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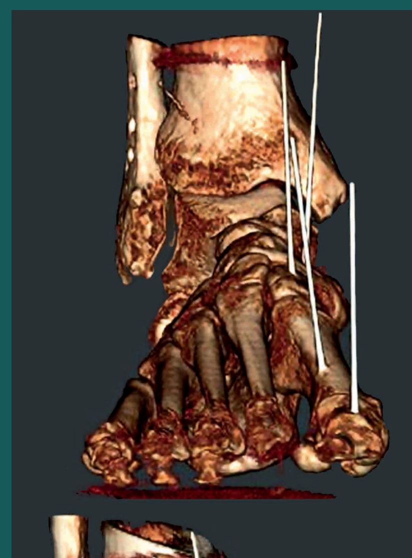

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Case Report

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Editorial

JOURNAL OF THE Foot & Ankle JFA

What is new about *hallux rigidus*?

RAMÓN VILADOT-PERICÉ

SPAIN

PAST - PRESIDENT OF THE SPANISH SOCIETY OF FOOT AND ANKLE SURGERY AND MEDICINE (SOCIEDAD ESPAÑOLA DE MEDICINA Y CIRUGÍA DEL PIE Y TOBILLO, SEMCPT).

PAST - PRESIDENT OF THE COLLÈGE INTERNATIONAL DE PODOLOGIE (CIP), (PREDECESSOR OF THE CURRENT INTERNATIONAL FEDERATION OF FOOT & ANKLE SOCIETIES ,IFFAS).

ANTONIO VILADOT VOEGELI

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Hallux rigidus (HR) represents one of the most frequent forefoot disorders, together with *hallux valgus* and lateral toe deformities, being the most frequent degenerative process in the foot and ankle.

This publication is the result of the collaboration of colleagues of the Spanish Society of Medicine and Foot and Ankle Surgery (*Sociedad Española de Medicina y Cirugía del Pie y Tobillo*, SEMCPT) and the Argentinean Society of Medicine and Foot and Leg Surgery (*Sociedad Argentina de Medicina y Cirugía de Pie y Pierna*, SAMCPP). It is an honor for us to have this work edited in the *Journal of the Foot & Ankle*, a journal with a marked Latin identity. We really thank Alexandre Leme Godoy-Santos, Chairman of the Editorial Board, for his help and contribution. This update topic has been coordinated by R. Viladot Pericé and A. Viladot Voegeli, together with M. Herrera and M. Núñez-Samper.

Considering the interest and the extent of this topic and, according to the coordinators, we have divided the publication into two parts. The first one describes general aspects (definition, etiology, classification, treatment algorithm, etc.) and the conservative treatment of HR, whereas the second one addresses the different surgical techniques described to treat this disease.

The aim of this work is to review our knowledge on HR and to perform an update on the innovations that have emerged during the last years.

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Special Article

Concept, etiology, and pathomechanics of hallux rigidus

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Abstract

There is a continuous anatomical, functional and pathomechanical roadmap from functional hallux limitus to hallux rigidus. Although many etiologies for hallux rigidus have been studied it is very probable that it has a primary origin with less-than-ideal movement when we are born. Upon a restricted range of motion, symptoms may arise depending on the amount of work and how compensatory mechanisms work around the first metatarsophalangeal joint. Changes occurring at the joint that allow the transition from a sliding movement mechanism (physiological) to a rolling mechanism (pathological) may trigger anatomical and functional changes resulting in pain and dysfunction. Any surgical technique that is able to restore the sliding mechanism to the first metatarsophalangeal joint will have a positive impact on pain and function in a patient with a symptomatic functional hallux limitus/rigidus.

Level of Evidence V; Therapeutic Study; Expert opinion.

Keywords: Hallux limitus/etiology; Hallux rigidus/etiology; Biomechanics.

Introduction

Hallux rigidus (HR) is the second most frequent disease of the great toe, after hallux valgus[1]. Lower dorsiflexion mobility of the first toe under weight-bearing conditions is initially known as functional hallux limitus (FHL). In some patients, the evolution of FHL leads to the development of HR[2]. Both FHL and HR may be more or less symptomatic in our patients. The pathogenic mechanisms of disease progression remain unknown, as well as the reason why an asymptomatic foot eventually develops symptoms. This study presents a pathogenic mechanism that may explain these issues.

Definition and concepts

The term "hallux rigidus" originates from the Latin words *"hallux"* and *"rigeo"*, i.e., rigid great toe. In the field of Orthopedic Surgery, this term is used to describe a condition that affects the metatarsophalangeal joint (MTPJ) of the great toe and is characterized by a progressive loss of dorsiflexion and the formation of periarticular osteophytes that eventually cause stiffness, generally painful, which may even become incapacitating.

In 1887, Davies-Colley described the existence of a plantar flexion position of the proximal phalanx in relation to the first metatarsal head and coined the term "hallux flexus"[3]. Some months later, Cotterill[4] described the same disease, but named it as "hallux rigidus". During the years following the initial definition, other names were also used to refer to HR: "dorsal bunion," "hallux dolorosus," and "hallux malleus"[1].

Each person is born with a given mobility in their great toe joint. Mobility examined with the patient seated (open kinetic chain) may be very different from mobility while walking (close kinetic chain). When walking, around 60° of dorsiflexion in the first MTPJ is required for feet to take off during the third rocker of gait without generating loading transfers nor changes that may be mechanically detrimental to neighboring structures. Great toes that are unable to perform this ideally necessary dorsiflexion are known as *"functional hallux limitus"*. This condition is not pathological as long as it does not cause pain and limitation. When the mechanics of the structures that land and stabilize the first metatarsal head over the sesamoid flexor complex of the first toe fails, there is a pathological change in the way how the first MTPJ works, which will produce a greater contact between the dorsum of

Study performed at Trauma and Orthopaedic Department. Hospital Universitario Quirónsalud Madrid. Faculty of Medicine UEM, Madrid, Spain.

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the metatarsal head and the dorsum of the proximal phalanx of the hallux. After this moment, and always determined by patient's intrinsic (internal compensation mechanisms) and extrinsic circumstances (physical activity, footwear), there will be progression to the development of HR (Figure 1). This condition is the second leading cause of great toe problems, after hallux valgus[4]. Gould at al.[2] found an incidence of 1 in every 45 individuals older than 40 years.

Etiology

We classically make a distinction between primary etiology (birth or constitutional and mechanical ones) and secondary etiology (posttraumatic ones, systemic diseases, osteochondritis dissecans, iatrogenic ones after hallux valgus surgery). In this section of our study, we will focus on primary etiology and its relationship with intrinsic, constitutional, and mechanical factors that could favor the development of HR. Several factors have been proposed to explain its development, but none of them could be proven with a significant level of evidence.

Sometimes, an anatomical disposition and its opposite have been correlated with the etiology of HR. For instance, an excessively long first MTPJ (index plus) has been related to increased pressure on the first MTPJ that could have a harmful effect on this joint[5,6]. Similarly, an excessively long first toe (Egyptian foot) in relation to the smaller toes have also been proposed by the same mechanism[6-8]. However, other authors have suggested that a short first metatarsus (index minus) could be the origin of HR[9]. The existence of hallux valgus interphalangeal or intraphalangeal has also been associated with the development of HR, but this finding seems to be an adaptive consequence rather than a cause[10].

Retraction of plantar soft tissues, with consequent limitation of first toe dorsal mobility, was one of the most debated etiological theories in the past[11]. Retraction of intrinsic muscles affects hallux dorsiflexion[12]. Excessive traction of plantar fascia in cadavers reduces hallux dorsiflexion, which increases by nearly 10° when plantar fascia is sectioned close to the hallux[13]. Progressive flexor hallucis longus fibrosis at its myotendinous junction leads to a significant limitation in hallux dorsal mobility and increases compressive forces on the first MTPJ[14]. Distal plantar fascia release is able to improve first MTPJ dorsiflexion[11,13,15]. Theories centered on soft tissues are inconsistent and often refer to consequences rather than to causes of HR.

Figure 1. Osteology of hallux rigidus in the first ray of a cadaver with large osteophytosis. (Photograph Pau Golanó†/Patricia Ruiz, Universidad de Barcelona).

For a long time, one of the etiopathogenic theories on HR had been centered on the existence of primary first metatarsal elevation (*"metatarsus primus elevatus"*) in relation to smaller metatarsi[16]. It was tempting to think that primary first metatarsal elevation would considerably change the reverse windlass mechanism of plantar fascia and would significantly limit dorsal mobility of the first MTPJ, causing the well-known chain of pathogenic events culminating in joint destruction. In 1938, Lambrinudi[17] suggested that primary first metatarsal elevation is a causal factor of HR. However, several authors have shown that an elevation of 5 mm could be observed in up to two-thirds of normal feet and advised against first metatarsal plantar flexion osteotomy in the treatment of symptomatic HR[16,18-20]. Most first metatarsal elevations improve after any surgery, with positive effects on pain and first MTPJ motion; thus, this elevation is currently considered a possible consequence rather than a cause of HR[21].

The non-spherical morphology of first metatarsal head has been also associated with the development of HR. Studies by Coughlin and Shurnas and by Shumas reported up to 74% of flat, quadrangular, and chevron-shaped metatarsal heads in their patients with HR[10,22], and other authors found similar figures[23]. Again, it was not possible to demonstrate what is a cause and what is a consequence. Inconsistence in the bilateral involvement of HR prevented to draw reliable conclusions about the contralateral foot with regard to the morphology of the first metatarsal head.

Other possible mechanical causes reported, such as metatarsus adductus, pronated foot, hallux valgus, first cuneometatarsal joint hypermobility, effect of footwear, an anomalous nucleus of ossification within the metatarsal, could not be demonstrated, and several studies show lack of cause-effect relationship to produce HR[24-27]. Behind these mechanical causes, there is instability, which would be easily responsible for joint degeneration[10].

There is a family cluster in the presentation of cases, and Coughlin and Shurnas[10] suggested that almost two-thirds of patients had a family history among their close relatives. However, no genetic review could make us think of some type of concrete heritage.

Pathomechanics

Normal first MTPJ range of motion is around 110°, with a plantar flexion of 35° and dorsiflexion of 75°. Although there is great variability in the estimated values, nearly 60° of first MTPJ dorsiflexion are required for a normal third rocker of gait[28]. It is not clear yet why great toes with good or acceptable mobility eventually develop painful and limiting HR, but it is known that the etiological factors that have been historically proposed in the literature and mentioned in the previous section of this study do not justify this transition.

Maceira and Monteagudo[21] worked on a pathomechanical explanation to elucidate why hallux limitus eventually becomes symptomatic and progresses to HR. There would be an explanation to understand why, at a certain point of life, the great toe becomes symptomatic and does not improve. This explanation should also justify clinical and radiological findings and elucidate why apparently different surgical treatments, such as a plantar flexion osteotomy or an extensive cheilectomy, can both improve symptoms[21]. In a normal foot, the first MTPJ works with a sliding mechanism on the sesamoids while there is an advance of the mass center of the body during the transition from the second to the third rocker of gait. In this sliding mechanism, rotation centers remain constant and centered throughout the entire joint movement and are located in the anatomical center of the first metatarsal head[21]. In HR, rotation centers are located in an eccentric position, dorsal to the first metatarsal head, thus causing compression with greater friction between the first metatarsus and the dorsal region of the first phalanx. In this line of mechanical knowledge, transition from the sliding mechanism to the rolling mechanism would make FHL symptomatic. When maintained over time, the rolling mechanism would progressively tear the joint, causing HR (Figure 2).

The first MTPJ range of motion with which one is born may significantly determine the age of symptom onset. Patient's physical fitness also determines the action mechanisms that impair the proper functioning of the first MTPJ and determines the onset of pain. For the ideal functioning of the joint during sliding, the triceps and the subtalar joint should allow for the peroneus longus to promote plantarization of the first metatarsus, in order to stabilize the metatarsal head by "sinking it" into the sesamoid flexor apparatus. In this position, the head would be "trapped" in the plantar position, favoring passive dorsiflexion of the toe by the reverse winch mechanism. Conversely, when these mechanisms are not able to effectively achieve plantarization of the first metatarsal head (eg, due to foot aging), the head starts to work with a rolling mechanism, thus "jumming into" the dorsal proximal phalanx of the hallux and producing the chain of damages known as incipient HR (Figure 3). This anomalous dorsal compression of the head against the phalanx would lead to greater supination of the forefoot, with the emergence of secondary symptoms. The associated morphological changes are justifiable within this context. The Delpech's Law explains that, when the proximal phalanx is obliged to exert greater pronation efforts during the third rocker of gait and has an asymmetrical shape, it may cause hallux valgus inter/intraphalangeal, present in almost 100% of cases of HR. Two of the common, but very different, surgical techniques, such as extensive cheilectomy with Möberg-Akin osteotomy and proximal plantarization osteotomy of the first metatarsal, produce the same effect of restoring the sliding mechanism, obliging the metatarsal head to plantarize itself against the sesamoid flexor apparatus and favoring the passive dorsiflexion mechanism without the jamming of the metatarsal head into the dorsal aspect of the proximal phalanx (Figure 4). Any surgical technique for

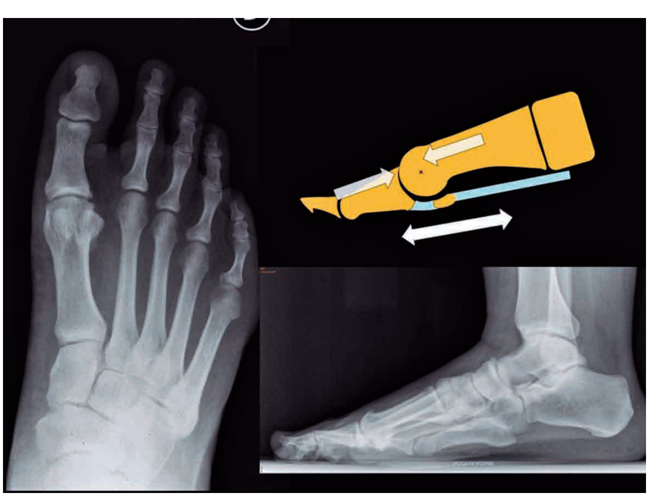

Figure 2. The rotating mechanism represented here favors the relative first metatarsal elevation and dorsal jumming against the phalanx in functional hallux limitus. Weight-bearing radiographs show radiological signs of incipient osteophytes, relative first metatarsal head elevation, and hallux valgus inter/intraphalangeal.

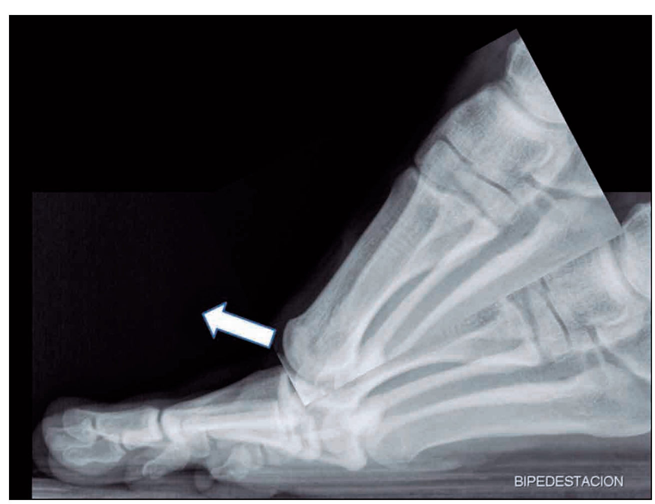

Figure 3. Radiological representation of progression of the third rocker of gate when the metatarsophalangeal joint of the first ray works with a pathological rolling mechanism. It is possible to predict harmful mechanical effects on the site of pressure and jumming between the first metatarsal head and the proximal phalanx of the hallux.

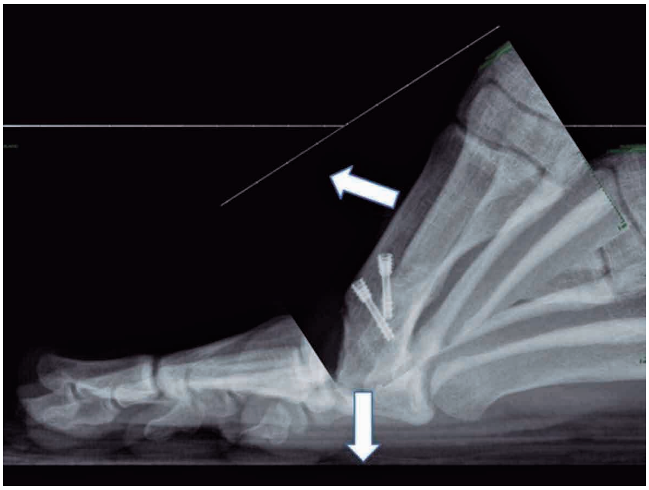

Figure 4. Same representation after first metatarsal Weil osteotomy with lowering of the metatarsal head and cheilectomy. The created "hinge" region restores the sliding mechanism that prevents the jumming of the first metatarsal head over the proximal phalanx of the hallux.

treating FHL that manages to put the sliding mechanism into operation and to prevent the rolling mechanism from working will achieve a good mechanical effect on the first MTPJ and to inhibit progression to HR.

Conclusion

Progression from FHL to HR often leads to the onset or worsening of patient's painful symptoms. Although many etiopathogenic factors have been described for the emergence and worsening of this condition, it is not clear which of them cause a patient to present with pain and to eventually require surgery. We do believe that the mechanical work of the MTPJ has an "expiration date" when the compensation mechanisms wear out and inexorably replaces the physiological sliding mechanism with the rotating mechanism, which is pathologic. Conservative and surgical treatments that manage to restore the sliding mechanism to the first MTPJ and to prevent the rolling mechanism will be successful in promoting pain relief and functional improvement.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MMR *(https://orcid.org/0000-0002-0107-5675) Wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study, performed the surgeries; RVP *Conceived and planned the activity that led to the study, participated in the review process, bibliographic review, interpreted the results of the study. *(https://orcid.org/0000-0002-8254-2916) All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Yee G, Lau J. Current concepts review: hallux rigidus. Foot Ankle Int. 2008;29(6):637-46.
2. Gould N, Schneider W, Ashikaga T. Epidemiological survey of foot problems in the continental United States: 1978-1979. Foot Ankle. 1980;1(1):8-10.
3. Davies-Colley N. Contraction of the metatarsophalangeal joint of the great toe (hallux lexus). Br Med J. 1887;1:728.
4. Cotterill JM. Stiffness of the great toe in adolescents. Br Med J. 1888;1(1378):1158-62.
5. Nilsonne H. Hallux rígidus and its treatment. Acta Orthop Scand. 1930;1:295-303.
6. Munuera PV, Domínguez G, Castillo JM. Radiographic study of the size of the first metatarso-digital segment in feet with incipient hallux limitus. J Am Podiatr Med Assoc. 2007;97(6):460-8.
7. Calvo A, Viladot R, Giné J, Alvarez F. The importance of the length of the first metatarsal and the proximal phalanx of hallux in the etiopathogeny of the hallux rigidus. Foot Ankle Surg. 2009; 15(2):69-74.
8. Calvo A. Case-control study for the evaluation of the association between morphological parameters of the foot and the presence of hallux rigidus [thesis]. Tarragona: Universitat Rovira i Virgili; 2005.
9. Ogilvie-Harris DJ, Carr MM, Fleming PJ. The foot in ballet dancers: the importance of second toe length. Foot Ankle Int. 1995; 16(3):144-7.
10. Coughlin MJ, Shurnas PS. Hallux rigidus: demographics, etiology, and radiographic assessment. Foot Ankle Int. 2003;24(10):731-43.
11. Asunción Marquez J. Martín Oliva X. Hallux rigidus: aetiology, diagnosis, classification and treatment. Rev Esp Cir Ortop Traumatol. 2010;54(5):321-8.
12. Durrant MN, Siepert KK. Role of soft tissue structures as an etiology of hallux limitus. J Am Podiatr Med Assoc. 1993;83(4):173-80.
13. Harton FM, Weiskopf SA, Goecker RM. Sectioning the plantar fascia. Effect on first metatarsophalangeal joint motion. J Am Podiatr Med Assoc. 2002;92(10):532-6.
14. Flavin R, Halpin T, O'Sullivan R, FitzPatrick D, Ivankovic A, Stephens MM. A finite-element analysis study of the metatarsophalangeal joint of the hallux rigidus. J Bone Joint Surg Br. 2008;90(10):1334-40.
15. Rochera R, Lluis L, Viladot R. The importance of plantar muscles in the Hallux-Rigidus. In: Actas del 2nd EFORT Congress, 1995. Munich, Alemania: EFORT. p. 74-5.
16. Meyer JO, Nishon LR, Weiss L, Docks G. Metatarsus primus elevatus and the etiology of hallux rigidus. J Foot Surg. 1987;26(3):237-41.
17. Lambrinudi C. Metatarsus Primus Elevatus. Proc R Soc Med. 1938;31(11):1273.

