteotomies, with favorable outcomes in all cases.

Pagenstert et al. indicated fibula osteotomy when the IM angle had a difference of at least 5° compared to the contralateral angle, or in fracture sequelae that, on tomographic evaluation, showed a rotational deformity or subluxation at the level of the syndesmosis; they performed either a shortening or lengthening Z osteotomy.[26] Recently, Lim et al. published a series of patients with medial ankle osteoarthritis who were treated with a comparative medial opening-wedge osteotomy with or without the addition of a fibula osteotomy; the results were increased medial gutter space and greater lateral translation of the talus in the fibula osteotomy group.[27] In our experience, fibula osteotomy was performed in patients with varus deformity to create more space for the mortise and thus reduce the talus. In patients with valgus deformity, lengthening of the fibula was chosen when the fibula was shorter (because of a history of ankle fracture) and did not adequately hold the talus in its correct position.

In relation to ligament instability of the ankle and hindfoot, it is important to perform joint stress maneuvers under fluoroscopy before starting surgery and repeat them after tibial osteotomy. Some authors explain that the improvement of the distal tibial angle after tibial osteotomy results in better ankle stability, making ligament reconstruction unnecessary in some cases.[8] In our series, after supramalleolar osteotomy, two (25%) of the ankles with valgus deformity still had medial ligament instability and required a deltoid ligament reconstruction, two (25%) with lateral instability required a lateral anatomic ligament reconstruction, and two (40%) with varus instability required a lateral ligament reconstruction.

In a series with a long follow-up, Krähenbühl et al. reported that the greatest number of complications occurred during the first two years,[2] which is precisely the minimum follow-up time in our series. Hintermann et al. stated that the complication rates of supramalleolar osteotomies are low.[25] It has been reported that opening-wedge osteotomies take longer to heal[23] than closing-wedge osteotomies. Takakura et al[8] reported four pseudarthroses in 18 operated ankles. In our series, the only case that evolved with pseudarthrosis was an opening-wedge osteotomy. Hintermann et al. also described a revision rate of 19%, while ours was 7%. In their series of 294 supramalleolar osteotomies, Krähenbühl et al. reported that 38 (12.95%) patients required conversion to arthroplasty or arthrodesis, at an average of five years after surgery (range 2-16).[2] Therefore, it is not surprising that we have not yet reported reconversions despite our two-year average follow-up period. In their series of nine supramalleolar osteotomies, Harstall et al. reported the need to remove the osteosynthesis in two patients.[23] In our series, the osteosynthesis material had to be removed in only one patient due to intolerance.

The median time to consolidation in our series was 10.4 weeks (IQR 8-12), while other authors report similar average times, from 10 to 15.2 weeks.[21-23]

When analyzing the different series for comparison, the stage of the operated patients must be considered. Hongmou et al. reported that the preoperative Takakura stage with the highest number of cases was IIIA;[22] in our sample, it was II. There were no cases of radiographic regression of Takakura stage after surgery, but we did observe two cases of radiographic progression: one from stage IIIA to stage IIIB and one from IIIB to IV; both with initial valgus deformity. Other authors reported that two of the nine operated ankles showed radiographic progression of osteoarthritis, which coincides with our results.[23]

In several studies, pain improved by about 3 to 4 points after supramalleolar osteotomy.[20,21,26,28] In our series, the VAS score improved similarly to other published series, based on greater preoperative pain in patients with varus deformity. As for the evaluation with the AOFAS scale, something similar occurred. This scale has shown statistically significant improvements when comparing scores before and after surgery.[22,23] In our series, there was also a statistically significant improvement in this score postoperatively for both varus and valgus deformities. Kim et al. stated that 90.6% of patients reported good to excellent postoperative subjective outcomes.[28] In our case, 12 (92.3%) reported satisfactory subjective outcomes, and responded that they would undergo surgery again.

Our study has certain limitations. The data were collected retrospectively, the number of patients is small and the follow-up is short; several patients had undergone other added surgical procedures (calcaneal osteotomies, fibula osteotomies, etc.) that could affect the final result of the supramalleolar osteotomy. However, it is difficult to study SMOT in isolation, and this problem is present in all published studies.

Regarding strengths, we have not found a series of cases on this technique published in Argentina. All surgeries were performed by the same surgical team. In the future, the results of series with a larger number of patients, with more homogeneous pathology and longer follow-up should be published. Additionally, the evolution of patients in equal stages treated with ankle arthroplasty or arthrodesis should be compared. The strategy of conducting multicenter studies to increase the number of cases could also be considered.

CONCLUSIONS

SMOT as a treatment for asymmetric ankle osteoarthritis is a predictable technique, with very good clinical and radiographic outcomes in the short and medium term. The results of our series are similar to those published by other studies. This surgical technique had a low complication rate and no re-conversion was necessary during the average 2-year follow-up.

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Arthroscopy and Percutaneous Internal Fixation in Maisonneuve Fractures. Imaging Evaluation

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ABSTRACT

Introduction: Maisonneuve fracture (MF) is an injury characterized by the subcapital fracture of the fibula associated with a capsuloligamentous injury of the ankle. Treatment involves the restoration of normal bone and capsuloligamentous anatomy in order to reestablish physiological tibiotalar contact forces. This quality of reduction can be difficult to achieve, especially with percutaneous techniques. **Objective:** To evaluate the quality of reduction in Maisonneuve fractures reduced in a closed manner (under direct arthroscopic visualization) and fixed percutaneously. **Materials and Methods:** We analyzed comparative preoperative and postoperative radiographs and CT scans of the operated and healthy ankles. **Results:** 13 fractures were evaluated. Radiographic parameters of postoperative procedures (medial clear space, distal tibiofibular overlap, tibiofibular clear space) did not register differences except for the anterior tibiofibular space, which had increased in 1 case. Postoperative tomographic measurements of tibiofibular clear space and anterior tibiofibular space showed 100% satisfactory reductions. Two patients presented altered distal tibiofibular overlap values with a difference greater than 2 mm compared to the healthy ankle. **Conclusion:** We recommend arthroscopy for the management of MF as an intraoperative control tool for safer percutaneous fixation.

Keywords: Maisonneuve fracture; tibiofibular instability; syndesmotic injury; ankle arthroscopy; imaging evaluation.

Level of Evidence: IV

Asistencia artroscópica y fijación interna percutánea en fracturas de Maisonneuve. Evaluación por imágenes de los resultados

RESUMEN

Introducción: La fractura de Maisonneuve es una lesión caracterizada por la fractura subcapital del peroné asociada a una lesión capsuloligamentaria de tobillo. Su tratamiento supone la restauración de la anatomía ósea y capsuloligamentaria normal para restablecer las fuerzas de contacto tibioastragalinas fisiológicas. Esta calidad de reducción puede ser difícil de alcanzar, sobre todo, con técnicas percutáneas. **Objetivo:** Evaluar mediante imágenes la calidad de la reducción de fracturas de Maisonneuve reducidas en forma cerrada (bajo visualización directa artroscópica) y fijadas por vía percutánea. **Materiales y Métodos:** Se analizaron radiografías e imágenes de tomografía computarizada preoperatorias y posoperatorias, comparativas de los tobillos operado y sano. **Resultados:** Se evaluaron 13 fracturas. Los parámetros radiográficos posoperatorios (espacio claro medial, solapamiento tibioperoneo distal, espacio claro tibioperoneo) no registraron diferencias, excepto por el intervalo tibioperoneo anterior que aumentó en un caso. La medición tomográfica posoperatoria del solapamiento tibioperoneo distal y el intervalo tibioperoneo anterior reveló que todas las reducciones eran satisfactorias. Dos pacientes tenían valores alterados en la sindesmosis tibioperonea distal con diferencia >2 mm respecto del tobillo sano. **Conclusión:** Recomendamos la asistencia artroscópica para el manejo de la fractura de Maisonneuve como herramienta de control intraoperatorio para una fijación percutánea más segura.

Palabras clave: Fractura de Maisonneuve; inestabilidad tibioperonea; rotura sindesmal; artroscopia de tobillo; evaluación por imágenes.

Nivel de Evidencia: IV

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INTRODUCTION

In 1840, the French surgeon Jules Maisonneuve described an injury characterized by a subcapital fracture of the fibula associated with a distal tibiofibular syndesmosis (DTFS) injury and produced by a traumatic mechanism of external rotation.[1,2] Currently, the term Maisonneuve fracture (MF) is used ambiguously to refer to ankle injuries presenting a fibula fracture in its proximal third or fourth, associated with ankle capsuloligamentous involvement with joint displacement, produced by rotational forces.

MF requires the restoration of normal bone and capsuloligamentous anatomy. This ensures the restitution of physiologic tibiotalar contact forces, minimizing the risk of posttraumatic osteoarthritis.[3-12] Such anatomic reduction cannot be easily achieved given the complexity of the local anatomy and the low sensitivity of intraoperative fluoroscopy for detecting residual reduction defects.[13] It is known that fibular displacements of up to 6 mm in the sagittal plane are compatible with normal parameters (distal tibiofibular clear space [DTFCS], distal tibiofibular overlap) on the AP radiograph.[14] In a cadaveric study, it was demonstrated that there are no reliable radiographic parameters to assess the indemnity of the DTFS and its correct reduction, since reproducibility in the positioning of each ankle to be analyzed cannot be assured even under laboratory conditions. The technical difficulty in assessing the quality of reduction during surgery can be further interpreted if we consider that all reduction techniques, open or closed, have poor reduction rates of between 24% and 50%,[3,8,11,15,16] when assessed by computed tomography (CT). According to a recent article from a European Level 1 trauma center, 1.6% of all operated ankle fractures will require revision surgery due to failed osteosynthesis, with poor syndesmotic reduction being the leading cause (59%).[17]

Arthroscopic assistance in MF allows, in our opinion, to solve the technical difficulties of the condition. First, it enables a closed reduction of the DTFS under direct arthroscopic visualization; second, it allows the diagnosis and eventual treatment of chondral lesions, in general, associated with this type of lesions.

The objective of this study was to evaluate the reduction of DTFS in closed reduced MF (under direct arthroscopic visualization and percutaneously fixed) using imaging (correlating radiographs and CT).

MATERIALS AND METHODS

The inclusion criteria were: patients with Maisonneuve ankle fracture (fracture of the proximal third of the fibula associated with ligament injury at the DTFS and medial ligament injury or bony avulsion of the tibial malleolus), acute and subacute (less than 6 weeks of evolution), treated by reduction under direct arthroscopic visualization and percutaneous internal fixation.

Exclusion criteria were: patients with altered talocrural angle observed in the initial radiographs and that conditioned open reduction and internal fixation of the fibula, with previous degenerative ankle disease, history of hindfoot fracture in the treated or contralateral ankle, who refused to have a control postoperative CT scan, polytraumatized and with open fracture.

Surgical technique

The patient is placed in the supine position, under locoregional block and sedation. A hemostatic cuff inflated to 270 mmHg pressure is put on the inguinal region, and the glute homolateral to the injured limb is elevated. Conventional anterior arthroscopic portals are used and a systematic examination of the joint is carried out, evaluating ligamentous and chondral lesions and the presence of intra-articular free bodies. A 4 mm 30° Storz arthroscope is used for this purpose. After documenting the associated injuries, arthroscopic debridement of the DTFS and medial gutter is performed. The free bodies are removed, if applicable, and the synovitis is shaved, thus facilitating the correct visualization of the DTFS. The fibula is then reduced within the tibial notch under direct arthroscopic visualization. We consider that the reduction is adequate when the complete closure of the distal tibiofibular joint space is dynamically visualized by means of internal rotation and hindfoot inversion maneuvers. Secondly, the medial gutter is reduced, and the quality of the reduction in malleolar fractures and the complete closure of the articular space in pure ligament injuries are evaluated. We then proceed to the transitional fixation of the DTFS with a sharp-tipped clamp, followed by a second arthroscopic control to evaluate the preservation of the reduction in the DTFS (continuity of the articular cartilage of the anterior tibial lip with its corresponding one on the anterior aspect of the fibula) that could have been lost when closing the clamp (Figures 1 and 2).

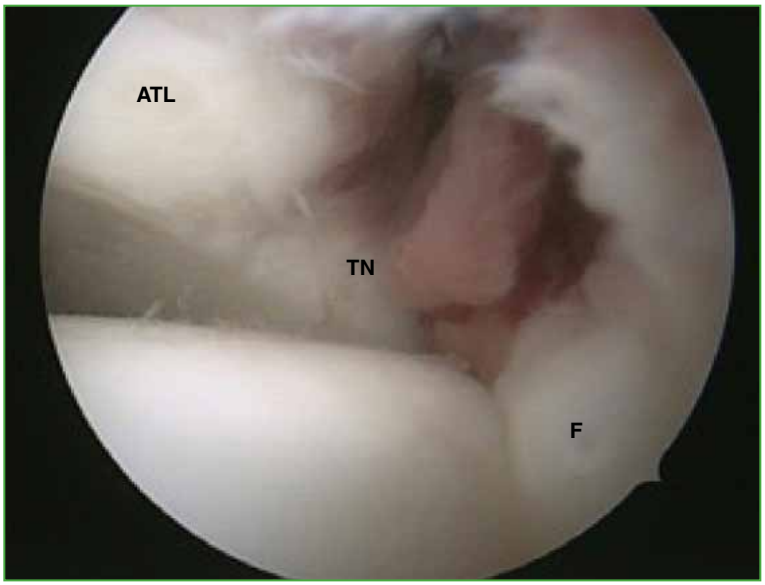

Figure 1. Open syndesmosis.
ATL = anterior tibia lip; TN = tibial notch; F = fibula.

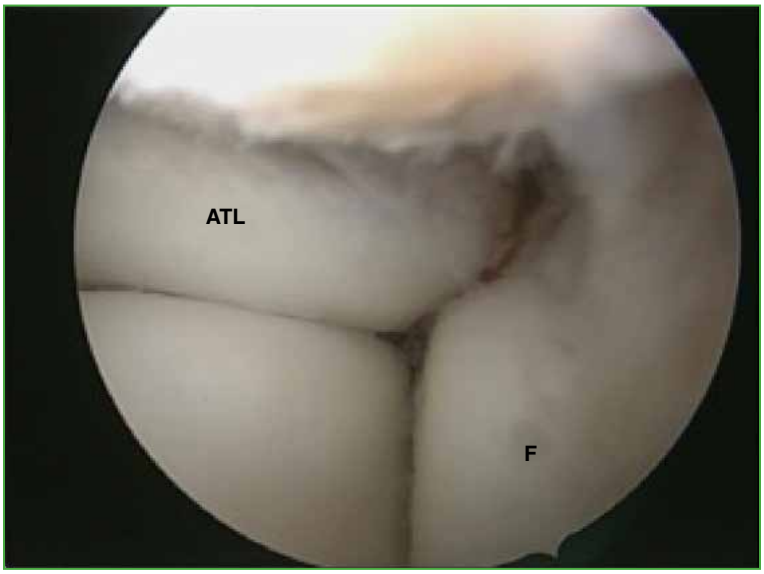

Figure 2. Closed syndesmosis.
ATL = anterior tibia lip; F = fibula.

Finally, percutaneous fixation is carried out with cannulated screws (cortical, fully threaded, 4 mm, proximal to the notch, number 1). Fluoroscopy is used to evaluate the quality of the reduction and osteosynthesis.

The patient is immobilized with a posterior plaster cast until healing (48-72 hours), after which the limb is transferred to an offloading walking boot for four weeks. At the beginning of the second week, the patient is instructed to remove the boot to perform ankle flexion-extension exercises. From the fourth week onwards, the walker boot is removed and partial weight-bearing (30%) begins until the implants are removed in the twelfth week.

Radiographic evaluation

For this study, preoperative (non-weight-bearing) and long-term postoperative comparative radiographs of the operated ankle and the healthy contralateral (weight-bearing) ankle were obtained during control. On AP radiographs, the following parameters were evaluated: medial clear space (MCS) (the distance from the lateral edge of the medial malleolus to the medial edge of the talus, measured at the level of the talar dome), DTFCS (the distance between the lateral edge of the posterior tibial tubercle and the medial edge of the fibula, measured 1 cm proximal to the tibial plafond), and tibiofibular overlap (overlap of the fibula with the anterior tubercle of the tibia, measured 1 cm proximal to the plafond). The reduction was considered satisfactory if the difference between the operated ankle and the healthy ankle did not exceed plus or minus 2 mm for any of the aforementioned parameters.

A medial injury was considered to be present if, on initial radiographs, an MCS >4 mm or a fracture of the tibial malleolus was observed. The talocrural angle was also evaluated as a measure of fibula shortening, which was considered abnormal if it differed by more than 2° with respect to the non-operated ankle.

In the lateral radiographs, the anterior tibiofibular interval (ATFI) (distance between the anterior border of the tibia and the anterior border of the fibula) was evaluated. The contralateral healthy ankle was taken as the normal reference value. The reduction was considered satisfactory if the difference between the operated ankle and the healthy ankle did not exceed 2 mm for the aforementioned parameter.

The original full leg radiographs were examined, as well as the characteristics of the proximal fibula fracture, such as if it affected the fibular head, if it was a high subcapital fracture, a low subcapital fracture, or if it was comminuted.

Tomographic evaluation

Preoperative CT images of the injured side and postoperative comparative CT images of both ankles taken in the control were evaluated for this study. Standardized cuts parallel to the tibial plafond in neutral position were used. The vertical axis of the tibia and the horizontal axis of the tibial plafond were used to confirm such parallelism, and the neutral position was defined as the bimalleolar axis, a line tangential to the anterior process of the medial and lateral malleolus. The axial section performed 10 mm proximal to the tibial plafond was evaluated in all cases. Axial tibiofibular relationships and measurements were analogous to those evaluated on plain radiographs. The distal tibiofibular joint was evaluated by seven measurements (Figure 3): A) the distance between the most anterior point of the notch, and the closest and most anterior point of the fibula; B) the distance between the tibia and the fibula at the middle of the notch; C) the distance between the most posterior point of the notch, and the closest and most posterior point of the fibula; D) the DTFCS defined as the distance between the medial edge of the fibula and the tip of the lateral edge of the posterolateral tibial tubercle; E) the DTFS defined as the maximum overlap between the anterolateral tibia and the medial fibula measured in mm; F) the ATFI, defined as the distance between the anterior edge of the tibia and the anterior edge of the fibula; G) the angle of rotation: angle between a line join-

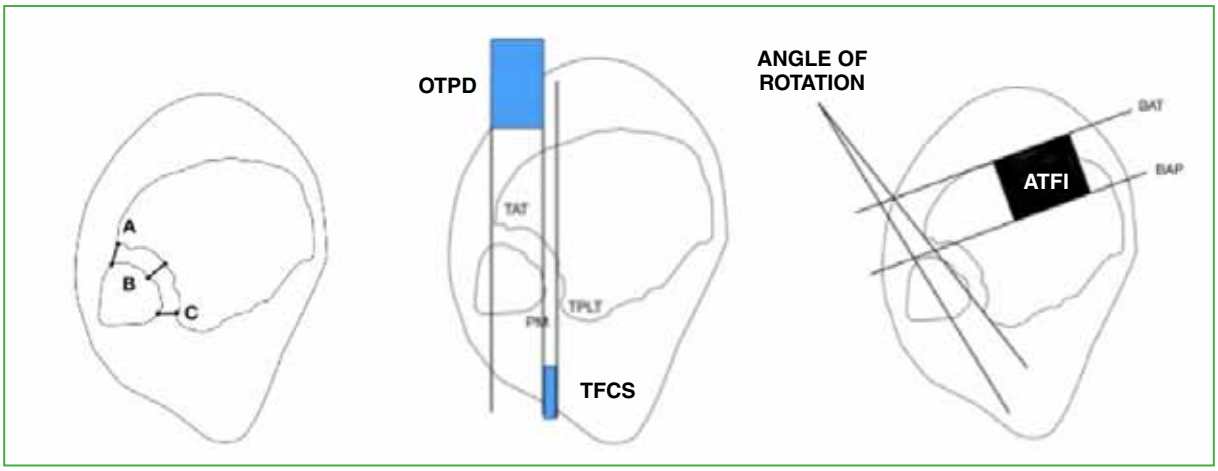

Figure 3. Evaluation of the distal tibiofibular joint using seven measurements.
DTFCS = distal tibiofibular clear space; DTFS = distal tibiofibular syndesmosis; ATFI = anterior tibiofibular interval. ATT = anterior tibial tuberosity; MF = medial edge of the fibula; PLTT = posterolateral tibial tubercle; AT = anterior edge of the tibia; AF = anterior edge of the fibula.

ing the anterior and posterior point of the notch and another line joining the anterior and posterior tubercle of the fibula. The measurements taken on the contralateral healthy ankle were taken as the normal reference value. The reduction was considered satisfactory if the discrepancy between the operated ankle and the healthy ankle was no more (open DTFS) or less (closed DTFS) than 2 mm.

All radiographic and tomographic measurements were performed independently by two senior physicians from the Imaging Department. For this, they were asked to evaluate CT scans and radiographs of both ankles and upload the results blindly, in a spreadsheet.

RESULTS

Between May 2013 and January 2019, 16 fractures were treated in 16 patients, 13 met the inclusion criteria. The mean postoperative follow-up was 31 months (range 14-84). The sample included 12 men and one woman, with a mean age of 39.1 years (range 18-69). The affected side was the right in seven patients, and the left in six. All reported external rotation trauma with the foot fixed to the ground, nine suffered the fracture during sports practice. Twelve medial injuries were recorded, 10 of them ligament injuries (76.9%), two tibial malleolus fractures (15.38%), one patient (7.69%) had no medial injury. Eight (61.5%) had posterior malleolus involvement, it was not fixed in any case. The proximal fibula fracture was classified as high subcapital in five cases (38.4%), low subcapital in five (38.4%), comminuted subcapital in two (15.3%), and capital in one (7.6%). For internal fixation, two 4-mm fully threaded quadricortical screws were used in 10 cases (76.9%) and one 4-mm fully threaded quadricortical screw in three cases (23.1%). Screw breakage was recorded in two patients. In one case, it was a single screw and, in the remaining case, it was one of two screws (Table 1).

Radiographic outcomes

There were no differences in MCS, DTFCS or DTFS with respect to the healthy side. The ATFI increased in one case and the talocrural angle decreased in one patient (Table 1).

Table 1. Radiographic outcomes

Evaluator 1					Evaluator 2				
	MCS	DTFCS	DTFS	ATFI		MCS	DTFCS	DTFS	ATFI
Patient 1	0.1 mm	1.7 mm	-0.3 mm	0.2 mm	Patient 1	-0.1 mm	0.6 mm	-0.1 mm	0.9 mm
Patient 2	0.9 mm	-0.9 mm	-0.4 mm	-1.5 mm	Patient 2	0 mm	0.1 mm	0.7 mm	0 mm
Patient 3	0.3 mm	0.6 mm	-1 mm	-0.3 mm	Patient 3	0.1 mm	0.4 mm	-1.7 mm	1.7 mm
Patient 4	0.2 mm	0.5 mm	-0.6 mm	0.4 mm	Patient 4	0 mm	0.1 mm	-0.4 mm	0 mm
Patient 5	0 mm	0.1 mm	0.9 mm	1.6 mm	Patient 5	-0.1 mm	0.4 mm	0 mm	0.4 mm
Patient 6	0.1 mm	1.7 mm	0 mm	2.5 mm	Patient 6	-0.2 mm	-0.8 mm	0.4 mm	2.5 mm
Patient 7	0.2 mm	0.7 mm	-0.2 mm	-1.5 mm	Patient 7	0.1 mm	-1 mm	0.8 mm	-1 mm
Patient 8	0.2 mm	0.5 mm	-0.5 mm	-0.2 mm	Patient 8	0.1 mm	0.6 mm	0 mm	-0.5 mm
Patient 9	0 mm	0.2 mm	-1.7 mm	1.5 mm	Patient 9	-0.1 mm	-0.7 mm	-1.2 mm	1.5 mm
Patient 10	0.9 mm	-1 mm	-0.1 mm	1.6 mm	Patient 10	0 mm	-1 mm	0 mm	1.8 mm
Patient 11	0.3 mm	0.3 mm	-1 mm	0.6 mm	Patient 11	0 mm	0.9 mm	0 mm	1.6 mm
Patient 12	0.4 mm	0.1 mm	-0.5 mm	0 mm	Patient 12	0.4 mm	0.3 mm	-0.2 mm	0.2 mm
Patient 13	0.1 mm	1.8 mm	0.6 mm	1 mm	Patient 13	0 mm	0.6 mm	1 mm	1.5 mm

MCS = medial clear space; DTFCS = distal tibiofibular clear space; DTFS = distal tibiofibular syndesmosis; ATFI = anterior tibiofibular interval.

Tomographic outcomes

Preoperative tomographic evaluation showed deviations of up to 4 mm in ATFI, 3 mm in DTFCS, and DTFS, 4.7º in rotation angle and 4 mm in A and B measurements. No abnormal values were recorded in the measurement of C. Postoperative tomographic measurement of DTFCS and ATFI revealed that all reductions were satisfactory. Two patients had DTFS values with a difference >2 mm from the contralateral healthy ankle, the maximum difference was 3 mm. Three patients (23.1%) with an abnormal preoperative A value continued with altered measurements. One had a difference of 2 mm in B on the preoperative CT and a postoperative B value of 3 mm. Regarding the comparative angle measurement, the angle had increased in three patients in the postoperative controls (Table 2).