18. Horton GA, Park YW, Myerson MS. Role of metatarsus primus elevatus in the pathogenesis of hallux rigidus. Foot Ankle Int. 1999;20(12):777-80.
19. Caminear DS. Role of metatarsus primus elevatus in the pathogenesis of hallux rigidus. Foot Ankle Int. 2000;21(11):967.
20. Roukis TS. Metatarsus primus elevatus in hallux rigidus: fact or fiction? J Am Podiatr Med Assoc. 2005;95(3):221-8.
21. Maceira E, Monteagudo M. Functional hallux rigidus and the Achilles-calcaneus-plantar system. Foot Ankle Clin. 2014;19(4): 669-99.
22. Shurnas PS. Hallux rigidus: etiology, biomechanics, and nonoperative treatment. Foot Ankle Clin. 2009;14(1):1-8.
23. Hunt KJ, Anderson RB. Biplanar proximal phalanx closing wedge osteotomy for hallux rigidus. Foot Ankle Int. 2012;33(12):1043-50.
24. McMaster MJ. The pathogenesis of hallux rigidus. J Bone Joint Surg Br. 1978;60(1):82-7.
25. Blázquez Viudas R. Hallux Limitus and relationship with the foot pronated as etiological factor. Rev Int Cienc Podol 2011;5(1):21-7.
26. Colò G, Fusini F, Zoccola K, Rava A, Samaila EM, Magnan B. May footwear be a predisposing factor for the development of hallux rigidus? A review of recent findings. Acta Biomed. 2021; 92(S3):e2021010.
27. Saggini R, Colotto S, Innocenti M. [Presence of a nucleus of distal ossification of the first metatarsus and its correlation with the pathogenesis of juvenile hallux rigidus]. Arch Putti Chir Organi Mov. 1984;34:59-69.
28. Camasta CA. Hallux limitus and hallux rigidus. Clinical examination, radiographic findings, and natural history. Clin Podiatr Med Surg. 1996;13(3):423-48.

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Special Article

Hallux rigidus: clinical examination, radiology, and classification

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Abstract

The severity of hallux rigidus depends on the degree of joint involvement, from local pain to stress fractures of other bones of the foot due to hyper-support. Radiology is mandatory to have an accurate diagnosis and gives us a parameter of joint injury. We use the Coughlin and Shurnas classification as the gold standard for treatment.

Level of Evidence IV.

Keywords: Hallux rigidus/therapy; Hallux rigidus/classification; Hallux rigidus/diagnostic imaging; Metatarsophalangeal joint.

Introduction

Hallux rigidus is a disabling disease that affects the first metatarsophalangeal joint (MTPJ), causing arthritis/arthrosis. Different classifications have been described to assess and treat this condition, the most used of which is that of Coughlin and Shurnas[(1)].

Clinical assessment

The severity of signs and symptoms of hallux rigidus depends on the degree of MTPJ involvement, ranging from mild local pain just before the takeoff phase of the gait to ambulation disorders, with hyper-support in the lateral of the foot that may cause bursitis in the fifth MTPJ, overload of calcaneocuboid and metatarsocuboid joints, and sometimes even fifth metatarsal fractures in athletes. Shoes often hurt due to the proliferation of dorsal osteophytes, and wearing heel shoes lead to increased symptoms. This osteophyte proliferation in the dorsal and medial edges of the primer metatarsal head and in the base of the first phalanx increases over time, which reduces range of mobility and may compress the dorsal cutaneous nerve, thus producing numbness in the medial edge of the foot and possible Tinel's sign with paresthesia in chronic cases[(2,3)] (Figure 1A).

On physical examination with the patient seated with no support, the hallux is usually in the equine position with regard to the other toes, a deformity that is exacerbated when pressure is applied to the plantar surface of the first metatarsal head (Figure 1B). Erythema, edema, and hyper-pigmentation due to footwear pressure may occur; therefore, differential diagnosis with crystal deposits and septic arthritis is mandatory.

The joint is painful; in milder disorders, this pain is observed at the end range of motion, and pain throughout the entire range of motion indicates a more diffuse level of arthritics changes[(4)]. Vulcano et al.[(5)] showed the clinical versus radiographic difference in range of motion measures, with clinical dorsiflexion being equal to or lower than dorsiflexion as measured radiologically. This difference was significantly greater in patients with a clinical dorsiflexion of less than 30 degrees of dorsiflexion than in patients with 30 degrees or more (14° versus 9.9° respectively)

Radiology

Radiographic evaluation is performed with the patient in the standing position, requiring anteroposterior (AP) (15° of cephalic angulation)[(6,7)] and lateral views of the foot, the oblique incidence is the best one to assess joint space narrowing, since dorsal osteophytes may give the impression of a more advanced degree of joint impingement on AP view[(2)] and it was also described that osteophytes may maintain the joint space in a distracted position[(4)].

Profile radiograph may allow for observing dorsal osteophytes (Figure 2A2 and B2), equine position of the hallux, and metatarsus primus elevates, which was measured according

Study performed at the CEPP del Instituto Dupuytren de la Ciudad de Buenos Aires, Buenos Aires, Argentina.

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to the method proposed by Bouaicha et al.[8]. According to this method, first a circle (Mose's technique) is fit within in the first metatarsal head congruent with the joint surface, then a line is drawn from the dorsal surface of the first metatarsus, and a perpendicular line is drawn from the point where this line insects with proximal end of circle until the dorsal aspect of the second metatarsal. A distance along the perpendicular line greater than 5 mm indicates metatarsus primus elevatus (Figure 1C). It firstly affects the dorsal surface of the joint and, as disease advances, cartilage is lost towards the plantar surface, the joint space is narrowed, and dorsal and lateral osteophytes emerge both in the head and in the base of the phalanx (Figure 2C1 and C2).

Degenerative changes and sesamoid arthrosis may occur independently and are less symptomatic. Sesamoids may be bipartite but with no associated disease (Figure 2A1), hypertrophic on AP incidence, enteropathic at distal and proximal sites due to constant traction, and osteopenic possibly due to lack of use. In many changes, sesamoids may be found much behind their usual location (sesamoid retraction) due to flexor hallucis brevis spasm[3,9]. It is possible to measure sesamoid retraction in profile radiographs by drawing a mid-diaphyseal line along the first metatarsal and a perpendicular line along to the articular facet of the first metatarsal head, with the distance between the latter and the sesamoid being the distance of sesamoid retraction (Figure 1D).

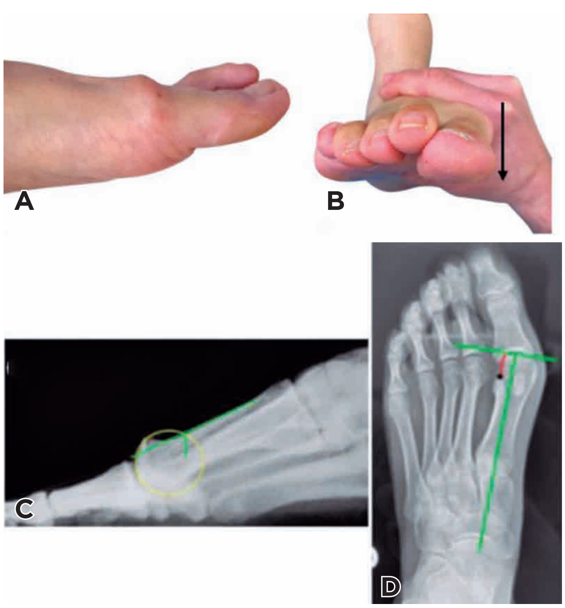

Figure 1. A) Clinical image showing skin protrusion resulting from osteophyte proliferation in the MTPJ of the hallux. B) Hallux in the equine position, a deformity that is increased when pressure is applied to the plantar surface of this joint. C) Method by Bouaicha et al., with a distance greater than 5 mm indicating the presence of metatarsus primus elevatus. D) Mid-diaphyseal line passing along the first metatarsal and a perpendicular line along the articular facet of the first metatarsal head. The distance between the latter line and the sesamoid is the distance of sesamoid retraction.

Magnetic resonance imaging and axial computed tomography are needed when there is no radiological evidence of lesion and in case of other suspected diseases, such as osteochondral lesion.

Classification

Many classifications of hallux rigidus have been developed[10]. Regnauld[11] radiologically describes degenerative MTPJ changes and divides them into 3 grades: Grade 1: flattening of metatarsal head, incipient peripheral osteophytosis; Grade 2: there is also joint impingement, subchondral sclerosis, dorsal osteophytes, sesamoid changes; and Grade 3: disappearance of joint space, major sclerosis, ankylosis between the sesamoid and the joint. The most used classification, i.e., the gold standard, is that proposed by Coughlin and Shurnas[1], which modifies the classification proposed by Easley et al.[12] and divides the disease into 5 grades (0 to 4), considering MTPJ range of motion, radiological changes, and clinical manifestations (Table 1).

Conclusion

The diagnosis of hallux rigidus is clinical and radiological; with regard to the latter, the oblique incidence is very useful to predict articular status. We used the Coughlin and Shurnas classification, since it encompasses clinical and radiological criteria and provides us with therapeutic parameters for the different disease stages.

Figure 2. A1) Front and A2) Profile: dorsal osteophyte, minimum joint space narrowing, minimum periarticular sclerosis, minimum metatarsal head narrowing, emergence of osteophytes. B1) Front and B2) Profile: dorsal, lateral, and possibly medial osteophytes that give a flattened aspect to the metatarsal head, not more than 1/4 of dorsal joint space involvement on lateral radiography, mild to moderate joint space narrowing, and sclerosis. C1) Front and C2) Profile: considerable narrowing, possible periarticular cystic changes, more than 1/4 dorsal joint space involvement on lateral radiography, enlarged, cystic, and/or irregular sesamoid.

Table 1. Clinical and Radiological Classification of Hallux Rigidus by Coughlin and Shurnas (1999)

Grade	Range of motion	Radiographic findings	Clinical findings
0	Dorsiflexion of 40°-60° (10-20% below normal motility)	Normal	No pain
1	Dorsiflexion of 30°-40° (20-50% below normal range of motion)	Main finding is dorsal osteophyte, minimal or no joint changes.	Mild pain and stiffness
2	Dorsiflexion of 10°-30° (50-75% below normal range of motion)	Mild joint flattening, not greater than1/4 of dorsal MTPJ seen on a profile radiograph, mild to moderate reduction in joint space, osteophytes, and sesamoid sclerosis	Moderate to severe pain and stiffness
3	Dorsal and plantar flexion below 10° (75-100% below normal range of motion)	More than 1/4 of dorsal joint space involvement on profile radiographic view, severe radiological changes with subchondral cysts or erosions, sesamoid involvement, constant moderate to severe pain and pain at extremes of motion	Near-constant pain and major stiffness
4	Stiff joint	Radiographs show free bodies or osteochondral defects and pain throughout range of motion (no mobility)	Constant pain, stiffness, supination

Source: Coughlin MJ, Shurnas PS. Hallux rigidus. Grading and long-term results of operative treatment. J Bone Joint Surg Am. 2003;85(11):2072–88.

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References

1. Coughlin MJ, Shurnas PS. Hallux rigidus. Grading and long-term results of operative treatment. J Bone Joint Surg Am. 2003;85(11):2072-88.
2. 2. Keiserman LS, Sammarco VJ, Sammarco GJ. Surgical treatment of the hallux rigidus. Foot Ankle Clin. 2005;10(1):75-96.
3. Camasta CA. Hallux limitus and hallux rigidus. Clinical examination, radiographic findings, and natural history. Clin Podiatr Med Surg. 1996;13(3):423-48.
4. Deland JT, Williams BR. Surgical management of hallux rigidus. J Am Acad Orthop Surg. 2012;20(6):347-58.
5. Vulcano E, Tracey JA 3rd, Myerson MS. Accurate Measurement of First Metatarsophalangeal Range of Motion in Patients With Hallux Rigidus. Foot Ankle Int. 2016;37(5):537-41.
6. Meschan I. Radiology of the normal foot. Semin Roentgenol. 1970;5(4)327-40.
7. Karasick D, Wapner KL. Hallux rigidus deformity: radiologic assessment. AJR Am J Roentgenol. 1991;157(5):1029-33.
8. Bouaicha S, Ehrmann C, Moor BK, Maquieira GJ, Espinosa N. Radiographic analysis of metatarsus primus elevatus and hallux rigidus. Foot Ankle Int. 2010;31(9):807-14.
9. Jack EA. The aetiology of hallux rigidus. Br J Surg. 2005;27(107):492-7.
10. Beeson P, Phillips C, Corr S, Ribbans W. Classification systems for hallux rigidus: a review of the literature. Foot Ankle Int. 2008;29(4):407-14.
11. Regnauld B. The Foot: Pathology, Aetiology, Semiology, Clinical Investigation and Therapy. In: Regnauld B, editor. Disorders of the Great Toe. Berlin: Springer-Verlag Berlin Heidelberg; 1986. p. 249–90.
12. Easley ME, Davis WH, Anderson RB. Intermediate to long-term follow-up of medial-approach dorsal cheilectomy for hallux rigidus. Foot Ankle Int. 1999;20(3):147-52.

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Special Article

Conservative treatment of hallux rigidus: narrative review of scientific evidence

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Abstract

This study proposes an update on conservative treatment of hallux rigidus based on scientific evidence. This is a narrative review of 19 articles that analyzed conservative treatment of hallux rigidus in its different modalities. Conservative treatment is effective in approximately half of the patients with hallux rigidus, and footwear modifications, use of insoles, and hyaluronic acid injections are the most effective treatments, according to evidence-based medicine.

Level of Evidence III; Therapeutic Studies; Systematic Review of Level III Studies.

Keywords: Hallux rigidus; Conservative treatment; Evidence-based medicine; Review.

Introduction

Conservative treatment of hallux rigidus is especially indicated in mild and moderate stages. Its objective is to relief pain and to facilitate gait. It is also indicated, regardless of disease stage, in patients with a high number of medical comorbidities, in which surgery could compromise their baseline state. Although different therapeutic alternatives have been described, high quality scientific evidence is scarce[1-5]. However, most clinical guidelines recommend initiating conservative treatment, since it is effective in approximately half of the patients[3]. The aim of the present study is to conduct an update on the conservative treatment of hallux rigidus.

Rehabilitation treatment

Physical therapy

Manual therapy in hallux rigidus consists basically of mobilizing the first ray and the glenosesamoid system, as well as stretching flexor hallucis longus muscle and tendon and plantar short foot muscles[6,7]. However, scientific evidence on this therapy is uniformly low[4,8,9].

Modification of usual footwear and plantar orthosis

These treatment modalities may play an important role in conservative treatment of forefoot diseases, but scientific evidence remains weak[5].

Footwear

Footwear modifications seek to maintain the toe immobile during the third rocker, in order to promote pain relief. It is worth remembering that the third rocker, or propulsive phase, accounts for 30% of the gait cycle and that the fulcrum of the movement is at the level of the forefoot, in the metatarsophalangeal joint (MTPJ)[10,11]. General recommendations are based on the use of shoes with wide toe box, rigid sole, short heels, and rocker bottom sole[2]. Rocker bottom shoes, marketed as MBT® shoes, have been successfully used, although their efficacy has not been widely supported[12]. They are designed to facilitate normal gait with no need of mobilizing the MTPJ of the first ray during the take-off phase. The rocker bottom may be applied only in the anterior portion of the sole or cover the entire sole (Figure 1).

Study performed at the Orthopaedic Department, University Hospital of Canary Islands, La Laguna, Tenerife, Spain.

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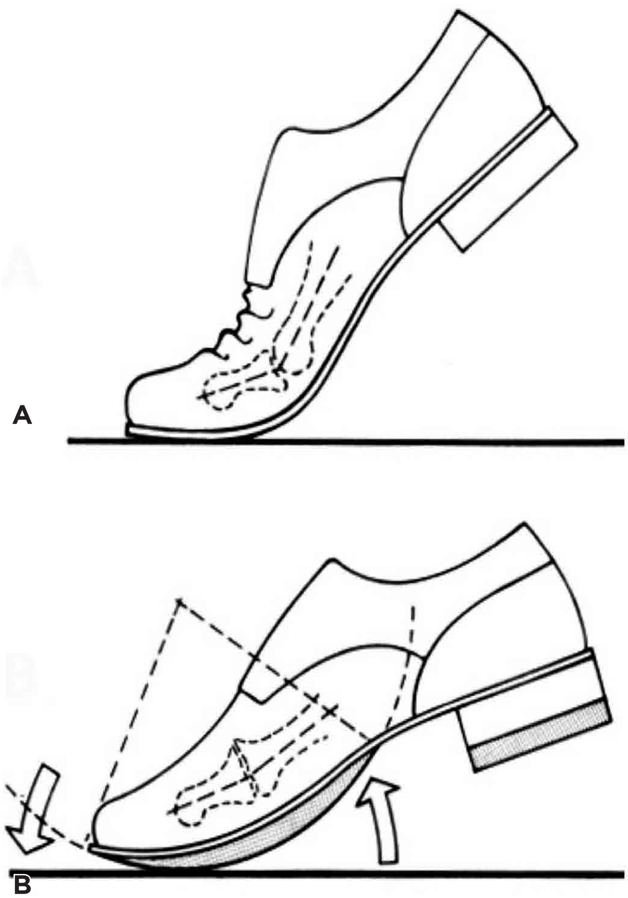

Figure 1. A) Normal shoe; B) Modified shoe with rocker bottom anterior insole, compensated with an elevation in the heel, during the third rocker of gait.

Figure 2. Profile radiography during the third rocker of gait. A) Bare foot. B) Foot with a normal shoe. C) Foot using an MBT® shoe. Remarkable loss of mobility in the metatarsophalangeal joint during the third rocker of gait.

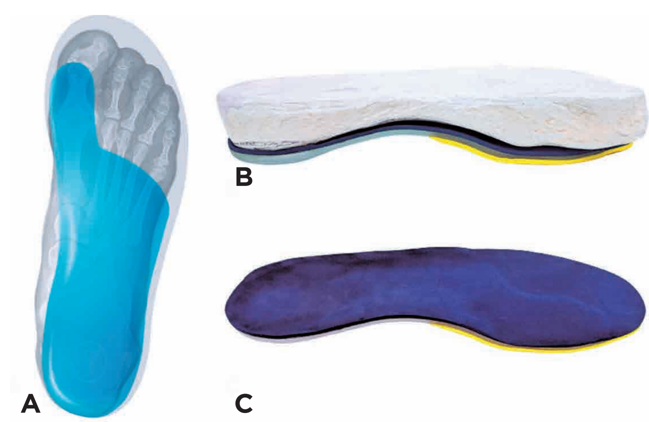

Figure 3. A) Scheme of plantar support with Morton's extension in a foot with hallux rigidus. B) Adaptation of the custom plantar support to a patient mold. C) 4-mm thick polypropylene insole with Morton's extension.

Viladot-Pericé et al.[11] and Ruiz-Escobar et al.[13] performed a radiological study comparing bare feet, feet wearing regular shoes, and feet wearing rocker bottom shoes, showing that the mobility of the first MTPJ is practically null during the third rocker of the gait (Figure 2).

Plantar orthosis

The most recommended are custom plantar orthosis with Morton's extension at the level of the first ray (Figure 3). A retrocapital bar may be added to improve adaptation of hallux to insole lengthening. The insole base should be made of a rigid material to properly maintain splinting of the first ray. The most common materials for their production are polypropylene and carbon fiber[13]. These orthoses may reduce symptoms (in the study by Grady et al.[2], 47% of patients respond to the use of insoles) but they are not usually well tolerated, and rates of withdrawal are high. Welsh et al.[14] performed an observational study of 35 patients with plantar orthosis with a 24-week follow-up. The authors concluded that orthoses could promote a reduction in mechanically induced pain at a level similar to that of analgesic treatment. Smith et al.[15] conducted a long-term study (average 14.4 years) of 22 patients to explore the efficacy of conservative treatment with footwear modification, with an average follow-up of 14.4 years: 13 patients modified their footwear by wearing shoes with wide toe box and 7 patients reported pain relief by simply avoiding the use of high heels. Of the entire series, 63% of patients would maintain their decision to undergoing conservative treatment. Moreover, pain intensity remained constant in 92%

of cases and apparently there is no association between the symptoms reported by patients and radiological evidence of disease.

Pharmacological treatment

Nonsteroidal anti-inflammatory and analgesic drugs

No report has been published specifically investigating the use of these drugs in the treatment of hallux rigidus; thus, their systematic use is not recommended[16].

Symptomatic slow action drug osteoarthritis -SYSADOA-(glucosamine, chondroitin, diacerein)

There is no scientific evidence justifying its indication in hallux rigidus[16].

Injections

Solan et al.[17] state that with steroid injections are effective in early stages. Pons et al.[18] published a comparative study of steroid versus hyaluronic acid and showed the superiority of the latter with regard to duration of the analgesic effect.

Literature on conservative treatment of hallux rigidus is not only scarce but also has low scientific evidence. However, it seems advisable to start this therapy before evaluating the possibility of surgical treatment, because conservative treatment is apparently effective in at least 50% of patients[3]. There is a moderate grade of recommendation for footwear modifications, use of custom plantar orthoses, and injections[1-3,19]. It was not possible to demonstrate the usefulness of either anti-inflammatory or analgesic drugs, or of manual therapy (physical therapy) in any of its modalities[1].

Conclusions

Conservative treatment of hallux rigidus is supported by the scientific literature, being effective in 50% of patients. The grade of recommendation is moderate with regard to footwear modifications, use of custom insoles, and injections, especially intra-articular hyaluronic acid injections.

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References

1. Herrera-Pérez M, Andarcia-Bañuelos C, de Bergua-Domingo J, Paul J, Barg A, Valderrabano V. [Proposed global treatment algorithm for hallux rigidus according to evidence-based medicine]. Rev Esp Cir Ortop Traumatol. 2014;58(6):377-86.
2. Grady JF, Axe TM, Zager EJ, Sheldon LA. A retrospective analysis of 772 patients with hallux limitus. J Am Podiatr Med Assoc. 2002;92(2):102-8.
3. Ho B, Baumhauer J. Hallux rigidus. EFORT Open Rev. 2017;2(1):13-20.
4. Zammit GV, Menz HB, Munteanu SE, Landorf KB, Gilheany MF. Interventions for treating osteoarthritis of the big toe joint. Cochrane Database Syst Rev. 2010;(9):CD007809.
5. Lam A, Chan JJ, Surace MF, Vulcano E. Hallux rigidus: How do I approach it? World J Orthop. 2017;8(5):364-71.
6. Talarico LM, Vito GR, Goldstein L, Perler AD. Management of hallux limitus with distraction of the first metatarsophalangeal joint. J Am Podiatr Med Assoc. 2005;95(2):121-9.
7. Shamus J, Shamus E, Gugel RN, Brucker BS, Skaruppa C. The effect of sesamoid mobilization, flexor hallucis strengthening, and gait training on reducing pain and restoring function in individuals with hallux limitus: a clinical trial. J Orthop Sports Phys Ther. 2004;34(7):368-76.
8. Brantingham JW, Globe G, Pollard H, Hicks M, Korporaal C, Hoskins W. Manipulative therapy for lower extremity conditions: expansion of literature review. J Manipulative Physiol Ther. 2009;32(1):53-71.
9. Brantingham JW, Bonnefin D, Perle SM, Cassa TK, Globe G, Pribicevic M, et al. Manipulative therapy for lower extremity conditions: update of a literature review. J Manipulative Physiol Ther. 2012;35(2):127-66.
10. Janisse DJ, Janisse E. Shoe modification and the use of orthoses in the treatment of foot and ankle pathology. J Am Acad Orthop Surg. 2008;16(3):152-8.
11. Viladot-Pericé R, Salinas-Castro F, Rodríguez-Boronat E, Álvarez-Goenaga F. Procedimientos ortopédicos en fracasos de cirugía del hallux. In: Asunción J, Martín-Oliva X, Curto JM y Prados N. Procedimientos de rescate de la 1ª MTF en fracasos de cirugías previas. Madrid: Acción Médica; 2011. p. 37-42.
12. Becker BA, Childress MA. Common foot problems: over the-counter treatments and home care. Am Fam Physician. 2018;98(5):298-303.
13. Ruiz-Escobar J, Viladot-Pericé R, Salinas-Castro F, Viladot-Voegeli J. Lección XXV: Ortésis, prótesis y calzado. In: Viladot A, Viladot R. 25 lecciones sobre patología del pie. Sevilla: Editorial Punto Rojo Libros; 2020. p.297-313.
14. Welsh BJ, Redmond AC, Chockalingam N, Keenan AM. A case-series study to explore the efficacy of foot orthoses in treating firt metatarsophalangeal joint pain. J Foot Ankle Res. 2010;3:17.
15. Smith RW, Katchis SD, Ayson LC: Outcomes in hallux rigidus patients treated nonoperatively: a long-term follow-up study. Foot ankle Int. 2000,21(11):906-13.

16. Primorac D, Molnar V, Matišić V, Hudetz D, Jeleč Ž, Rod E, et al. Comprehensive Review of Knee Osteoarthritis Pharmacological Treatment and the Latest Professional Societies' Guidelines. Pharmaceuticals (Basel). 2021;14(3):205.
17. Solan MC, Calder JD, Bendall SP. Manipulation and injection for hallux rigidus: Is it worthwhile? J Bone Joint Surg Br. 2001; 83(5):706-8.
18. Pons M, Alvarez F, Solana J, Viladot R, Varela L. Sodium hyaluronate in the treatment of hallux rigidus. A single-blind, randomized study. Foot Ankle Int. 2007;28(1):38-42.
19. Bacca-Insuasty GA, Romero-Cárdenas C, Daher-Hallak NM, Valcarcel-Rojas PA, Benavides-de la Rosa MR, Kalb-Heckel JP, et al. Hallux Rigidus. Rev Colomb Ortop Traumatol. 2019;33(S3):66-82.

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Special Article

Proposed treatment algorithm for hallux rigidus

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Abstract

This study performs a literature review on the treatment of hallux rigidus and proposes a treatment algorithm.

This literature systematic review expanded a similar study conducted in 2014 by the authors and analyzed the levels of recommendation according to scientific evidence.

Most articles found in the search present scarce evidence (level IV or case series), we only found 8 articles with an at least moderate level of recommendation (B); of these, only one article had a level of evidence I.

Conservative treatment is effective with the implementation of footwear modifications, use of insoles, and infiltrations with hyaluronic acid. Cheilectomy, either isolated or combined with Moberg osteotomy, shows good outcomes in stage III, or moderate, although its outcomes worsen after 5 years. Metatarsophalangeal joint (MTPJ) arthrodesis is still the gold standard in stage IV, or advanced. In recent years, the technique of interposition arthroplasty has re-emerged, especially with the use of a synthetic cartilage implant (Cartiva®), with outcomes at least similar to those of MTPJ arthrodesis in comparative studies.

Level of Evidence III; Therapeutic Studies; Systematic Review of Level III Studies.

Keywords: Hallux rigidus; Conservative treatment; Algorithms.

Introduction

Therapeutic algorithms based on scientific evidence are desirable both in Orthopedic Surgery and in other medical fields. They may be helpful in the sequential treatment of patients, according to the stage of their disease.

Hallux rigidus, or arthrosis of the first metatarsophalangeal joint (MTPJ), is the most frequent arthrosis of the foot, affects 2.5% of the population older than 50 years[(1)], and has 4 evolutionary stages described (mild-moderate: I and II; moderate-severe: III and IV). This article aims to present a global algorithm for the treatment of this disease, both conservative and surgical, following the principles of a similar study published in 2014, adding new evidence from the last 7 years[(2)].

A search was conducted on the main databases, including PubMed and PEDro. The search period used in a similar article published in 2014 was expanded to present times[(2)]. Inclusion criteria were as follows: randomized clinical trials, prospective studies, systematic reviews, or meta-analysis that studied conservative or surgical treatments of hallux rigidus and that described their level of scientific evidence. For those studies that did not provide information on scientific evidence, we used the Jadad scale[(3)].

Search criteria for conservative treatment: Hallux rigidus and "conservative treatment", "nonoperative treatment", "manual therapy", "chiropractic therapy", "physical therapy", "injection".

- Search criteria for surgical treatment: Hallux rigidus and (arthrodesis or arthroplasty or osteotomy or cheilectomy or osteophytectomy or exostectomy or surgery).
- Exclusion criteria: articles not in English or Spanish, clinical cases, surgical techniques, experimental techniques, biomechanical studies, studies in cadavers or in artificial bones, articles that did not report their results, articles whose level of evidence could not be obtained.
- Final selection criteria: treatments with a grade of recommendation A or B and/or a Jadad score higher than 3 were considered as recommendable.

Study performed at the Orthopaedic Department, University Hospital of Canary Islands, La Laguna, Tenerife, Spain.

Correspondence: Mario Herrera-Pérez. Carretera de Ofra S/N, La Cuesta – 38320, La Laguna, Tenerife, Spain. **E-mail:** herrera42@gmail.com. **Conflicts of Interest:** none. **Source of funding:** none. **Date received:** September 12, 2021. **Date accepted:** October 27, 2021. **Online:** December 20, 2021.

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Results

With regard to conservative treatment, we found only three articles with a grade of recommendation of at least B: Pons et al.[4] showed the superiority of injections of hyaluronate compared to corticosteroids. Zammit et al.[5] confirm the effectiveness of custom orthosis and footwear modifications. Finally, Menz et al.[6] studied the predictors of response to custom orthoses and rocker-sole footwear in patients with hallux rigidus, but they were not able to identify any specific individual factor (Figure 1).

In relation to surgical treatment, we found 5 articles with grade of recommendation A or B[7-11]: Roukis and Townley[7] published an article with level II evidence comparing BIOPRO resurfacing endoprosthesis versus Youngswick or Watermann-type osteotomy of the primer metatarsal and did not find significant differences, showing a high percentage of satisfaction in both groups. Kilmartin[8] performed a study with moderate grade of recommendation, ie, B, comparing phalangeal versus metatarsal osteotomy and concluded that none of them can be definitely recommended for the treatment of hallux rigidus. A prospective study with level II evidence conducted by Gibson and Thomson[9] stated that MTPJ arthrodesis is more effective than total joint arthroplasty. In 2016, Baumhauer et al.[10] conducted the only prospective, randomized, controlled trial (level I) that compared MTPJ arthrodesis versus interposition arthroplasty with synthetic cartilage implant (Cartiva®), showing equivalent pain relief and functional outcomes. Finally, Glazebrook et al.[11] attest the efficacy and safety of synthetic cartilage implant (Cartiva®), demonstrating satisfactory outcomes at 5.8 years in a prospective article with 112 patients.

Innovations in the treatment of hallux rigidus in the last 5 years are related to the implementation of joint preservation techniques in moderate and even advanced stages, which may achieve at least the same functional outcome than arthrodesis[1,5,10,11]. If we obviate this treatment, cheilectomy as a treatment that preserves mobility in stages of moderate compromise and metatarsophalangeal arthrodesis in advanced stages are still the treatments with the greater scientific evidence and confirmed efficacy in mid- and long-term studies[1,5,12-14]. Conversely, the literature sustains that conservative treatment is efficient in at least 50% of patients and thus should always be the first treatment of choice, regardless of the evolutionary course of the disease[1].

Conclusions

Conservative treatment is effective in 50% of patients (footwear modifications, plantar orthosis, and infiltrations with hyaluronic acid),

Cheilectomy, either isolated or in combination with Moberg osteotomy, shows good outcomes in moderate stages (II and selected III), although its outcomes worsen after 5 years.

MTPJ arthrodesis is still the gold standard in advanced stage (IV).

In recent years, the technique of interposition arthroplasty has re-emerged, especially with the use of a synthetic cartilage implant as a mobile alternative in patients who reject MTPJ arthrodesis.

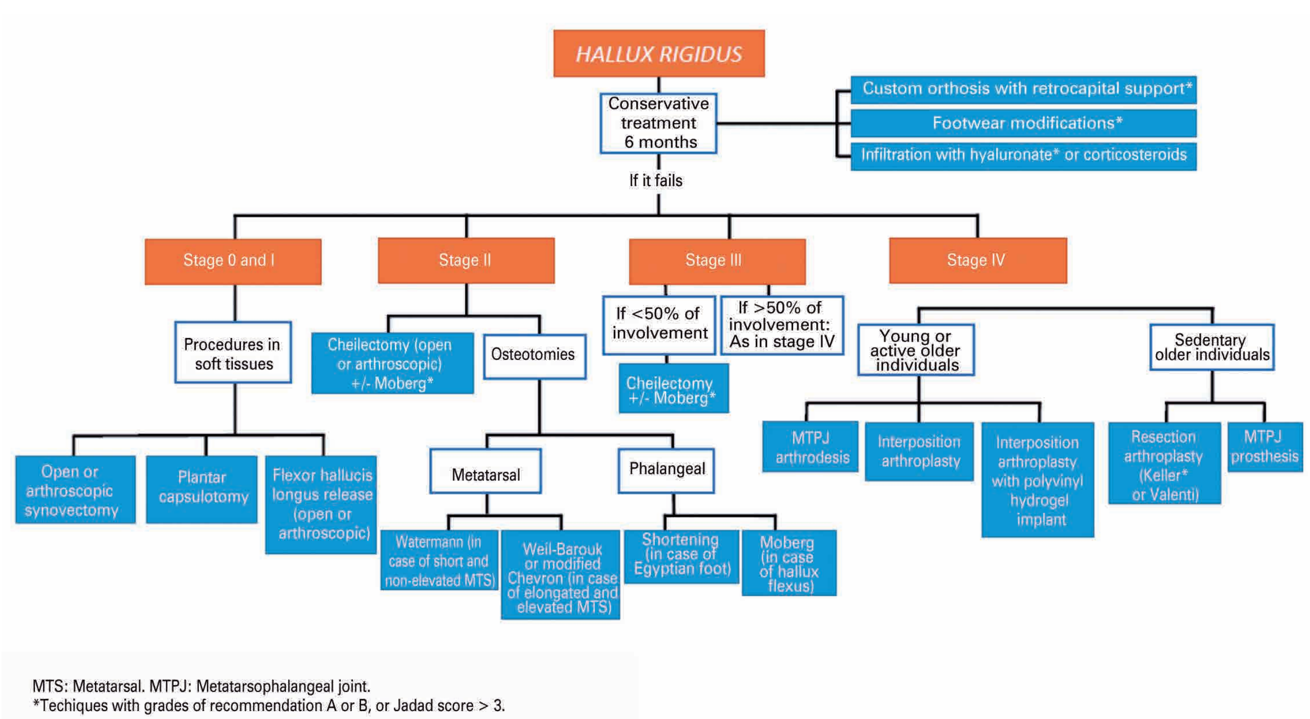

Figure 1. Global treatment algorithm of hallux rigidus.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MHP *(https://orcid.org/0000-0001-6188-5269) Conceived and planned the activities that led to the study, wrote the paper, approved the final version; DGM *(https://orcid.org/0000-0002-4891-515X) Participated in the review process and approved the final version; RVP*(https://orcid.org./0000-0002-8254-2916) Participated in the review process and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Ho B, Baumhauer J. Hallux rigidus. EFORT Open Rev 2017;2(1):13-20.
2. Herrera-Pérez M, Andarcia-Bañuelos C, de Bergua-Domingo J, Paul J, Barg A, Valderrabano V. [Proposed global treatment algorithm for hallux rigidus according to evidence-based medicine]. Rev Esp Cir Ortop Traumatol. 2014;58(6):377-86.
3. Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJ, Gavaghan DJ, et al. Assessing the quality of reports of randomized clinical trials: is blinding necessary? Control Clin Trials. 1996;17(1):1-12.
4. Pons M, Alvarez F, Solana J, Viladot R, Varela L. Sodium hyaluronate in the treatment of hallux rigidus. A single-blind, randomized study. Foot Ankle Int. 2007;28(1):38-42.
5. Zammit GV, Menz HB, Munteanu SE, Landorf KB, Gilheany MF. Interventions for treating osteoarthritis of the big toe joint. Cochrane Database Syst Rev. 2010;(9):CD007809.
6. Menz HB, Auhl M, Tan JM, Levinger P, Roddy E, Munteanu SE. Predictors of response to prefabricated foot orthoses or rocker-sole footwear in individuals with first metatarsophalangeal joint osteoarthritis. BMC Musculoskelet Disord. 2017;18(1):185.
7. Roukis TS, Townley CO. BIOPRO resurfacing endoprosthesis versus periarticular osteotomy for hallux rigidus: short-term follow-up and analysis. J Foot Ankle Surg. 2003;42(6):350-8.
8. Kilmartin TE. Phalangeal osteotomy versus first metatarsal decompression osteotomy for the surgical treatment of hallux rigidus: a prospective study of age-matched and condition-matched patients. J Foot Ankle Surg. 2005;44(1):2-12.
9. Gibson JN, Thomson CE. Arthrodesis or total replacement arthroplasty for hallux rigidus: a randomized controlled trial. Foot Ankle Int. 2005;26(9):680-90.
10. Baumhauer JF, Singh D, Glazebrook M, Blundell C, De Vries G, Le IL, et al. Prospective, Randomized, Multi-centered Clinical Trial Assessing Safety and Efficacy of a Synthetic Cartilage Implant Versus First Metatarsophalangeal Arthrodesis in Advanced Hallux Rigidus. Foot Ankle Int. 2016;37(5):457-69.
11. Glazebrook M, Blundell CM, O´Dowd D, Singh D, de Vries G, Le ILD, et al. Midterm outcomes of a synthetic cartilage implant for the first metatarsophalangeal joint in advanced hallux rigidus. Foot Ankle Int. 2019;40(4):374-83.
12. Lam A, Chan JJ, Surace MF, Vulcano E. Hallux rigidus: How do I approach it? World J Orthop. 2017;8(5):364-71.
13. Cöster MC, Cöster ME, Montgomery F. Hallux rigidus - Osteoarthritis of the first MTP-joint. Surgical and patient-reported results from Swefoot. Foot Ankle Surg. 2021;27(5):555-8.
14. Hoveidaei AH, Roshanshad A, Vosoughi AR. Clinical and radiological outcomes after arthrodesis of the first metatarsophalangeal joint. Int Orthop. 2021;45(3):711-9.

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Original Article

Metatarsophalangeal arthrodesis of the hallux using a minimally invasive technique

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Abstract

Objective: To evaluate the outcomes of the metatarsophalangeal arthrodesis (MTPA) of the hallux using a percutaneous technique.

Methods: The MTPA of the hallux was performed in a total of 27 feet: 20 patients diagnosed with hallux rigidus and 7 with rheumatoid arthritis. The mean postoperative follow-up time was 30.7 months. The results were evaluated using the visual analogue scale (VAS) for pain, the American Orthopaedic Foot & Ankle Society (AOFAS) forefoot score, and regards to union rate.

Results: All 27 patients were operated percutaneously and noticed relief of the pain, with a mean increase of 50.9 points in AOFAS scores and a mean decrease of 7.4 points in the VAS. The mean union time was 10 weeks. There were no cases of nonunion.

Conclusion: Percutaneous first MTP arthrodesis proved effective for treating hallux rigidus and degenerative rheumatic pathologies.

Level of Evidence IV; Therapeutic Studies; Cases Series.

Keywords: Arthrodesis; Metatarsophalangeal joint; Hallux rigidus; Minimally invasive surgical procedures.

Introduction

Hallux rigidus is the second most common pathology of the first ray of the foot, involving pain and stiffness of the first metatarsophalangeal (MTP) joint[1]. Several surgical techniques have been described to relieve symptoms, such as cheilectomy, distal metatarsal osteotomies, MTP arthrodesis, and arthroplasties[2].

MTP arthrodesis was first described in 1883 by Clutton[3], who recommended it for hallux valgus. In 1887, Cotterill[4] proposed using arthrodesis to treat hallux rigidus after having good results with said technique.

Currently, first MTP arthrodesis is considered the gold standard for surgical treatment of hallux rigidus, especially in cases classified as Shurnas and Coughlin[5] grades 3 and 4. Coughlin and Shurnas[6] found good or excellent results in 90% of the feet they treated with this procedure. The technique can also be used to treat severe deformities, such as those due to rheumatoid arthritis (RA) and post-traumatic sequelae. In search of minimally invasive techniques, several authors have described arthroscopic[7,8] or percutaneous[1,2,9,10] versions of the procedure.

This study aimed to evaluate the results of percutaneous first MTP arthrodesis, including union rate, pain improvement, and patient satisfaction.

Methods

This retrospective study, which was approved by our institution's ethics committee and registered in Plataforma Brasil (number 36116220.8.0000.5501), was conducted at a university hospital and the private clinic of two of the authors between January 2016 and January 2020. All patients underwent percutaneous MTP arthrodesis following the technique proposed by Bauer et al.[9] in 2010.

The patients underwent pre- and postoperative assessment with the American Orthopaedic Foot and Ankle Society (AOFAS) forefoot score[11], which had been previously translated into Portuguese, and the visual analog scale (VAS) for pain[12], in addition to weight-bearing radiographs in the anteroposterior and lateral projections of the foot. The clinical and radiographic stage of MTP joint arthrosis was classified using the Hattrup and Johnson grading system as modified by Coughlin and Shurnas[6]. In the postoperative radiographic

Study performed at the Hospital Municipal Universitário de Taubaté, Taubaté, SP, Brazil.

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routine, the first MTP joint angle of the hallux was digitally measured on the weight-bearing anteroposterior and lateral view of the foot.

Our sample included patients with moderate or severe arthrosis (grades 3 and 4) of the first MTP joint of the hallux who reported a pain level >7 on the VAS.

We excluded patients who had undergone previous surgery on the evaluated foot, had MTP arthrosis due to traumatic sequelae or had less than 6 months of postoperative follow-up.

Initially, the data were analyzed descriptively. Categorical variables were expressed as absolute and relative frequencies, while numerical variables were expressed as summary measures (mean, median, minimum, maximum, and standard deviation).

The distributions of characteristics and means between the groups were compared using Fisher's exact test and Student's *t*-test for independent samples, respectively. The mean AOFAS and VAS scores between the time points were compared using Student's *t*-test for paired samples. The mean AOFAS scores between the time points according to the group diagnose were compared using a mixed linear model. The mixed linear model incorporated the effect of each patient in the form of a random effect, considering a possible dependence between observations in the same individual.

Normal distribution of the data was assumed in both Student's *t*-test and the mixed linear model, which was verified with the Kolmogorov-Smirnov test. A significance level of 5% was used for all tests. The statistical analyses were performed in SPSS 20.0 and Stata 12.

Material and patient positioning

The procedures were performed by a team of five orthopedic surgeons specialized in Foot and Ankle Surgery. While preparing for the procedure, the patient was positioned in horizontal dorsal decubitus with the feet off of the operating table, under locoregional anesthesia[13]. No tourniquets were used. A MIS 64 blade (BD Beaver Blades, Becton Dickinson, 1 Becton Drive, Franklin Lakes, NJ), a 3.1 mm wedge burr, and a long Shannon burr were used to perform the technique.

Surgical approach

The initial approach was at the medial edge of the MTP joint, guided by a gauge needle inserted in the joint space. Next, a 0.5 cm incision was made with the MIS 64 blade. A second lateral access to the MTP joint was made using the same technique. In patients with a prominent dorsal exostosis, a third, more dorsal incision was used for adequate resection (Figure 1).

Exostectomy and joint preparation

The exostosis was thinned using a 3.1 mm wedge burr through a dorsomedial surgical access point. The resection was guided by radioscopy until a flat surface was obtained on the metatarsal head.

The joint was prepared with a long Shannon burr, seeking to remove the entire cartilaginous surface (Figure 2). With a rasp, joint fragments were removed.

Arthrodesis and fixation

The MTP joint was positioned for arthrodesis under fluoroscopy and with a radiolucent platform to imitate plantar foot support. After obtaining the ideal position of 15° dorsiflexion in relation to the platform and 5-10° of valgus in the MTP joint, provisional fixation of the MTP joint was performed using two 1.5 mm Kirschner wires crossed in a medial and lateral configuration. Fixation was then performed with self-compressing 2.7 mm Herbert-type cannulated screws (Figure 3).