Table 2. Tomographic outcomes

Evaluator 1

	ATFI	DTFCS	DTFS	Rotation angle	Anterior	Medial	Posterior
Patient 1	- 2 mm	0 mm	-2 mm	-0.5°	2 mm	1 mm	-1 mm
Patient 2	1 mm	2 mm	0 mm	3°	4 mm	2 mm	2 mm
Patient 3	0 mm	2 mm	-1 mm	0.4°	0 mm	2 mm	1 mm
Patient 4	1 mm	3 mm	-3 mm	-0.8°	3 mm	1 mm	0 mm
Patient 5	1 mm	-1 mm	- 1.5 mm	2°	1.4 mm	0 mm	-1 mm
Patient 6	4 mm	0 mm	0 mm	4.7°	4 mm	1 mm	0 mm
Patient 7	- 2 mm	- 2 mm	0 mm	0.1°	2 mm	1 mm	1 mm
Patient 8	2 mm	0 mm	2 mm	-0.1°	-1 mm	-1 mm	0 mm
Patient 9	0 mm	0 mm	2 mm	1.4°	0 mm	1 mm	-1 mm
Patient 10	1 mm	-2 mm	0 mm	-1.3°	0 mm	1 mm	-2 mm
Patient 11	2 mm	0.5 mm	1 mm	2°	1.6 mm	-0.5 mm	-1 mm
Patient 12	0 mm	1 mm	-2 mm	-1°	1 mm	0 mm	1 mm
Patient 13	1 mm	0 mm	0 mm	0°	1 mm	0 mm	2 mm

Evaluator 2

	ATFI	DTFCS	DTFS	Rotation angle	Anterior	Medial	Posterior
Patient 1	-2 mm	-1.8 mm	-2 mm	-0.27°	2 mm	1 mm	-1 mm
Patient 2	2 mm	2 mm	2 mm	-0.1°	5 mm	3 mm	1 mm
Patient 3	1 mm	-1 mm	0 mm	1.25°	2 mm	1 mm	0 mm
Patient 4	0.7 mm	-0.5 mm	-2.5 mm	-1°	2.3 mm	1.3 mm	0 mm
Patient 5	2 mm	-0.5 mm	1.5 mm	0.1°	2 mm	0.2 mm	-1.5 mm
Patient 6	2 mm	0 mm	-3 mm	-2°	5 mm	1 mm	0 mm
Patient 7	0 mm	0 mm	-1 mm	0°	1 mm	0 mm	0 mm
Patient 8	1 mm	0 mm	2 mm	0°	-1 mm	0 mm	0 mm
Patient 9	0 mm	0 mm	0 mm	1°	1 mm	0 mm	-1 mm
Patient 10	0 mm	0 mm	0 mm	-0.3°	-1 mm	0 mm	0 mm
Patient 11	0 mm	0 mm	0 mm	0°	1 mm	0 mm	0 mm
Patient 12	0 mm	1 mm	-2 mm	-0.5°	1 mm	0 mm	0 mm
Patient 13	0 mm	1 mm	-1 mm	0.5°	1 mm	1 mm	2 mm

ATFI = anterior tibiofibular interval; DTFCS = distal tibiofibular clear space; DTFS = distal tibiofibular syndesmosis.

DISCUSSION

We use the term MF ambiguously to refer to fractures of the proximal third or fourth of the fibula associated with capsuloligamentous involvement of the ankle, produced by external rotation trauma. The classic conception of this injury is that the position of the rearfoot in pronation would initially affect the medial structures (fracture by avulsion of the tibial malleolus or involvement of the superficial and deep bundles of the deltoid ligament); and that the force acting in external rotation would produce ligament injury in the DTFS and injury to the interosseous membrane that should extend to the fracture line.[2] However, publications that have attempted to corroborate this pathophysiology are inconclusive.[3,18-20] One of the controversial points is the level of involvement of the interosseous membrane. Several studies have analyzed this structure using magnetic resonance imaging. Nielson et al.[13] demonstrated that the height of the fibula fracture does not necessarily correlate with the level of the interosseous membrane tear. Manyi et al.[14] studied 12 patients, and found a membrane lesion in all, but in no case more proximal than 112 mm from the joint line. Morris et al. found the lesion in only four of the five patients evaluated by magnetic resonance imaging.[19]

Bartoníček et al. published the largest series of this condition and redescribed the fracture based on imaging analysis and intraoperative findings in 54 patients. They found that only the distal anterior tibiofibular ligament and the interosseous ligament were constant lesions, that the interosseous membrane was almost always affected, but only in its distal third and exceptionally the lesion reached the level of the fracture line, and that up to 80% of the patients had a fracture of the posterior malleolus. Regarding the specific medial injury, they recorded 50% ligament injuries, 37% tibial malleolus fractures and, in 13.6% (7 cases), no medial injuries were detected. In our series, the most frequent medial injury was ligamentous and represented 76.9% of the cases, there were 15.3% of malleolar fractures and a medial injury in one case. The absence of medial injuries recorded in both series cannot explain pronation and external rotation as the mechanisms of injury. According to Bartoníček et al.,[15]MFs could be produced both by a pronation and external rotation mechanism and by one in supination and external rotation. In the first case, the medial lesion is a constant and represents the initial point of injury according to the classic Lauge-Hansen interpretation for these lesions. For cases without medial injury, Bartoníček et al. considered that they could be the consequence of supination and external rotation trauma that had not reached the final stage of medial injury, but had affected the anterior and posterior DTFS.

Regarding gender distribution, our sample included 12 males and one female. Sproule et al. also reported this higher incidence in the male sex (12 males, 2 females).[20] However, this finding is significant given that the rest of the published series report a similar sex distribution.[7,18,20]

To treat MFs, normal bone and capsuloligamentous anatomy must be restored, as well as physiological tibiotalar contact forces, to reduce the possibility of post-traumatic osteoarthritis.[3-9] It is difficult to evaluate the reduction's correctness intraoperatively. A cadaveric study demonstrated that there are no reliable radiographic parameters to assess the indemnity of the DTFS, because even in laboratory conditions, reproducibility in the positioning of the ankle to be analyzed cannot be assured.[5] It is also known that fibular displacements of up to 6 mm in the sagittal plane are compatible with normal parameters in the anteroposterior radiograph.[13] Finally, rotation of the fibula within the notch is even more difficult to evaluate with radiographs, because it is a two-plane deformity and radiographs can only evaluate uniplanar displacements. Arthroscopy is then proposed as a solution to the problem. Takao et al. compared the sensitivity of radiography and arthroscopy in diagnosing syndesmosis injuries in 52 treated patients. In comparison to arthroscopy, the sensitivity and specificity for anteroposterior radiographs were 44.1% and 100%, respectively, and 58.3% and 100% for the mortise view; thus, they concluded that arthroscopic examination of syndesmotic reduction should be a standard procedure.[21]

The syndesmotic radiographic parameters were normal in 12 of our patients. The remaining case presented an increased ATFI. This was a patient with a posterior malleolus fracture that had not been fixed, which facilitated displacement of the fibula in the sagittal plane. The talocrural angle was altered in one case. This patient had a shortening of the fibula visible on AP radiographs, but the syndesmotic parameters measured by radiography and CT were normal. Consequently, we consider that radiographic assessment of the talocrural angle should never be omitted, nor can it be replaced by tomographic evaluation.

In an ankle fracture, the fibula may shorten or rotate on itself, or shift coronally, rotationally or sagittally within the notch. Therefore, the exact assessment of syndesmotic reduction cannot be determined with two-dimensional

studies and CT appears as the logical solution. Again, there is no consensus on what to measure in CT, or how to measure it. We took these seven tomographic parameters as sufficient to evaluate a poor reduction with all its possible displacements. Also noteworthy is the considerable interindividual variation in DTFS morphology[22,23] as well as the minimal differences between the two ankles of an individual.[13] Therefore, the contralateral uninjured ankle should be the parameter of normality when we analyze the outcomes.[24] In our sample, there were three cases with poor CT-assessed outcomes, all associated with a fracture of the posterior malleolus. In one, the posterior malleolus fracture (Rammelt type 2) consolidated in an elevated way and displaced medially, generating a posterior displacement of the fibula in the sagittal plane, associated with external rotation and coronal translation with widening of the syndesmosis (Figure 4).

The second patient also had a type 2 posterior malleolus fracture, but without displacement. In this case, the posterior malleolus consolidated anatomically, but the fibula remained in external rotation and displaced in the coronal plane (Figure 5).

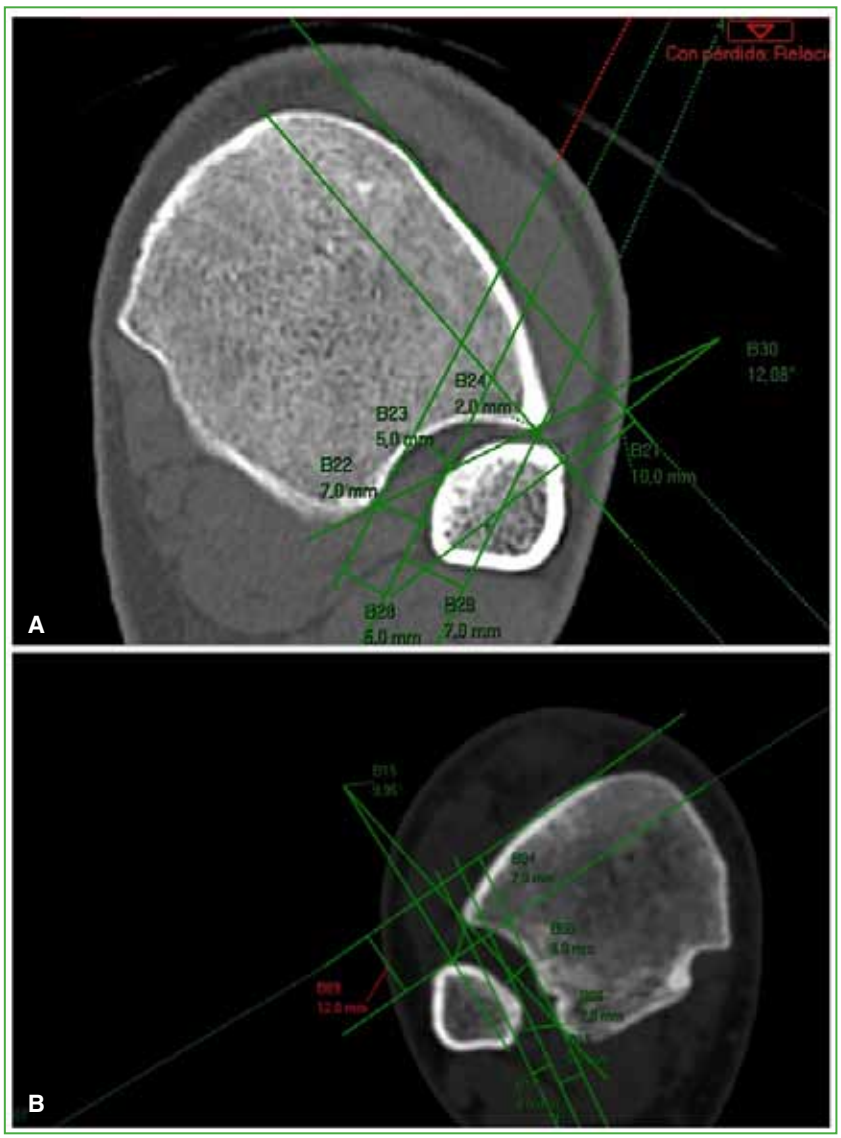

Figure 4. A. Normal parameters in the contralateral healthy ankle. **B.** Morphological alteration in the tibial notch due to malunion of the posterior malleolus associated with a posterior, lateral and externally rotated translation of the fibula.

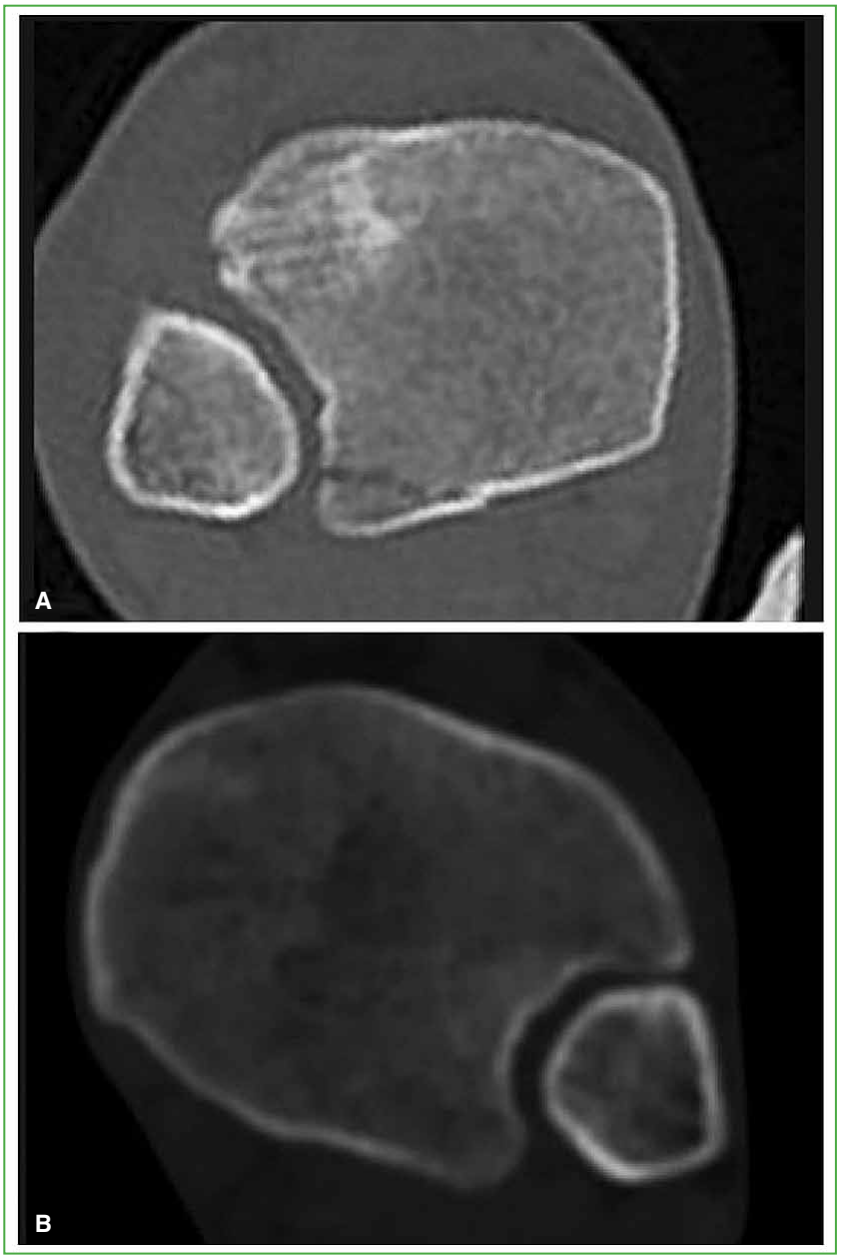

Figure 5. **A.** Poor reduction in external rotation of the fibula. **B.** Healthy contralateral ankle.

The third malreduction was associated with a type 1 posterior malleolus fracture and the abnormal displacement occurred in the coronal plane, without a rotational deficit in the fibula. Only the first patient had poor clinical evolution; in the other two, the unsatisfactory reduction had no functional implications.

It is striking that two of the three poor reductions record an externally rotated fibula within the notch. Anterior arthroscopic visualization of the syndesmosis should avoid the problem. Several publications have warned about the effect that the depth and version of the notch can have on correct syndesmotic reduction.[14,17,22] Cherney et al. were able to establish a relationship between the depth of the notch and reduction defects in external rotation and posterior translation of the fibula.[23] The authors consider that, when placing a reduction clamp and closing the syndesmosis, the patient's anatomy could predispose to a poor coronal or rotational reduction. If the patient has a flat

notch, the pressure exerted by the forceps will produce an anterior or posterior translation of the fibula. In turn, in a deep notch, the prominent anterior and posterior tibial tuberosities do not allow anterior translation of the fibula. In this case, the force exerted by the clamp will produce a posterior or rotational displacement. Ideally, the force exerted by the clamp should be perpendicular to the axis of the tibial notch, thus limiting the rotation and lateral translation that could be generated by the clamp when closing.

In our study, the rate of poor results was 23% (assessed by CT), close to the values obtained with open reductions and far from the high rates of poor reductions (assessed by CT) of percutaneous techniques. Miller et al.[24] compared the results obtained in 25 patients treated with percutaneous reduction with those of 149 patients treated prospectively but with an open reduction protocol using a posterolateral approach and subsequent fixation of the syndesmosis. In the direct visualization group, the rate of poor outcomes was 16% compared to 52% in the percutaneous technique group, all evaluated by CT. In a similar study, Pelton et al.[25] recorded a statistically significant difference when treating fractures with an open reduction. The authors concluded that percutaneous reduction has unacceptably poor reduction rates, so they discontinued its use. Furthermore, they caution that the requirement for a second approach at the syndesmotic level or to prolong the one employed for fibula reduction and fixation increases the procedure's risk of complications.

CONCLUSIONS

Arthroscopic assistance for the treatment of MFs has allowed us to obtain reasonably low rates of poor reductions, as measured by CT. The low sensitivity of radiographs to measure reduction deficits during surgery, as well as the lack of a CT scanner in our setting, make arthroscopy a vital tool for the treatment of this condition. We recommend arthroscopic assistance for safer percutaneous fixation and because it provides the same favorable outcomes with fewer complications.

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

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Tibial Stress Fractures and Associated Diseases in Military Recruits

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ABSTRACT

Introduction: Tibial stress fractures are a very common condition in military recruits. Our objective is to demonstrate that stress fractures are associated with other diseases. **Materials and Methods:** 42 stress fractures in 34 patients were retrospectively evaluated. Every patient had recently joined the Argentine Army and consulted for painful symptoms in the tibia. A clinical and scintigraphic diagnosis of stress fracture was made. Patient data, associated diseases, and risk factors were documented. Inclusion criteria: recent incorporation, same training, age between 16 and 23 years. Trauma, simulators, tumoral pathology, and cases with negative scintigraphy were excluded. **Results:** We studied 42 stress fractures in 34 patients, 14 were men and 20 were women. The average age was 20 years. There were no significant differences in the number of injuries regarding the affected limb. 64.7% had associated diseases, 73% in women and 27 % in men. Among the women with stress fractures, 80% had associated diseases, compared to 43% for men. Different diseases were found with lower limb varus and valgus imbalances. Varus was the most associated with fractures. **Conclusions:** A high rate of associated diseases was found in patients with tibial stress fractures with a predominance of lower limb varus imbalances. Associated diseases were more likely to be found in women with stress fractures than in men.

Keywords: Stress fractures; associated pathology; tibia; recruits.

Level of Evidence: IV

Fracturas de tibia por estrés y enfermedades asociadas en reclutas

RESUMEN

Introducción: Las fracturas de tibia por estrés son un cuadro muy frecuente en el personal militar recién incorporado. Nuestro objetivo fue demostrar que existe una asociación entre fracturas por estrés y otras enfermedades. **Materiales y Métodos:** Se evaluaron retrospectivamente 42 fracturas por estrés en 34 pacientes, entre noviembre de 2012 y septiembre de 2014. Todos se habían incorporado recientemente al Ejército Argentino y consultaron por cuadros dolorosos en la tibia. Se realizó el diagnóstico clínico y centellográfico de fractura por estrés. Se documentaron datos filiatorios, cuadros asociados y factores de riesgo. Los criterios de inclusión fueron: reciente incorporación, mismo entrenamiento, edad 16-23 años. Se excluyó a pacientes con traumatismos, cuadro tumoral o centellograma negativo, y a los simuladores. **Resultados:** Se evaluaron 42 fracturas por estrés en 34 pacientes (14 hombres y 20 mujeres). La edad promedio era de 20 años. No hubo diferencias significativas en el número de lesiones respecto al miembro afectado. El 64,7% tenía enfermedades asociadas (mujeres 73%, hombres 27%). El 80% de las mujeres y el 43% de los varones tenían un cuadro asociado. Se hallaron diversos cuadros con desejes de miembros inferiores en varo y en valgo, los primeros fueron los que más se asociaron con fracturas. **Conclusiones:** La tasa de asociación con enfermedades en los miembros inferiores fue alta, con predominio de los desejes en varo. Las mujeres con fracturas por estrés tenían más cuadros asociados que los hombres.

Palabras clave: Fracturas por estrés; enfermedad asociada; tibia; reclutas.

Nivel de Evidencia: IV

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INTRODUCTION

In the military setting, tibial stress fractures are a frequent entity and have a high incidence in newly recruited personnel[1] subjected to intense training and psychophysical demands. The aim of this study was to demonstrate that patients with stress fractures have associated diseases.

MATERIALS AND METHODS

A total of 42 stress fractures in 34 patients were retrospectively evaluated between November 2012 and September 2014. All of them were recent Argentine Army NCO Academy cadets with up to a year of service who sought treatment for medial tibial pain. Stress fractures were diagnosed clinically and by scintigraphy. An Excel spreadsheet was created with all of the personal data, including age, gender, laterality, associated conditions, sleep deprivation, irregular menstrual cycles, body mass index (BMI), appropriate or inappropriate footwear, terrain on which they ran, and type of training. Shoes that were hard, non-cushioned, flat or broken were defined as inappropriate.

Palpatory discomfort in the anterointernal region of the tibial diaphysis in various patterns, such as vertical, focused on or transverse, was utilized to raise clinical suspicion.

The incidence of associated diseases was compared with that of recruits without fractures. The sample was ethnically heterogeneous.

The inclusion criteria were a maximum of one year of service in the Force, the completion of the same training, and an age range of 16 to 23 years old.

Those who reported any form of trauma, as well as those suspected of simulation, tumor disease, or negative scintigraphy for stress fractures, were excluded.

RESULTS

The 42 stress fractures studied corresponded to 34 patients (14 men and 20 women), with an average age of 20 years. Eight were bilateral stress fractures. Twenty injuries were right and twenty-two were left.

There were no significant differences in the number of injuries with respect to the affected limb.

Of the patients with stress fractures, 64.7% had an associated disease (16 women and 6 men). 80% of women and 43% of men with stress fractures had a concomitant condition.

The diseases associated with stress fractures were, in order of frequency: cavovarus foot (7 cases), pes planovalgus (5 cases), rearfoot varus (1 case), plantar fasciitis (1 case), tibia vara (1 case), tibia vara associated with extreme thinness and facial malformations (1 case), cavovarus foot associated with tibia vara (1 case), cavovarus foot with genu valgum and short stature (1 case), external tibial torsion (1 case), short stature (1 case), hindfoot valgus (1 case) and pes cavus plus brachymetatarsia (1 case) (Figure 1).

Fourteen patients had cavovarus feet and sixteen had varus deformities in the lower limbs (Figure 2).

BMI was normal in 60% of the cases and low in 30%. 29% wore inappropriate footwear.

Only one patient reported irregular menstrual cycles since joining the Army.

The clinical findings were characterized by referred pain in the anterointernal aspect of the tibial diaphysis, which manifested in different patterns on palpation, whether vertical, centered or not on the medial border of the tibia, transverse, combined, or localized, the latter referred to as “fingertip”. All had slender legs with moderate muscle mass.

Initial radiographic findings were positive in only two patients with periosteal reactions, while scintigraphy was positive in all cases.

In the control group, without stress fractures, no associated diseases were detected.

DISCUSSION

Stress fractures are defined as fractures resulting from repetitive and sustained stress over time that exceeds the physiological capacity for adaptation and bone remodeling.[1] They are a known entity with several statistics that are difficult to compare since they allude to the patients’ military training but do not clarify what it entails or provide key parameters such as frequency and intensity. There is also no consensus regarding treatment.