Postoperative care

Walking with hard-soled sandals was allowed after the first postoperative day. The patients returned to our office in each of the first 4 postoperative weeks to change the dressing and, in the subsequent 4 weeks, they changed the dressing

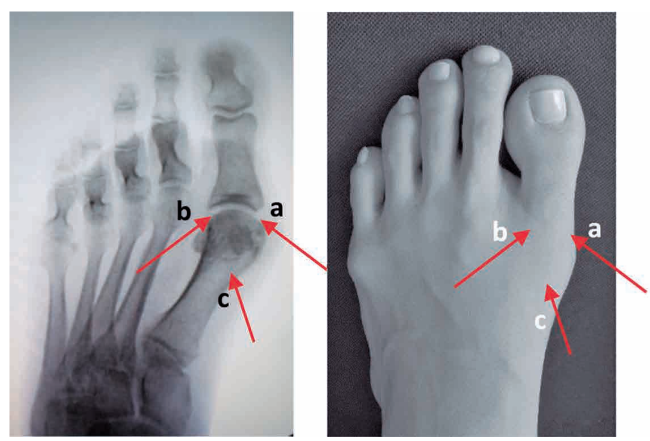

Figure 1. Radioscopy-guided access routes (A) and their skin incision sites (B): A – medial route; B – lateral route for joint preparation; C – accessory pathway for dorsal thinning.

Figure 2. A) Intraoperative radioscopy illustrating the technique for removing dorsal osteophytes and B) removing articular cartilage and C) preparing the surfaces for arthrodesis.

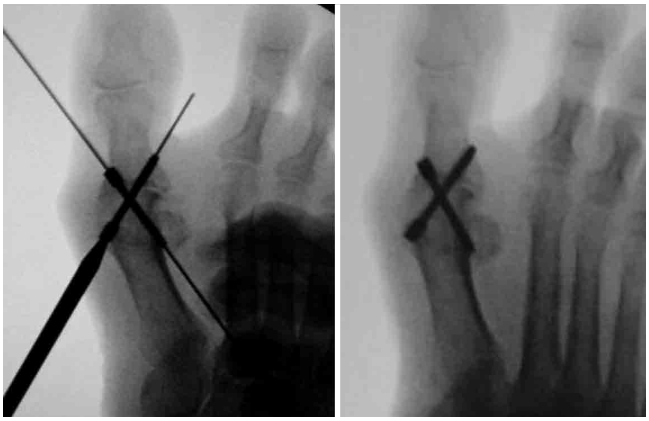

Figure 3. Intraoperative radioscopic image demonstrating the fixation technique with self-compressing Herbert screws.

at home. Radiographic control was requested in the 1st, 4th, 8th, and 12th postoperative weeks. In cases of delayed union, new monthly radiographs were requested until the union was radiographically proven.

Results

We analyzed data from 27 patients with a mean age of 57.4 years (SD, 8.5 years; range 38 to 73 years). Twenty of these patients (74.1%) were diagnosed with hallux rigidus, and the other 7 were diagnosed with RA.

Overall, 63% (17) of the patients were female. The mean follow-up time was 30.7 months (SD, 8.7) and the mean union time was 2.8 months (SD, 1.2), ranging from 4 to 24 weeks (or 1 to 6 months, as shown in Table 1). The patients' mean VAS pain score decreased by 8.4 points (SD, 1.3) between the pre- and postoperative periods.

Table 2 shows the differences in mean AOFAS ($p<0.001$) and VAS ($p<0.001$) scores between the time points. There was a mean increase of 50.9 points (SD, 13.5) in AOFAS scores and a mean reduction of 7.4 points (SD, 1.5 points) in VAS scores. In both groups, mean increases were observed between the first and second AOFAS applications ($p<0.001$): 62.1 points in the RA group, and 47.0 points in the hallux rigidus group. However, the mean increase in the RA group was 15.2 points higher than that of the hallux rigidus group (95% CI: 5.3 – 25.1).

Among the complications, there was a case of intraoperative guidewire breakage. The patient initially complained of grade 3 pain on the VAS scale in the lateral and dorsal region of the MTP, but it evolved to spontaneous resolution. Thus, there was no need to remove the wire, which remained in place as a lost synthesis. In 2 feet, screw removal was necessary due to complaints of discomfort. The arthrodesis union was delayed in 1 patient, including signs of bone callus only after 24 weeks postoperatively. There were no cases of malunion, infection, deep vein thrombosis, or severe pain.

Discussion

Two pathologies were found to cause alterations in the MTP joint in this sample: rheumatoid arthritis and hallux rigidus. Most of the cases were due to hallux rigidus (20 feet), with only 7 patients in the RA group. This finding may be because hallux rigidus is the main degenerative pathology of the first MTP joint, which typically causes pain, limited mobility, and periarticular exostosis with subsequent deformation of the joint itself[14-16]. Even with radiographs indicating osteodegenerative changes in the joint, we believe that pain is an important clinical parameter for indicating MTP arthrodesis, since this is the main patient complaint, and pain improvement helps quantify postoperative results[17,18]. Although there is no gold standard for analyzing the results, the AOFAS forefoot scale provided us with enough information to compare the results of this surgical technique.

Although other studies have shown good or excellent results for first MTP arthrodesis through open[4,17-21] and arthroscopic[7,8] surgery, percutaneous surgery has certain advantages over these techniques, since it is less invasive and involves little aggression to the soft tissues, in addition to being performed with locoregional anesthesia and allowing early ambulation[2,11].

Unlike Bauer et al.[9], we did not use a tourniquet on the calf to keep the member exsanguinated, since the blood flowing through the incision helps cool the burr, preventing bone and soft tissue burns.

With the percutaneous technique, the joint can be prepared with a "flat to flat" interface[1,9,10] whose results are very similar to the convex-concave joint preparations of open surgery[1,2,17].

Another divergent point in the literature is whether or not to maintain the bone debris produced by the exostectomy[2]. We understand that it should be maintained and that it helps in the bone callus formation process. We agree with Bauer[10] and Nogueira et al.[18] that bone resection must be performed carefully to avoid shortening the first ray and poor positioning.

Regarding fixation methods, according to the literature, using plates and screws specifically designed for MTP arthrodesis and fixation with two crossed screws are equally rigid and strong[19,20]. Thus, percutaneous screw fixation can obtain excellent results. Coughlin and Shurnas followed up more than 200 patients who received fixation with 2 percutaneous screws, finding good results in more than 90% of cases, in addition to short surgery time, quick recovery, and few surgical complications[6].

The mean union time in our sample was 2.8 months, slightly higher than that of Nogueira et al.[18], who reported bone callus formation 2 months after surgery. Regarding possible nonunions, Bauer[10] reported that radiological nonunion occurred in 10% of his patients, although they were asymptomatic. Union occurred in all of the feet in our sample. Callus formation was delayed in only one foot, although complete MTP fusion had occurred 6 months postoperatively.

Table 1. Patient characteristics

	Total (N=27)	RA (N=7)	HR (N=20)	p
Sex				0.678[a]
Female	17 (63.0)	5 (71.4)	12 (60.0)	
Male	10 (37.0)	2 (28.6)	8 (40.0)	
Age (years)				0.195
Mean ± SD	57.4 ± 8.5	61.0 ± 6.2	56.1 ± 9.0	
Median (Minimum - Maximum)	58 (38 - 73)	62 (51 - 68)	56.5 (38 - 73)	
Follow-up (months)				0.420
Mean ± SD	30.7 ± 8.7	33.0 ± 11.6	29.9 ± 7.6	
Median (Minimum - Maximum)	28 (22 - 52)	30 (22 - 52)	26.5 (22 - 43)	
Preoperative AOFAS				0.020
Mean ± SD	29.3 ± 11.7	20.7 ± 12.7	32.4 ± 9.9	
Median (Minimum - Maximum)	30 (5 - 45)	15 (5 - 40)	35 (15 - 45)	
Preoperative VAS				0.711
Mean ± SD	8.4 ± 1.3	8.3 ± 1.4	8.5 ± 1.3	
Median (Minimum - Maximum)	9 (6 - 10)	8 (7 - 10)	9 (6 - 10)	
UT (months)				0.257
Mean ± SD	2.8 ± 1.2	2.4 ± 0.5	3.0 ± 1.3	
Median (Minimum - Maximum)	2.5 (1 - 6)	2 (2 - 3)	2.8 (1 - 6)	

p: descriptive level of Student's *t*-test or Fisher's exact test(a).
AOFAS: American Orthopedic Foot and Ankle Society Forefoot Score. HR: hallux rigidus. RA: rheumatoid arthritis; SD: standard deviation; UT: union time; VAS: Visual analog scale for pain.

Table 2. Measures - summary of AOFAS and VAS scores according to assessment time

	Time of evaluation		Post-Pre	p
	Pre	Post		
AOFAS	29.3 ± 11.7	80.2 ± 6.6	50.9 ± 13.5	<0.001
VAS	8.4 ± 1.3	1.0 ± 1.1	-7.4 ± 1.5	<0.001

p: descriptive level of t-test for paired samples.
Mean ± SD.
AOFAS: American Orthopedic Foot and Ankle Society Forefoot Score; VAS: Visual analog scale for pain.

We agree with Bauer[10] that the main strategies for a successful first MTP arthrodesis are decortication of the entire articular surface, fixation with 2 cannulated or self-compressing screws, correct positioning of the MTP joint for arthrodesis, and avoiding excessive bone decortication in patients with extensive osteochondral lesions or severe osteoporosis. Following these guidelines, firm and stable fixation is guaranteed[9]. We believe that no cases of malunion (or union in a non-ideal position) occurred because we maintained the angle described in the surgical technique.

As study limitations, we point out that the same team of surgeons performed both the surgeries and the pre- and postoperative assessments, which could lead to performance bias. Since this was a retrospective study to assess the results of a single surgical technique, there was no control group.

The percutaneous technique results in less aggression to soft tissues and allows ambulation in the immediate postoperative period[1,2,9,10]. However, the surgeon's experience level is also important, since the learning curve for this technique is long and can lead to unsatisfactory results if performed poorly. Since no large-scale randomized comparative studies have demonstrated the superiority of any one technique, we conclude that both open and minimally invasive procedures are useful tools in the arsenal of orthopedists and podiatrists.

Conclusions

Percutaneous arthrodesis proved to be an effective treatment for hallux rigidus and RA in the first MTP joint, with an excellent rate of union and patient satisfaction. Both AOFAS and VAS pain scores improved significantly in the postoperative period.

Authors' contributions: Each author contributed individually and significantly to the development of this article: LCRL *(http://orcid.org/0000-0003-1158-2643) Conceived and planned the activities that led to the study, performed the surgeries, data collection, clinical examination, approved the final version; LCATF *(https://orcid.org/0000-0002-0778-2506) Conceived and planned the activities that led to the study, performed the surgeries, data collection, clinical examination; GLFC *(https://orcid.org/0000-0001-5470-8379) Conceived and planned the activities that led to the study, performed the surgeries, data collection, clinical examination; JAG *(https://orcid.org/0000-0003-4652-4400) Conceived and planned the activities that led to the study, performed the surgeries, data collection, clinical examination; GB *(https://orcid.org/0000-0001-5273-4303) Wrote the article, interpreted the results of the study, participated in the review process, statistical analysis, bibliographic review, survey of medical records, formatting of the article; LFL *(https://orcid.org/0000-0003-1048-7134) Wrote the article, interpreted the results of the study, participated in the review process, statistical analysis, bibliographic review, survey of medical records, formatting of the article; DVBS *(https://orcid.org/0000-0001-6988-1609) Wrote the article, interpreted the results of the study, participated in the review process, statistical analysis, bibliographic review, survey of medical records, formatting of the article; IM *(https://orcid.org/0000-0002-1733-3747) Conceived and planned the activities that led to the study, performed the surgeries, data collection, clinical examination; DRR *(https://orcid.org/0000-0001-9594-2006) Conceived and planned the activities that led to the study, performed the surgeries, data collection, clinical examination. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

References

1. Sott AH. Minimally Invasive Arthrodesis of 1st Metatarsophalangeal Joint for Hallux Rigidus. Foot Ankle Clin. 2016;21(3):567-76.
2. Fanous RN, Ridgers S, Sott AH. Minimally invasive arthrodesis of the first metatarsophalangeal joint for hallux rigidus. Foot Ankle Surg. 2014;20(3):170-3.
3. Clutton H. The treatment of hallux valgus. St Thomas Hosp Rep 1894;22:1-12.
4. Cotterill JM. Stiffness of the great toe in adolescents. Br Med J. 1887;1(1378):1158.
5. Shurnas PS, Coughlin MJ. Arthritic Conditions of the Foot. Coughlin MJ, Mann RA, Saltzman CL. Surgery of the Foot and Ankle. 8th ed. Philadelphia: Mosby Elsevier; 2007. p. 837-51.
6. Coughlin MJ, Shurnas PS. Hallux rigidus: demographics, etiology, and radiographic assessment. Foot Ankle Int. 2003;24(10):731-43.
7. Carro LP, Vallina BB. Arthroscopic-assisted first metatarsophalangeal joint arthrodesis. Arthroscopy. 1999;15(2):215-7.
8. Walter R, Perera A. Open, Arthroscopic, and Percutaneous Cheilectomy for Hallux Rigidus. Foot Ankle Clin. 2015;20(3):421-31.
9. Bauer T, Lortat-Jacob A, Hardy P. First metatarsophalangeal joint percutaneous arthrodesis. Orthop Traumatol Surg Res. 2010; 96(5):567-73.
10. Bauer T. Percutaneous First Metatarsophalangeal Joint Fusion. Open Orthop J. 2017;11:724-31.
11. Johnson C. Measuring Pain. Visual Analog Scale Versus Numeric Pain Scale: What is the Difference? J Chiropr Med. 2005;4(1):43-4.
12. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15(7):349-53.
13. Torres Filho LCA, Lara LCR, Cervone GLF, Figueiredo RN, Lancia LF. 4-in-1 and 5-in-1 blocks in percutaneous forefoot surgery. J Foot Ankle. 2020;14(1):79-83.
14. Hogan MV, Mani SB, Chan JY, Do H, Deland JT, Ellis SJ. Validation of the Foot and Ankle Outcome Score for Hallux Rigidus. HSS J. 2016;12(1):44-50.
15. Lucas DE, Hunt KJ. Hallux Rigidus: Relevant Anatomy and Pathophysiology. Foot Ankle Clin. 2015;20(3):381-9.
16. Hattrup SJ, Johnson KA. Subjective results of hallux rigidus following treatment with cheilectomy. Clin Orthop Relat Res. 1988;(226):182-91.
17. Coughlin MJ, Shurnas PS. Hallux rigidus. Grading and long-term results of operative treatment. J Bone Joint Surg Am. 2003;85(11):2072-88.
18. Nogueira VB, Pereira Filho MV, Mattos e Dinato MC, Freitas MTP, Pagnano RG. Treatment of hallux rigidus with percutaneous arthrodesis: a case series. Sci J Foot Ankle. 2018;12(2):90-5.
19. Harris E, Moroney P, Tourné Y. Arthrodesis of the first metatarsophalangeal joint-A biomechanical comparison of four fixation techniques. Foot Ankle Surg. 2017;23(4):268-74.
20. Korim MT, Mahadevan D, Ghosh A, Mangwani J. Effect of joint pathology, surface preparation and fixation methods on union frequency after first metatarsophalangeal joint arthrodesis: A systematic review of the English literature. Foot Ankle Surg. 2017;23(3):189-94.
21. Curtis MJ, Myerson M, Jinnah HR, Cox QG, Alexander I. Arthrodesis of the first metatarsophalangeal joint: a biomechanical study of internal fixation techniques. Foot Ankle. 1993;14(7):395-9.

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Original Article

Complications of first tarsometatarsal joint arthrodesis

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Abstract

Objective: First tarsometatarsal joint (TMTJ) arthrodesis, also known as Lapidus, is a surgical procedure used to treat severe hallux valgus, associated hypermobility of the first ray, and/or osteoarthritis of the first TMTJ. Despite the high satisfaction rate and high corrective power, this technique is not without complications. This study aimed to report the complications of first TMTJ arthrodesis.

Methods: This is a case series of 16 patients treated with first TMTJ arthrodesis. Patients were evaluated based on foot radiographs, clinical alignment of the hallux, and signs and symptoms.

Results: Eight patients had either major or minor complications. Three patients had recurrent deformity (1 with associated nonunion), 2 had delayed union, 2 had hardware loosening (1 with associated nonunion), and 1 had wound dehiscence.

Conclusion: First TMTJ arthrodesis requires greater care in choosing the surgical technique for the treatment of hallux valgus. In addition, some points should be considered to minimize complications as much as possible. We believe that data are still scarce to provide a concrete basis.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus; Metatarsal bones; Tarsal bones; Pseudarthrosis; Arthrodesis.

Introduction

Hallux valgus, a term introduced by Carl Hueter[1] to define static subluxation of the first metatarsophalangeal joint characterized by lateral deviation of the hallux and medial deviation of the first metatarsal,[1,2] is a disease for which different corrective surgical techniques can be used, depending on its severity. First tarsometatarsal joint (TMTJ) arthrodesis, also known as Lapidus, is one of the surgical procedures used in the treatment of severe hallux valgus, among other alterations[3-5].

Despite the high satisfaction rate and high corrective power, this technique is not without complications. The main complications include delayed union, malunion, chronic edema, persistent pain, nonunion, joint stiffness, recurrent deformity, and varus deformity[6]. However, there is little scientific evidence of these complications after first TMTJ arthrodesis.

The purpose of this study was to report the complications of first TMTJ arthrodesis performed by orthopedic surgeons specializing in foot and ankle surgery.

Methods

This study was approved by the institutional research ethics committee and registered at Plataforma Brasil. We evaluated 16 patients undergoing first TMTJ arthrodesis, who denied any comorbidities. The procedures were performed by 7 different orthopedic surgeons specializing in foot and ankle surgery with different levels of experience, ranging from 1 to 29 years of experience in the field. All patients underwent arthrodesis with plates and screws. The plate was placed on the plantar aspect of the first tarsometatarsal in 4 patients and on the anteromedial aspect in all other patients. The dorsomedial incision was used, centered on the first TMTJ, for the 12 cases in which the plate was positioned in the dorsomedial region, and the medial incision was used for the 4 cases in which the plate was positioned on the plantar aspect. Also, articular cartilage was resected using a chisel and microperforations. All 16 patients were followed up in an outpatient clinic at 1, 2, 4, 6, 12, and 24 weeks postoperatively. The follow-up visits included the evaluation of anteroposterior, lateral, and oblique

Study performed at the Universidade Federal de São Paulo - Escola Paulista de Medicina, São Paulo, SP, Brazil.

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radiographs of the foot, clinical alignment of the hallux, and patients' signs and symptoms. For all patients, postoperative care included immobilization in a non-weight-bearing cast for 4 weeks, initiation of physical therapy with range of motion gain at 4 weeks, and partial weight-bearing at 6 weeks.

Results

We evaluated 16 patients operated on over an 18-month period (from February 2017 to August 2018). We measured preoperative and postoperative hallux valgus and intermetatarsal angles (Table 1). Eight patients had either major or minor complications (Table 2). Three patients had recurrent deformity (1 with associated nonunion), 2 had delayed union, 2 had hardware loosening (Figure 1) – 1 with associated nonunion (Figure 2), and 1 had wound dehiscence.

Discussion

Surgical correction of hallux valgus using first TMTJ arthrodesis is technically difficult, requiring a steep learning curve to perform the procedure[7]. Our literature review identified several articles describing the results and complications of this surgical technique, such as nonunion, delayed union, hardware-related discomfort, recurrent deformity, and loss of correction, among others[8,9].

Nonunion was the most common complication in our study (25%). Unlike our study, Mallette et al.[10] reported a much lower rate of nonunion (8.3%), as well as Espinosa et al.[6] and Prissel et al.[11], who reported lower rates of 16% and 6.5%, respectively. In our study, patients who developed this complication underwent revision arthrodesis, with improved pain and stability after 1 year of outpatient follow-up.

Regarding hardware-related discomfort, Peterson et al.[12] reported a rate of 15.2%, thus requiring hardware removal. Of these, 72% had plates and 28% had crossed screws. This rate is also very different from that of our study (25%). Our patients also required hardware removal to relieve pain resulting from hardware-related discomfort.

Regarding recurrent deformity, Schmid and Krause[13] reported 16% of cases with this complication. In our study, we found a rate of 37.5%, much higher than that reported in the literature, being the most common complication in our study. We defined recurrent deformity based on hallux valgus and intermetatarsal angles assessed on radiographs. At 24 weeks postoperatively, the 3 patients with this complication had a hallux valgus angle of 25°, 29°, and 30° and an intermetatarsal angle of 13°, 14°, and 14°, respectively. Despite deformity recurrence, all 3 patients chose not to undergo another surgical procedure because they no longer had pain complaints.

Delayed union occurred as frequently as nonunion, with a rate of 25% in our study. Klos et al.,[14] however, reported a much lower rate of only 1.72%. Our patients had pain complaints and no radiographic evidence of union until postoperative week 12. At 24 weeks, the patients had no pain complaints and showed evidence of union on radiographs; therefore, no additional procedure was performed.