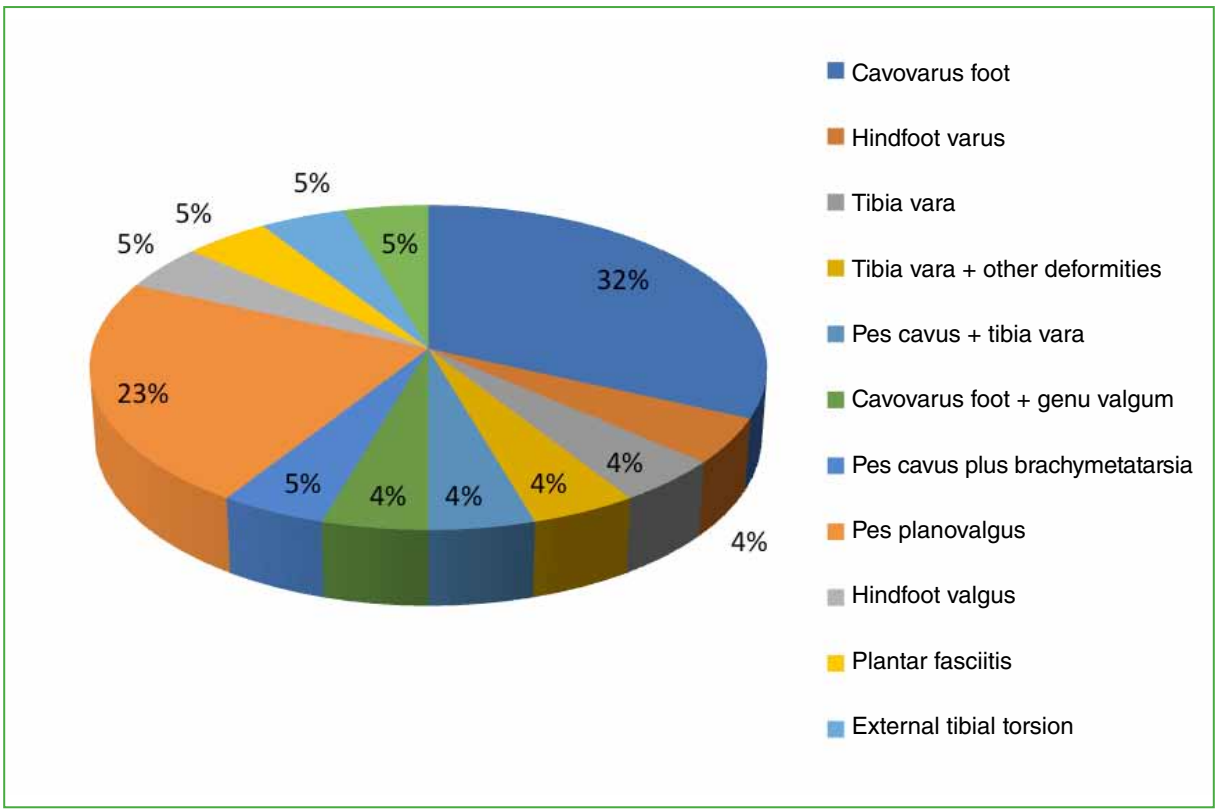

Figure 1. Associated diseases.

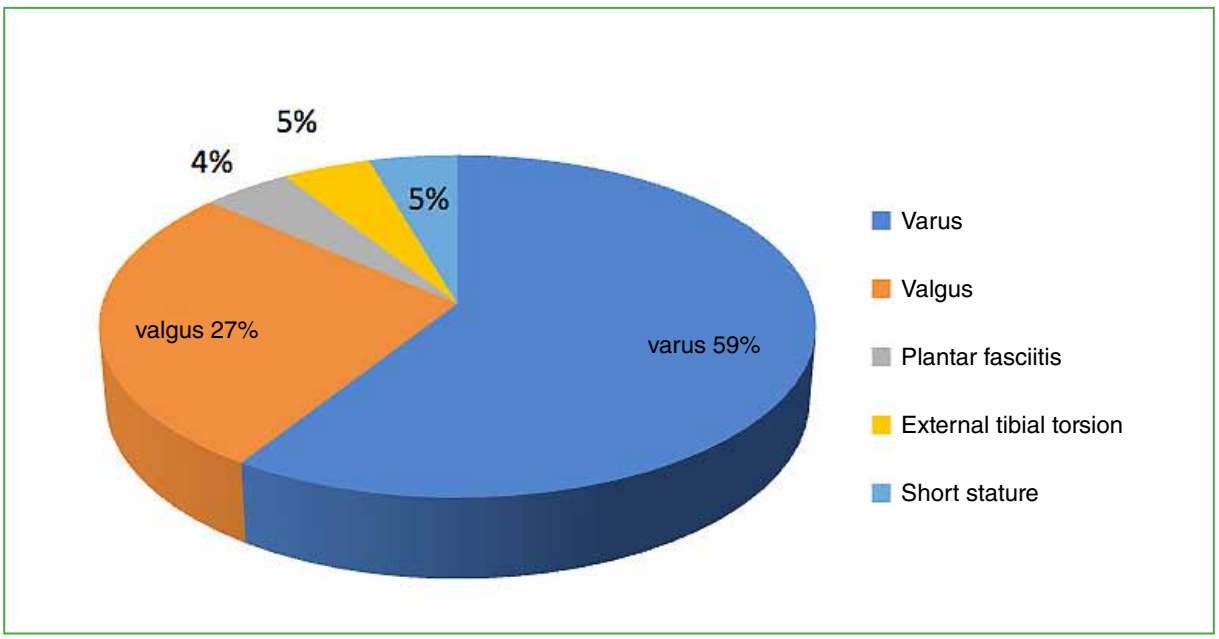

Figure 2. Associated diseases, grouped according to whether they present varus or valgus misalignment, or other components.

According to Devas, there are two types: compression and distraction;[2] however, we must distinguish between stress microfracture and macrofracture.

The clinical presentation is characterized by pain focused on the anterointernal aspect of the tibia,[3] but it may not be clear and it is necessary to know the epidemiology and risk factors of the patient in order not to confuse this condition with others with a similar presentation, such as periostitis and chronic compartment syndrome, which are the main differential diagnoses.[4]

Regarding epidemiology, all authors point out a predominance in recruits, a term that includes personnel recently incorporated into the Armed Forces, who begin a period of military instruction, with intense training and psychophysical demands. The reported incidence of stress fractures in this risk group is 31% (80% in the tibia) and 60% of concomitant asymptomatic contralateral asymptomatic fractures.[5]

There is a clear prevalence of the female sex (2:1),[6] and the findings of our series coincide with this data. This condition is more frequent in military women than in civilians,[6] the prevalence is higher and they suffer a more severe condition, with the same training as men, even in military units with low physical demands.[7]

Regardless of sex, the incidence is higher in patients with thinner tibial cortices[8] or low muscle mass,[8,9] the latter was a generalized finding in our sample.

Regarding ethnicity, in studies conducted in the American and Israeli armies, the incidence was higher in white patients.[10,11] In our series, this comparison was not possible given the ethnic heterogeneity of the sample.

One problem in comparing the results of the studies is that they all refer to military training without detailing it.

Associated diseases is not addressed as a main topic by any published study, but as one of the risk factors,[1] which are multiple and can be classified according to:

- Type of training: they can be found in both civilian and military settings, with the latter being the most relevant predictor.

- Patient characteristics: among the characteristics predisposing to stress fractures, female sex, as already mentioned, is a very important risk factor reported in the literature, which is consistent with the findings of our study. It may be aggravated in women with hormonal disorders and irregular cycles, but there is no evidence that hormonal treatment improves the condition.[6] The triad of eating disorders, menstrual alterations and low bone density is an important predictor of stress fractures in women, increasing the risk by 30-50%.[12] In our series, we were unable to identify patients with disorders of this type, only one reported irregular cycles.

- Dietary factors: in military recruits, the diet is not always sufficient to meet the high metabolic requirements, it is usually rich in carbohydrates and fats, and low in protein.[13] It has been published that low vitamin D intake is a risk factor in the military[13] and civilian populations.[14] Because our research was retrospective, we were unable to conduct hormonal testing or assess the participants' food intake throughout the study period.

- Technical aspects of running: although the technique used for running is beyond the scope of our study, we believe it is important to mention that several authors have evaluated the incidence of technical issues in running and reported that the gait or running pattern is a modifiable risk factor. Those who impact with the heel during running have a higher risk than those who impact with the forefoot.[15]

Not having trained or played sports prior to joining the Force would not raise the likelihood of stress fracture;[16] however, abrupt onset, intensity, and lack of progression might. The remaining risk factors are hard flat footwear without cushioning, such as flat-soled shoes and sneakers, a finding in 29% of patients.

- Associated pathologies: although there is a significant amount of published research on stress fractures in recruits, we were unable to find any studies that focused on associated conditions as the primary topic. In our series, the percentage of patients with stress fractures and associated disease in the lower limbs was high (64.7%), especially in the lower limbs with varus misalignments (Figure 2).

Short stature, progressive weight loss during training and decreased tibial mineral mass in such patients constitute other risk factors.[17] Low muscle mass in the lower limbs was a frequent finding in our series.

Yagi et al.[18] conducted a prospective study in runners, and identified high BMI in women and increased internal rotation of the hip as risk factors. In our series, the impact of high BMI on the incidence of this disease could not be evaluated, because all had a normal or low BMI. Nunns et al.[19] evaluated a large series of Royal Marines, and identified four risk factors predictive of stress fractures, such as lower BMI, smaller bimalleolar width, greater peak heel pressure, and a lower range of tibial rotation during running, but they did not refer to conditions such as those found in our series.

The same is true of many other studies conducted on military personnel, possibly due to the exclusion of personnel with orthopedic conditions.

Hetstroni et al.[20] described foot supination and the protective role of pronation in gait, without mentioning varus as a risk factor; they also indicated that valgus during running is protective against stress fractures.

Other authors, such as Hadid et al.[21] observed that a slender tibia and muscle fatigue in the legs generated greater pressure on the anteromedial cortex of the tibia.

Imaging studies

Radiographs are negative in the early stages, thus if a stress fracture is suspected, scintigraphy or magnetic resonance imaging should be sought to visualize edema in the periosteum, bone, and even fracture lines.[6,22]

Several authors report that the best diagnostic method is Tc-99m scintigraphy,[6,23] a highly sensitive study, but which does not allow the exact site of the fracture to be observed.

Milgrom et al. suggested that, even with positive radiographs, a scintigraphy should be performed, because it may reveal asymptomatic fractures,[5] as was observed in our series.

Among the strengths of our study, we can mention the strict selection and study of the sample and the association of the disease with other comorbidities and not only the running technique or the type of footwear or terrain.

Weaknesses include the retrospective nature of the study, which prevented evaluations of running technique, food intake, and hormone levels.

CONCLUSIONS

Stress fractures are more common in the military population than in the civilian population.

New recruits are more likely to sustain stress fractures.

In the sample studied, a high rate of association with lower limb diseases was found, with a predominance of varus disorders over other conditions.

The rate of associated disease was higher in the female population with stress fractures than in the male population.

We believe that the physical examination of patients with suspected stress fractures should include screening for associated conditions and evaluating therapeutic measures to prevent recurrence.

Conflict of interest: None of the authors have any conflict of interest.

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Dermatotraction: A Retrospective Study on its Effectiveness in the Closure of Soft Tissue Leg Defects

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ABSTRACT

Introduction: Viscoelasticity is a distinctive characteristic of the human skin. A constant force pulling on the skin and subcutaneous tissue allows it to cover exposed areas in relatively short periods of time. The objective of this study is to analyze a series of cases with soft tissue leg defects where integumentary closure was accomplished with a skin stretching technique using 'traction bands' in order to determine which injuries can benefit from this treatment. **Materials and Methods:** This is a retrospective, descriptive, longitudinal study carried out in the period between 2012 and 2019. The inclusion criteria for this study were: 1) wounds with a soft-tissue coverage deficit in the leg of diverse traumatic etiology (surgical wound dehiscence, fasciotomies due to compartment syndrome, open fractures, and open wounds with soft tissue deficit). **Results:** 36 patients (mean age: 28 years) with injuries with loss of coverage in different regions of the leg were analyzed. Closure was achieved in 27 patients (75%), without the need for additional procedures. In three patients (8.3%), the exposed area was reduced, requiring skin grafting as a complementary procedure. Six patients required myocutaneous and fasciocutaneous soft tissue reconstructive procedures. **Conclusions:** This technique is effective, simple, and economical for closing complex wounds and/or fasciotomies. Dermatotraction allows closure a few days after the trauma.

Keywords: Coverage defect; open wound; traction bands; viscoelasticity; integumentary closure.

Level of Evidence: IV

Dermotracción por bandas: estudio retrospectivo sobre su efectividad en el cierre diferido de defectos de cobertura en la pierna

RESUMEN

Introducción: Una propiedad característica del tegumento humano es la viscoelasticidad. La piel y el tejido celular subcutáneo traccionados por una fuerza constante pueden llegar a cubrir áreas expuestas en lapsos relativamente breves. El objetivo de este estudio fue analizar una serie de casos con defectos de cobertura de la pierna. Se realizó la síntesis tegumentaria con técnica de dermotracción mediante "bandas de tracción", con la finalidad de poder precisar qué lesiones pueden beneficiarse de este método. **Materiales y Métodos:** Estudio retrospectivo, descriptivo, longitudinal realizado entre 2012 y 2019. Los criterios de inclusión fueron: 1) heridas con déficit de cobertura tegumentaria en la pierna, de etiología traumática diversa (dehiscencia de abordajes quirúrgicos, fasciotomías por síndrome compartimental, fracturas expuestas y heridas abiertas con déficit de partes blandas). **Resultados:** Se analizó a 36 pacientes (edad promedio 28 años) que tenían lesiones con pérdida de cobertura localizadas en distintas regiones de la pierna. En 27 pacientes (75%), se logró el cierre sin necesidad procedimientos complementarios. En el 8,3%, se logró la reducción del área expuesta y fue necesario un procedimiento complementario (injerto de piel). Seis pacientes requirieron técnicas reconstructivas de partes blandas miocutáneas y fasciocutáneas. **Conclusiones:** Esta técnica es efectiva, simple y económica para lograr el cierre diferido de las heridas complejas o fasciotomías. La dermotracción permite el cierre diferido en pocos días luego del trauma.

Palabras clave: Defecto de cobertura; herida abierta; bandas de tracción; viscoelasticidad; síntesis tegumentaria.

Nivel de Evidencia: IV

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INTRODUCTION

Viscoelasticity is a distinctive characteristic of the human skin. A constant force pulling on the skin and subcutaneous tissue allows it to cover exposed areas in relatively short periods of time.[1] At the same time, the constantly tractioned skin will progressively elongate, reducing the tension to which it was subjected: this phenomenon is called "stress relaxation".[2]

In the context of high-energy trauma, complex wounds characterized by exposure of the deep planes are frequent, often with integumentary deficits that make primary synthesis impossible.

Reconstructive surgery has a long learning curve, reflecting the difficulty and complexity of the procedures available for extensive wound coverage. Reconstructive procedures, such as free or rotation flaps, are not only technically more demanding, but also take longer, cost more, and are associated with significant complications and donor site morbidity.

Traditionally, surgeons attempted wound synthesis with as simple a procedure as possible, and its complexity increased with the evolution of each individual case, as the wounds became more complex.[3] Today, some surgical schools prefer to use less technically complex reconstructive procedures in the acute phase.[4]

The aim of this study was to analyze a series of cases with coverage defects in different regions of the leg where skin closure was accomplished using the dermatotraction technique with "traction bands", in order to determine which wounds can benefit from this method.

MATERIALS AND METHODS

A retrospective, descriptive, longitudinal study was conducted between 2012 and 2019. The inclusion criteria were: 1) wounds with soft tissue coverage deficits in the leg caused by diverse traumatic etiologies (dehiscence of surgical approaches, fasciotomies due to compartment syndrome, open fractures, and open wounds with soft tissue deficit), and 2) complete follow-up in hospital records.

All patients were operated on by the same surgical team, trained in traumatic pathology of the lower limbs following the same therapeutic guidelines.

Initial wound management

On admission, all patients underwent wound cleaning and treatment with a vacuum aspiration system. Depending on the availability of each case, portable industrial equipment at 100 mmHg was used intermittently for 5-10 days until granulation was achieved, or homemade equipment with polyurethane sponge, suction cannula, transparent nylon film, and suction connection at the patient's bed. If the patient had an underlying infection, antibiotics were administered according to the culture report.

Debridement

Once the vacuum suction system was removed, systematic debridement was performed, paying special attention to the regularization of the skin edges to a bleeding plane.

Surgical technique and threading

Four standard-length Kirschner pins, 1.5-1.8 mm in diameter, were used, two on each side of the wound, although sometimes, in smaller wounds, the procedure was performed with two pins. The pins were inserted through the skin and subcutaneous tissue, parallel to and about 1 cm from the incision margin. The contiguous ends of each pin in the middle of the wound were bent into a hook shape and joined together forming a hinge, while the far ends were left free or secured to the pin at the opposite skin edge with a nylon suture. Surgical glove rims were used as traction bands, placed underneath the Kirschner pins and tied to the opposite side in tension. Once the skin edges were satisfactorily opposed and tension-free, the Kirschner pins and traction bands were removed and the wound was sutured at the same time (Table 1).

Table 1. Technical tips for proper wound closure.

- Debride the edges before placing the Kirschner pins.
- Place the pins only in the skin and subcutaneous tissue.
- Prevent the formation of inverted skin edges.
- If the injury is in an articular area, we recommend immobilizing it.
- If areas of traction necrosis are observed, remove the pins.

The number of traction bands used depends on the size of the wound (Figure 1).

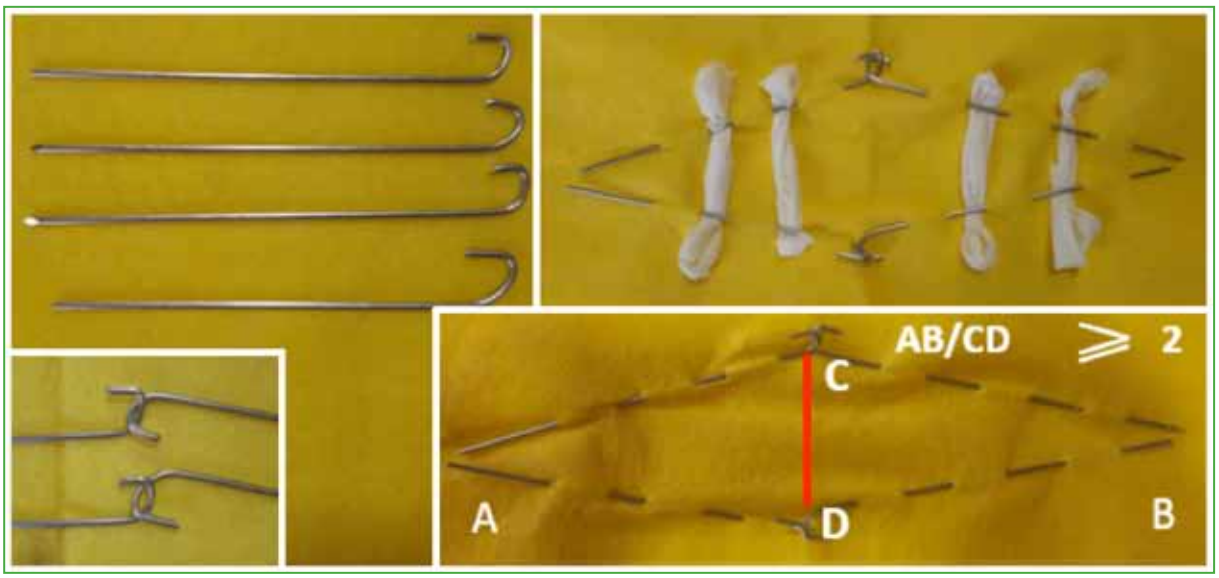

Figure 1. Hook-shaped pins at one end. Placement of the pins 1 cm from the skin margin, arrangement of traction bands between opposing pins. Better results were observed when the AB length exceeded twice the CD length.

Generally, small wounds up to approximately 6 cm require two traction bands and larger wounds require three or four.

The magnitude of the tension applied to the traction band is determined manually; there are no instruments available to measure the tension at the edges. The tension is determined by the following factors: a) the flap's distensibility when mobilized (clinical mobility of the skin next to the wound), b) avoiding flap pallor, and c) limiting tension when pain arises.

In general, 50% of the defect can be closed in 48 hours, but we do not encourage hurrying the procedure; traction adjustment of the bands is performed at the patient's bedside after 48 hours.

Once the patient was discharged, outpatient controls were performed 10 days after the removal of the pins, and one month, two months, three months, and six months later, followed by a yearly control (Table 2).

Table 2. Strengths of the surgical technique

- Simple method. The learning curve is relatively fast
- Can be performed under local anesthesia
- It is economical
- Achieves closure of most wounds
- Does not preclude the use of other reconstructive procedures.
- Avoids donor site morbidity
- Can be used in infected wounds after debridement.

RESULTS

Thirty-six patients were analyzed (mean age: 28 years; range 19-37) who suffered injuries with loss of soft tissue coverage located in different regions of the leg. Twenty-seven were men and six were women. The pathogenesis of the injuries was as follows: fasciotomy due to compartment syndrome (12 cases, 33%), exposed Gustilo IIIb fractures (9 cases, 25%), dehiscence of surgical wounds due to fibula osteosynthesis (8 cases, 22%), full-thickness skin tears (7 cases, 20%).

In 27 patients (75%), closure was achieved without the need for complementary procedures. In three patients (8.3%), reduction of the exposed area was achieved with a skin graft. These patients had large wounds in regions close to the knee.

Six patients required myocutaneous and fasciocutaneous reconstructions, all of whom had sustained high-energy injuries with significant soft tissue loss. When performing the initial cleaning, we observed a great compromise of the tissues around the injury and poor vascularity in the underlying muscle. In these cases, we made a new evaluation when removing the suction system, where the vascular status was evaluated by observation along with the state of the tissues at the site of the injury. We noticed that the skin's elongation capacity was limited due to substance loss, aggressive cleaning, and fibrosis; thus, we opted for reconstructive techniques with the following procedures: gastrocnemius rotational flap (8.3%), associated gastrocnemius and soleus flaps (5.6%) and anterolateral thigh free flap (2.8%).

The procedure was always successful when applied to cases of dehiscence and fasciotomy and failed in patients with exposed fractures or full-thickness skin tears.

Six (16.6%) infections were recorded: three in patients with open fractures, the microorganisms found were: *Staphylococcus aureus* (2 cases), enterococcus (1 case), *S. aureus* in the dehiscence of a fibula wound (1 case) and *Pseudomonas aeruginosa* in full-thickness skin tears (2 cases). All patients were treated according to sensitivity testing. The infection did not interfere with the application of the method.

Although the aesthetic outcome is not the procedure's primary goal, the patients treated reported a high level of satisfaction.

Three cases are illustrated: two with four pins (Figures 2 and 3) and one with two pins (Figure 4).

Figure 2. 18-year-old male, with traumatic posterior dislocation of the knee with vascular compromise and subsequent compartment syndrome. A femoral-tibial bypass with contralateral reversed internal saphenous vein and decompressive fasciotomy were performed. After healing of an infection, closure with pins was performed.

Figure 3. 22-year-old male with an open tibial plafond fracture and an ongoing infection in the open wound. A mechanical-surgical cleaning was performed and treated with a vacuum aspiration system. The external fixator was repositioned and the wound was closed with this pin method.

Figure 4. 35-year-old man with an operated ankle fracture. The wound presents dehiscence with exposure of the surgical material. The material is removed, the wound is treated with a vacuum aspiration system and closed with two pins.

DISCUSSION

The literature describes numerous complex leg wound closure techniques that use a variety of materials ranging from surgical tapes, skin staples, and subcutaneous sutures to more sophisticated, high-cost devices that have evident limitations in their application. Few studies describe the use of Kirschner pins for skin closure.[5,6] It is a simple method that, if unsuccessful, does not result in significant difficulties for local or free flaps. It is extremely useful to describe and incorporate simple surgical techniques for the treatment of severe soft tissue defects, because it has made a true solution available to everyone in our environment, significantly broadening the horizons in this field, extending indications, and improving functional and aesthetic outcomes.

Our successful outcomes correspond to the closure of surgical wound dehiscences and fasciotomies. In such scenarios, controlled dermatotraction maintains uniform tension along the system at the entire skin edge, reducing the risk of skin necrosis. Similarly, intramuscular pressure does not appear to increase beyond the safe limit during the procedure, ensuring proper perfusion pressures in the extremities.[7,8] Another advantage to consider is that the elongated skin retains similar properties to the adjacent skin in terms of color, hair distribution, sensitivity and functionality, which improves the cosmetic result and decreases aesthetic sequelae.

Finally, it does not have the disadvantages of more complex reconstructive procedures, such as skin grafts or flaps, which cause aesthetic sequelae, increase associated morbidity, and require a longer hospital stay.[9,10] Wounds associated with severe open fractures or full-thickness skin tears suggest an unfavorable outcome with this technique. In this group of patients, the elongation capacity of the skin does not compensate for the loss of substance secondary to the aggressiveness of the cleaning, so it is advisable to opt for more sophisticated reconstructive techniques, such as flaps of different types, where the success rate ranges between 91% and 93%.[11,12] However, we believe that the failure rate would be higher in our hands; this should be considered in the context of what it means to introduce a surgical technique with a long learning curve; thus, we recommend treatment with pins for wound closure in wounds that meet the characteristics described above as an initial method of treatment, with more complex procedures reserved for a second instance.

Since measurement instruments were not available in the workplace where this study was conducted, two prognostic scenarios for dermatotraction were segmented based on practical experience:

- A positive outcome is expected with dehiscences and fasciotomies.

- A negative outcome is expected with open fractures and full-thickness skin tears.

In our study, we demonstrated that the tension produced at the edge of the skin is evenly distributed throughout the system, thus reducing the risk of skin necrosis. As a result, this procedure is currently our preferred method for treating and closing complex wounds and fasciotomies.

CONCLUSIONS

Dermatotraction performed by hand with traction bands is an effective, simple, and cost-effective treatment for traumatic injuries with extensive exposure. It allows for deferred closure within a few days after trauma. In the series analyzed, the most favorable scenario for its application was in cases of dehiscence and fasciotomies, whereas open fractures and full-thickness skin tears had negative outcomes. Based on our experience, this technique has become our first choice for treating open wounds, as its failure does not interfere with more complex soft tissue coverage procedures.

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Tibial Fracture as a Complication of the Use of an Elastic Fixation Device in the Syndesmosis

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ABSTRACT
Elastic fixation in syndesmosis injuries is a widely performed procedure with good outcomes. We report a case of a tibial fracture as a complication of the elastic fixation of the syndesmosis, its treatment, and a literature review, in which we have not found reports of this complication.
Keywords: Ankle fracture; elastic syndesmotic fixation; tibial fracture.
Level of Evidence: IV

Fractura de tibia como complicación del uso de dispositivo de fijación elástica en la sindesmosis

RESUMEN
La fijación elástica en las lesiones de la sindesmosis es un procedimiento que se realiza ampliamente y brinda buenos resultados. Presentamos un caso de una fractura de tibia como complicación de la fijación elástica de la sindesmosis, su tratamiento y una revisión bibliográfica en la cual no hemos encontrado reportes sobre esta complicación.
Palabras clave: Fractura de tobillo; fijación sindesmal elástica; fractura de tibia.
Nivel de Evidencia: IV

INTRODUCTION

Ankle fractures are common injuries, with a reported incidence of 180 cases per 100,000 people per year.[1] In 23% of ankle fractures, an injury to the lower tibiofibular joint (syndesmosis) is detected,[2] which requires surgical stabilization to obtain good outcomes.[3] The elastic device technique for the fixation of the syndesmosis [4] has some advantages over rigid fixation with screws.[5] However, complications associated with the use of these devices, such as neurovascular injury,[6] foreign body reaction,[7] and osteolysis[8] have also been reported.

We present the case of a complication associated with elastic fixation of the syndesmosis, for which we have not found a description in the literature.

CLINICAL CASE

A 60-year-old male, obese (body mass index 35), with no relevant history. He had suffered a fall from his own height at home, which caused swelling and pain in his right ankle, so he went to the emergency department where AP and lateral ankle radiographs were ordered. The diagnosis was an ankle fracture-dislocation. He underwent a reduction, was fitted with a posterior plaster cast and remained hospitalized. 24 hours later, he underwent reduction and osteosynthesis with interfragmentary screws and a neutralization plate in the fibula, as well as syndesmosis fixation with Endobutton® outside the plate (Figure 1).

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Figure 1. Post-surgical anteroposterior and lateral radiographs of the ankle after the first surgical procedure.

The patient evolved favorably and, after 48 h, he was discharged and monitored by the Outpatient Department. Two months after surgery, he was instructed to start progressive weight-bearing. A few days later, he began to experience sudden onset pain in the distal leg area, which did not improve with analgesics and rest, for which he consulted the emergency department after 48 hours.

After taking radiographs (Figure 2) and a three-dimensional reconstruction of the ankle (Figure 3), an OTA/AO42-A3.3 fracture of the distal tibia was diagnosed in the area where the Endobutton® suture passes, and the patient was immobilized with a posterior plaster cast.

In January 2023, he attended our institution where he received treatment for tibia fracture with an intramedullary malleolar entry nail (Figure 4). It was decided to use an intramedullary, malleolar entry nail because of the poor quality of the soft tissue in the anterointernal area of the leg and the high body mass index.[9] The postoperative evolution was favorable, with healing of the tibia fracture four months after the surgical procedure.

Figure 2. Anteroposterior and lateral radiographs of the distal tibia, two months after initial surgery. A fracture of the distal tibia is observed.

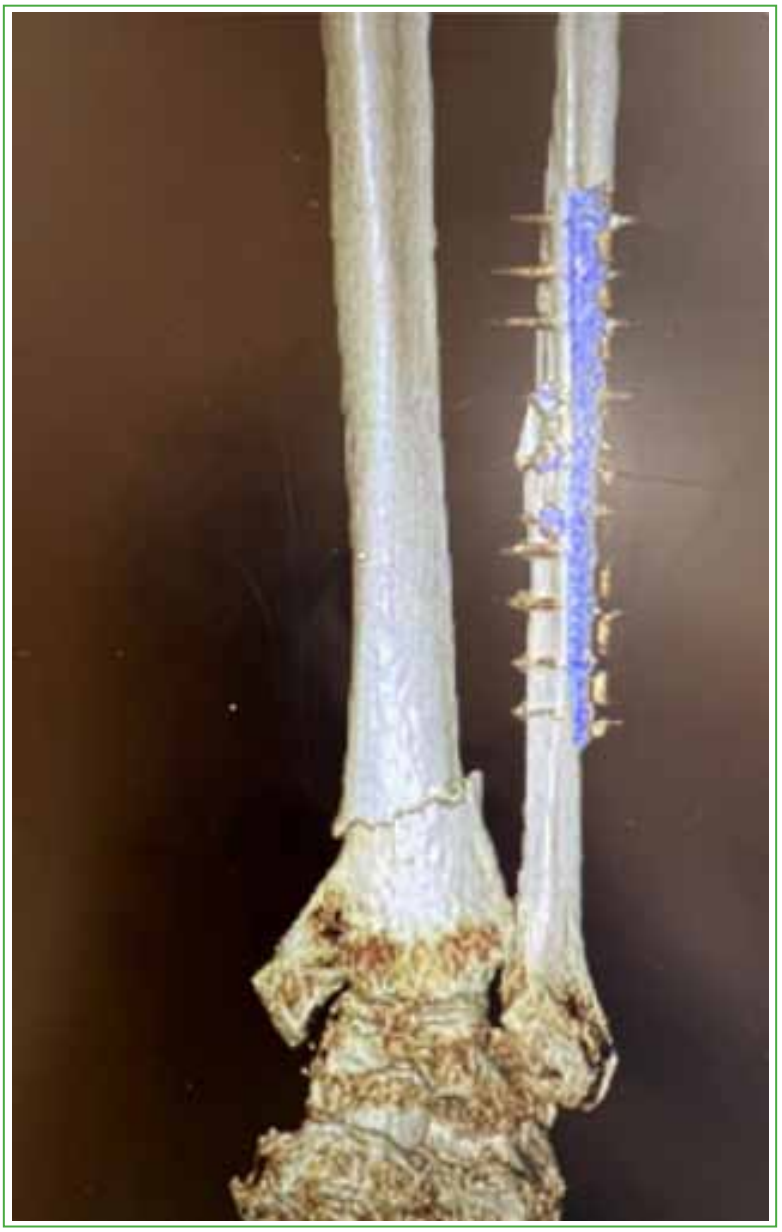

Figure 3. 3D reconstruction of the distal tibia. A distal tibia fracture is visualized.

Figure 4. Anteroposterior and lateral radiographs of the distal tibia, three months after surgery. Fracture healing is observed.

DISCUSSION

With the increased use of elastic fixation devices to treat ankle syndesmosis injuries, complications have also been reported. Storey et al.[8] observed three frequent complications: osteomyelitis around the high-strength suture, loss of the reduction obtained in the surgical procedure, and aseptic osteolysis around the suture. They specifically addressed the risk of fracturing part of the fibular cortices, hence they suggested inserting the device through the fibula osteosynthesis plate or using a washer. Kaiser et al.[10] reported fibula fractures when elastic devices were used, especially if they were not placed on a plate. They attributed this complication to the fact that the fibula is drilled with a drill bit ranging from 3.2 mm to 3.7 mm depending on the commercial brand of the implant, as opposed to the 2.5 mm drill bit used to place a screw. The second cause is the anatomical shape of the fibula in the 2-4 cm proximal to the syndesmosis where the fibula should be drilled, and the third cause is the incorrect orientation at the drilling start point in the fibula.

We have not found any literature reports on a fracture of the tibia as a complication of the use of this type of device. We believe the fracture in our patient was caused by the drill bit being very posteriorly oriented during perforating the fibula and tibia, resulting in an incomplete fracture of the tibia that was completed when the patient began weight bearing. To avoid this complication, we recommend visualizing the fibula correctly when drilling, angling the drill bit 30° from posterior to anterior, and using the image intensifier to evaluate the beginning of drilling in the tibia.

CONCLUSIONS

The use of elastic devices (Endobutton®) for the treatment of ankle fractures with lesions of the syndesmosis is very common and achieves good outcomes.

Despite multiple reports in the international literature, to date, we have not found a description of such a disabling complication as a distal tibial fracture due to the use of these implants. We suggest taking certain technical precautions when drilling the fibula and tibia to avoid iatrogenic bone injuries.

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Use of Masquelet Technique for the Reconstruction of Bone Defects in the Ankle. Case Report

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ABSTRACT
Segmental bone defects in the foot and ankle represent a challenge due to their anatomical characteristics, limited vascularization, and poor muscle coverage. The technique described by Masquelet has shown excellent results for the treatment of segmental bone defects in long bones. However, there are few studies in the literature on its use in the foot and ankle. The induced membrane technique offers a valid treatment alternative to solve bone defects. It allows treatment without the need for complex procedures, such as vascularized bone grafts or distraction osteogenesis, with a high rate of consolidation, preserving the length and function of the limb. Although we cannot prove that this procedure is the most indicated for the treatment of bone defects, we can affirm that all our patients have achieved consolidation, which encourages us to continue performing this same technique.
Keywords: Bone defect; foot and ankle; distal tibia; Masquelet technique.
Level of Evidence: IV

Reconstrucción de defectos óseos en la región del tobillo mediante la técnica de Masquelet. Presentación de casos

RESUMEN
Los defectos óseos segmentarios en la región del tobillo y el pie representan un desafío dadas sus características anatómicas con limitada vascularización y pobre cobertura muscular. La técnica descrita por Masquelet para el tratamiento de defectos óseos segmentarios en huesos largos ha logrado excelentes resultados. Sin embargo, se han publicado pocos estudios sobre su uso en la región del pie y tobillo. La técnica de la membrana inducida ofrece una alternativa terapéutica válida para resolver problemas de difícil solución en Ortopedia, como los defectos óseos. Permite tratarlos sin necesidad de procedimientos complejos, como el uso de injertos óseos vascularizados o de callotasis, con una alta tasa de consolidación, conservando la longitud del miembro y con una buena función. Entre enero de 2016 y diciembre de 2018, tres pacientes con defectos óseos segmentarios fueron tratados mediante la técnica de Masquelet en nuestra institución. Pese a que no podemos probar que este procedimiento es el más indicado en este tipo de casos, sí podemos afirmar que se logró la consolidación en todos los pacientes y se resolvió el defecto óseo, lo que nos anima a seguir utilizando esta misma técnica.
Palabras clave: Defecto óseo; pie y tobillo; tibia distal; técnica de Masquelet.
Nivel de Evidencia: IV

INTRODUCTION

The anatomic region of the ankle is a major challenge for the treatment of segmental bone defects (SBD) due to its limited vascularity and poor soft tissue coverage.[1,2] Among the main techniques for reconstruction are distraction osteogenesis, vascularized fibular grafting, intramedullary nail elongation, and trabecular titanium implants.[3,4] These are surgically complex and demanding procedures with unpredictable and potentially catastrophic outcomes.[5-7]

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Masquelet described a new technique for the treatment of SBDs.[8] This procedure allows reconstruction of the bone surface, without the need for microsurgical skills or highly complex hospital infrastructure.[9-14] In the first stage, a polymethylmethacrylate cement spacer is placed, which generates a foreign body reaction, with the subsequent development of an induced biological membrane. The spacer is removed in the second stage, which can be performed 6 to 10 weeks later, and the resulting cavity is filled with an autologous bone graft. The biomembrane's function is not just to prevent graft resorption and soft tissue interposition, but it also secretes growth factors that aid in bone consolidation.[15-18]

The purpose of this article is to present a series of patients with bone defects in the ankle region who were treated with the Masquelet technique, as well as to describe the technique's various applications in this region.

CLINICAL CASE 1

A 40-year-old man, with no relevant medical history, who had suffered an exposed fracture of the right tibial plafond in a car accident.

The initial treatment included surgical lavage, extensive debridement, and stability with a transarticular external ankle fixator.

After two weeks, a lateral fibula osteosynthesis was performed and, given the severe joint comminution, it was decided to maintain the distal tibia with a transarticular external fixator to recover bone stock, maintain length and consider a deferred tibiotalar arthrodesis.

Three months following the initial trauma, an ankle arthrodesis was performed using a specially designed anterior plate and cannulated screws to connect the metaphysis and tibial epiphysis to the talus, as well as ground bone allograft from our hospital's bone bank.

The soft tissue evolution was positive; nevertheless, there was a delay in tibiotalar fusion.

At 11 months after surgery, radiographs showed tibial plate fatigue associated with tibiotalar nonunion, and physical examination revealed movement at the fusion site (Figure 1).

Figure 1. Anteroposterior, lateral and oblique ankle radiographs showing pseudarthrosis of a distal tibia with a failed ankle arthrodesis.

Complete laboratory tests were requested and the results were within normal values: white blood cell count 8500/mm^3 (normal value: 4000-10,000/mm^3), C-reactive protein 0.9 mg/dL (normal value: 0.8-1.2 mg/dL) and erythrocyte sedimentation rate 12 mm (normal value: 8-20 mm).

Because of the suspicion of infection caused by a lack of consolidation, implant fatigue, and prolonged pain, a two-stage revision using Masquelet's principles was decided.

In the first stage, an anteromedial approach of the distal tibia was used to confirm the absence of bone graft integration at the fusion level, and a lateral approach was used to confirm the lack of consolidation at the fracture site in the fibula. Both tibia and fibula implants were removed, and an extensive surgical debridement of the bone and soft tissue was conducted, which was observed as devitalized and bleeding, until bleeding ends were obtained in both ends. Following lavage, bone and remnant tissue samples were collected for culture and pathological examination. A bone defect was created around the metaphysis, tibial epiphysis, and talar dome.

The remaining bone defect (5 cm) was filled with two doses of cement with 2 g of vancomycin per dose, after stabilization with a retrograde tibiotalocalcaneal nail (Figure 2).

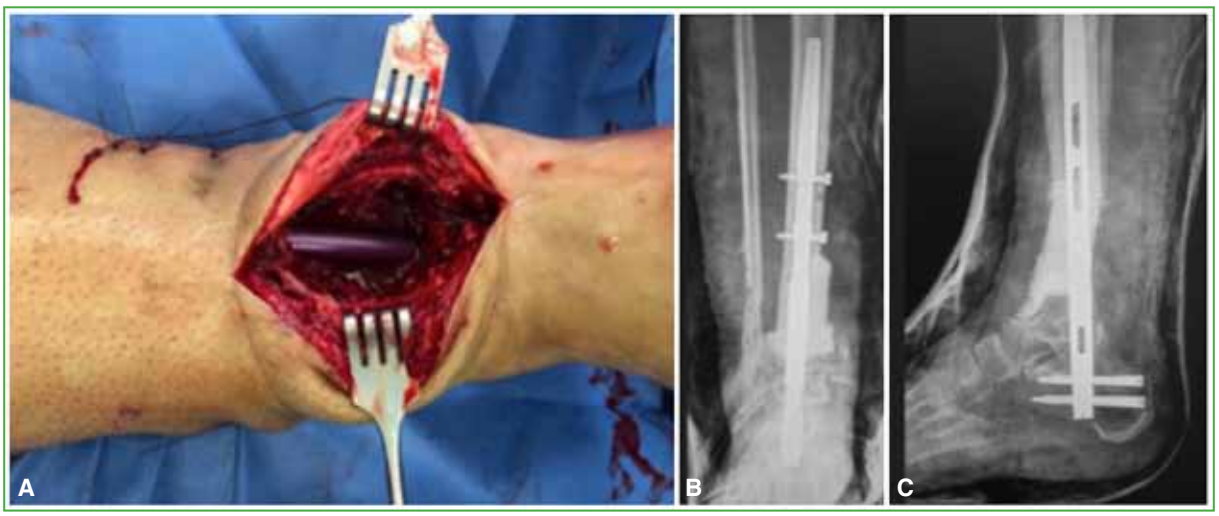

Figure 2. A. Intraoperative image of bone resection and stabilization with intramedullary nail. **B and C.** Anteroposterior and lateral ankle radiographs after the first surgical stage.

Cultures were positive for methicillin-sensitive *Staphylococcus aureus* in both bone and soft tissue.

The infection resolved after eight weeks of treatment with rifampicin and ciprofloxacin, as determined by sensitivity tests. For this reason, we proceeded with the second half of the Masquelet technique.

An anteromedial approach was performed through the previous scar. Once it was determined that the tissues were vital, Masquelet's membrane was incised and the antibiotic-loaded cement was completely removed. Finally, the remaining bone defect was filled with equal halves of ground allograft from the bone bank and autograft (obtained from the iliac crest) (Figure 3).

The remaining bone was sampled for culture and pathological anatomy, both of which yielded negative results. In any event, and given the patient's history, it was determined to complete one month of antibiotic treatment during the postoperative period, as recommended by the Infectious Diseases Department.

The rehabilitation protocol consisted of six months without weight bearing and immobilization with a walker boot and crutches. The patient then continued with progressive, crutch-assisted support. Full weight-bearing was authorized 11 months after the second surgical stage.

Serial clinical and radiographic controls were performed. At 13 months following the second operation, radiographic fusion was verified, and unassisted walking was authorized with a return to normal life (Figure 4).

After two years of follow-up, the patient walks unaided and without pain in the operated limb.

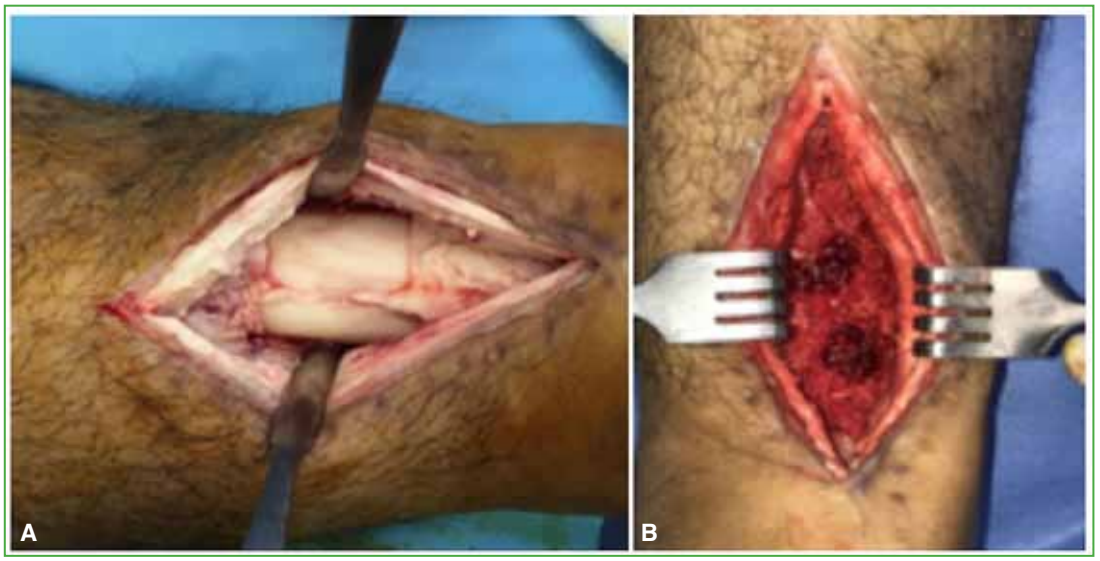

Figure 3. **A.** Intraoperative image of the second surgical stage (spacer). **B**. Filling of the bone defect.

Figure 4. Anteroposterior and lateral ankle radiographs, 11 months after the second surgical stage.

CLINICAL CASE 2

A 47-year-old man with a clinical history of arterial hypertension, who had sustained a talus fracture in a motorcycle versus car accident in 2015 and had been treated with open reduction and internal fixation with retrograde screws and a medial plate.

Postoperatively, he suffered partial necrosis of the talar body and pseudarthrosis of the neck associated with the development of subtalar osteoarthritis, for which, in 2017, he underwent revision osteosynthesis with subtalar arthrodesis, at our institution. Three years later, he was still in pain and walked with the aid of a crutch.

Due to the persistence of pain, periodic and exceptional radiographic controls revealed pseudarthrosis of the talar neck fracture, avascular bone necrosis of the talar body, and a lack of consolidation of the subtalar arthrodesis, as well as the development of tibiotalar osteoarthritis.

With a preliminary diagnosis of infected pseudarthrosis based on prolonged pain, implant fatigue, and lack of consolidation, Masquelet's guidelines were used as the basis for a two-stage revision. In the first surgery, an extended medial approach was performed over the surgical scar. The osteosynthesis was removed, a bony sequestrum was discovered at that level, samples were collected for culture, and extensive debridement was performed until vital, bleeding bone was retrieved.

A defect was created around the talar body, tibial articular surface, and medial malleolus. Culture samples were collected from tibia and talus remnant bone, as well as soft tissue containing superficial fascia and anterior tibial tendon sheaths.

The calcaneus was stabilized with the tibia using a retrograde tibiocalcaneal nail, which kept the limb's length, and the defect was filled with two doses of cement containing 2 g of vancomycin each (Figure 5). In cultures, *Staphylococcus epidermidis* was isolated from distal tibia bone tissue.

Figure 5. Anteroposterior and lateral ankle radiographs two months after the first surgery for pseudarthrosis of the talar neck plus necrosis of the talar body.

The infection resolved after nine weeks of treatment with levofloxacin and rifampicin, as determined by sensitivity tests.

Ten weeks following surgery, with the infection properly treated, it was agreed to proceed with the second surgical stage. The anterior scar was approached and, after visualizing that the tissues looked vital and bleeding, Masquelet's membrane was incised. All antibiotic-loaded cement was removed, the residual bone ends were treated, and samples were collected for culture and pathological anatomy, which were both negative. Finally, the remaining bone defect was filled with equal halves of autologous bone (obtained from the iliac crest) and ground allograft.

Antibiotics would not be administered beyond the second stage, as agreed upon by the Infectious Diseases Department.

Complete consolidation was observed 12 months after surgery (Figure 6). The rehabilitation protocol included six months of non-weight bearing immobilization with a walker boot, followed by six months of partial weight bearing with a walker boot and two crutches after the second surgical stage.

The patient achieved full unassisted weight bearing at 14 months after the second surgical stage.

Figure 6. Anteroposterior and lateral ankle radiographs, eight months after the second surgical stage.

CLINICAL CASE 3

A 61-year-old man, with no relevant medical history, who had undergone left ankle arthroplasty for primary osteoarthritis in August 2017, at another institution. He developed an acute prosthetic infection, necessitating two surgical debridements one month after surgery. He received antibiotic treatment for three months, and the final cultures from both surgical debridements were negative.

He developed an anterior soft tissue coverage defect, which was treated with VAC® negative pressure wound therapy, resulting in wound closure nine months following the initial postoperative period.

The patient consulted our institution one year after surgery due to persistent pain in the left ankle. Physical examination revealed a limited and painful range of motion. The wounds were healed, with no signs of active infection.

The radiographs showed an alteration of the structure compatible with loosening of the prosthesis (Figure 7).

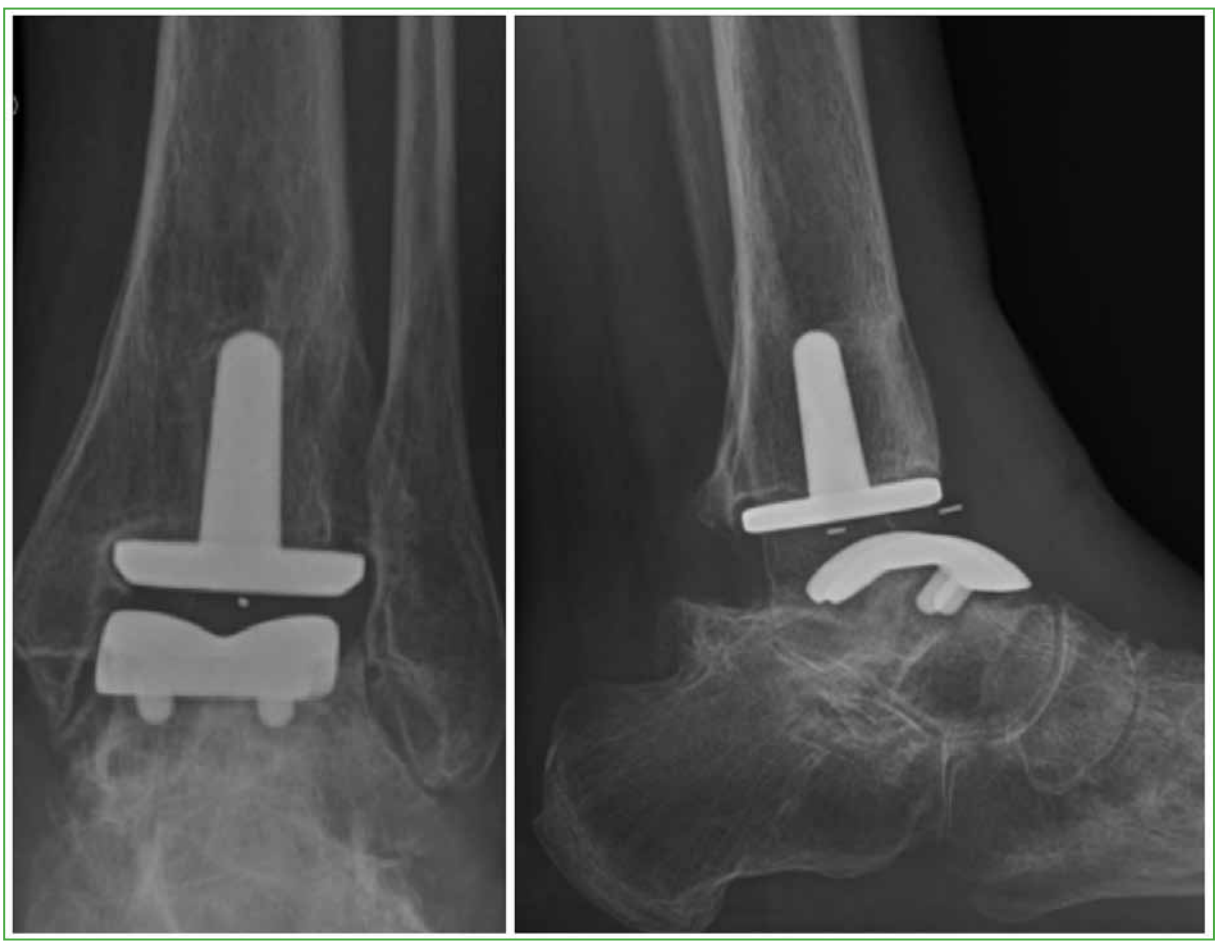

Figure 7. Anteroposterior and lateral ankle radiographs, one year after surgery. Loosening of the prosthesis is observed at the level of the tibia and talus.