In an attempt to avoid the most fearsome complication, nonunion, the literature describes several related factors that should be avoided or minimized. Barp et al.[15] showed no statistically significant difference in the type of fixation used (plate vs screw). Blitz et al.[16] reported that early weight-bea-

Table 1. Preoperative and postoperative hallux valgus angle (HVA) and intermetatarsal angle (IMA)

Patient no.	Preop HVA	Postop HVA	Preop IMA	Postop IMA
1	38	13	17	7
2	40	12	17	6
3	42	12	15	6
4	43	14	14	5
5	37	25	20	13
6	35	15	22	10
7	30	11	23	10
8	39	29	17	14
9	29	8	22	11
10	27	7	22	9
11	25	3	21	8
12	29	10	19	5
13	31	11	17	4
14	31	12	17	10
15	32	30	18	14
16	26	5	16	10

Table 2. Description of 8 complications of first tarsometatarsal joint arthrodesis

Patient no.	Age	Sex	Diagnosis	Complication
1	71	Female	Hallux valgus	Hardware loosening + nonunion
2	55	Female	Hallux valgus	Delayed union
3	63	Female	Hallux valgus + hypermobility of the first ray	Delayed union
4	40	Female	Hallux valgus + hypermobility of the first ray	Wound dehiscence
5	60	Female	Hallux valgus + hypermobility of the first ray	Hardware loosening
6	63	Female	Hallux valgus + hypermobility of the first ray	Recurrent deformity
7	75	Female	Hallux valgus	Recurrent deformity + nonunion
8	73	Female	Hallux valgus	Recurrent deformity

ring does not lead to higher nonunion rates. Moore et al.[17] reported that patients with vitamin D deficiency, in addition to endocrine diseases such as thyroid dysfunction and parathyroid disease, are 8.1 times more likely to develop nonunion, with a statistically significant difference compared with the control group.

Figure 1. Radiographic evidence of hardware loosening in the left foot.

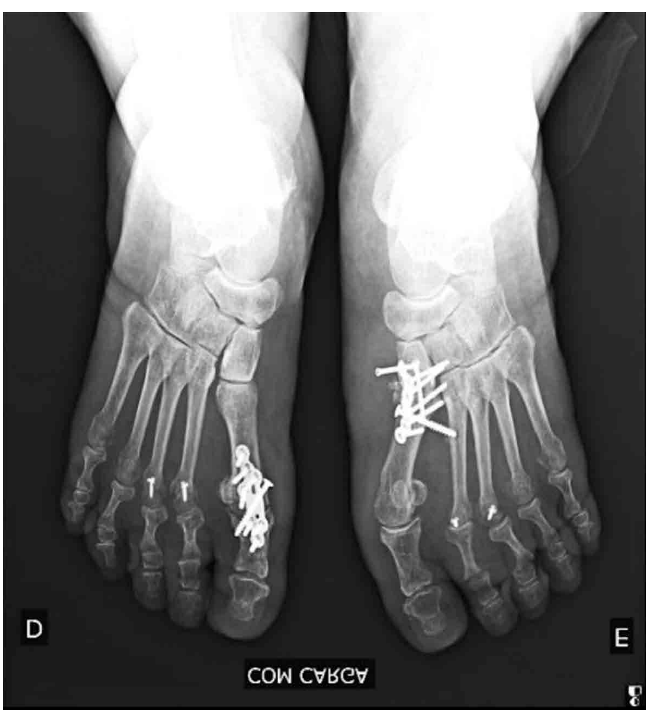

Figure 2. Radiographic evidence of hardware loosening in the left foot.

In order to reduce this complication, alternatives such as technique modifications and fragment rotation have produced encouraging results. Klemola et al.[18] described a new first TMTJ arthrodesis technique by combining rotational correction of the first metatarsal and reported a 2% rate of nonunion. Simons et al.[19] reported that first TMTJ arthrodesis with plantar plating resulted in lower rates of neurovascular injury. Klos et al.[14] reported a rate of only 1.72% of nonunion in patients undergoing first TMTJ arthrodesis with a plate placed on the plantar aspect of the first TMTJ. Li and Myerson[20] reported that some methods, such as plantar plating, nickel-titanium staples, and intramedullary fixation, produced greater biomechanical stability in cadaveric studies. In our study, 4 procedures were performed with plantar plating, and none of these patients developed nonunion. However, our small sample size prevents us from drawing conclusions that placing a plantar plate avoids this complication. Conti et al.[21] reported a significant decrease in recurrence rates in the decreased first metatarsal pronation group compared with the no-change/increased first metatarsal pronation group.

The most relevant finding of our study is the difference in complication rates compared with those found in previous studies. We found a much higher rate for all complications. We believe that this difference is mainly due to the limited experience of some surgeons who performed the procedures, since, of 8 patients who developed complications, 6 had the procedure performed by a surgeon with only 2 years of experience. The limitations of this study include a small sample size, the lack of a control group, and the great difference in experience across surgeons, thus making it difficult to determine the true factors that contribute to the development of complications. Therefore, all the disagreements found between our complication rates and those reported in the literature indicate that further prospective studies are needed. The indication of a surgical procedure or surgical technique must be very well evaluated to avoid as much as possible the complications that can be minimized.

Conclusion

Based on our study, we can conclude that first TMTJ arthrodesis requires greater care in choosing the surgical technique for the treatment of hallux valgus. In addition, some points should be considered to avoid complications as much as possible, such as the use of implants to increase stability, instruments for better articular cartilage resection, and improvement in the correction of the pronation deformity of the hallux. The limitations of our study prevent us from drawing a robust conclusion and defining consistent parameters related to the main factors that may affect the various complications described in the study. Therefore, we believe that data are still scarce to provide a concrete basis, and further studies are needed to make substantiated conclusions.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RYM *(https://orcid.org/0000-0003-0414-5752) Conceived and planned the activities that led to the study, data collection, statistical analysis, wrote the article and approved the final version; VFP *(https://orcid.org/0000-0002-1005-6089) Conceived and planned the activities that led to the study, wrote the article, critical analysis and approved the final version; AVKCL *(https://orcid.org/0000-0001-8974-5815) Performed the surgeries, conceived and planned the activities that led to the study, critical analysis and approved the final version; CASN *(https://orcid.org/0000-0002-9286-1750) Performed the surgeries, conceived and planned the activities that led to the study, critical analysis and approved the final version; NSBM *(https://orcid.org/0000-0003-1067-727X) Performed the surgeries, conceived and planned the activities that led to the study, critical analysis and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Hueter C. Klinik der Gelenkkrankheiten mit Einschluss der Orthopadie. Leipzig: Verlag Von FCW Vogel; 1871.
2. Nery CAS. Hallux valgus. Rev Bras Ortop. 2001;36(6):183-200.
3. Hamilton GA, Mullins S, Schuberth JM, Rush SM, Ford L. Revision lapidus arthrodesis: rate of union in 17 cases. J Foot Ankle Surg. 2007;46(6):447-50.
4. Salomão O. Hallux valgus: etiology and treatment. Rev Bras Ortop. 2005;40(4):147-52.
5. Mansur NSB, de Souza Nery CA. Hypermobility in Hallux Valgus. Foot Ankle Clin. 2020;25(1):1-17.
6. Espinosa N, Wirth SH. Tarsometatarsal arthrodesis for management of unstable first ray and failed bunion surgery. Foot Ankle Clin. 2011;16(1):21-34.
7. Taylor NG, Metcalfe SA. A review of surgical outcomes of the Lapidus procedure for treatment of hallux abductovalgus and degenerative joint disease of the first MCJ. Foot (Edinb). 2008;18(4):206-10.
8. Wai-Chi Wong D, Wang Y, Zhang M, Kam-Lun Leung A. Functional restoration and risk of non-union of the first metatarsocuneiform arthrodesis for hallux valgus: A finite element approach. J Biomech. 2015;48(12):3142-8.
9. Young NJ, Zelen CM. New techniques and alternative fixation for the lapidus arthrodesis. Clin Podiatr Med Surg. 2013;30(3):423-34.
10. Mallette JP, Glenn CL, Glod DJ. The incidence of nonunion after Lapidus arthrodesis using staple fixation. J Foot Ankle Surg. 2014;53(3):303-6.
11. Prissel MA, Hyer CF, Grambart ST, Bussewitz BW, Brigido SA, DiDomenico LA, et al. A Multicenter, Retrospective Study of Early Weightbearing for Modified Lapidus Arthrodesis. J Foot Ankle Surg. 2016;55(2):226-9.
12. Peterson KS, McAlister JE, Hyer CF, Thompson J. Symptomatic Hardware Removal After First Tarsometatarsal Arthrodesis. J Foot Ankle Surg 2016;55(1):55-9.
13. Schmid T, Krause F. The modified Lapidus fusion. Foot Ankle Clin. 2014;19(2):223-33.
14. Klos K, Wilde CH, Lange A, Wagner A, Gras F, Skulev HK, et al. Modified Lapidus arthrodesis with plantar plate and compression screw for treatment of hallux valgus with hypermobility of the first ray: a preliminary report. Foot Ankle Surg. 2013;19(4):239-44.
15. Barp EA, Erickson JG, Smith HL, Almeida K, Millonig K. Evaluation of Fixation Techniques for Metatarsocuneiform Arthrodesis. J Foot Ankle Surg. 2017;56(3):468-73.
16. Blitz NM, Lee T, Williams K, Barkan H, DiDimenico LA. Early weight bearing after modified lapidus arthodesis: a multicenter review of 80 cases. J Foot Ankle Surg. 2010;49(4):357-62.
17. Moore KR, Howell MA, Saltrick KR, Catanzariti AR. Risk Factors Associated With Nonunion After Elective Foot and Ankle Reconstruction: A Case-Control Study. J Foot Ankle Surg. 2017; 56(3):457-62.
18. Klemola T, Leppilahti J, Kalinainen S, Ohtonen P, Ojala R, Savola O. First tarsometatarsal joint derotational arthrodesis--a new operative technique for flexible hallux valgus without touching the first metatarsophalangeal joint. J Foot Ankle Surg. 2014;53(1):22-8.
19. Simons P, Fröber R, Loracher C, Knobe M, Gras F, Hofmann GO, et al. First Tarsometatarsal Arthrodesis: An Anatomic Evaluation of Dorsomedial Versus Plantar Plating. J Foot Ankle Surg. 2015; 54(5):787-92.
20. Li S, Myerson MS. Evolution of Thinking of the Lapidus Procedure and Fixation. Foot Ankle Clin. 2020;25(1):109-26.
21. Conti MS, Patel TJ, Zhu J, Elliott AJ, Conti SF, Ellis SJ. Association of First Metatarsal Pronation Correction With Patient-Reported Outcomes and Recurrence Rates in Hallux Valgus. Foot Ankle Int. 2021;6:10711007211046938.

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Original Article

The SUPERankle procedure in the treatment of foot and ankle deformities in fibular hemimelia

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Abstract

Objective: To review indications for limb amputation or reconstruction using the SUPERankle procedure in patients diagnosed with Paley type 3 or 4 fibular hemimelia; To evaluate the correction of deformities needed to achieve a stable plantigrade foot, review variations of the original technique and their applicability, and describe challenges encountered in their execution.

Methods: Qualitative, retrospective, descriptive study of 4 patients who underwent the SUPERankle procedure between 2019 and 2020 for treatment of foot and ankle deformities in fibular hemimelia. Pre- and postoperative clinical and radiographic evaluations were performed to identify objective evidence of the correction of foot and ankle deformities. The operative techniques employed are described.

Results: The included patients met anatomical and psychosocial criteria for reconstruction, as established in the literature. Clinical correction of foot and ankle deformities was achieved, but on radiographic evaluation, there was no statistical difference; this was likely due to the small number of patients, given the rarity of fibular hemimelia.

Conclusion: The procedure is reproducible, but requires a knowledgeable, well-trained surgical team. Correction of foot and ankle deformities can be achieved. The choice between amputation or reconstruction should be the result of an informed decision by family members, supported by a multidisciplinary team.

Level of Evidence IV; Qualitative Study; Case Series.

Keywords: Hemimelia; Fibula; Reconstructive surgical procedures; Leg length inequality.

Introduction

Fibular hemimelia (FH) is part of a broad spectrum of lower-limb deformities that include partial or total absence of the fibula, associated with other abnormalities (Figure 1), including reduced length of the affected limb, angular deformities, ball-and-socket ankle joint, tarsal anomalies, absent lateral rays of the foot, short femur, and occasionally, hand anomalies[1-4].

It is a rare deformity, with an incidence ranging from 7.4 to 49 cases per 1,000,000 live births[1,4,5]. The etiology is still unknown, and most cases occur in the absence of a family history of birth defects. Bilateral HF is the exception, as it often represents an autosomal dominant condition[2]. The classification described by Achterman and Kalamchi[6] in 1979 divided FH into 2 types, according to its anatomical and radiographic characteristics[1,6,7]. More recently, Paley's classification became the first one developed specifically to provide surgical options for reconstruction[1]. This classification is based on clinical examination and plain radiographs of the foot and ankle. If there is no foot deformity and the ankle is stable, the condition is Paley type 1. If the ankle deformity is dynamic, it is type 2. If there is a fixed equinovalgus deformity, it is type 3. In type 3A, the deformity is located in the ankle; in type 3B, it is subtalar; and in type 3C, it is combined ankle and subtalar. In type 4, there is a fixed equinovarus deformity. MRI is not required to distinguish types 1, 2, 3, and 4, but it helps subdivide type 3 into A, B, or C[2].

Study performed at the Hospital das Clínicas da Universidade Federal de Goiás, Goiânia, Goiás, Brazil.

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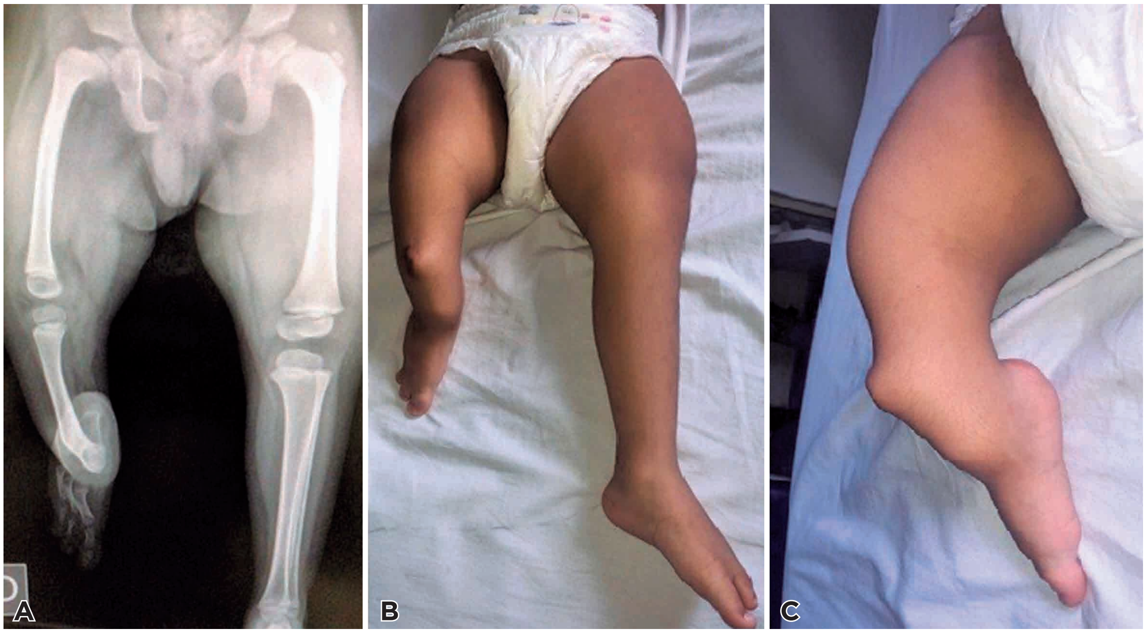

Figure 1. A) Plain radiograph of lower limbs. B) Clinical picture (anteroposterior view). C) Clinical picture (lateral view).

Syme or Boyd amputations were long the only treatment option, and are still indicated by several authors and used to good effect; however, advances in bone reconstruction have enabled an alternative to amputation[8,9]. The SUPERankle procedure, SUPER standing for Systematic Utilitarian Procedure for Extremity Reconstruction, is the term used by Paley[2] to describe a systematic procedure for ankle and foot extremity reconstruction. A combination of surgical approaches to bone and soft tissues, stabilizing the foot and correcting the associated deformities, it is indicated for the treatment of Paley type 3 and 4 FH[2].

The present study was designed to obtain clinical and radiographic evidence of correction of foot and ankle deformities in 4 patients who underwent the SUPERankle procedure, as well as to analyze the reproducibility of the original technique and its variations, describe the surgical procedure, and discuss in detail the technical challenges encountered.

Methods

This study was approved by the local ethics committee and registered on Plataforma Brasil. Four patients (Table 1) diagnosed with Paley type 3 or 4 FH underwent reconstructive treatment with the SUPERankle procedure between January 2019 and February 2020. All procedures were performed by the same team.

Patients were evaluated for descriptive variables, age, sex, affected side, associated deformities, and previous surgeries. To evaluate surgical correction, all cases underwent detailed radiographic evaluation before and after surgery, where we measured the talocalcaneal, tibiotalar, and plantigrade angles of the foot (Figure 2) on lateral views of the foot and ankle. The talocalcaneal angle is calculated by tracing lines through the axis of the talar neck and the long axis of the calcaneus. The tibiotalar angle is calculated by tracing lines through the axis of the talar neck and the anatomical axis of the tibia. Finally, the plantigrade angle of the foot is the angle between the anatomical axis of the tibia and the load-bearing surface of the foot[10]. These angles were compared with normal values described in the literature[10] (Table 2), and the mean angles before and after surgical treatment were calculated. The degree of satisfaction of patients and their families was evaluated dichotomously as "satisfied" or "dissatisfied" with the surgery.

Surgical technique

The patient was placed in supine position with a 20-degree lateral positioning on the operated side. The whole procedure is performed under pneumatic tourniquet control.

Step 1: A longitudinal incision was made on the lateral aspect of the leg, with layered dissection to avoid injury to the sural nerve.

Step 2: The lateral structures were identified; when both the peroneus brevis and longus tendons are present, the brevis was lengthened by z-plasty. Three patients had only the peroneus longus, which did not need to be lengthened, as it was not tense nor prevented subtalar reduction.

Step 3: The cartilaginous fibular anlage (Figure 3), which corresponds to the fibular remnant[2], was identified. This structure can range from a soft, fibrous cord to a dysplastic fibula with structured bone tissue. In older patients, the anlage is more evident. In three patients, it was adherent to

Table 1. Data on patients who underwent the SUPERankle procedure

	Sex	Paley type	Age	Side	Associated deformities	Previous surgery
Patient 1	F	3B	8 years	L	Short femur	Yes
Patient 2	M	3A	7 years	R	Short femur Absence of single ray	No
Patient 3	F	3C	8 years	R	Short femur Absence of single ray	Yes
Patient 4	M	3B	4 years	R	Short femur Absence of two rays	No

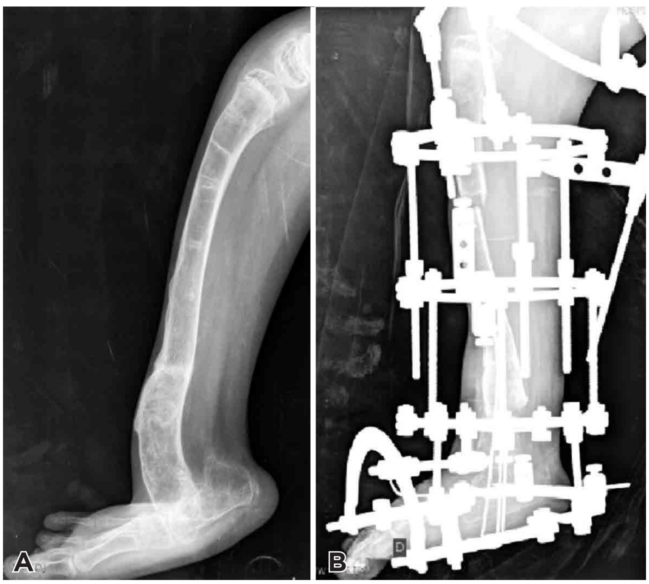

Figure 2. A) Preoperative radiograph. B) Postoperative radiograph.

Table 2. Reference values of angles

Lateral talocalcaneal angle	35-50
Tibiotalar angle	68 (64-72)
Plantigrade angle of the foot	88 (85-91)

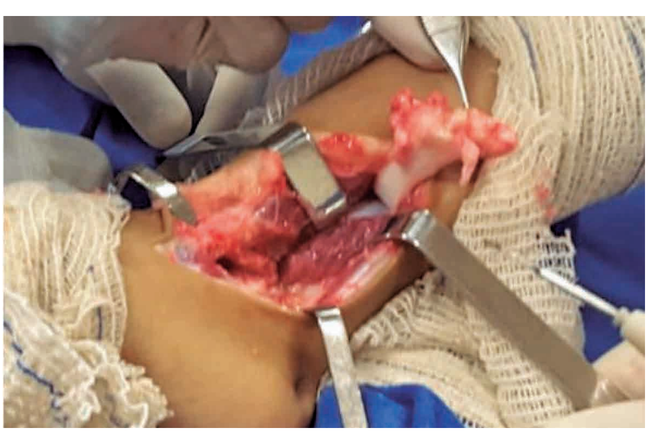

Figure 3. Fibular anlage.

the lateral aspect of the calcaneus, and was dissected and removed with a scalpel and a delicate osteotome. Unlike in the technique originally described by Paley, we performed the lateral incision only distally. We achieved good resection of the cartilaginous anlage and dysplastic fibula through this distal incision, with no need to extend the incision proximally.

Step 4: After resection of the fibular anlage, the flexor hallucis and neurovascular structures were identified, and the neurovascular bundle dissected and decompressed.

Step 5: The lateral wall of the calcaneus was then cleaned, and the sinus tarsi and posterior edge of the calcaneus identified. A lateral capsulotomy was performed, and the ankle and subtalar joints were identified. The cartilaginous talocalcaneal junction was identified and the osteotome advanced at a 45° angle to cut through the subtalar coalition, starting the cut posteriorly and moving towards the sinus tarsi.

Step 6: After subtalar release, the calcaneus was reduced by medializing it and bringing it under the talus, correcting the hindfoot valgus, and pinning the calcaneus, talus, and tibia with two 2.0 K-wires.

Step 7: A T-shaped incision was made in the periosteum of the distal tibia. Two guide wires were inserted parallel to the plantar surface in the frontal and sagittal planes, and a distal osteotomy was made parallel to the guide wires with a saw.