Given the suspicion of septic loosening due to an infection history, a soft tissue coverage defect for nine months, and pain persistence at one year and three months, Masquelet's guidelines were adopted to direct a two-stage revision.

In the first surgery, an extended anterior ankle approach was performed over the surgical scar. The prosthesis components were removed, remnant bone samples were taken for bacteriological study and debridement was performed until vital and bleeding bone was obtained. A 2.5 cm remnant bone defect was noted. Distraction was performed to maintain the length of the limb and a tibiotalocalcaneal nail was placed retrogradely. The bone defect was filled with two doses of cement containing 2 g of vancomycin per dose (Figure 8).

Figure 8. Anteroposterior and lateral ankle radiographs taken in the immediate postoperative period. Note the stabilization with a retrograde tibiotalocalcaneal nail and the antibiotic-loaded cement that fills the bone defect.

After 10 weeks of treatment with minocycline and ciprofloxacin, and negative cultures, it was decided to continue with the second Masquelet stage.

The approach was made through the surgical scar. After observing that the tissues had a vital and bleeding appearance, Masquelet's membrane was incised and all the antibiotic-loaded cement was removed. Remnant bone samples were collected and yielded negative results. Finally, the bone defect was filled with equal halves of autologous bone (from the homolateral iliac crest) and ground allograft from the bone bank.

The patient was immobilized with a cast boot for three weeks and then continued with a non-weight-bearing walker boot. Progressive partial weight bearing began at three months protected with a walker boot and two crutches. Consolidation was achieved eight months after surgery. 9.5 months after the second surgery, the patient was able to bear full weight on his limb without help (Figure 9).

Figure 9. Anteroposterior and lateral ankle radiographs, one year after surgery. The consolidation and integration of the graft can be visualized.

DISCUSSION

SBD in the ankle and foot region represents a challenge due to its anatomical characteristics, limited vascularization, and poor muscle coverage.[1,2] Excellent outcomes have been obtained with the technique described by Masquelet for the treatment of SBDs in long bones.[9,10,12-14] However, there are few studies on its use in the foot and ankle region.

There are numerous causes for the generation of SBD in this region. Although most published studies correspond to defects secondary to open fractures, causes such as gouty tophi and osteomyelitis have also been reported.[19-21] In our case series, SBD was generated by extensive surgical debridement. In two of them, as a treatment for a deep infection caused by a surgical site infection, and in the other, as a result of an ankle prosthesis loosening.

Initially used for the treatment of long bone SBD, the Masquelet technique began to be used in other regions of the body due to its good results.[9-14] This two-stage procedure has unique characteristics. The cement spacer acts as a foreign body, causing the organism to generate a kind of vascularized capsule or biomembrane that surrounds it. This provides a privileged environment for the growth and incorporation of the bone graft. It also has the function of preventing graft resorption and secreting and maintaining osteoinductive growth factors.[15-18] According to the literature, by the sixth week, the membrane is 1-2 mm thick, hypervascularized, and free of adhesions with the underlying spacer, indicating an optimal timing for the second surgical stage.[15,17,18] In our case series, the time elapsed between the first and second surgeries was eight weeks (2 patients) and 10 weeks for the remaining patient. These times are very similar to those published on this region. Luo et al. performed the second surgery eight weeks later in their study of 19 patients who were treated for osteomyelitis in the distal third of the tibia.[22] In a study of infected pseudarthrosis in the metatarsal region, Giannoudis et al. performed the second surgery between the 6th and 8th week.[11]

In the second stage, the remaining cavity should be filled with bone grafts. Because of its osteogenic, osteoconductive and osteoinductive properties, the iliac crest is the reference site.[14,15,18] In cases of larger defects, where the graft is insufficient, ground allograft from a tissue bank can be used, but without exceeding a ratio of 1 to 3.[11,14] Despite this, consolidation rates of >90% have been published using a ratio of 1 to 1.[23,24] Pesciallo et al. used up to 64% autologous graft, and obtained a consolidation rate of >90%.[23] In our series, the defects were filled with equal halves of autologous bone graft and ground allograft to avoid the need to use both iliac crests and we achieved consolidation rates similar to those published for the diaphyseal and distal tibial region.[19,25,26]

The size or length of the defects, as in the rest of the long bones, does not appear to influence consolidation rates or the patient's ability to fully bear weight.[19] However, in the foot and ankle region, these times are somewhat longer. Siboni et al. treated patients with defects up to 18 cm secondary to septic pseudarthrosis in the distal tibia and achieved consolidation in 93% of the cases, in an average of 14 months (range 3-32).[27] Similarly, Zooler et al. reported defects between 3 and 10 cm in the distal tibial region, with a 100% consolidation rate between two and nine months.[28] In our series, the defects measured 2.5; 6 and 5 cm, dimensions quite similar to those published, and consolidation was achieved in all patients, in an average of 10.3 months.

A strength of this study is that it is one of the few of its kind at the national level on a disease with few international publications, for which there are multiple treatment options and adequate management remains unclear. Its retrospective nature, the low number of patients and the heterogeneity of the variables under study are its main weaknesses.

We believe that more studies with a greater number of patients, as well as prospective comparative studies with other techniques, are required to obtain findings that will help us reach a therapeutic consensus in the treatment of SBD.

CONCLUSIONS

The induced membrane technique offers a valid treatment alternative to solve problems that are difficult to solve in orthopedics, such as bone defects. It enables us to treat them without the need for complex treatments such as vascularized bone grafts or callus distraction, while also retaining the length of the limb and ensuring good function.

Although we cannot prove that this procedure is the most indicated in this type of cases, we can affirm that consolidation was achieved in all patients and resolution of the bone defect, which encourages us to continue using this same technique.

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

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Solitary Calcaneal Osteochondroma with Growth After Skeletal Maturity. Case Report and Literature Review

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ABSTRACT
Osteochondroma is the most common benign bone tumor, accounting for 35% of benign bone tumors and 8% of bone tumors. It is formed by an exostosis of trabecular bone covered with cartilage that affects the metaphyseal region of long bones, from the growth plate, around the knee, in the shoulder or wrist, and it is extremely rare in the phalanges of the hand or foot. It grows during childhood and adolescence until skeletal maturity. Therefore, its growth in an adult suggests a malignant transformation into chondrosarcoma, although there are also reports without malignancy. Furthermore, the calcaneus is a short bone, so the appearance of this type of injury would be pathophysiologically unexpected. Our objective is to present a case of solitary calcaneal osteochondroma with growth after skeletal maturity, its diagnosis and treatment, as well as a review of the literature. Its relevance stems from the scarcity of literature, its uncommon location, and the possibility of malignancy.
Keywords: Calcaneus; osteochondroma.
Level of Evidence: IV

Osteocondroma de calcáneo solitario con crecimiento después de la madurez esquelética. Reporte de un caso y revisión bibliográfica

RESUMEN
El osteocondroma es el tumor óseo benigno más frecuente, representa el 35% de los tumores óseos benignos y el 8% de los tumores óseos. Está formado por una exostosis de hueso trabecular recubierta de cartílago que afecta la región metafisaria de los huesos largos, a partir del cartílago de crecimiento, alrededor de la rodilla, en el hombro o la muñeca, y es extremadamente raro en las falanges de la mano o el pie. Crece durante la niñez y la adolescencia hasta alcanzar la madurez esquelética; por lo tanto, su crecimiento en un adulto sugiere la transformación maligna en condrosarcoma, aunque también existen reportes sin malignización. Además, el calcáneo es un hueso corto, por lo que, desde el punto de vista fisiopatológico, sería inesperada la aparición de este tipo de lesión. El objetivo de este artículo es presentar un caso de osteocondroma de calcáneo solitario con crecimiento después de la madurez esquelética, su diagnóstico, tratamiento, así como una revisión bibliográfica. Esta presentación de caso es importante, dados la localización infrecuente y el potencial de transformación maligna del osteocondroma, y la escasa bibliografía sobre el tema.
Palabras clave: Osteocondroma; calcáneo.
Nivel de Evidencia: IV

INTRODUCTION

Osteochondroma is the most common benign bone tumor, accounting for 35% of benign bone tumors and 8% of bone tumors.[1,2] It is formed by an exostosis of cartilage-covered trabecular bone that affects the metaphyseal region of the long bones, starting from the growth plate, around the knee, in the shoulder or wrist, and is extremely rare in the phalanges of the hand or foot.[3,4]

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Most osteochondromas are asymptomatic, but may cause mechanical symptoms depending on size and location.[5] They grow during childhood and adolescence until skeletal maturity is reached. Therefore, their growth in adults suggests malignant transformation to chondrosarcoma.[1] However, cases without malignant transformation have also been published.[6-21]

Osteochondromas in the ankle and foot are infrequent (10%), and the calcaneus is an extremely unusual site.[12] Moreover, it is a short bone and, in the context of skeletal maturity, the occurrence of this type of lesion is unexpected from a pathophysiological point of view.

The aim of this article is to present a case of solitary calcaneal osteochondroma with growth after skeletal maturity, including its diagnosis, treatment, and a literature review. The relevance of this publication lies in the scarce literature on this condition, and the infrequent location and malignant potential of osteochondroma.

CLINICAL CASE

A 24-year-old man consulted the Orthopedics and Traumatology Department of our institution for the first time in June 2022, due to discomfort and a palpable tumor in the plantar region, with no significant history of trauma. Physical examination revealed a hard, immobile tumor that had evolved over three years, with significant growth in the last few months, and was accompanied by difficulty standing, walking, and putting on shoes. The ankle and hindfoot joints had full range of motion, with no stiffness. Radiographs were requested and showed an isolated, large, pedunculated, radiopaque image arising from the plantar aspect of the calcaneus and extending towards the metatarsals (Figure 1).

Figure 1. Preoperative foot radiograph, lateral view. A large, pedunculated tumor with clear borders is observed, emerging from the plantar base of the calcaneus.

In addition, radiographs of all long bones, pelvis and spine were obtained, revealing the absence of other osteochondromas, and ruling out the diagnosis of hereditary multiple exostoses. Ultrasonography showed plantar fascia enthesis with a calcaneal spur (Figure 2).

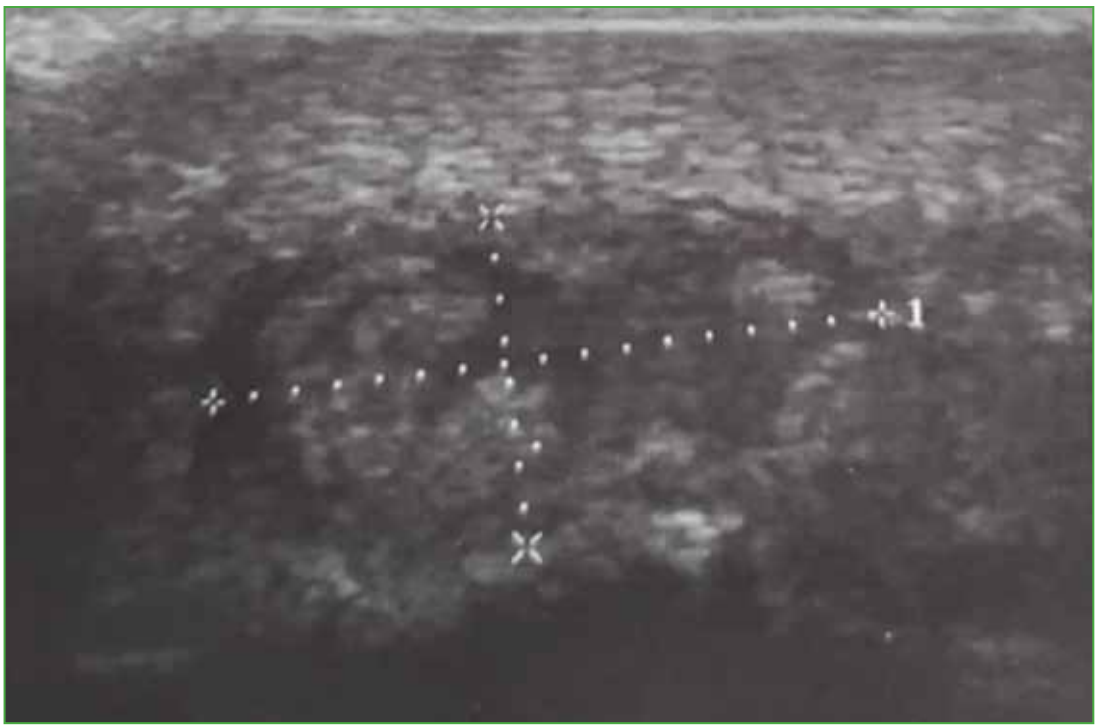

Figure 2. Soft tissue ultrasound of the sole of the left foot. An echogenic image compatible with enthesis and chronic plantar fasciitis with a calcaneal spur is visualized.

The computed tomography revealed an isolated exostosis with defined borders, medullary and cortical continuity with normal bone, images consistent with an osteochondroma, and complete closure of the epiphyseal plate (Figure 3).

Figure 3. Multislice computed tomography of the left ankle. Complete closure of the epiphyseal plate and a sharp-edged lesion emerging from the plantar aspect of the calcaneus are observed.

Magnetic resonance imaging revealed that the tumor was not connected to soft tissues (Figure 4).

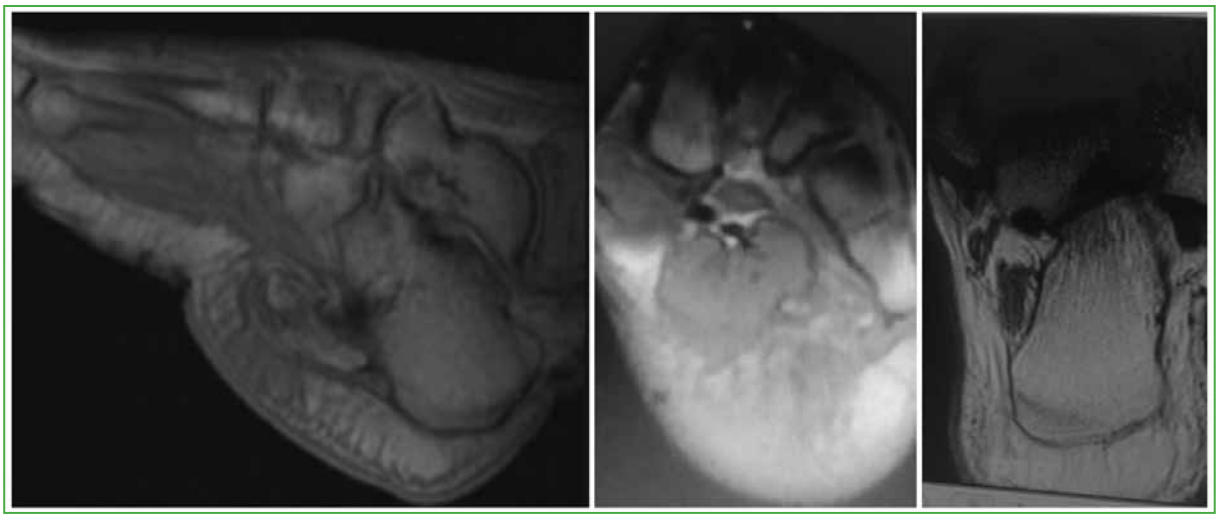

Figure 4. MRI of the left ankle. The tumor emerging from the plantar aspect of the calcaneus is not attached to the soft tissues.

Considering the symptoms and that the images showed a single, encapsulated tumor with benign characteristics, it was decided to perform an excisional biopsy by lateral approach (horizontal branch of Benirschke's extended lateral approach) (Figure 5) on August 30, 2022.

Figure 5. Surgical approach used.

The patient was placed in the right lateral decubitus position, under spinal anesthesia and with a homolateral supramalleolar tourniquet. Given that the tumor was not attached to the soft tissues and had the macroscopic appearance of osteochondroma, it was completely resected in one piece (70 mm x 50 mm x 30 mm, Figure 6) with a safety margin via an osteotomy from the base using a laminar spreader. Finally, the entire specimen was sent for a pathology report.

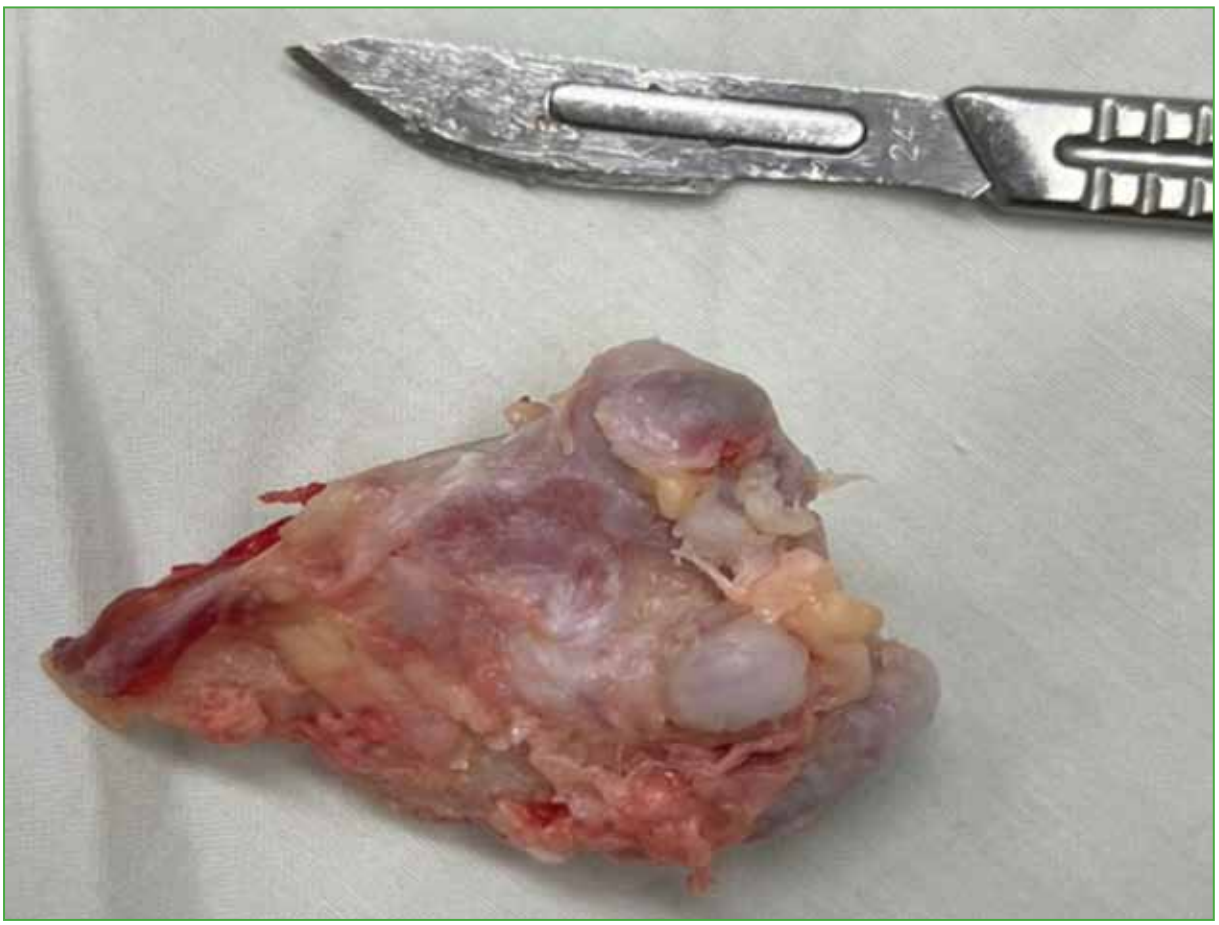

Figure 6. Tumor resected in one piece.

The patient's postoperative recovery progressed well, and radiographs showed that the tumor had been completely removed (Figure 7).

Figure 7. Postoperative radiograph of the left ankle, lateral view, showing complete tumor resection.

Five weeks later, the pathology report confirmed an osteochondroma of typical architecture (Figure 8), with chondrocytes arranged in groups and no morphological evidence of secondary malignant transformation.

Although the follow-up period is only one year, the clinical evolution will be monitored.

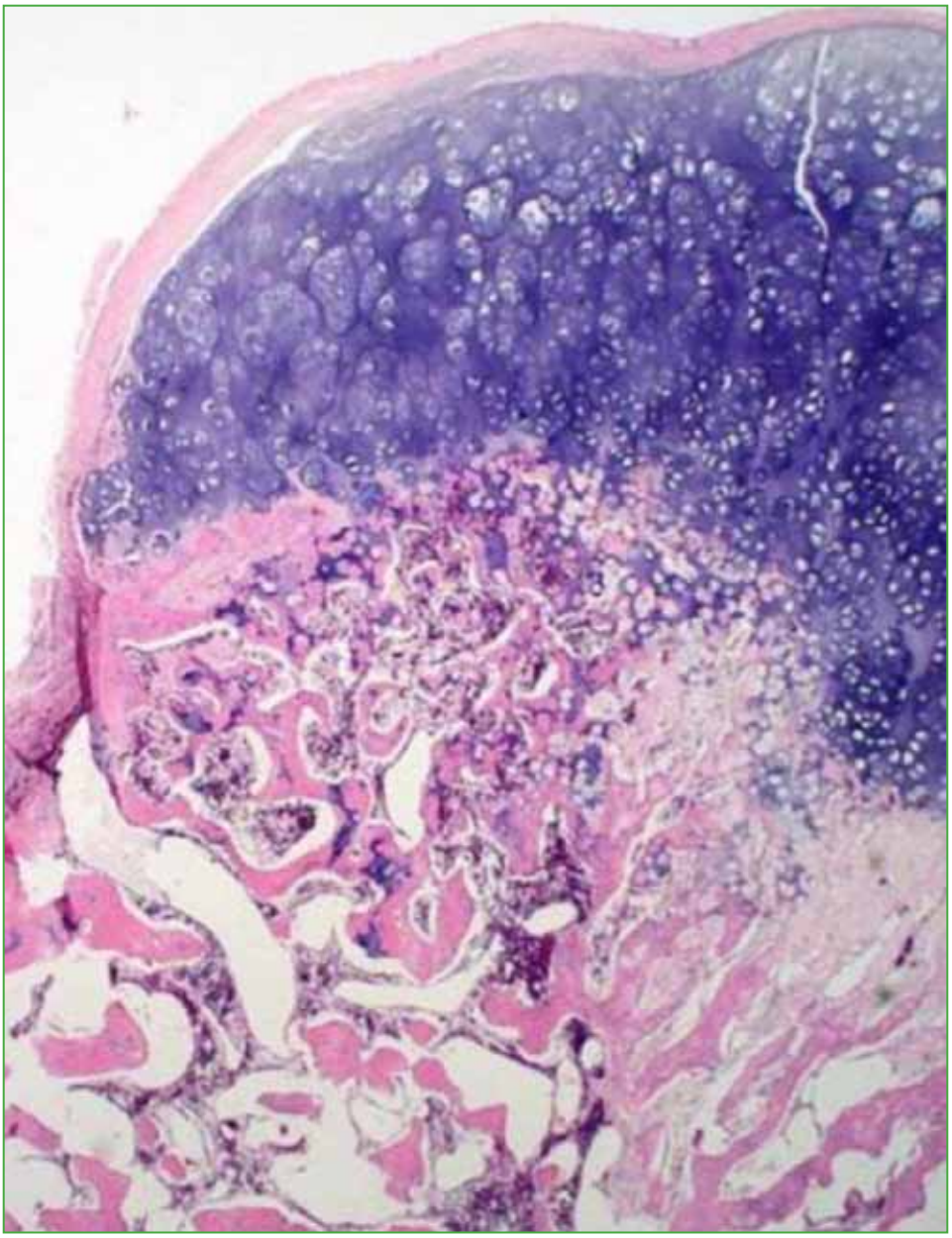

Figure 8. Pathology analysis compatible with osteochondroma.

DISCUSSION

Osteochondroma is the most frequent benign bone tumor, accounting for 35% of benign bone tumors and 8% of bone tumors; however, because many cases are asymptomatic, the incidence is likely higher than reported.[1,2] It is a developmental anomaly that grows from the physis and is composed of bone covered by a thin layer of growth plate that retains all of its histologic characteristics.[3,4] The majority (85%) manifest as solitary, non-inherited lesions, while 15% occur in the context of hereditary multiple exostoses, a genetic disorder inherited in an autosomal dominant manner and associated with germline mutations in the *EXT1* or *EXT2* tumor suppressor genes in nearly 90% of cases.[1] It is more common in males (1.5:1), and in the first and second decades of life.[5]

It is usually located in the long bones and exceptionally in the bones of the hands and feet (usually in the phalanges). It appears during adolescence, during the period of greatest growth of the long bones, causing symptoms around the knee, shoulder or wrist, where the greatest activity of these cartilages occurs. Its expansion stops with the cessation of growth and closure of the epiphyseal plates, and the lesion remains inactive.[3,4] For this reason, the appearance of pain in a previously stable lesion, as well as accelerated or new growth, growth beyond skeletal maturity, or large lesions may indicate malignant transformation to chondrosarcoma,[14,22-24] which occurs in 1% of solitary osteochondromas and up to 10% of cases of hereditary multiple exostoses.[12,14] Willms et al. included a case of malignant transformation of a calcaneal osteochondroma in a literature review of 50 cases.[23] Malik et al. reported a solitary osteochondroma of the calcaneus that transformed into chondrosarcoma.[24] In a review of 75 cases of chondrosarcoma secondary to osteochondroma, Garrison et al. identified chondrosarcoma of the calcaneus in a patient with hereditary multiple exostoses.[22]

Chondrosarcoma secondary to an osteochondroma is often a well-differentiated tumor that is histologically close to the cartilage layer with increased chondrocyte cellularity and significant cytologic atypia, without extensive myxoid changes. For this reason, its diagnosis is based first on the architectural appearance of the cartilaginous layer and not on its thickness. Malignant transformation alters the cap's architecture, which is destroyed by thin fibrous septa, resulting in a lobulated architecture at low magnification, and some may detach and penetrate the peripheral soft tissues.[12]

The characteristic clinical presentation of this tumor is a palpable, hard, immobile mass. Some patients suffer from symptoms, especially pain due to bursitis, tendon or muscle inflammation due to friction, or vascular or nerve compression.[5]

Plain radiographs (which are frequently diagnostic on their own) and further imaging procedures such as a CT scan, MRI, or bone scan are used for surgical planning or to rule out sarcomatous degeneration in osteochondromas.[14]

Radiography is the main diagnostic method, allowing visualization of classic features such as orientation, medullary continuity, and whether the tumor is pedunculated or sessile.[14] On the other hand, ultrasonography can be used to measure the thickness of the hyaline cartilage layer. However, ultrasonography is an operator-dependent study with limited utility in obese patients and minimal relevance to the tumor's bone components.[15] Computed tomography, especially with multiplanar reconstruction, is useful for localizing the tumor and planning its resection,[12] and can determine whether the growth plates are closed.[12] Magnetic resonance imaging shows the extent of the lesion, the possible involvement of soft tissues, and the thickness and location of the cartilage layer. A thick cartilage layer that has a high signal intensity on the T2-weighted sequence may suggest malignant transformation.[5,12,14,15] On bone scans, osteochondromas may appear as focal uptake adjacent to the growth plate, especially in patients whose skeleton has not yet reached maturity. Stable tumors in adults may not show uptake. Bone scintigraphy is useful for detecting asymptomatic deep tumors, especially in the context of hereditary multiple exostoses, but is not specific for distinguishing between osteochondromas and malignant chondrosarcomas.[14]

The differential diagnosis includes benign and malignant primary bone tumors, as well as a spectrum of reactive bone disorders, such as Turret's exostosis, bizarre parosteal osteochondromatous proliferation, and florid reactive periostitis.[14] On the other hand, calcaneal spurs are traction lesions located at the insertion site of the plantar aponeurosis and are not true osteochondromas.[14]

When lesions are asymptomatic, the behavior is expectant, with clinical and radiographic follow-up. However, symptomatic lesions or lesions that grow after skeletal maturity require complete surgical excision with a tumor-free resection margin, as any remnant may lead to recurrence.[14,15,22]

There are only a few reports of calcaneal osteochondroma with growth after skeletal maturity.[6-21]

In 1992, Techner and DeCarlo reported a case of osteochondroma in a unilateral peroneal tubercle with symptoms in association with peroneal tenosynovitis in a runner, suggesting microtrauma and long-term repetitive stress as possible etiological factors.[6]

Martin et al. presented two patients with stenosing tenosynovitis of the peroneal tendons caused by an osteochondroma of the peroneal tubercle of several years' evolution. One 25-year-old woman and one 48-year-old woman improved after resection. The histologic report reported a benign osteochondroma. Clinical and radiological follow-up at 10 and 2 years, respectively, showed no recurrence.[7]

Sella and Chrostowski reported two cases of calcaneal osteochondromas with accelerated growth from the plantar region that were treated with excision via a plantar approach: one in a 6-year-old child and the other in a 71-year-old woman, with no histological evidence of malignancy.[8]

Karakurum et al. reported a case of bilateral symmetric solitary osteochondroma of the peroneal tubercle in a 24-year-old woman. The osteochondroma was discovered when the lesion on the left side became symptomatic and was resected through a lateral approach. Pathologists confirmed the disease, but it is unclear whether it is a real osteochondroma or tubercle hypertrophy.[9]

Sánchez-Mariscal Díaz et al. published the case of a 69-year-old patient with stenosing tenosynovitis of the peroneal tendons caused by osteochondroma of the peroneal tubercle of two years' evolution. The histological report confirmed the diagnosis of benign osteochondroma. No recurrence was observed three years after surgery.[10]

Akmaz et al. described a case of calcaneal plantar osteochondroma, approximately 5 cm in diameter, in a 21-year-old man, with progressive pain (10 months), especially with excessive weight bearing during military training. The diagnosis was corroborated histologically and symptoms resolved within two months of resection by a lateral approach.[11]

Nogier et al. reported an osteochondroma in a 36-year-old man who, after nine years of follow-up, had extensive growth (60 mm x 55 mm x 30 mm; cartilage thickness 12 mm) on the inferolateral aspect of the calcaneus. Histological analysis confirmed the presumptive diagnosis, although without signs of malignancy, and there was no recurrence throughout the four-year follow-up period after surgical excision.[12]

Uğurlu et al. published the first case of bilateral peroneal tendon stenosing tenosynovitis secondary to osteochondroma of the peroneal tubercles and bilateral os peroneum. The 23-year-old woman made a full recovery after the operation. The pathology diagnosis was osteochondroma of the calcaneus without malignant degeneration.[13]

Blitz and Lopez reported a large osteochondroma (80 mm x 42 mm x 21 mm) of the medial inferior calcaneal tubercle in a 40-year-old woman with a history of painful mass of six months' evolution. A biopsy of the tumor confirmed its benign nature, so, two months later, a complete excision was performed through a medial incision. At 3.5 years of follow-up, no recurrences were observed, but the patient never recovered her initial level of activity and was unable to return to work.[14]

Koplay et al. described the case of an osteochondroma of one year of evolution, located in the posteromedial region of the calcaneus, in a 25-year-old woman. There was transient improvement after surgical excision, but it subsequently manifested with pain and rapid growth (18 mm x 12 mm; cartilage thickness 6 mm), so it was reoperated six months later. The pathology report again revealed a benign osteochondroma. No tumor recurrence was detected during the nine months following the second excision.[15]

Jung et al. reported a case of an exceptionally large Haglund's deformity (32 mm x 23 mm x 21 mm) in a 22-year-old woman, which had developed over the previous decade. Surgical resection of the prominence and retrocalcaneal bursa was performed, as well as reinsertion of the Achilles using 3.5 mm harpoons. Histopathological analysis confirmed the diagnosis of calcaneal osteochondroma, this is the first time this situation has been reported. There was no recurrence 18 months after surgery.[16]

Kumar et al. presented a case of symptomatic retrocalcaneal bursitis in a 58-year-old farmer due to the late growth of a posteromedial osteochondroma of the calcaneus. The tumor (31 mm x 17 mm; cartilage thickness 4 mm) and the bursa were removed through a posterolateral approach. After six months of follow-up, there was no sign of malignancy on histological testing and no recurrence, however the ankle joint's range of motion remained limited.[17]

Koh et al. published the case of a 41-year-old obese patient with long-standing left heel pain. He was treated for plantar fasciitis and gastrocnemius contracture, but both conservative and surgical treatments proved ineffective. MRI revealed a plantar, posterolateral osteochondroma (11 mm x 9 mm) that was removed en bloc and confirmed by histology. No recurrence was detected within nine months after resection.[18]

Raviraj et al. reported a case of bilateral Haglund's syndrome secondary to calcaneal osteochondroma, a situation never reported in the English literature. After resection of the tumor and retrocalcaneal bursa, histopathological study revealed no malignancy. The condition had not recurred at the two-year follow-up.[19]

Bilekli presented the first case of bilateral peroneal tendon tear, together with edema of the calcaneal bone marrow, secondary to osteochondroma of the peroneal tubercle. The 50-year-old patient underwent surgery (resection and tubularization) in the lateral decubitus position. The pathology report confirmed a benign osteochondroma. No recurrences were detected after a year of follow-up.[20]

Avramidis et al. reported an osteochondroma (45 mm x 30 mm x 25 mm) in the lateral process of the calcaneal tuberosity, of seven years of evolution, in a 27-year-old patient. After surgical removal of the tumor, the histological study showed no malignancy, and there were no recurrences during the three years of follow-up.[21]

Our report is another case of extensive growth of a calcaneal osteochondroma after epiphyseal plate closure that, after excision, was confirmed as benign on histopathologic examination. The patient quickly recovered his previous level of activity shortly after surgery, and no recurrences were observed during one year of follow-up.

In this presentation, we report one of the largest solitary calcaneal osteochondromas (70 mm x 50 mm x 30 mm) described in the literature, along with those of Blitz and Lopez[14] and Nogier et al.[12]

The Table summarizes the 18 reports to date, including ours. No differences were found in the distribution by sex (9 men vs. 9 women), the mean age was 38.7 years (range 21-71), and the most affected side was the right (12 of 18 cases), although on three occasions, it occurred bilaterally. The most frequent location was in the peroneal tubercle (7 of 18 cases), followed by the inferior region of the calcaneus (2 of 18 cases), the inferolateral region of the calcaneus (2 of 18 cases), the dorsum of the protuberance (2 of 18 cases), the posteromedial region (2 of 18 cases), the inferior medial tubercle (1 of 18 cases), and the lateral process of the calcaneal tuberosity (1 of 18 cases). Its manifestations included a painful mass in the heel (8 of 18 cases), peroneus longus lateralis tendonitis (5 of 18 cases), Haglund's deformity (2 of 18 cases), a tear of both peroneal tendons (1 of 18 cases), and plantar fasciitis with gastrocnemius contracture (1 of 18 cases). Treatment was always excision, sometimes accompanied by tenosynovectomy (4 of 18 cases), bursectomy (3 of 18 cases), Achilles reinsertion (1 of 18 cases) and tubularization (1 of 18 cases). The most commonly used approach was lateral (6 of 18 cases), followed by posterolateral (3 of 18 cases), curvilinear, posterior to the lateral malleolus (1 of 18 cases), plantar (1 of 18 cases), medial (1 of 18 cases), and medial to the Achilles tendon (1 of 18 cases). Only eight reports indicated the size of the tumor, with the largest measuring 80 mm x 42 mm x 21 mm,[14] in this present report (70 mm x 50 mm x 30 mm), 60 mm x 55 mm x 30 mm,[12] 45 mm x 30 mm x 25 mm,[21] 32 mm x 23 mm x 21 mm,[16] 31 mm x 17 mm,[17] 18 mm x 12 mm,[15] 11 mm x 9 mm.[18] Of these, only four specified cartilage thickness at 12 mm,[12] two at 18 mm,[14] 6 mm,[15] and 4 mm.[17] There were no recurrences of the lesion and only one patient had postoperative complications requiring surgical drainage of a large hematoma, four days after surgery and 40 days after the second surgery. *Escherichia coli* was isolated, and amoxicillin with clavulanic acid was indicated for 20 days.[12] The average follow-up was 2.4 years (range 6 months-10 years), no clinical or radiological recurrences were observed, although one patient was left with a permanent work disability.[14]The location in the peroneal tubercle is the most frequent and this may attract attention, but it would be difficult to generate future lines of research due to the infrequency of the lesion.

CONCLUSIONS

Calcaneal osteochondromas are extremely rare, and most are asymptomatic. They should be treated conservatively unless they cause symptoms such as pain, have rapid or new growth, increase in size after skeletal maturity or show signs of malignant transformation. In these cases, imaging studies and an extensive resection with healthy bone margins are necessary. Inadequate excision of the remaining cartilage layer can lead to tumor recurrence.

However, benign osteochondromas can grow and become symptomatic in skeletally mature patients without malignant transformation. We present a case of giant solitary osteochondroma of the calcaneus in a skeletally mature patient. This is one of the few and largest osteochondromas reported in the international literature.

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Table. Published cases of solitary calcaneal osteochondroma with growth after skeletal maturity.

Author	Year	Gender	Age (years)	Side	Trauma/History	Preoperative symptoms	Duration of preoperative symptoms	Intraoperative findings	Tumor size (mm)	Cartilage thickness (mm)	Surgery	Anesthesia	Position	Approach	Complications	Follow-up	Outcomes (clinical and radiographic)
Techner and DeCarlo[6]	1992	M	NR	NR	Runner (microtrauma and long-term repetitive stress)	Peroneal tendon impingement	NR	Osteochondroma in peroneal tubercle	NR	NR	NR	NR	NR	NR	NR	NR	NR
Martin et al.[7]	1995	F	48	R	NR	Distal peroneal tendonitis	10 years	Osteochondroma in peroneal tubercle, peroneus longus tenosynovitis	NR	NR	Excision, tenosynovectomy	NR	NR	NR	NR	2 years	Asymptomatic
Martin et al.[7]	1995	F	25	R	Recurrent sprains	Distal peroneal tendonitis	5 years	Osteochondroma in peroneal tubercle (negative pathology), peroneus longus tenosynovitis	NR	NR	Excision, tenosynovectomy	NR	NR	NR	NR	10 years	No recurrence
Sella and Chrostowski[8]	1995	F	71	L	NR	Heel pain and mass	NR	Osteochondroma in the inferior region of the calcaneum	NR		Excision	NR	NR	Plantar	NR	1 year	No recurrence
Karakurum et al.[9]	1998	F	24	R and L	No	Pain and mass in lateral region of both ankles	4 months	Osteochondroma in peroneal tubercle	NR	NR	Excision	Root block	NR	Longitudinal, parallel to plantar, 2 cm inferior to fibula	No	NR	
Sánchez-Mariscal Díaz et al.[10]	2001	M	69	R	No	Distal peroneal tendonitis	2 years	Osteochondroma in peroneal tubercle, peroneus longus tenosynovitis	NR	NR	Excision, tenosynovectomy	NR	Curvilinear, posterior to lateral malleolus	No	3 years	Asymptomatic	
Akmaz et al.[11]	2004	M	21	L	No	Pain and mass (5 cm) in the plantar-lateral region of the ankle	10 months	Osteochondroma in the inferior region of the calcaneum	NR	NR	Excision	Root block	Lateral	Longitudinal, parallel to plantar, 2 cm inferior to fibula	No	NR	NR
Nogier et al.[12]	2006	M	36	R	No	Heel pain	9 years	Inferolateral osteochondroma of the calcaneum	60 x 55 x 30	12	Excision	NR	NR	NR	Infection (*E. coli*; required 2 other surgeries)	4 years	No recurrence
Uğurlu et al.[13]	2007	F	23	R and L	Repetitive bilateral ankle sprains	Bilateral stenosing tendonitis of peroneal tendons	5 weeks	Osteochondroma in peroneal tubercle, peroneus longus tenosynovitis, os peroneum	NR	NR	Excision, tenosynovectomy	Root block	NR	Over the prominence	NR	Asymptomatic	
Blitz and Lopez[14]	2008	F	40	L	No	Heel pain and mass	6 months	Osteochondroma in the inferior medial tubercle	80 x 42 x 21	2- 18	Biopsy and excision	NR	NR	Medial	NR	3.5 years	No recurrence. Permanent work disability

(Continues.)

Table. (*Cont.*)

Author	Year	Gender	Age (years)	Side	Trauma/History	Preoperative symptoms	Duration of preoperative symptoms	Intraoperative findings	Tumor size (mm)	Cartilage thickness (mm)	Surgery	Anesthesia	Position	Approach	Complications	Follow-up	Outcomes (clinical and radiographic)
Koplay et al.[15]	2009	F	25	R	No	Pain and mass in the posteromedial region of the ankle	1 year	Posteromedial osteochondroma of the calcaneum	18 x 12	6	Excision	NR	NR	NR	Reoperated 6 months later due to painful regrowth	9 months	No recurrence
Jung et al.[16]	2011	F	22	R		Haglund's deformity and distal Achilles tendinopathy	12 years	Osteochondroma on the dorsum of the calcaneal protuberance	32 x 23 x 21	Excision, bursectomy, Achilles reinsertion	General	NR	NR	Medial to the Achilles tendon	No	18 months	No recurrence
Kumar et al.[17]	2016	M	58	R	No	Pain and mass in the posterior region of the ankle	years	Posteromedial osteochondroma of the calcaneum	31 x 17	4	Excision, bursectomy	NR	NR	Posterolateral	No	6 months	No recurrence
OKoh et al.[18]	2019	M	41	L	No	Plantar fasciitis and gastrocnemius contracture	years	Plantar, posterolateral calcaneus osteochondroma	11 x 9	NR	Excision	NR	NR	Posterolateral	No	9 months	No recurrence
Raviraj et al.[19]	2021	F	56	R and L	No	Haglund's deformity	6 months	Osteochondroma on the dorsum of the calcaneal protuberance	NR	NR	Excision, bursectomy	NR	NR	Posterolateral	No	2 years	No recurrence
Bilekli[20]	2022	M	50	R	No	Tearing of both peroneal tendons		Osteochondroma in peroneal tubercle	NR	NR	Excision, tubularization		Lateral	Over the prominence	No	1 year	No recurrence
Avramidis et al.[21]	2023	M	27	R	No	Pain and mass in the plantar-lateral region of the ankle	7 years	Osteochondroma in the lateral process of the calcaneal tuberosity	45 x 30 x 25	NR	Excision	NR	Lateral	Lateral	No	3 years	No recurrence
Trebino Molteni et al.	2023	M	22	L	No	Pain and mass in the plantar-lateral region of the ankle	3 years	Osteochondroma in the inferior region of the calcaneum	70 x 50 x 30	NR	Excision	Root block	Lateral	Lateral	No	1 year	No recurrence

M = male; F = female; NR = not reported; R = right; L = left.

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True Closed Posterior Subtalar Dislocation Without Fracture or Associated Malalignment. Case Report and Literature Review

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ABSTRACT
Subtalar dislocation is a rare type of dislocation that is characterized based on the relationship of the calcaneus to the talus, with the medial and lateral forms being more prevalent and the posterior and anterior forms appearing only in isolated cases in the literature. We present the case of a patient with a closed posterior subtalar dislocation without an associated fracture, as documented clinically and radiologically. We also include a video of the technique for closed reduction under anesthesia, as well as a review of the existing literature on this rare type of dislocation.
Keywords: Dislocation; subtalar; posterior; closed reduction.
Level of Evidence: IV

Luxación periastragalina posterior genuina cerrada sin fractura ni mala alineación asociada. Reporte de un caso y revisión bibliográfica

RESUMEN
La luxación periastragalina es un tipo de luxación infrecuente. Se clasifica según la relación del calcáneo con respecto al astrágalo, y las más comunes son las formas medial y lateral; y hay casos aislados de las variantes posterior y anterior. Presentamos el caso de un paciente con una luxación periastragalina cerrada posterior sin fractura asociada, el video de la técnica para la reducción cerrada bajo anestesia y también una revisión bibliográfica de esta infrecuente variedad de luxación.
Palabras clave: Luxación; periastragalina; posterior; reducción cerrada.
Nivel de Evidencia: IV

INTRODUCTION

The talus represents the point of interconnection between the bones of the leg and the foot, thus constituting the hinge between both segments and the weight-bearing support during the different activities carried out by human beings. The bone surface of the talus is two-thirds covered with cartilage and does not represent the site of origin or insertion of any musculotendinous unit.[1] Because of its position, it is prone to traumatic forces that, depending on their intensity or direction, as well as the ankle and foot's position in respect to the ground, can induce fractures or dislocations.

Subtalar dislocation is a special type of injury because it involves simultaneous dislocation of the talocalcaneal and talonavicular joints while leaving the tibiotalar and calcaneocuboid joints intact.[2] In 1811, Judcy[3] and Dufaurest[4] made the first descriptions of this type of dislocation. They are classified according to the direction in which the calcaneus deviates in relation to the talus. In 1853, Broca[5] initially identified medial, lateral and posterior forms; later, in 1856, Malgaigne and Buerger[6] added a rare anterior variant. The prevalence of different forms of dislocations has fluctuated throughout time, but depending on the source, it is clear that the medial variant is the most prevalent (73-85%),[7] followed by lateral dislocation (17%).[8]

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In contrast, the posterior and anterior variants are the least frequent (1-2.5%)[9] and their description is limited to isolated published cases.

We present the case of a patient with a closed posterior subtalar dislocation without associated fracture, resulting from a traffic accident, and confirmed by clinical and radiological evaluation. We also share a video of the technique for its closed reduction under anesthesia and a literature review on this rare variety of dislocation.

CLINICAL CASE

A previously healthy 25-year-old man with adequate function who worked in construction arrived at the Emergency Department after being involved in a traffic accident three hours earlier while riding a motorbike and colliding with a car, resulting in direct trauma to his left foot and ankle.

During the physical examination, the patient was conscious (Glasgow scale 15/15), had adequate hemodynamic stability, pain, edema, a deformity of the foot's neck with bony prominence in the anterior region, and a laceration at that level as well as another on the lateral aspect of the ankle; no wounds or loss of skin integrity were found. Toe range of motion and sensitivity were normal, and capillary refill and palpable pedal pulse were adequate and symmetrical (Figure 1).

Figure 1. A. Anterior view of the ankle. **B.** Lateral aspect, deformity with equinus tendency caused by Achilles tendon contraction, loss of heel height caused by anterior talus dislocation, and marked anterior deformity. **C.** Dysmetria, external rotation, and an anterior ankle deformity are visible on the medial aspect due to the prominence of the talar head.

Anteroposterior and lateral ankle radiographs revealed loss of talar joint congruence with posterior talocalcaneal dislocation, talonavicular dislocation with preservation of tibiotalar and calcaneocuboid joint connections, and no talar neck fractures. As a complementary study, computed tomography revealed no non-obvious associated lesions (Figures 2 and 3).

Figure 2. A. Lateral radiograph of the ankle shows apparent "verticalization" of the talus to almost 90° and loss of the talocalcaneal and talonavicular joint relationships, while the tibiotalar and calcaneocuboid relationships remain intact. **B.** Anteroposterior radiograph of the ankle. Talar head overlapping the midfoot (anterior displacement), with no lateral/medial displacement of the midfoot or calcaneus (non-rotational).

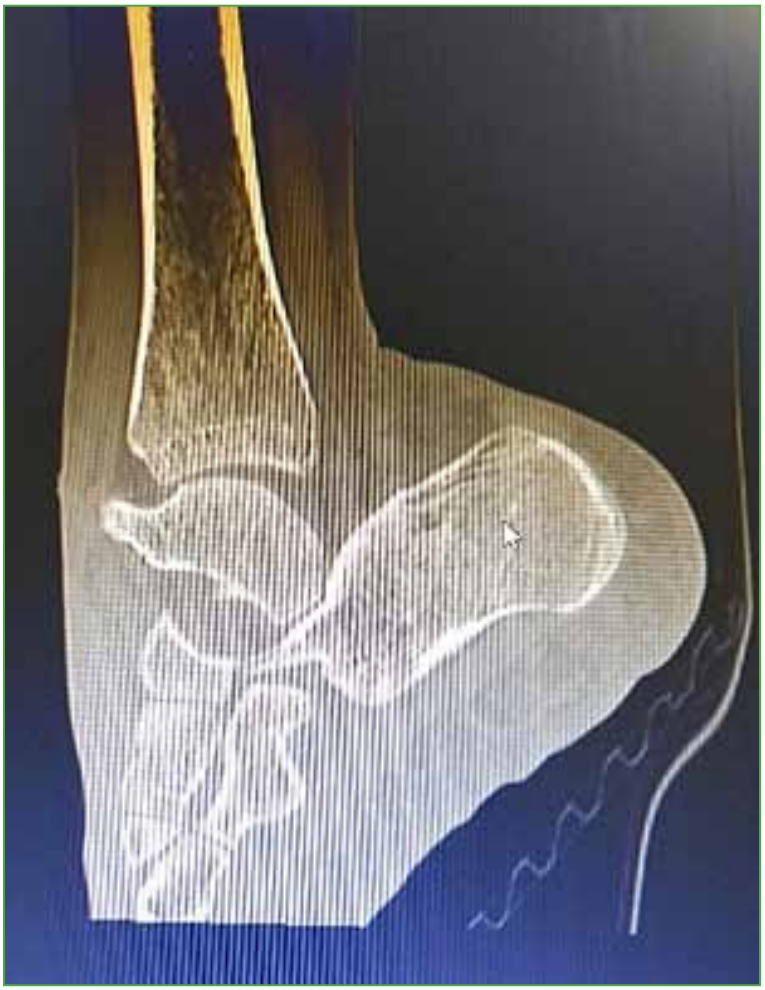

Figure 3. Computed tomography of the ankle, sagittal section. Empty talonavicular space with verticalized subtalar articular surface. The talus appears in the pseudo-zenith direction.