Step 8: After tibial osteotomy, the distal segment was shifted medially to overlap the tibial bone ends. The level of the overlap was marked. Guide wires were inserted at the level of the overlap, which is the site of the second shortening osteotomy. This osteotomy was made perpendicularly to the axis of the proximal diaphysis of the tibia, forming a trapezoidal-shaped piece of bone to be resected (Figure 4). If there is *procurvatum* angulation or diaphyseal deformity, the second osteotomy can be distal to or at the apex of this deformity. This second osteotomy is performed to straighten and shorten the tibia. In naturally shorter tibias, this shortening of the limb hinders later assembly of the Ilizarov frame.

Step 9: After the guide wires and bone segment were removed, the tibia was realigned and shortened. The retrograde axial K-wires used for subtalar fixation were advanced up the tibia (Figure 5). If the cuts were performed correctly, the foot should be plantigrade at this point. In one case, we used three 2.0 K-wires. The skin over the anterior distal tibia can be dissected to avoid creating an anterior skin fold. Hemostasis is then achieved and the lateral incision closed in layers. The foot is plantigrade for assembly of the external ring fixator.

Figure 4. Tibial osteotomy.

Figure 5. Fragment reduction and retrograde wire fixation.

Step 10: A traditional Ilizarov external ring fixator was placed. The assembly consists of a tibial block with two or three rings depending on the length of the tibia. The foot assembly is then applied, fixing the hindfoot and forefoot in plantigrade position. Schanz pins are used to fix the calcaneus, and smooth wires to fix the forefoot.

Step 11: The femoral block was assembled with an arch and a ring, which were connected with struts to the tibial block. Addition of the femoral assembly is necessary due to knee instability caused by agenesis of the cruciate ligaments in these cases.

Step 12: After assembly of the external fixator, tibial osteotomy for lengthening was performed through an anteromedial approach in the proximal third of the leg. Finally, the skin was sutured and the wound was dressed.

Results

The mean age was 6.7 years (range, 4-8 years); 50% (n=2) were female and 50% (n=2) were male. There was a predominance of right-sided involvement. Two patients had previously undergone surgery on the affected limb (Table 1).

Results regarding angular correction of foot and ankle deformities, as determined by comparison of pre- and postoperative period radiographs, are shown in Table 3. There was a trend toward near-normal angular values after surgery, as shown in Table 2.

The mean and standard deviation of the angles obtained after surgery were compared with the normal values using the one-sample *T*-test. P-values <0.05 were considered significant. By this measure, there was no significant difference between postoperative angular values and normal values (Table 4). Statistical analyses were performed in SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp). In terms of satisfaction with the procedure, all patients and family members were satisfied with the outcome of treatment. In all patients, clinical correction of the deformity was observed, with a stable plantigrade foot that can bear weight for walking and provide support for subsequent reconstruction procedures (Figure 6).

Discussion

The SUPERankle procedure for reconstruction in fibular hemimelia, devised by Paley, uses a hexapod external fixator. This system uses the 6-axis correction principle, guided by computer software. The tibial ring block assembly uses only two rings, the reference (or stationary) ring and the mobility ring.

In this study, we used the Ilizarov ring fixator, as it is the only circular fixator available at our facility. This external fixator offers a smaller working area after placement of the rings in

Table 3. Pre- and postoperative angles

	Talocalcaneal		Tibiotalar		Plantigrade	
	Pre	Post	Pre	Post	Pre	Post
Patient 1	20.1	50	57.4	72.1	114.2	89.9
Patient 2	18.6	44.5	59.4	81.4	81.4	88
Patient 3	18.3	25.8	24	66	66	85
Patient 4	14	23	58.1	74	57.5	78.9

Table 4. Mean (standard deviation) postoperative angles and their reference ranges

	Talocalcaneal			Tibiotalar			Plantigrade		
	Post	Reference range	*p**	Post	Reference range	*p**	Post	Reference range	*p**
X̄	35.8±13	42.5	0.394	73.4±6	68.0	0.18	85.4±4	88.0	0.36
±S	4			4		9	8		0

X̄: mean. S: standard deviation. *One-sample *T*-test.

Figure 6. Clinical picture after removal of the external fixator.

the tibial assembly, causing greater difficulty in managing the proximal tibial osteotomy to initiate bone lengthening during the same surgical stage of the SUPERankle procedure. This technical difficulty was also reported by Alaseirlis et al.[11].

We believe that a conventional external ring fixator is suitable for performing the SUPERankle procedure, and if technical difficulty in performing the proximal tibial osteotomy is encountered, lengthening can be performed later. The same conclusion was reached by Kulkarni et al.[12], who recommend that lengthening be performed 1 or 2 years after the SUPERankle procedure.

Paley advocates that treatment of fibular hemimelia should preferably be carried out between 18 and 24 months of age. When performed after 5 years of age, there is a greater chance of recurrence of deformities and joint stiffness in the ankle[12]. Three patients in the present study only had access to surgery at such relatively advanced ages. The indication for limb reconstruction should be maintained, and future recurrence of deformities, if any, should be corrected during treatment. Major residual deformities include lower limb length discrepancy, calf atrophy, and ankle valgus[13]. All patients in this study will remain under follow-up by the attending medical team to correct any associated deformities, obtain a stable limb, and ensure no length discrepancies remain once they reach skeletal maturity.

Patients 1 and 3 had already undergone previous surgeries for lengthening and correction of the tibial deformity, but unsuccessfully, as a plantigrade foot had not been achieved. The success of limb reconstruction treatment in patients with Paley type 3 and 4 FH depends on the specific approach to these foot and ankle deformities.

All patients included herein had at least three rays in the foot and, as proposed by Birch et al.[14], would thus be candidates for limb reconstruction as an alternative to amputation. This criterion-presence of at least three rays-is indispensable to obtaining a plantigrade, stable foot for ambulation.

We did not any find data in the literature regarding radiological evaluation of foot and ankle angles in patients undergoing the SUPERankle procedure for the treatment of FH. We believe that measuring these angles provides objective criteria for evaluating the correction of foot and ankle deformities. Although we found a tendency toward near-normal angular values, there was no significant difference, probably due to the small number of patients, which, in turn, is expected given the rare nature of this deformity.

Calder et al.[15] suggest that an expected discrepancy greater than 20 cm would be a formal indication for amputation, due to the need for more than three lengthening procedures or epiphysiodesis of the normal limb. In none of the cases presented herein would the shortening predicted by the Multiplier method[16] upon reaching skeletal maturity exceed 20 centimeters.

The external fixator was removed an average of 11 to 12 months after the initial procedure, and tibial lengthening was performed to approximately 4 to 5 centimeters on average. This is within the expected range, as all patients will undergo 2 more lengthening procedures during skeletal maturation. Lengthening is performed at home, with guidance to family members regarding proper handling of the device. Outpatient visits took place every other week in the first 3 months and monthly thereafter until the fixator was removed.

Another factor to be analyzed when deciding between early amputation or correction of deformities and limb growth discrepancy are the psychological consequences of such procedures. Studies show that no significant differences were found in psychological adjustment and quality of life when comparing amputation and reconstruction in patients with FH[8]. Patients undergoing Syme amputation have good psychological and functional outcomes[17].

Moraal et al.[7] state that patients undergoing serial reconstruction procedures with prolonged use of the Ilizarov technique experience improvement in self-esteem after correction of the deformity and limb discrepancy. A decrease in pain and a greater degree of satisfaction were also found after correction of the length discrepancy, with better psychological and satisfaction outcomes. In the present study, all family members showed interest and were 100% satisfied with the outcome of reconstructive treatment. If they decide to interrupt reconstruction of the affected limb and undergo amputation, the procedure can still be performed by the team.

White ethnicity, higher education, and higher family income are associated with choosing reconstructive treatment[8]. The findings of the present study are not consistent with the international literature. Of the four patients whose families chose reconstruction surgery, three are Black and one White; all come from low-income, low-education background.

All patients are being actively followed, with the expectation of undergoing an additional lengthening procedure 3 to 4 years after the first procedure. During this period, they will undergo serial clinical and radiological examinations to screen for recurrence of deformities or other complications.

Conclusion

SUPERankle reconstruction surgery requires a team of operators knowledgeable in foot and ankle anatomy and familiar with external fixation techniques. In such hands, it is reproducible and achieves good clinical and radiological outcomes. In all cases presented herein, correction of foot and ankle deformities was achieved, obtaining a plantigrade foot which can provide stability and function to the limb after reconstruction.

Authors' contributions: Each author contributed individually and significantly to the development of this article: CECF *(https://orcid.org/0000-0002-3832-7397) Conceived and planned the activities that led to the study, interpreted the results of the study, data collection, participated in the review process, performed the surgeries, clinical examination and approved the final version**;** GJFS *(https://orcid.org/0000-0001-8490-6085) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; JSM *(https://orcid.org/0000-0003-4742-1905) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, clinical examination and approved the final version, formatting of the article, bibliographic review and approved the final version; MVMLS *(https://orcid.org/0000-0003-1003-7328) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, statistical analysis and approved the final version; RACCP *(https://orcid.org/0000-0001-7434-1279) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, clinical examination and approved the final version; TRTC *(https://orcid.org/0000-0003-2772-4802) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, clinical examination and approved the final version, formatting of the article, bibliographic review and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Zhang Z, Yi D, Xie R, Hamilton JL, Kang QL, Chen D. Postaxial limb hypoplasia (PALH): the classification, clinical features, and related developmental biology. Ann N Y Acad Sci. 2017;1409(1):67-78.
2. Paley D. Surgical reconstruction for fibular hemimelia. J Child Orthop. 2016;10(6):557-83.
3. Catagni MA, Radwan M, Lovisetti L, Guerreschi F, Elmoghazy NA. Limb lengthening and deformity correction by the Ilizarov technique in type III fibular hemimelia: an alternative to amputation. Clin Orthop Relat Res. 2011;469(4):1175-80.
4. Oberc A, Sułko J. Fibular hemimelia - diagnostic management, principles, and results of treatment. J Pediatr Orthop B. 2013; 22(5):450-6.
5. Froster UG, Baird PA. Congenital defects of lower limbs and associated malformations: a population based study. Am J Med Genet. 1993;45(1):60-4.
6. Achterman C, Kalamchi A. Congenital deficiency of the fibula. J Bone Joint Surg Br. 1979;61-B(2):133-7.
7. Moraal JM, Elzinga-Plomp A, Jongmans MJ, Roermund PM, Flikweert PE, Castelein RM, et al. Long-term psychosocial functioning after Ilizarov limb lengthening during childhood. Acta Orthop. 2009; 80(6):704-10.
8. Birch JG, Paley D, Herzenberg JE, Morton A, Ward S, Riddle R, et al. Amputation Versus Staged Reconstruction for Severe Fibular Hemimelia: Assessment of Psychosocial and Quality-of-Life Status and Physical Functioning in Childhood. JB JS Open Access. 2019;4(2):e0053.
9. Rogala EJ, Wynne-Davies R, Littlejohn A, Gormley J. Congenital limb anomalies:frequency and aetiological factors. Data from the Edinburgh Register of the Newborn (1964-68). J Med Genet. 1974;11(3):221-33.
10. Lamm BM, Stasko PA, Gesheff MG, Bhave A. Normal Foot and Ankle Radiographic Angles, Measurements, and Reference Points. J Foot Ankle Surg. 2016;55(5):991-8.
11. Alaseirlis DA, Korompilias AV, Beris AE, Soucacos PN. Residual malformations and leg length discrepancy after treatment of fibular hemimelia. J Orthop Surg Res. 2011;6:51.
12. Kulkarni RM, Arora N, Saxena S, Kulkarni SM, Saini Y, Negandhi R. Use of Paley Classification and SUPERankle Procedure in the Management of Fibular Hemimelia. J Pediatr Orthop. 2019;39(9): e708-e717.
13. Unprasert P, Kaewpornsawan K, Chotigavanichaya C, Eamsobhana P. Management of fibular hemimelia using the Ilizarov method at Siriraj Hospital in Thailand. J Med Assoc Thai. 2014;97 Suppl 9:S44-S49.
14. Birch JG, Lincoln TL, Mack PW, Birch CM. Congenital fibular deficiency: a review of thirty years' experience at one institution and a proposed classification system based on clinical deformity. J Bone Joint Surg Am. 2011;93(12):1144-51.
15. Calder P, Shaw S, Roberts A, Tennant S, Sedki I, Hanspal R, et al. A comparison of functional outcome between amputation and extension prosthesis in the treatment of congenital absence of the fibula with severe limb deformity. J Child Orthop. 2017;11(4):318-25.
16. Paley D, Bhave A, Herzenberg JE, Bowen JR. Multiplier method for predicting limb-length discrepancy. J Bone Joint Surg Am. 2000; 82(10):1432-46.
17. Birch JG, Walsh SJ, Small JM, Morton A, Koch KD, Smith C, et al. Syme amputation for the treatment of fibular deficiency. An evaluation of long-term physical and psychological functional status. J Bone Joint Surg Am. 1999;81(11):1511-8.

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Original Article

Evaluation of the clinical-radiographic results of patients undergoing arthroscopic metatarsal-phalangeal arthrodesis of the hallux

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Abstract

Objective: To present the clinical and radiographic results of patients undergoing arthroscopic metatarsal-phalangeal arthrodesis of the hallux, depict the technique and report complications.

Methods: This study involves a series of 9 patients (10 feet), all with advanced hallux rigidus (Coughlin-Shurnas grades 3 and 4). All patients underwent an arthroscopic procedure through two dorsal portals with small-joint instruments. Outcomes were assessed using the AOFAS functional score and a visual analogue scale of pain. The radiographic parameters of interest were metatarsal-phalangeal angulation in the anteroposterior (pre- and postoperative) and lateral (post-operative) views, as well as ray shortening.

Conclusion: Arthroscopic metatarsal-phalangeal arthrodesis is an excellent treatment option in advanced stages of hallux rigidus, with minimal disruption, excellent outcomes, and a low incidence of complications.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Arthrodesis; Metatarsalphalangeal joint; Hallux; Arthrosis.

Introduction

Hallux rigidus (HR) is a degenerative disease that affects the first metatarsal-phalangeal joint (1st MTP), characterized by pain and progressive loss of movement in this joint. It was first described by Davies-Colley[(1)] in 1887 using the term hallux flexus, with "hallux rigidus" later coined by Cotterill[(2)]. HR represents the second most common pathological condition in this joint. It is a cause of important functional impairment, especially for women, who eventually develop great restriction to the use of high-heeled shoes. The main radiographic changes are reduced joint space, dorsal osteophyte formation, and development of sclerosis/cysts. This condition most commonly affects women, and is initially unilateral, but 80% of the patients develop a contralateral lesion within 9 years[(3)].

The cause of the disease is not fully understood, but it seems to be related to factors such as trauma, osteochondral injuries, rheumatic diseases, and anatomical issues, such as the shape of the head of the first metatarsal bone and the length of this bone. The Coughlin and Shurnas[(4)] classification is the one most used today, based on clinical and radiographic criteria, which include changes in joint space reduction, osteophyte formation, intensity of symptoms, and range of motion of the 1st MTP. Coughlin-Shurnas grades 3 and 4 represent advanced disease and almost always translate into major functional impairment.

There are numerous treatment options, including analgesics, modifications and adaptations to shoes, physical therapy, joint injections, and surgical treatment. Surgery is usually per-

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formed when conservative treatment fails, but it may be the first option in advanced conditions.

The main procedures described for advanced stages of HR are arthrodesis and interposition arthroplasty[(5)], but osteotomies have also been described[(6,7)]. Metatarsal-phalangeal arthrodesis is a safe approach that provides a high level of patient satisfaction, with marked improvement in pain and gait quality.

The gold standard for the treatment of the final stages of HR is arthrodesis of the 1st MTP, which can be performed through an open, minimally invasive[(8)] or arthroscopic approach. Lui reported good outcomes in the treatment with arthroscopic arthrodesis in cases of severe hallux valgus[(9)] and in hallux varus[(10)].

In this study, we report the clinical and radiographic results of arthroscopic metatarsal-phalangeal arthrodesis in the treatment of advanced RH.

Methods

This study was approved by the Ethics Committee on 05/17/2021 and started the following week, with the provision of an informed consent form and application of postoperative functional scores.

A consecutive series of nine patients (seven women and two men, 10 feet), with a mean age of 61.2 years (range 54 to 69 years, SD 4.49) underwent metatarsal-phalangeal arthrodesis of the hallux for the treatment of advanced HR (Coughlin-Shurnas grades 3 and 4) from November 2016 to October 2020. The mean duration of follow-up was 27.8 months (7 to 54 months, SD 16.97). The average time from first visit to surgery was 25 days. All the patients were operated on by the senior surgeon.

HR was diagnosed after clinical and radiographic evaluation, including pre- and postoperative radiographs in anteroposterior and lateral views, under load. The 1st MTP joint alignment angle was measured in AP (pre- and postoperative) and lateral (postoperative only) views. The length of the first ray was measured by tracing the first metatarsal center-base in the joint with the cuneiform to the midpoint of the joint line of the proximal phalanx in the interphalangeal joint, on pre- and postoperative radiographs (Figure 1). Thus, we sought to assess the postoperative shortening created by the arthrodesis.

All patients were evaluated by the AOFAS functional score[(11)] and by a visual analogue scale of pain before and after surgery.

The patients were all ambulatory in the community, and did not depend on external aids for walking. No patient had undergone previous surgery on the forefoot; one patient had a history of a malignant calcaneal tumor being resected during childhood. One patient was diabetic, two were smokers (10 cigarettes/day), and two were hypertensive.

Surgical technique

The surgical procedure was performed in the supine position, under spinal anesthesia. We placed an Esmarch band in the middle third of the leg and administered antibiotic pro-

Figure 1. Method for measuring the length of the first ray on anteroposterior radiography, under load.

Figure 2. Portal placements and their relationship with the extensor hallucis longus tendon and medial dorsal cutaneous nerve.

phylaxis 20 minutes before exsanguination. The foot was placed at the edge of the surgical table for better access.

We created two classic 5-mm dorsomedial and dorsolateral portals, placed 5 to 7 mm medial and lateral to the extensor hallucis longus tendon (Figure 2), respectively. Under manual finger traction, we introduced a curved hemostat through the portals to make room for the video instruments. After properly opening the joint, we entered with the optics and shaver. We used 2.7-mm instruments (30-degree optics, bone shaver, and synovial shaver).

The endoscope was positioned on the medial portal and the shaver on the lateral one, enabling us to identify the joint surfaces of the metatarsal head and the base of the proximal phalanx. The procedure was continued with bone head decortication of the three central zones and three lateral zones of the head, as well as of the corresponding region of the phalanx, using a 2.7 round bur (Figure 3). We then inverted the instruments' position, placing the shaver through the medial portal, and performed the same procedure in the medial areas. Manual traction was done only when introducing the instruments.

After joint-surface decortication, we fixed the arthrodesis in 9 of the 10 feet with two 4.5-mm cannulated steel screws (AMGS, Belo Horizonte, Brazil) in a crisscross setup. In one patient, we used a single 4.5-mm cannulated screw and 1.5-mm Kirschner wire instead. In all cases, fixation was guided by fluoroscopy. The first screw was passed obliquely from the medial proximal part of the metatarsal head (immediately proximal to the bunion) to the lateral part of the proximal phalanx. The second screw was passed after initial drilling from the base of the proximal phalanx (10 to 12 mm from the articular surface) to the lateral area of the first metatarsal. The initial perforation and fixation were performed by keeping the proximal phalanx at 10 to 15 degrees in dorsiflexion in relation to the ground, while trying to maintain an alignment of 10 to 15 degrees with the axis of the first metatarsal (Figures 4 A, B and C).

Once the arthrodesis fixation was completed, we sutured the wounds with 3-0 nylon and applied a sterile dressing, without any external fixation. All patients were discharged from hospital the next day, with a prescription to wear Barouk shoes for support for 6 weeks. The stitches were removed at 15 to 20 days, and control radiographs were obtained at 6 and 10 weeks. Most patients started physical therapy within 6 weeks, requiring 15 to 30 sessions for complete recovery.

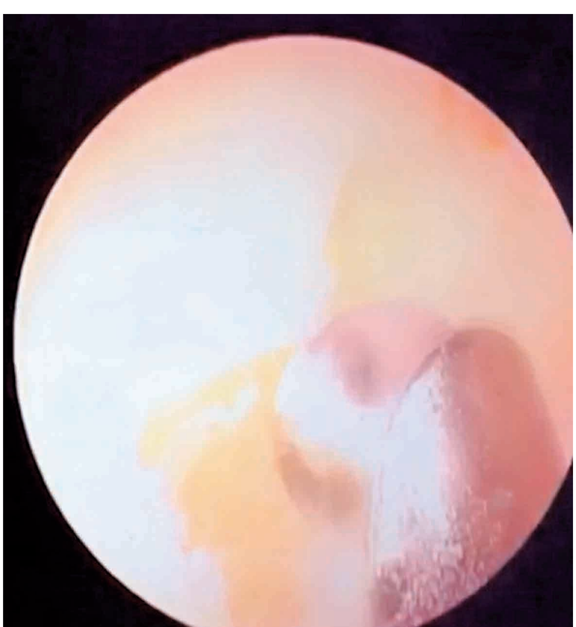

Figure 3. Decortication of the first metatarsal head with a bone shaver.

Figure 4. Preoperative (A), 10-week postoperative (B), and late postoperative (C) radiographs.

Statistical analysis

Initially, we ran an exploratory analysis to establish data normality, using the Shapiro-Wilk test, ideal for the number of samples in our study. We also performed an outlier detection test in GraphPad QuickCalcs Outlier Calculator software.

Considering the parametric nature of the data (normal distribution), we obtained the mean, standard deviation, and minimum and maximum values for each variable analyzed; we also obtained the absolute frequency (n) and percentage (%) values for descriptive analyses.

We used the paired Student's t-test for comparative analysis between the preoperative and postoperative periods. For all analyses performed, the differences obtained were considered statistically significant when the p-value was less than 0.05 ($p<0.05$).

We used GraphPad Prism® version 5.0 for Windows and Stata® version 14.0 software for the statistical analyses.

Results

On postoperative clinical-radiographic follow-up of our nine patients (10 feet), eight feet showed a healed arthrodesis with radiographic control within 6 weeks. The other two feet showed no more than 50% healing of the articular surface at this time, but within 10 weeks of surgery both showed clear radiographic healing.

All patients had improvement of pain within 6 weeks, sustained at later visits. Two patients had sensory changes in the area of the medial dorsal cutaneous nerve, with recovery 4 months after the surgical procedure. One patient developed pain in the central region of the forefoot, improving with transient adaptation to footwear. No patient had superficial or deep infection upon follow-up, nor were there any systemic complications such as fever or thromboembolic events.

Statistical analysis of the data shown in table 1 revealed no shortening of the first ray after arthrodesis. There was a reduction and relative correction of the metatarsal-phalangeal angle in anteroposterior radiographs after the procedure (Table 2).

The results were evaluated comparing the pre- and postoperative functional score using the AOFAS score and the visual analogue scale of pain (Table 3).

Statistical analysis showed significant improvement in functional scores and in AOFAS score analysis (Tables 3 and 4).

Discussion

The main findings of this study are the effectiveness of the arthroscopic technique to achieve arthrodesis healing, the low morbidity of the procedure, and its success when considering the clinical outcome of pain and gait quality improvement. All patients showed significant clinical improvement at 10-week follow-up.

Arthroscopic procedures are less aggressive, with consequent preservation of periarticular vascularization, enabling the healing process to occur more quickly and with a shorter recovery period, as already shown in studies for other joints of the foot[12] and ankle[13].

Forefoot endoscopic and arthroscopic procedures have been performed for almost 40 years[14] and, in the last 15 years, have been developed to perform or assist in the treatment of various pathological conditions, such as hallux valgus[9], hallux varus[10], osteochondral lesions of the 1st MTP[15], and arthrodesis. Successive studies have shown safety and success in approaching these different lesions of the metatarsal-phalangeal joint of the hallux.

A cadaver study showed that the arthroscopic procedure was able to decorticate an area greater than 90% of the joint surface of both the metatarsal head and the base of the proximal phalanx, with an average shortening of 2.2 mm in the first ray[16].

In our study, we confirmed that the arthroscopic procedure does not shorten the first ray (88.5 mm –87.7 mm, p=0.15). In four of the ten feet we studied, there was instead lengthening

Table 1. Pre- and postoperative general clinical and radiographic data

Patient	Report	Sex	Age	Follow-up (months)	Fixation technique	Preop AP MTP angle	Postop AP MTP angle	Postop lateral MTP angle	Preop length (mm)	Postop length (mm)
1	E	F	60	50	2 screws	15	15	29	87.9	84.4
2	D	F	62	54	2 screws	13	5	27	84.4	82.6
3	D	F	62	41	1 screw + 1 K-wire	10	13	25	82.8	81.9
4	D	F	58	29	2 screws	16	18	31	87.8	85.7
5	D	M	61	34	2 screws	16	12	29	92.8	94.4
6	E	F	65	26	2 screws	19	13	27	90.5	89
6	D	F	65	16	2 screws	26	20	25	88.9	89.7
7	D	M	69	14	2 screws	19	7	29	101.6	102.1
8	D	F	54	7	2 screws	20	18	28	81.7	82.1
9	E	F	56	7	2 screws	26	21	23	86.8	85.5

Table 2. Pre- and postoperative measurements of metatarsal-phalangeal length, anteroposterior (AP) angle, and lateral angle in patients with metatarsal-phalangeal arthrodesis of the hallux

	Mean (± SD)	Min-Max	p-value
Length (mm)			
Preop	88.52 (± 5.71)	81.70 – 101.60	0.1505
Postop	87.74 (± 6.40)	81.90 - 102.10	
MTP AP angle			
Preop	18.00° (± 5.16)	10 - 26	0.0292*
Postop	14.20° (± 5.31)	5 - 21	
MTP side angle			
Postop	27.30° (± 2.41)	23 - 31	-

SD= standard deviation.
AP= anteroposterior angle.
MTP= metatarsal-phalangeal joint.
* Statistically significant according to the paired Student's t test ($p<0.05$).

Table 3. Pre- and postoperative AOFAS functional scores and visual analogue scale of pain

Patient	Preop AOFAS score	Postop AOFAS score	Preop VAS	Postop VAS
1	39	85	10	0
2	28	85	10	0
3	49	70	7	3
4	39	87	10	0
5	52	87	8	0
6	47	90	9	0
6	47	90	10	0
7	49	90	6	0
8	45	90	8	0
9	49	80	10	3

Table 4. General and stratified assessment of AOFAS score for the forefoot obtained from patients with metatarsal-phalangeal arthrodesis of the hallux, in the pre- and postoperative periods

	Mean (± SD)	Min-Max	p-value
General AOFAS score			
Preop	44.40 (± 7.17)	28 - 52	<0.0001*
Postop	85.40 (± 6.29)	70 - 90	

of the ray, probably as a result of correcting the preoperative valgus. This condition was reflected in the clinical findings, in which only one patient had transient transfer metatarsalgia, which resolved after 6 months. The procedure also reduced or corrected the 1st MTP valgus in six of seven patients with an angle greater than 15 degrees.

Arthroscopic arthrodesis of the 1st MTP provided an improvement in AOFAS functional score (44.4 – 85.4, $p<0.0001$), and all patients improved in their functional condition for activities of daily living when compared to their preoperative baseline.

For several reasons, arthroscopic arthrodesis seems to be a very attractive treatment option. Low aggressiveness, minimal postoperative pain, quick recovery, fair cosmetic appearance of the scars and the ability to resolve pain and function issues encourages us to apply this technique in future cases. We know that video-assisted surgery requires skill and experience, which are developed over time and with practice in larger joints over the years. The instruments are delicate and require care in handling.

The present study has some limitations. First, the small number of patients precludes more solid conclusions about the procedure. Second, we did not run a gait analysis comparing forefoot biomechanics before and after surgery. Such an analysis would certainly provide important data regarding the reestablishment or improvement of load distribution in the metatarsal heads and in gait pattern. A larger number of patients and longer follow-up would be important to confirm the positive preliminary findings of our study.

Conclusions

Arthroscopic metatarsal-phalangeal arthrodesis is an excellent treatment option for advanced stages of hallux rigidus, with minimal invasiveness and excellent outcomes, in addition to a low incidence of complications.

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References

1. Davies-Colley M. Contraction of the metatarsophalangeal joint of the great toe. Br Med J 1887;1:728.
2. Cotterill J. Stiffness of the great toe in adolescents. Br Med J 1888;1:1158.
3. Coughlin MJ, Shurnas PS. Hallux rigidus: demographics, etiology, and radiographic assessment. Foot Ankle Int. 2003;24(10):731-43.
4. Coughlin MJ, Shurnas PS. Hallux rigidus. Grading and long-term results of operative treatment. J Bone Joint Surg Am. 2003;85(11):2072-88.
5. Johnson JE, McCormick JJ. Modified oblique Keller capsular interposition arthroplasty (MOKCIA) for treatment of late-stage hallux rigidus. Foot Ankle Int. 2014;35(4):415-22.
6. Cancilleri F, Russo F, Torre G, Vadalà G, Marineo G, Papalia R, Denaro V. Weil osteotomy for the treatment of grade III hallux rigidus: a case series. J Biol Regul Homeost Agents. 2020;34(4 Suppl. 3):337-43.
7. Cho BK, Park KJ, Park JK, SooHoo NF. Outcomes of the Distal Metatarsal Dorsiflexion Osteotomy for Advanced Hallux Rigidus. Foot Ankle Int. 2017;38(5):541-50.
8. Sott AH. Minimally Invasive Arthrodesis of 1st Metatarsophalangeal Joint for Hallux Rigidus. Foot Ankle Clin. 2016;21(3):567-76.
9. Lui TH. Arthroscopic Arthrodesis of the First Metatarsophalangeal Joint in Hallux Valgus Deformity. Arthrosc Tech. 2017;6(5):e1481-e7.
10. Lui TH. Arthroscopic First Metatarsophalangeal Arthrodesis for Repair of Fixed Hallux Varus Deformity. J Foot Ankle Surg. 2015;54(6):1127-31.
11. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15(7):349-53.
12. Rungprai C, Phisitkul P, Femino JE, Martin KD, Saltzman CL, Amendola A. Outcomes and Complications After Open Versus Posterior Arthroscopic Subtalar Arthrodesis in 121 Patients. J Bone Joint Surg Am. 2016;98(8):636-46.
13. Quayle J, Shafafy R, Khan MA, Ghosh K, Sakellariou A, Gougoulias N. Arthroscopic versus open ankle arthrodesis. Foot Ankle Surg. 2018;24(2):137-42.
14. Watanabe M. Selfoc-Arthroscope (Watanabe no. 24 arthroscope) [monograph]. Tokyo: Teishin Hospital; 1972. p. 46–53.
15. Kuyucu E, Mutlu H, Mutlu S, Gülenç B, Erdil M. Arthroscopic treatment of focal osteochondral lesions of the first metatarsophalangeal joint. J Orthop Surg Res. 2017;12(1):95. Erratum in: J Orthop Surg Res. 2019;14(1):460.
16. McKissack H, Alexander B, Viner GC, Abyar E, Andrews NA, Shah A. Joint preparation and ray shortening in arthroscopic versus open first metatarsophalangeal fusion: a cadaver study. Cureus. 2020;12(8):e9633.

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Original Article

Ankle arthrodesis through Meary's anterolateral access

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Abstract

Objective: This study aimed to assess indications for surgical treatment, position of the ankle, time and rate of fusion after arthrodesis; to ascertain whether the technique provides fusion rates similar to those described in the published literature; and to quantify patients' improvement according to the AOFA and VAS scores, and patients' satisfaction using a Likert scale.

Methods: This is a clinical study with a cohort of 18 patients (9 women and 9 men) with a mean age of 49.10 years, conducted from 2006 and 2016.

Results: Post-traumatic arthrosis (88.88%), rheumatoid arthritis (5.56%), and Charcot-Marie-Tooth disease (5.56%) motivated the surgeries. Six ankles fused in an equinus position, and 12 of them in a neutral position. Five ankles fused in valgus angulation, and 13 in a neutral position. Five ankles fused in external rotation, 2 in internal rotation and 11 in a neutral position. In the postoperative period, American Orthopaedic Foot and Ankle Society (AOFAS) and visual analogue scale (VAS) scores showed an improvement of 31.6 points and 5.1 points, respectively. Regarding the Likert scale, 2 patients reported being very satisfied, 14 satisfied, and 2 partially satisfied.

Conclusion: Fusion in a 100% of cases and patients' overall satisfaction have led to the conclusion that this treatment method is appropriate to attain ankle fusion, with results similar to those found in the medical literature.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Ankle; Arthrodesis; Bone screws; Orthopedic procedures.

Introduction

Severe instabilities, deformities, and arthrosis resulting from trauma or chronic diseases compromise patients' ankle and locomotion[1,2].

The quality of life of these patients requires improving their gait, which in turn requires simultaneously neutralizing pain and aligning and stabilizing the ankle for weight-bearing. Arthrodesis is the main option of surgical treatment of these ankles[1]. Arthroplasty is also an option, but it is not indicated or available for all patients. Being first described by Albert in 1878, it was been widely used until today[3,4]. In a critical analysis of the literature, Brazilian authors stated that arthroplasty has been the best option in the country until recent years to achieve a stable, pain-free ankle[4].

Since the original description, many techniques have been described for ankle arthrodesis[1]. Different approaches and different methods of fixation portray considerable variations in fusion rates with this type of arthrodesis[1-7]. Such outcome is a challenging task, but it may be achieved with the materials available in hospitals for orthopedic care. Furthermore, it depends on patient's clinical conditions and bone quality, position and quality of ankle fixation, and appropriate postoperative follow-up[1-7].

Orthopedists and patients look forward to improving gait with a pain free ankle and a stable axis. Arthrodesis fusion contemplates this desire.

Arthrodesis approach is chosen by the surgeon, but fixation requires availability of material. The 4.5 mm screws used in this study are always available in hospitals that provide orthopedic trauma care.

Since good bone contact, opening, functional positioning, and joint stabilization are essential to achieve fusion, they determine the approach of choice[5,8-11]. We believe that Meary technique allows for positioning the ankle in a neutral position and with good bone contact; furthermore, well-positioned screws are sufficient to attain fusion[4]. This retrospective study had the following objectives: 1- To identify the causes that motivated surgeries, as well as rates, position, and time

Study performed at the Hospital Universitário Evangélico Mackenzie, Curitiba, Paraná, Brazil.

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of arthrodesis fusion; 2- To ascertain whether this technique provides fusion rates similar to those found in the published literature; 3- To quantify improvements in American Orthopaedic Foot and Ankle Society (AOFAS) and visual analog scale (VAS) scores and patients' satisfaction using a Likert scale.

Methods

This research was approved by the Research Ethics Committee, being registered on Plataforma Brasil under number: CAAE: 50802021.8.0000.0103.

This is a retrospective non-randomized study involving 18 patients diagnosed com disabling arthrosis of the ankle. Nine men and 9 women aged from 39 to 71 years underwent ankle arthrodesis by 2 senior surgeons of the Foot and Ankle Group from 2006 to 2018. Surgeries were motivated by post-traumatic arthrosis in 16 patients and of rheumatoid arthritis (RA) and Charcot Marie Tooth (CMT) disease in 2 women. The greatest deformity was severe equinus deformity in the patient with CMT sequelae. Trauma sequelae resulted from malleolar fractures (none of them involving the pilon) that progressed to arthrosis due to incomplete reduction and/or instability in the initial treatment, which was conservative in 5 patients and surgical in 11.

Data from medical records identified the causes of pain and/or deformity, time of preoperative progression, day of surgery, and time for clinical and radiographic fusions. At the end of 2019, the patients were called for an outpatient evaluation and signed an informed consent form to participate in the study approved by hospital Research Ethics Committee.

This final evaluation consisted of clinical history and physical and radiographic tests. We assessed gait and checked for varus or valgus rotational deformities of the ankle, plantigrade posture, and changes in the dorsoplantar position. Weight-bearing radiographs of front, profile, and Saltzman views showed radiographic fusion, well-centralized talus, and position of the fused ankle.

Results were assessed according to AOFAS scales for ankle and hindfoot, pain VAS, and satisfaction questionnaire with agreement criteria applying a Likert scale.

Surgical procedures were performed using the technique described by Meary *apud* Tomeno and Piat[10] and fixed with 4.5-mm non-cannulated screws, in order to maintain the ankle in a functional position. Figure 1 portrays skin incision up to the sinus tarsi and exposure of superficial nerves.

Figure 2 depicts opening of retinaculum, isolation of extensor tendons and the vasculo-nervous beam, and cross-shaped opening of the capsule, with longitudinal and horizontal incisions at the center of the joint line in order to expose the joint.

Regularization of joint contour and opening of surfaces were performed to achieve bone contact, joint position, and centralization of the talus. Aligned in the coronal, sagittal, and horizontal planes, the ankle was provisionally stabilized with Kirschner wires. Definite fixation started with the screw from distal to proximal, under radioscopic control (Figure 3).

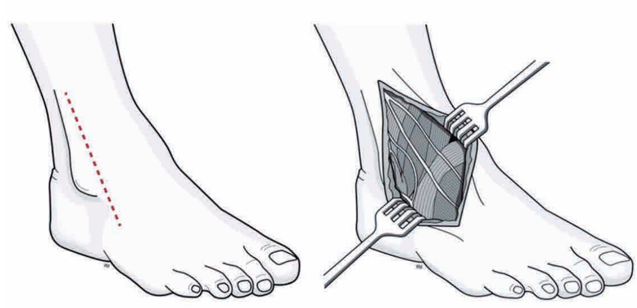

Figure 1. (A) Schematic drawing of the Meary technique and (B) Identification of superficial nerves.

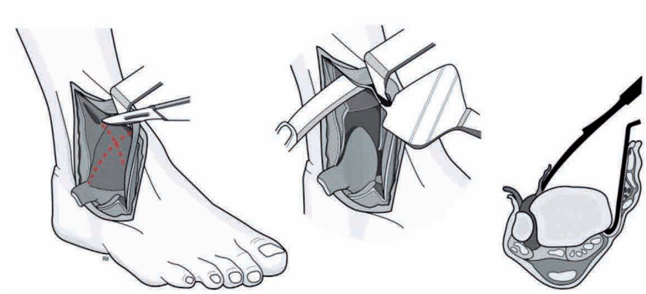

Figure 2. Incision of the capsule.

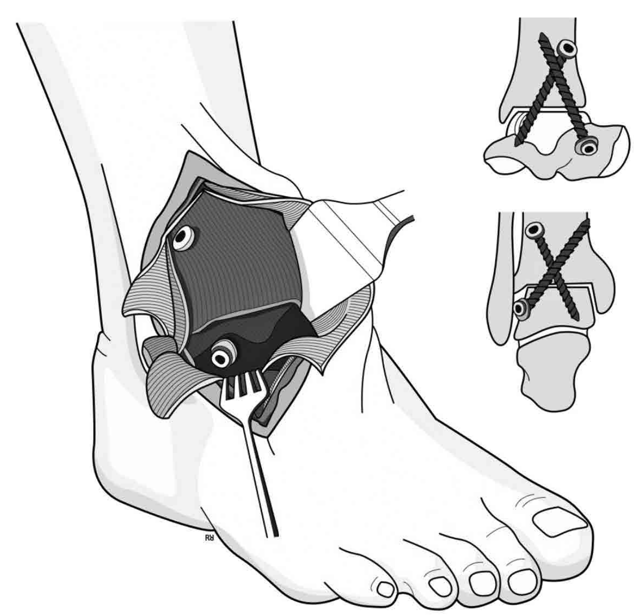

Figure 3. Position of screws for ankle fixation.

Subsequently, the wound was closed by planes, a Hemovac drain and bandage were placed, and the knee was immobilized with a plaster cast splint at 90 degrees.

Patients were discharged on the second postoperative day after dressing, removal of the drain, and cast boot with no bear weighting. Outpatient follow-up assessments were conducted every 3 weeks for 60 days, and then patients were allowed for weight-bearing with removable orthosis and crutches. Weight-bearing radiographs were performed every 6 weeks. Patients with pain-free full weight-bearing and were instructed to wear conventional shoes, with radiological controls up to fusion.

Results

Data from the study sample are reported in table 1.

Results were recorded on spreadsheets and underwent statistical calculations.

Preoperative progression was 2.6 years (1.5 to 4 years), and mean follow-up duration was 3.7 years (1.4 to 14 years).

Participants' age and sex are shown in table 2.

There was no significant difference between sexes with regard to age (p=0.25).

The percentages of reasons for arthrodesis are reported in table 3.

The most frequent reason was post-traumatic arthrosis.

The methods of arthrodesis fixation were the following: 2 patients with 2 screws, 15 patients with 3 screws, and 1 patient with 5 screws. One patient was treated only proximal-to-distal fixation with 3 screws.

Average time of clinical fusion (pain-free full weight-bearing) was 6.1 months after surgery (6 patients at 4 postoperative months, 5 patients at 6 months, and 7 patients at 8 months). Average time of radiographic fusion was 7.7 months de PO (2 patients at 4 postoperative months, 5 patients at 6 months, 6 at 8 months, 3 at 10 months, and 1 patient at 12 months). With regard to the position of the fused ankles, 5 fused in valgus angulation and 13 ankles in neutral position (72.22%), 6 fused in an equinus position and 12 of them in a neutral position (66.66%), 5 ankles fused in external rotation, 2 in internal rotation, and 11 in a neutral position (61.11%). A well-centralized talus was observed in all ankles.

Four patients experienced changes in dorsal sensitivity of the foot, which improved up to 12 months after surgery. Superficial infection and partial skin necrosis occurred in 2 patients, requiring only outpatient care.

AOFAS scores are shown in table 4.

There was a significant improvement in AOFAS postoperative scores (p=0.0002), with no significant differences between the sexes (p=0.80) and between ages (p=0.83). Mean VAS scores decreased from 7.7 points (7 to 10) preoperatively to 2.6 points (0 to 5) postoperatively, showing a significant improvement (p=0.0002). The Likert-scale satisfaction questionnaire showed that 2 patients were very satisfied, 14 were satisfied, 2 were partially satisfied, and none was dissatisfied. There were no complaints with regard to gait, pain, and/or ankle position. Figures 4 and 5 show pre- and postoperative radiographs of the patient with RA. Figures 6 and 7 show postoperative radiographs and pictures of the ankle of a patient with post-traumatic arthrosis.

Table 1. List of patients subjected to ankle arthrodesis

	Age	Sex	Reason	Side	Preoperative AOFAS score	Day of surgery	Postoperative AOFAS score
1	39	F	Trauma	L	35	08/17/17	66
2	41	F	Trauma	R	40	01/18/18	75
3	56	F	RA	L	50	06/25/18	80
4	59	F	Trauma	L	44	04/13/13	74
5	62	F	Trauma	R	42	10/26/17	76
6	43	F	Trauma	L	47	11/26/12	72
7	50	M	Trauma	R	48	11/03/14	70
8	45	M	Trauma	L	46	04/04/13	68
9	54	M	Trauma	L	45	07/07/17	79
10	39	M	Trauma	L	40	04/18/17	71
11	60	M	Trauma	R	44	11/12/18	74
12	47	M	Trauma	L	48	10/24/18	76
13	49	F	CMT	R	51	08/17/19	77
14	43	M	Trauma	R	49	07/13/14	76
15	25	M	Trauma	R	40	11/12/19	78
16	71	F	Trauma	R	55	05/05/06	88
17	45	M	Trauma	R	48	07/06/20	85
18	56	F	Trauma	L	52	05/03/10	85

AOFAS: American Orthopaedic Foot and Ankle Society; F: female; L: left; R: right; RA: rheumatoid arthritis; M: male; CMT: Charcot Marie Tooth disease.