It was decided to attempt a closed reduction in the operating room. After informed consent was given, the patient was placed in the supine position under general anesthesia to achieve the greatest possible relaxation. The knee was brought into slight flexion to decrease the tension of the gastrocnemius/soleus complex. In plantar flexion, the rearfoot was tractioned and direct pressure was applied with the thumbs to the head of the talus at the anterior region of the ankle neck, followed by progressive dorsiflexion (Figure 4) until a non-audible snap was perceived and the deformity was corrected. Immediately, the passive range of motion of the tibiotalar/subtalar and talonavicular joints was assessed and found to be stable, with no cramping or locking (Video).

Figure 4. The reduction maneuver consists of knee flexion, traction in plantar flexion of the foot, and direct pressure on the talar head.

Reduction was verified by fluoroscopy and the limb was immobilized with a posterior ankle splint (Figure 5).

The patient remained under observation for 24 h to treat pain and to perform a CT scan in order to properly evaluate a congruent reduction, and rule out associated fractures, free bodies or previously undiagnosed lesions. Control imaging studies showed correction of the dislocation without talus fractures or occult fractures (Figure 6).

Figure 5. Immobilization with a plaster cast.

After this observation period, the patient was discharged with the splint. He was allowed to use crutches without unloading the limb, an articulated ankle brace was prescribed, and he was scheduled for an outpatient follow-up appointment. At his two-week outpatient evaluation, he had full ankle range of motion, adequate mobility and sensitivity in his toes, but he still lacked strength in plantar/dorsiflexion, as well as in the invertor and evertor muscles. The patient had already removed the splint and was wearing the ankle brace. He was instructed to start physiotherapy, and was scheduled for another outpatient consultation with a follow-up radiograph.

He was referred to the Physical Therapy Service for early rehabilitation, but did not return for follow-up, because the SARS-CoV-2 pandemic confinement had begun. After almost 18 months of trying to contact him, he did not attend the follow-up visit.

Figure 6. A. Computed tomography of the ankle, sagittal section. Talonavicular, subtalar, tibiotalar, and calcaneocuboid joints with congruent anatomical reduction. **B.** Computed tomography of the ankle, axial section. No free bodies are observed in the talonavicular or talocalcaneal joints.

DISCUSSION

Subtalar dislocation occurs when the talus loses articular contact with any of its surrounding osteoarticular components. As the foot's point of union with the rest of the lower appendicular skeleton, the talus participates in movement transmission, primarily flexion-extension via the tibiotalar hinge, but it is also responsible for the foot's pronation and supination movements in the subtalar joint, as it is articulated with the calcaneus. Similarly, it forms the talonavicular joint, which responds to changes in calcaneal position, eversion, and inversion, providing flexibility or stability to the midfoot via the transverse tarsal joint, as described by Elftman in 1960.[10] This central position exposes it to a range of high-energy loading forces, such as those found in traffic accidents, falls from great heights, and extreme sports, with the possibility of sustaining fractures, dislocations, or a combination of these. The posterior variety of subtalar dislocation is rare (1.7%).[11]

A literature review was carried out covering the last 70 years. The search included articles in English and Spanish, in databases such as PubMed, EMBASE and Cochrane, and yielded 10 articles (with an equal number of cases) that specifically refer to the posterior variety of subtalar dislocation.[9,12-20] However, when reading them in detail, we noticed that some of these cases were associated with other injuries: open injury,[13] open dislocation with fracture of the talar neck and cuboid,[14] fracture of the posterior malleolus and talus,[15] and a report on a follow-up of a previous case.[19] This left only seven cases of posterior subtalar injuries without associated injuries.

In this extensively illustrated article, we present the case of a patient with a "true" subtalar dislocation, defined as a closed posterior subtalar dislocation with no lateral or medial malalignment of the calcaneus or accompanying fracture. It is an infrequent condition (8 true cases in the last 7 decades); therefore, we believe it is important to publish this case to draw attention to a type of injury that, despite its rarity, requires a prompt diagnosis that is easily reached with an appropriate pair of both anteroposterior and lateral radiographs, where this type of "bi-articular" injury can be identified, since, unlike other dislocations in which only two articular surfaces lose their normal relationship, subtalar dislocations involve two joints, both the talonavicular and the talocalcaneal, and sometimes there are other associated injuries.

We believe that after the initial diagnosis, the procedure should be performed under general anesthesia to allow for a painless and atraumatic reduction maneuver under fluoroscopic control, followed by an evaluation of joint stability. Immobilization with a cast is required as part of joint protection, edema and pain management, as well as to limit weight bearing for 2 to 3 weeks. Post-procedure follow-up will include anteroposterior and lateral radiographs to confirm reduction, as well as a CT scan if a previous occult fracture is suspected, or to rule out an iatrogenic fracture or free bodies within the joint.

After completing the initial immobilization period, the patient should begin an early physical rehabilitation process with the use of an ankle brace that allows the patient to do reconditioning exercises without weight-bearing Regarding the period of weight-bearing restriction, Camarda et al.,[16] Jungbluth et al.,[17] Bali et al.,[18] and Gaba et al.[20] only allowed protected weight bearing in weeks 3 and 4 after reduction. Our patient started physical therapy in the third week, and after that, we lost contact with him.

Follow-up of these few patients lasted between 6 and 24 months,[18,20] and clinical outcomes were good, including pain-free return to work. Camarda et al. published the longest follow-up (58 months) at the end of which the patient had an *American Orthopaedic Foot and Ankle Society* scale score of 88.[16] This may indicate that, in the absence of associated injuries, the functional prognosis appears favorable.

The strengths of our presentation are the early diagnosis with only a couple of radiographs properly taken when the patient was admitted to the Emergency Department, an atraumatic reduction under general anesthesia, appropriate immobilization with weight-bearing restriction, and a postoperative control with imaging studies that confirmed a congruent "bi-articular" reduction without iatrogenic fractures or intra-articular free bodies.

The weakness of our article is the lack of a longer follow-up that would allow us to clinically and radiologically evaluate the outcome in this type of case.

CONCLUSIONS

Hindfoot dislocations can easily go unnoticed, some are frequent, such as tibiotalar or medial subtalar dislocations, but there are more unusual cases, such as the one presented here: pure posterior. In the event of a loss of normal joint relationships as a result of trauma, it is critical to obtain appropriate radiographic images in the Emergency Department and, if in doubt, to request complementary studies, such as a CT scan, which can provide additional information to confirm or rule out these or other occult injuries. Our report presents a rare case, but one that should not be overlooked, given the risk of serious future sequelae.

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

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Myths, Truths, Doubts and Confusions About Shockwave Therapy and Its Role in Musculoskeletal Pathology

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ABSTRACT
The advent of renal lithotripsy in the 1980s had a disruptive effect on the treatment of kidney stones. The discovery of the biological effects of shock waves quickly expanded the use of this therapeutic method to the field of Orthopedics and Traumatology. Although the topic has advanced significantly in recent years, there are still many questions and confusions in our specialty's environment, particularly among professionals who are not directly involved in the field. The objective of this presentation is to provide a scientific analysis of the points of controversy and the most frequent doubts.
Keywords: Shock waves; radial pressure waves; mechanotransduction.
Level of Evidence: V

Mitos, verdades, dudas y confusiones sobre las ondas de choque y su rol en la enfermedad musculoesquelética

RESUMEN
El advenimiento de la litotricia renal en la década de los 80 tuvo un efecto disruptivo en el tratamiento de los cálculos renales. El descubrimiento de los efectos biológicos de las ondas de choque expandió rápidamente el uso de este método terapéutico al campo de la Ortopedia y Traumatología. Si bien, en los últimos años, ha tenido un amplio desarrollo, persisten muchas confusiones y dudas en el ambiente de nuestra especialidad, sobre todo entre los profesionales que no están directamente involucrados en el tema. El objetivo de esta presentación es hacer un análisis de los puntos de controversia y las dudas más frecuentes, basado en la bibliografía científica.
Palabras clave: Ondas de choque; ondas radiales de presión; mecanotransducción.
Nivel de Evidencia: V

INTRODUCTION

The advent of renal lithotripsy in the 1980s had a disruptive effect on the treatment of kidney stones.[1] The application of mechanical waves made it possible to remove mineral deposits within the urinary tract and thus avoid surgery in a huge percentage of patients. Forty years later, the treatment, which was initially met with skepticism, is now a recognized and approved indication.[2]

Experience with the method led early urologists to notice consequences beyond the mechanical effect on the stones.[3-5] The biological response induced by the mechanical waves thus opened up a new therapeutic dimension. This knowledge was quickly applied to orthopedics and traumatology pathology.[3,6-9]

Despite more than 30 years since its first use in the field of musculoskeletal illnesses, traumatologists who are not directly involved in its usage continue to have several concerns and misinterpretations about the role of this therapeutic tool.

The objective of this presentation is to analyze the points of controversy and the most frequent doubts, based on the scientific literature.

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Confusion: are radial and focused waves the same thing?

The mechanical forces of nature have influenced living beings since the genesis of life on our planet.[3] Their use for therapeutic purposes began at the end of the 20th century.

There are two types of waves, electromagnetic and mechanical.[10] Both focused and radial waves are mechanical waves.

Shock waves or focused waves are mechanical waves with well-defined characteristics.[10-13] As seen in Figure 1A, they have a rapidly growing, short-lived peak positive pressure followed by a negative pressure phase. These waves are the ones initially described in the field of urology and they are the real shock waves. They can be generated by electrohydraulic, electromagnetic or piezoelectric sources.[10-13]

A decade after the first therapeutic application of focused waves, 'radial waves' appeared on the market as a more portable and cost-effective alternative.[3] Historical and commercial reasons have determined that radial waves are also called 'shock waves', but this is inaccurate.[10,13] The correct nomenclature is "focal shock waves" and "radial pressure waves," respectively. Unfortunately, in most publications, the correct nomenclature is not respected, which generates a great deal of confusion.[11]

From the physical point of view, radial waves (Figure 1B) are completely different from focused waves. Radial waves have a peak positive pressure 100 times lower and a pulse duration 1000 times longer.[10-12] The mechanisms of generation and action are also different.[10-12] Radial waves are generated by the impact of a projectile on an applicator, so they are also known as ballistic waves.[10,12] Their mechanism of generation is based on the principle of action and reaction described by Newton.[3,14]

The fact that they use different technology does not imply that one is superior to the other. In some cases, indications in the field of Orthopedics and Traumatology overlap and there are also specific indications for each method.[11,12]

The risk levels are also different.[12] Focused waves, when used incorrectly or with inadequate indications, can cause severe complications that radial waves would not.[13,15] This is one of the reasons why international societies recommend restricting focused waves to medical use.[16]

In short, radial waves and focused waves are mechanical waves that can have a therapeutic use in the field of Orthopedics and Traumatology, but they are completely different from the point of view of their generation and physical characteristics. Each method has its own set of indications, as well as some shared ones. Radial waves are not shock waves. It is recommended that focused waves be used by trained physicians.

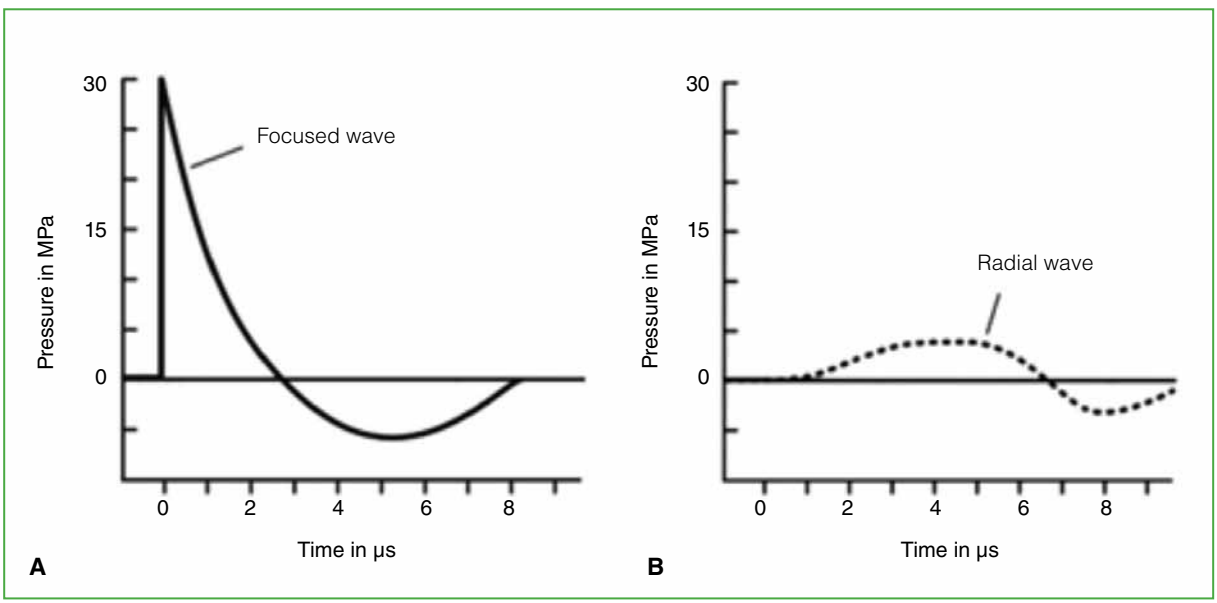

Figure 1. Comparison of the pressure profiles of a focused shock wave (**A**) and a radial wave (**B**).
Modified from: Loske AM, Moya D. Shock waves and radial pressure waves: time to put a clear nomenclature into practice. J Reg Sci 2021;1(1):4-8. https://doi.org/10.13107/jrs.2021.v01.i01.005

Myth: mechanical waves cause microtears in tissues (false)

It is common to hear that mechanical waves base their therapeutic action on microtrauma that cause bleeding and scarring processes. This is incorrect.

MRI studies performed after applying focused shock waves to the shoulder have ruled out any type of injury.[17] Histological evaluation of bone tissue after the application of focused waves ruled out the presence of "microfractures" when therapeutic doses are used.[18] The purely mechanical effect is only effective in the case of the destruction of calculi, which are inert mineral accumulations. In living tissues, the mechanism of action is biological, based on the phenomenon of mechanotransduction.[12,13,19] Cells and the extracellular matrix are influenced by mechanical stimuli. These structures recognize the mechanical stimuli and generate a biological response.[12,13,19]

It is perplexing that, in a field that has used mechanotransduction for over a century, this method of action is difficult to understand. All traumatologists know that by loading a fracture at the right time and under the right conditions, the healing process is accelerated. This is nothing more or less than applying mechanotransduction therapeutically as in the case of shock waves.

The process has four stages: physical, physico-chemical, chemical, and biological.[12,19] The stimulated cell nucleus determines the release of exosomes with angiogenic effects.[19-22] Vasculogenesis and angiogenesis are well-studied fundamental mechanisms of action in focused shock waves.[12,13,19-23] Countless studies have shown that the local concentration of nitric oxide, cell replication factors and vascular growth factors increases after applying shock waves.[12,19,19,21,23]

It is crucial to note that the therapeutic effects of mechanical waves are not solely based on mechanical effects, nor are they driven by microtrauma generation. The mechanism of action is biological and basically mediated by angiogenic and vasculogenic effects.

Confusion: what are the indications for each type of wave?

As mentioned above, there are ideal indications for each type of wave and other indications are shared (Figure 2).[12,13] Focused waves are indicated for conditions that require the use of higher levels of energy, such as tendon calcifications[24,25] and bone lesions.[6,26] They are also capable of accessing greater depths than radial waves.[27]

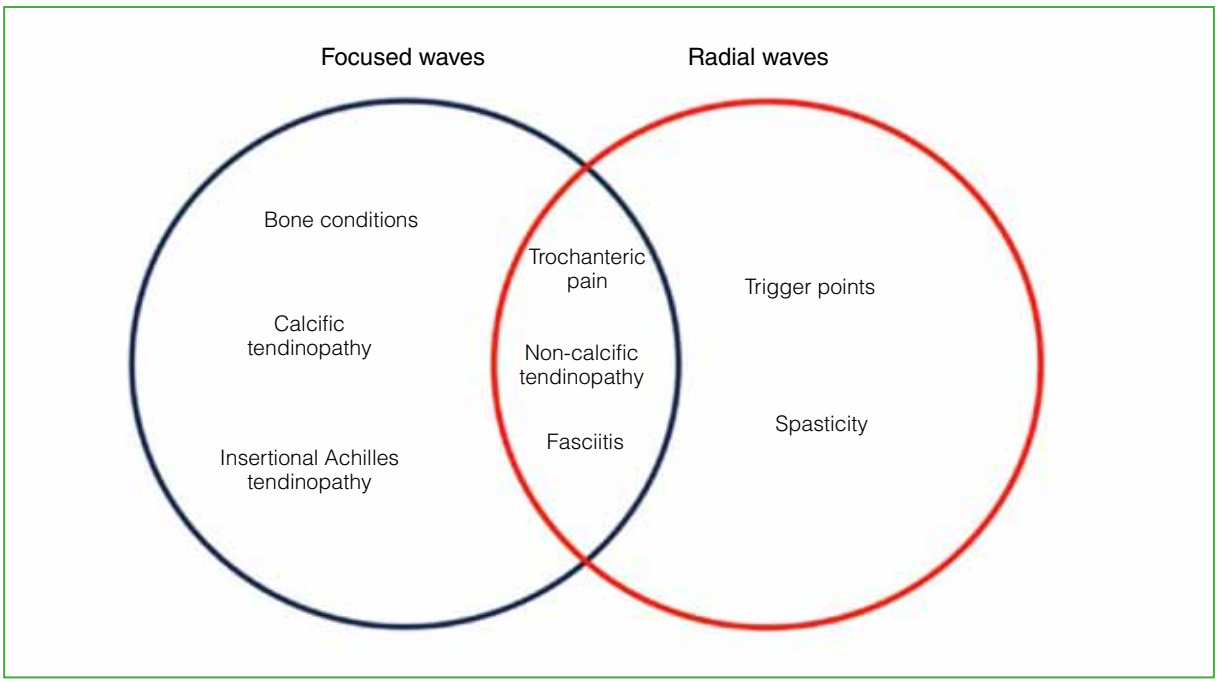

Figure 2. Indications for focused shock waves, indications for radial waves, and indications shared by both.
Modified from: Loske AM, Moya D. Shock waves and radial pressure waves: time to put a clear nomenclature into practice. J Reg Sci 2021;1(1):4-8. https://doi.org/10.13107/jrs.2021.v01.i01.005

Radial waves have a more superficial effect and pose less risk when applied in areas close to organs with gaseous content;[11,12,15] therefore, they can be used, for example, on trigger points in the dorsal region. They have also been advised for childhood spasticity due to their higher treatment tolerance.[28]

Radial waves allow for greater coverage of treatment areas than focused waves.

Both methods can be used interchangeably in most noncalcified tendinopathies[12] and plantar fasciitis.[12,13,16] In insertional Achilles tendinopathies, this author prefers focused waves.

Truth: there is solid scientific evidence of their efficacy

The majority of surgical methods used in Orthopedics and Traumatology are supported by a poor level of scientific evidence.[29,30] Stephen Burkhart, in his keynote address at the 2019 World Congress on Shoulder and Elbow Surgery in Buenos Aires, wondered whether shoulder arthroscopy could have been developed during the 21st century era of evidence-based medicine and *Food and Drug Administration* restriction policies.[31,32]

Shock waves arose a decade after arthroscopy, and they had to deal with the more demanding and critical context of new therapeutic alternatives.[31] This led to the generation of many studies and publications, not always with the utmost scientific rigor.[31]

In 2018, we published a study on the most frequent indications for radial and focused waves in the *Journal of Bone and Joint Surgery*.[12] We used the grades of recommendation based on scientific evidence according to the system proposed by the aforementioned publication[33] (Table 1).

The result, based on the evidence found in the literature at that time, can be seen in Table 2.

Table 1. Grades of recommendation based on scientific evidence.

Grade of recommendation	Type of study	Behavior
A	Level of Evidence: I	Definitively change the practice
B	Level of evidence: II and III	Probably change the practice
C	Level of evidence: IV and V or controversial	Define according to experience
I	Insufficient evidence	Cannot be recommended

Adapted from Wright JG, Einhorn TA, Heckman JD. Grades of recommendation. *J Bone Joint Surg Am* 2005;87(9):1909-10. https://doi.org/10.2106/JBJS.8709.edit

Table 2. Grades of recommendation for the most common indications for radial and focused waves in musculoskeletal disease.

Condition	Technology	Grade of recommendation
Calcific tendinopathy of the shoulder	Focused	A
Calcific tendinopathy of the shoulder	Radial	I
Non-calcific tendinopathy of the shoulder	Focused and radial	C
Epicondylar muscle tendinopathy	Focused and radial	B
Trochanteric pain syndrome	Radial	B
Patellar tendinopathy	Focused and radial	B
Achilles tendinopathy	Focused and radial	B
Plantar fasciitis	Focused and radial	A
Nonunion	Focused	B

Adapted from Moya D, Ramón S, Schaden W, Wang CJ, Guiloff L, Cheng JH. The role of extracorporeal shockwave treatment in musculoskeletal disorders. *J Bone Joint Surg Am* 2018;100(3):251-63. https://doi.org/10.2106/JBJS.17.00661

The highest level of evidence for rotator cuff calcifications is for focused waves and, in plantar fasciitis, for both focused and radial waves.[12] The *American College of Foot and Ankle Surgeons* incorporated the use of waves into its treatment algorithm for plantar fasciitis more than 10 years ago.[34]

The scientific evidence is moderate for most tendinopathies, except for non-calcific rotator cuff tendinopathy[12] and pseudarthrosis.[12]

The degree of evidence is low for non-calcified tendinopathies of the shoulder,[12] knee osteoarthritis,[35] wrist and hand tenosynovitis, and many other conditions. However, based on this author's experience, the empirical results in the non-advanced stages of knee osteoarthritis are very encouraging.

In conclusion, there is an acceptable degree of evidence for the use of focused shock waves and radial waves in most of their usual indications. In many of the cases, the level of evidence is similar to or greater than that of surgical procedures for the same conditions.

Doubt: what are their contraindications?

An important contraindication to the use of focused waves is if the patient is receiving intense anticoagulant therapy,[15,36] especially if high energy levels are to be used.

The application of focused waves to tissues with gaseous content (lungs, viscera) can cause serious injury.[15,37] Direct application to open physes, tumor areas, embryos, and fetuses is also contraindicated.[15,37,38] The application of focused waves to large vessels and nerves is contraindicated.[15,37,39]

The presence of a pacemaker is today a relative contraindication for focused waves due to changes in pacemaker design and focal equipment;[40] in any case, it is preferable to be in contact with the treating cardiologist.

As for radial waves, given their lower penetration, the possibility of complications is much lower. Absolute contraindications are the presence of tumors, embryos, or fetuses in the area to be treated.[37]

Doubt: when is the ideal time to indicate them?

The ideal indication for both focused and radial waves is chronic tendinopathy and fasciitis. It is recommended to exhaust other therapeutic options, such as medication, rest, rehabilitation, changes in habits and exercises, before starting shockwave treatment. Therefore, they are not usually the initial therapeutic indication in most cases.[12,16]

Confusion: are the results immediate?

Mechanical waves generate a biological process that includes modulation of inflammation and stimulation of healing.[12,13,16,19] A succession of biological phenomena occurs that require time.[12,16] The clinical response may not appear until three months in the case of tendinopathies.[16] Follow-up protocols for pseudarthrosis extend the basic radiological control to three months, but changes may occur up to one year after treatment is completed (Figure 3).

For these reasons, it is key to keep in mind that immediate responses should not be expected in the vast majority of cases.

Doubt: How many sessions are necessary?

The lack of strict consensus regarding the number of sessions and doses has been criticized. In most indications of musculoskeletal pathology, the current consensus advises three sessions at a weekly interval.[12,16,37] According to the generation source used, sessions may be added, but in general, no more than six in total. Additional sessions are added after a prudent wait to evaluate the effect of the initial dose. These additional doses are not necessary in most cases.

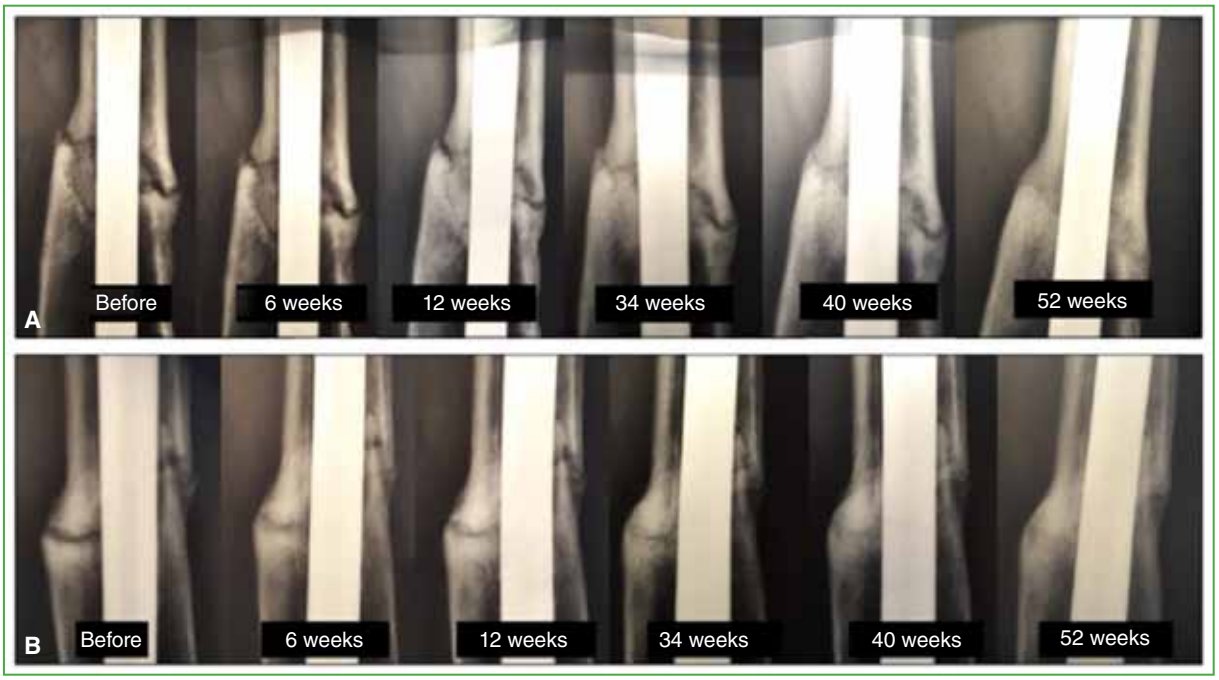

Figure 3. Progression of the consolidation process after applying a focused shockwave treatment plan in a patient with femoral pseudarthrosis of 20 months of evolution and two surgical procedures. The condition had progressed for ten months since the second surgery. **A.** Sequence of plain radiographs of the femur, AP view, with focus on the area of pseudarthrosis. **B.** Sequence of plain radiographs of the femur, lateral view, with focus on the area of pseudarthrosis.

Confusion: ossification versus calcification

A conceptual error is often made in practice, confusing calcification and ossification. Calcifications are mineral deposits in soft tissues. The best known case is hydroxyapatite crystal deposits in the rotator cuff tendons. In this case, shock waves are used to trigger a biological process that resorbs the mineral deposit (Figures 4A and B).

Heterotopic ossifications, on the other hand, are characterized by organized and structured bone tissue that shock waves are not able to "dissolve" and cannot stimulate its resorption. It is bone tissue, i.e., a calcified collagenous matrix that may or may not contain bone marrow elements.[41]

During the COVID-19 pandemic, we received patients referred with heterotopic hip ossifications after a stay in the intensive care unit (Figure 4C), with the aim of making the calcium deposit disappear, and unfortunately this is not possible. If it were, we would risk eliminating sections of normal bone, but focused waves do not have such an effect.

It is important to note that calcifications and ossifications are two different conditions in terms of histology, prognosis and treatment. Focused waves do not determine the disappearance of heterotopic ossifications.

Figure 4. Plain radiographs of the shoulder, AP view, showing calcification of the supraspinatus tendon (A) and the same case after a focused shockwave treatment plan (B). C. Radiograph of the hip, AP view. Heterotopic ossification of the hip is seen after a stay in intensive care for COVID-19.

Doubt: can they be used in cases of pseudarthrosis?

Focused waves can be used to treat pseudarthrosis and delayed consolidation (Figures 3, 5 and 6). It is an absolute condition that the fracture site must be stable.[12,16] The best results are obtained when the gap is <5 mm, in hypertrophic calluses, in patients with a short time of evolution and in non-infected patients.[12,16] High energy levels must be used.[12,16]

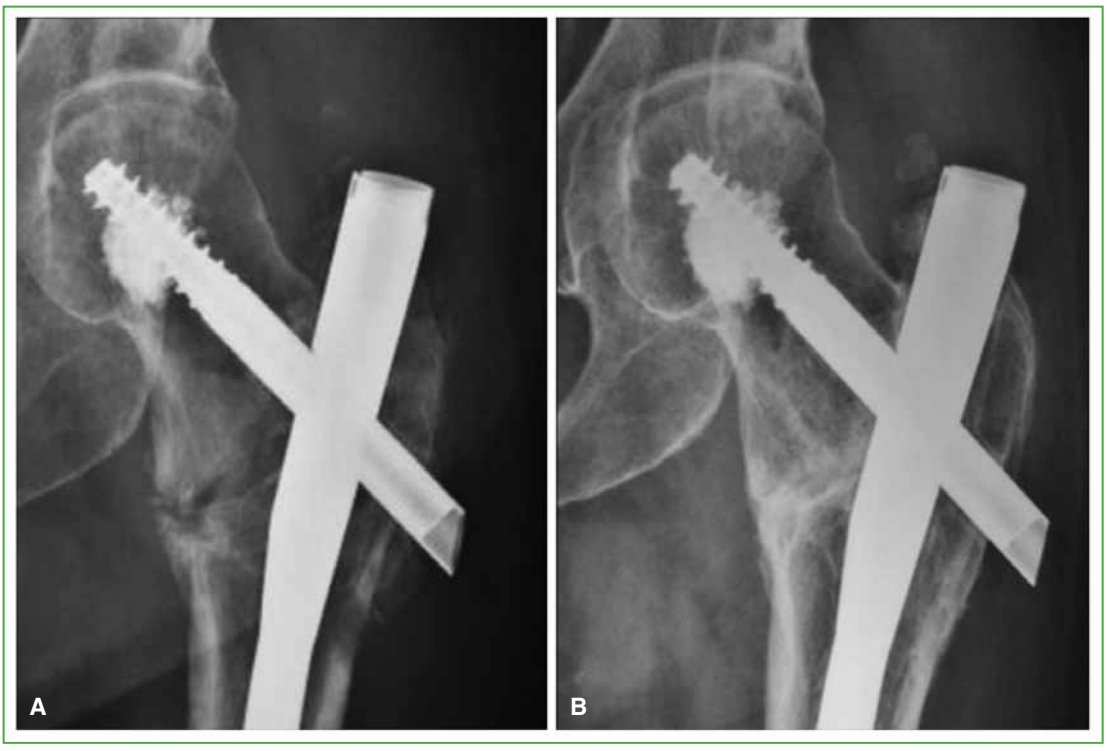

Figure 5. Plain radiographs of the hip, AP view. **A.** Revision surgery of a hip intertrochanteric fracture of one year of evolution, with no signs of consolidation. **B.** Results 5 months after the application of a focused shockwave treatment plan. The symptomatology disappeared.
With permission from the Journal of Regenerative Science.

The rate of favorable outcomes is around 70% under the best conditions.[12,13,16] Studies have been published comparing the results of focused waves and surgery in certain cases of pseudarthrosis, but no significant differences have been obtained.[41,42]

Likewise, we have obtained favorable outcomes in cases of failed arthrodesis (Figure 6).

In conclusion, focused waves can be applied as an alternative to surgery when the conditions are right for their use.

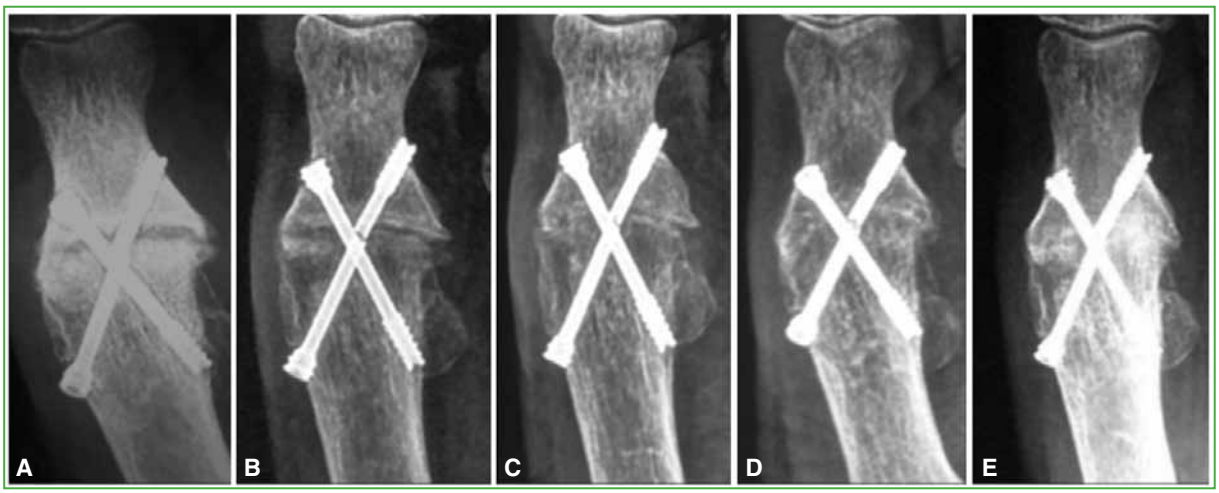

Figure 6. Sequence of plain radiographs of the forefoot with focus on the first metatarsophalangeal joint. **A.** Failed hallux arthrodesis of 18 months of evolution. **B.** Two months after three sessions of high-energy focused shockwaves. **C.** Three months after shock waves. **D.** Four months after shock waves. The arthrodesis has consolidated and the patient is asymptomatic. **E.** Radiographic control after 2 years.

Myth: they do not cause complications (false)

Like any therapeutic procedure, the outcome of shock waves can be poor.[15] The most common poor outcome is failure to produce the intended biological response, but complications have also been reported.

The most frequent cause of poor outcomes is diagnostic error.[15] The availability of shock wave or radial pressure wave equipment does not make the operator an expert in the disease being treated. For this reason, we emphasize the necessity of respecting the area of expertise[16] and collaborating with the subspecialist in Orthopedics and Traumatology.

Inadequate application and failure to follow contraindications can cause serious complications.[15,16,39] In Argentina, the equipment must be approved by the National Administration of Drugs, Food and Technology (ANMAT).

Reported complications range from episodes of lipothymia during application and a transient increase in pain after application, to complications such as isolated cases of humeral head necrosis.[13,15,43] Fortunately, most complications are avoidable and infrequent.

Advantages

One of the main advantages of mechanical wave therapy is that it is a non-invasive method with a low rate of severe complications.

Initially, it was reserved for situations in which, having exhausted conservative treatment options, the possibility of surgery was evaluated.[19] Over the years, the range of indications has increased.

An unsuccessful therapeutic attempt with focused waves has no bearing on the likelihood of success in subsequent surgery.[44]

The cost-effectiveness ratio is also adequate. For example, the success rate of open and arthroscopic surgery has been compared with that of focused shock waves for rotator cuff calcifications, and the outcomes were similar.[45,46] In addition to causing fewer and less severe complications,[45,46] focused waves have a much lower cost.[12,13,47,48]

Conflict of interest: The author declares no conflicts of interest.

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Case Resolution

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Case presentation on page 93.

DIAGNOSIS: Fracture of the lateral process of the talus.

DISCUSSION

Given the suspicion of a talar bone injury with joint involvement and the possibility of surgical resolution, it was decided to order a multiplanar computed tomography of the ankle and rearfoot with 3D reconstruction. The images show a fracture of the lateral process of the talus with fragmentation and displacement of the subtalar joint (Figure 4).

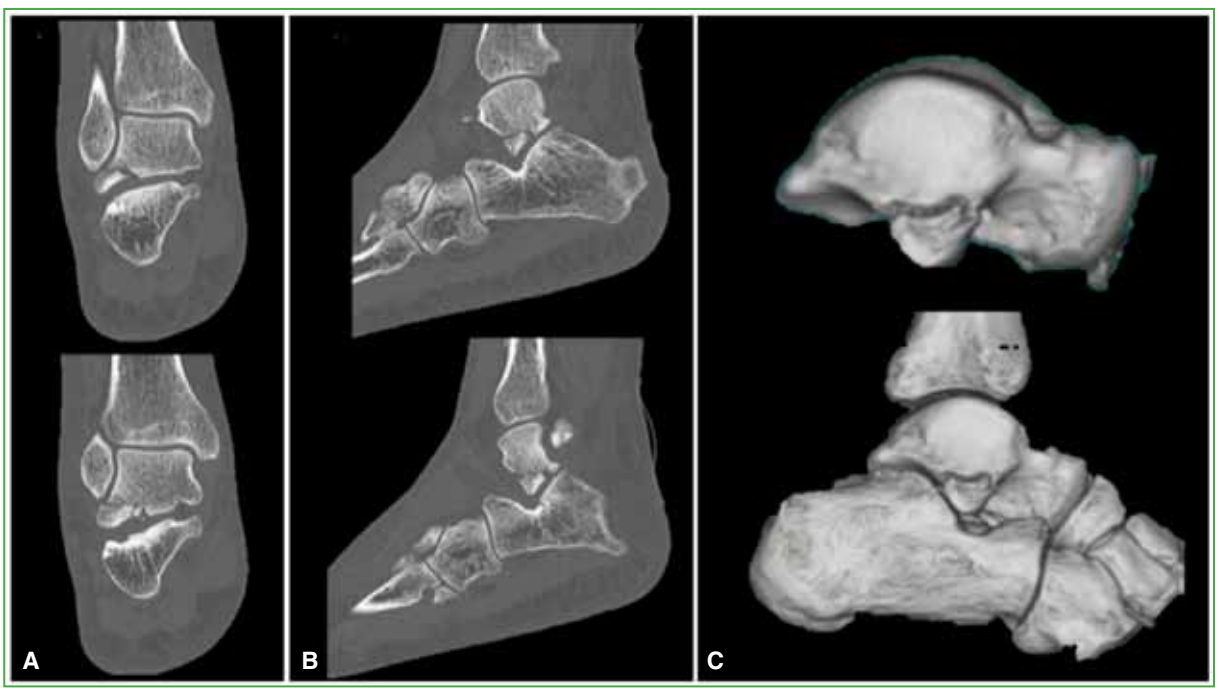

Figure 4. Computed tomography of the ankle and rearfoot requested in the outpatient consultation, 20 days after the accident. **A.** Coronal slices. **B**. Sagittal slices. **C.** 3D reconstruction.

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The patient underwent open reduction and lateral internal fixation 30 days after the initial trauma (Figure 5).

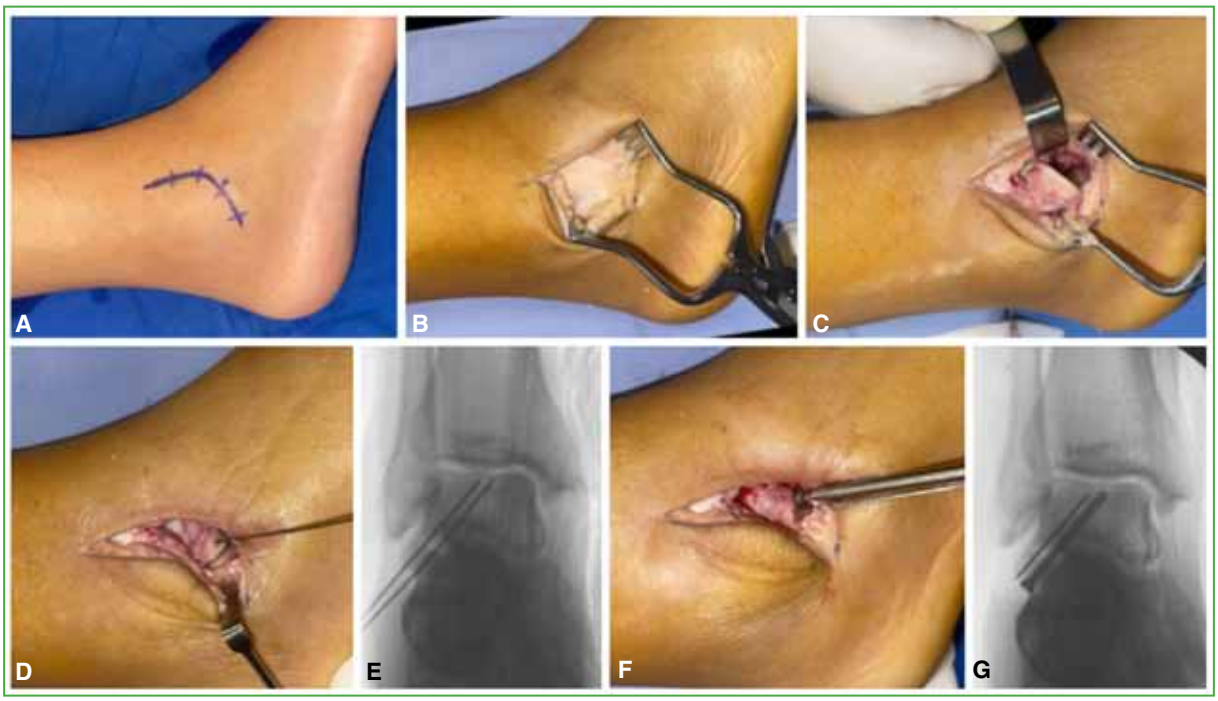

Figure 5. Open reduction and internal fixation by curved lateral approach. **A.** Cutaneous incision. **B.** Superficial dissection and visualization of the anterolateral ankle capsule. **C.** Deep dissection and individualization of the displaced fracture fragment. **D and E.** Transient reduction and fixation. **F and G.** Definitive fixation with 3.5 mm cannulated screw and anti-rotation pin.

Fractures of the lateral process of the talus are very rare, accounting for no more than 0.4-1% of all traumatic ankle injuries.[1-3] The mechanism of injury is axial loading or a forward fall on a foot in forced dorsiflexion and external rotation or eversion. It occurs in the context of certain sporting activities where this situation is common, such as snowboarding ("snowboarder's fracture").[4]

They may go undetected in 15-60% of cases because they have a clinical appearance similar to acute lateral instability and are difficult to see on radiographs in conventional projections.[4,5] Delayed treatment or an inadequate therapeutic decision can lead to considerable morbidity given the eminently articular nature of these injuries: the lateral talar process presents a double sliding surface for the distal fibula and for the lateral end of the posterior facet of the calcaneus and is the site of insertion of ligamentous structures involved in ankle and hindfoot stability.[1-5] Computed tomography is the study of choice for correct interpretation and decision making. Multiplanar slices every 1-2 mm are especially useful to define fragment size, degree of displacement, presence of comminution and percentage of subtalar or tibiotalar joint involvement.[5,6]

The therapeutic decision is based on the anatomical morphology of the injury, which is taken into account by all classifications attempting to standardize its treatment.[7-9] The one suggested by Macklin Vadell recognizes four main types: type 1, a small chip or avulsion fracture of the anteroinferior portion of the process; type 2, a simple fracture, with an intermediate or large fragment, no displacement, or displacement >2 mm; type 3, a comminuted fracture with an intermediate or large fragment that might be articular, metaphyseal, or affect the entire process; and type 4, a variant associated with subtalar instability or subtalar subluxation (Figure 6).[10]

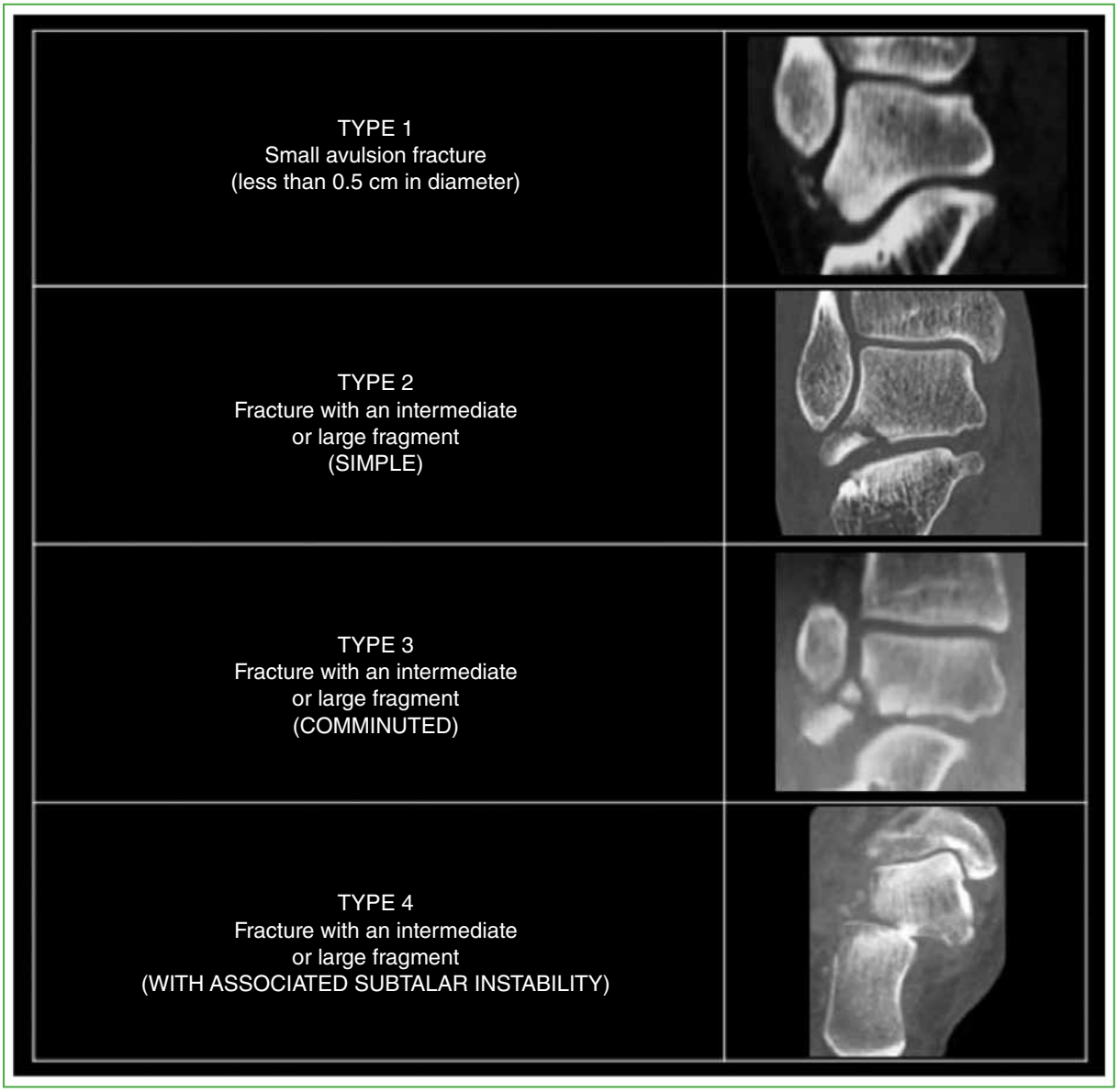

Figure 6. Macklin Vadell's morphological classification of fractures of the lateral process of the talus (2005).

Conservative management is reserved only for small avulsions without joint involvement or for simple fractures without displacement, with a protocol that includes non-weight bearing for at least six weeks, and active and passive range of motion exercises from the third week onwards. In all other situations, and because displacement is usually the rule, treatment is surgical.[7-10] Arthroscopic access through two ventral and dorsal anterolateral portals may be an option for both resection and debridement of small intra-articular injuries, and for fixation of intermediate or large fragments with minimal initial displacement.[7] Open surgery is the preferred technique for larger displaced injuries through a transverse Ollier access or a lateral longitudinal access slightly curved inwards toward the cuboid, as in the case presented. Single-line patterns can be fixed only with screws, since there is a uniform surface of bone contact between the main fragment and the fracture bed. The minimum size of a potentially 'fixable' fragment corresponds to three times the diameter of the screw head to be placed, which can be 2.0, 2.4 or 2.7 mm ('rule of thirds'). It is advisable to associate a second fixation with an anti-rotation

pin whenever possible. Patterns with intercalary fragmentation require plate augmentation, usually with a 2.0 mm T-plate for support.[8-10] If residual subtalar instability is detected, temporary transarticular stabilization with two pins, maintained for at least 21 days, is suggested.[10] Finally, in large injuries with complete fragmentation, excision of the process can be considered if the resected volume does not exceed 5-10 cm^3,[11] or primary subtalar arthrodesis if the involvement is greater.[7-9]

Early diagnosis and early treatment achieve the best long-term outcomes, because they allow a rapid normalization of subtalar function. When treated promptly with open reduction and internal fixation, 80% of patients with large simple fractures regain their pre-trauma level of function. The most frequently reported complication is osteoarthritis with subtalar stiffness, which may be associated with any subtype of injury even with appropriate treatment and requires subtalar arthrodesis as a salvage procedure.[6-10]

CONCLUSIONS

Fractures of the lateral process of the talus are rare but potentially disabling injuries if the diagnosis is missed and treatment is delayed. Surgical fixation of simple, large fragment patterns is the most recommended therapeutic approach and should be performed as soon as possible to avoid sequelae.

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