Table 2. Patients' age and sex

	Age				
Sex	**Mean**	**n**	**SD**	**Minimum**	**Maximum**
Female	52.89	9	10.69	39	71
Male	45.33	9	9.84	25	60
Total	49.11	18	10.70	25	71

SD: standard deviation.

Table 3. Reasons for ankle arthrodesis

Reason	n	%
Trauma	16	88.89
RA	1	5.56
CMT	1	5.56
Total	18	100

RA: Rheumatoid arthritis; CMT: Charcot Marie Tooth disease.

Table 4. Pre- and postoperative AOFAS score

AOFAS score	n	Mean	Minimum	Maximum	SD
Preoperative	18	45.78	35	55	5.05
Postoperative	18	76.11	66	88	5.87

AOFAS: American Orthopaedic Foot and Ankle Society; SD: standard deviation

Figure 4. Preoperative image. Patient 3, who has RA.

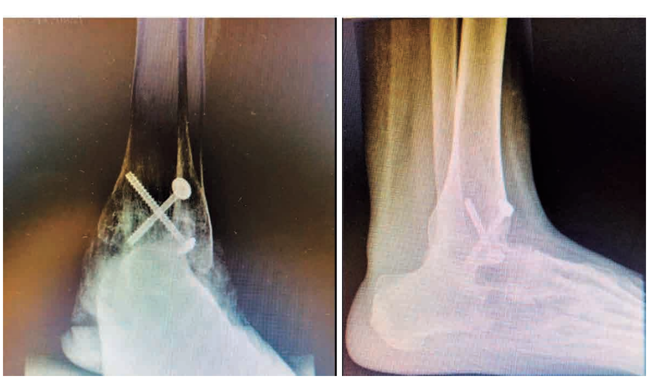

Figure 5. Postoperative image. Patient 3. Fixation with distal--to-proximal screw.

Figure 6. Postoperative 15-year follow-up. Patient 16. Fixation without distal-to-proximal screw.

Figure 7. Patient 16. Post-traumatic arthrosis. Current pictures.

Discussion

Arthrodesis in functional position allows for a stable and pain-free ankle, with relief of pain and improvement of gait. It is indicated in cases of painful arthrosis and severe instability and/or deformities resulting from trauma or diseases that cause gait limitation, such as rheumatoid arthritis, Charcot arthropathy, and Charcot Marie Tooth disease[6].

In the present series, the most frequent reason for arthrodesis was post-traumatic arthrosis (88.88%), a percentage similar to that reported by other authors[2-4,12-15] but higher than that described by Saltzmann et al.[16]. Rheumatoid arthritis and Charcot- Marie-Tooth disease were less frequently described in other studies[2,5-7]. There was no predominance of sex in the present sample, and mean age was lower for men (45.33 years) than for women (52.88 years).

Arthrodesis is not an easy procedure, and multiples factors are determining for fusion: routes of access, joint shape, complete opening of joint surfaces, good contact between them, and final position of the fixed joint. These factors act jointly to obtain fusion[1-8,11-19]. We believe that the Meary technique, with appropriate exposure and visibility of the joint, potentiates the interaction between these factors to achieve successful fusion.

There are multiple routes of access for this arthrodesis, with similar rates of fusion and complications[3,14]. Posterior approach is used when Achilles tendon elongation is also required, but it does not allow for an easy control of joint position. Medial approach provides good exposure of the joint even without resection of the medial malleolus[1]. The most frequently found in the published literature are anterior, lateral, and arthroscopic approaches[1,5,10,12,13,17-20].

Lateral access allows for lateral fixation of the plate and use of fibula as a graft, if necessary[1,12,19]. Initially indicated for ankles with low levels of deformity[1,2,17], arthroscopic approaches are currently used for ankles with great deformities[14,15,17,18,20]. Anterior approach, well tolerated by the patient and with few complications, is the most indicated to realign the ankle[1,2,6].

There is consensus on the importance of ankle position in arthrodesis. The neutral angle (zero degree) is portrayed in the medical literature as the optimal position. This position in the coronal, sagittal, and rotational planes minimizes hyperpressure on subtalar and talonavicular joints and provides a pain-free plantigrade foot[1,6,8,10,12]. When this position is not obtained, or angles close it, functional limitations are expected. Internal rotation is little tolerated by patients, plantar flexion affects knee function, and dorsal flexion overloads the calcaneus. The varus position makes the subtalar joint unstable, and the valgus position exerts stress to the medial surface of the knee. When mispositioned, this type of arthrodesis also compromises knee and foot functions and causes gait disorders[1,21,22].

The Meary anterolateral approach provides a visual control of the contact between bone surfaces and of the position of the ankle and of the screw from an anterolateral position in the talus to a posteromedial position in the tibia[10]. This approach optimizes the interaction between the determining factors for a successful arthrodesis that attains positions close to the optimal one. Gordon et al.[2] also described this type of fixation, but with an anterior approach.

There are several options for fixing ankle arthrodesis, all of them with varied rates of fusion and complications, according to the published literature[1,2,4-9,11,12,14,15,17,18].

In this series, arthrodeses were fixed with 4.5-mm screws, using 2 screws in 2 patients, 3 screws in 15 patients, and 5 screws in 1 patient. In 17 patients, 1 distal screw was placed from anterolateral in the talus to posteromedial in the tibia and the remaining screws were placed from proximal to distal. The patient who did not receive this distal-to-proximal screw received 3 proximal-to-distal screws. The method of screw fixation was chosen according to the availability in the surgical unit and their fixation capacity, as observed in daily procedures in the study hospital, which is specialized in the treatment of orthopedic trauma.

There is great variation in fusion rates for this type of arthrodesis, depending on the study population, approaches, and fixation methods[1-6,8,12]. Many studies showed fusion rates above 90%[1,14,19,21].

Dohm et al.[3] reported a variation from 29% to 100% within the same study, with different fixation methods performed by different surgeons. Frey et al.[7] reported a rate of nonunion of 43% in patients with trauma sequelae and 33% in patients with other diseases, with no association with fixation methods. Nonunion rates of from 8.6% to 20% were reported with screw fixations[3,17]. Even using an arthroscopic approach, ankle arthrodesis fixed with screws may present a nonunion rate of up to 13%, according to Collman et al.[18].

However, a fusion rate of 100% is not uncommon with different approaches and fixation methods, as reported by renowned authors[2,6,12]. The present series showed a fusion rate of 100% with the Meary technique and fixation with 4.5-mm screws, a rate higher than that of other publications[1,3,5,7,13-15,17-19]. Other authors also describe this rate in their series[2,3, 5,12]. It is not rare even with different approaches and fixation methods, as reported by Coughin et al.[12] with a sample similar to the present one. Clinical fusion before radiographic fusion was previously described by Chanrley and also occurred in the present sample[5]. Our patients achieved clinical fusion at an average time of 16.1 postoperative weeks, and radiographic fusion at a mean time of 30 postoperative weeks, a time greater than that described by Gordon et al.[2] with an open technique and screw fixation (13.3 weeks), by Myerson and Quill[23] (9 weeks with an arthroscopic approach and 15 with an open approach), and by Coughin et al.[12] with open approach and fixation with a locked plate (24 weeks) for radiographic fusion.

Variations in the position of arthrodesis fusion were up to 10 degrees in the coronal and horizontal planes and of up to 15 degrees of equinus position in the sagittal plane.

Variations consisted of plantar flexion in 6 ankles, valgus angulation in 5, and external rotation in 5. None of the ankles fused in varus angulation. The published literature reports complications with this position[6,18,13]. Plantar flexion, valgus angulation, and external rotation were within the tolerated thresholds described by several authors[1,12,14,15,17] and did not lead to patients' complaints of gait problems.

The most dreaded complication of ankle arthrodesis is nonunion[1,13], which was absent in the present series. Chalayon et al.[13] reported that the presence of previous subtalar arthrodesis and/or varus knee alignment represent the highest risks of nonunion. The patient with CMT disease presented the 2 previous risk factors simultaneously and attained radiographic fusion in 12 months.

Four patients experienced partial changes in dorsal sensitivity of the foot, with a gradual improvement up to 12 months after surgery. This complication is also reported by Tomeno and Piat[10], with the same favorable outcome, and by Ogilvie-Harris et al.[24] with arthroscopic approaches, but no report of resolution. We believe that time and stress resulting from displacing soft tissues were the causes of this complication. Superficial infection and partial skin necrosis occurred in 2 patients, requiring only outpatient care for healing. The rates of these complications were similar to those founds in other reports[1,4,6,7,12,14,19].

The mean AOFAS score for the hindfoot was 46 points (33 to 58) preoperatively and 74.6 points (59 to 90 points) postoperatively, with an increase of 32.6 points. The mean VAS score was 7.7 points (7-10) preoperatively and 2.9 points (0 to 10) postoperatively, with a decrease of 4.8 points, similar to that described in other studies[12,19].

The Likert-scale questionnaire confirmed patients' satisfactions, although many complaint about postoperative quality of life, according to the published literature[1,25]. The patients in the present study did not complain of pain or functional limitation, probably because loss of mobility is compensated by pain relief and full weight-bearing on the ankle, as reported in the medical literature[13,26].

Conclusion

Fusion in 100% of cases and patients' overall satisfaction have led to the conclusion that the Meary technique and screw fixation are appropriate to attain ankle fusion, with results similar to those found in the medical literature. The Meary technique provides excellent exposure of joint and visual control of fixation, in addition to optimizing arthrodesis fusion. We believe that this is an efficient, low-cost, reproducible method that can be performed in hospitals providing orthopedic trauma care.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JVP *(https://orcid.org/0000-0003-1445-946) Conceived and planned the activities that led to the study, performed the surgeries, evaluated and interpreted the results of the study, wrote the article, participated in the review process and approved the final version; CABP *(https://orcid.org/0000-0003-0401-1164) Conceived and planned the activities that led to the study, performed the surgeries, evaluated and interpreted the results of the study, wrote the article, participated in the review process and approved the final version; FSB *(https://orcid.org/0000-0001-6073-8523) Conceived and planned the activities that led to the study, participated in the review process and approved the final version; KS *(https://orcid.org/0000-0003-2371-7680) Assisted in surgeries, wrote the article, evaluated and interpreted the results of the study, approved the final version; CH *(https://orcid.org/0000-0002-6697-8197) Assisted in surgeries, evaluated and interpreted the results of the study, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Nihal A, Gellman RE, Embil JM, Trepman E. Ankle arthrodesis. Foot Ankle Surg. 2008;14(1):1-10.
2. Gordon D, Zicker R, Cullen N, Singh D. Open ankle arthrodeses via an anterior approach. Foot Ankle Int. 2013;34(3):386-91.
3. Dohm M, Purdy BA, Benjamin J. Primary union of ankle arthrodesis: review of a single institution/multiple surgeon experience. Foot Ankle Int. 1994;15(6):293-6.
4. Mercadante MT, Santin RAL, Ferreira RC. Overview of the surgical techniques for ankle arthrodesis. Rev Bras Ortop. 2000;35(6):187-93.
5. Charnley J. Compression arthrodesis of the ankle and shoulder. J Bone Joint Surg Br. 1951;33B(2):180-91.
6. Hendrickx RP, Stufkens SA, de Bruijn EE, Sierevelt IN, van Dijk CN, Kerkhoffs GM. Medium- to long-term outcome of ankle arthrodesis. Foot Ankle Int. 2011;32(10):940-7.
7. Frey C, Halikus NM, Vu-Rose T, Ebramzadeh E. A review of ankle arthrodesis: predisposing factors to nonunion. Foot Ankle Int. 1994;15(11):581-4.
8. Morgan CD, Henke JA, Bailey RW, Kaufer H. Long-term results of tibiotalar arthrodesis. J Bone Joint Surg Am. 1985;67(4):546-50.
9. Kennedy JG, Hodgkins CW, Brodsky A, Bohne WH. Outcomes after standardized screw fixation technique of ankle arthrodesis. Clin Orthop Relat Res. 2006;447:112-8.
10. Tomeno B, Piat C. Arthrodèse tibio-astragalienne. Techniques chirurgicales-Orthopédie-traumatologie. Encycl Méd Chir (Elsevier SAS, Paris); 1990.
11. Glick JM, Morgan CD, Myerson MS, Sampson TG, Mann JA. Ankle arthrodesis using an arthroscopic method: long-term follow-up of 34 cases. Arthroscopy. 1996;12(4):428-34.
12. Coughlin MJ, Nery C, Baumfeld D, Jastifer J. Tibiotarsal compression Arthrodesis using a lateral locking plate. Rev Bras Ortop. 2015; 47(5):611-5.
13. Chalayon O, Wang B, Blankenhorn B, Jackson JB 3rd, Beals T, Nickisch F, et al. Factors Affecting the Outcomes of Uncomplicated Primary Open Ankle Arthrodesis. Foot Ankle Int. 2015;36(10):1170-9.
14. Townshend D, Di Silvestro M, Krause F, Penner M, Younger A, Glazebrook M, et al. Arthroscopic versus open ankle arthrodesis: a multicenter comparativecase series. J Bone Joint Surg Am. 2013;95(2):98-102.
15. Goetzmann T, Molé D, Jullion S, Roche O, Sirveaux F, Jacquot A. Influence of fixation with two vs. three screws on union of arthroscopic tibio-talar arthrodesis: Comparative radiographic study of 111 cases. Orthop Traumatol Surg Res. 2016;102(5):651-6.
16. Saltzman CL, Salamon ML, Blanchard GM, Huff T, Hayes A, Buckwalter JA, et al. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. Iowa Orthop J. 2005;25:44-6.
17. Abicht BP, Roukis TS. Incidence of nonunion after isolated arthroscopic ankle arthrodesis. Arthroscopy. 2013;29(5):949-54.
18. Collman DR, Kaas MH, Schuberth JM. Arthroscopic ankle arthrodesis: factors influencing union in 39 consecutive patients. Foot Ankle Int. 2006;27(12):1079-85.

19. Kim JG, Ha DJ, Gwak HC, Kim CW, Kim JH, Lee SJ, et al. Ankle Arthrodesis: A Comparison of Anterior Approach and Transfibular Approach. Clin Orthop Surg. 2018;10(3):368-73.
20. Gougoulias NE, Agathangelidis FG, Parsons SW. Arthroscopic ankle arthrodesis. Foot Ankle Int. 2007;28(6):695-706.
21. Mann RA, Rongstad KM. Arthrodesis of the ankle: a critical analysis. Foot Ankle Int. 1998;19(1):3-9.
22. Buck P, Morrey BF, Chao EY. The optimum position of arthrodesis of the ankle. A gait study of the knee and ankle. J Bone Joint Surg Am. 1987;69(7):1052-62.
23. Myerson MS, Quill G. Ankle arthrodesis. A comparison of an arthroscopic and an open method of treatment. Clin Orthop Relat Res. 1991;(268):84-95.
24. Ogilvie-Harris DJ, Lieberman I, Fitsialos D. Arthroscopically assisted arthrodesis for osteoarthrotic ankles. J Bone Joint Surg Am. 1993; 75(8):1167-74.
25. Coester LM, Saltzman CL, Leupold J, Pontarelli W. Long-term results following ankle arthrodesis for post-traumatic arthritis. J Bone Joint Surg Am. 2001;83(2):219-28.
26. Waly FJ, Yeo EMN, Wing KJ, Penner MJ, Veljkovic A, Younger ASE. Relationship of Preoperative Patient-Reported Outcome Measures (PROMs) to Postoperative Success in End-Stage Ankle Arthritis. Foot Ankle Int. 2020;41(3):253-8.

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Original Article

One versus two adjacent interdigital neuroma excision: a patient outcome study

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Abstract

Objective: We aimed to evaluate patient satisfaction after surgery for both single and two adjacent neuromas.

Methods: We reviewed the data of patients treated operatively for interdigital neuromas between 2003 and 2016. We interviewed them and administered the Self-Reported Foot and Ankle Score questionnaire. Patient scores were then analyzed categorically, and variation between groups was assessed.

Results: Sixty-two patients were available for review. Thirty-one patients had a single interdigital neuroma excised and 31 had two adjacent interdigital neuromas excised. Twenty-eight of the 31 (90%) patients with a single neuroma had good or excellent results while 23 (74.2%) of those with adjacent neuromas had similar outcomes. One patient with a single neuroma had a poor result while four patients with adjacent neuromas had poor results. The mean score was 41 (excellent) for patients with a single interdigital neuroma and 37 (good) for those with adjacent neuromas (p=0.473). The majority of patients in both groups would undergo surgery again.

Conclusion: We found no statistically significant difference in outcomes of patients who undergo surgery for either single or two adjacent interdigital neuromas. General patient satisfaction is good and/or excellent post excision.

Level of Evidence II; Prognostic Studies; Retrospective Study.

Keywords: Foot; Morton neuroma; Neuroma; Patient satisfaction.

Introduction

The clinical symptoms of interdigital neuroma, also known by the eponym Morton's neuroma, were first described by Civinni[(1)] in 1835, Durlacher[(2)] in 1845, Coughlin and Pinsonneault in 2001[(3)]. In 1876, Morton[(4)] reported on a case series of patients with similar symptoms. However, he attributed the symptoms to trauma/injury to the fourth metatarsophalangeal joint.

Interdigital neuroma is now known to be a benign condition of the interdigital plantar nerve. Clinically, patients present with pain in the forefoot, typically radiating to the toes and aggravated by wearing tight shoes[(5)]. It commonly affects the third web space, followed by the second web space, and rarely occurs in the first and fourth web spaces. The common digital nerve in the third web space, formed by branches of the lateral and medial plantar nerve, is thought to be relatively thicker and more tethered in the web space, making it more susceptible to microtrauma. In addition, high-heeled shoes with a narrow toe box can cause compression of the metatarsal heads and push the common digital nerve up against the unyielding transverse intermetatarsal ligament[(6-8)].

An interdigital neuroma is a tumor-like mass of perineural, epineural, and endoneural fibrosis with loss of myelinated nerve fibers[(9,10)]. The diagnosis of interdigital neuroma is mainly a clinical one[(5,11)]. Pastides et al.[(5)] reported a 98% sensitivity based on history and clinical examination alone. They recommended the use of magnetic resonance imaging (MRI) or ultrasound (US) to identify multiple neuromas or localize the web space when it is clinically unclear. Sobiesk et al.[(12)] assessed the effectiveness of US to accurately identify interdigital neuromas and reported that it can predict the presence, size, and location of neuromas with a 100% sensitivity and an 83.3% specificity. US is therefore a cost-effective, noninvasive modality that can be used for equivocal cases

Study performed at the Linksfield Private Hospital, Johannesburg, Gauteng, South Africa.

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of neuroma to confirm the diagnosis. The management of interdigital neuromas includes both conservative and operative treatment. Conservative therapies include accommodative footwear, anti-inflammatory medications, innersoles, and physiotherapy[9,13-15]. In addition, local injection of corticosteroids, sclerosing agents, and local anesthetic has been found to provide short-lived relief of symptoms. Surgery is usually reserved for intractable symptoms despite optimal conservative therapy. Outcome studies of operative treatment of neuromas generally address patients with a single neuroma. Most of these studies have reported satisfactory outcomes following operative management of single interdigital neuromas[3,6,7,11,16,17]. To our knowledge, only one study looked primarily at the clinical results of patients who had more than one neuroma excised[18].

The existence of multiple interdigital neuromas in the same foot has been reported as rare by some authors; however, Valero et al.[17] recently showed a 65.2% prevalence of multiple neuromas in the same foot. Benedetti et al.[18] evaluated 19 feet with simultaneous adjacent neuromas, which were managed surgically, and reported outcomes that were comparable to those reported by other authors for single neuromas[17]. To our knowledge, no other studies in the published English medical literature have addressed this since Benedetti et al. No studies have directly compared outcomes in patients with single versus adjacent neuromas.

Our study reviewed a series of patients who underwent surgery by a single surgeon, and we investigated their self-reported satisfaction after surgery for both single and adjacent neuromas. The hypothesis of this study was that simultaneous excision of adjacent neuromas would yield poorer outcomes compared to single neuroma excision.

Methods

Ethics approval was obtained from the University of Witwatersrand ethics and scientific committee (M171067).

The primary aim of this study was to assess the outcomes of surgery undertaken for interdigital neuroma. Secondarily, we compared the outcomes in patients with a single neuroma versus those with adjacent neuromas in the same foot. We reviewed the data of patients managed surgically for interdigital neuromas by a single surgeon between January 2003 and January 2016. We included all adult patients who had undergone surgery for either single or adjacent interdigital neuromas. Patients with concomitant foot disorders or those who had other surgery to the foot in question were excluded. All patients had undergone preoperative US investigation, which confirmed the presence of either single or double neuromas in the foot. The US was performed by a sonographer with 21 years of musculoskeletal experience using a 12 MHz linear-array transducer. A hypoechoic mass, which could be identified in the longitudinal plane and on dynamic studies during side-to-side compression of the forefoot, was considered diagnostic of a Morton's neuroma (Figure 1).

The surgery was performed by the senior author. All operations were performed under general anesthesia with a tourniquet. No nerve blocks were used. A dorsal incision was made either over the second or third web space for excision of single neuromas, or the third metatarsal for excision of two adjacent neuromas to allow access to both the second and third web spaces. The deep transverse ligament was then transected. Each neuroma was then excised (Figure 2). All specimens were sent for histology, and analyses confirmed them to be interdigital neuromas. The wounds were closed using subcuticular sutures. Postoperatively, patients were placed in a padded dressing and kept heel walking as tolerated for two weeks.

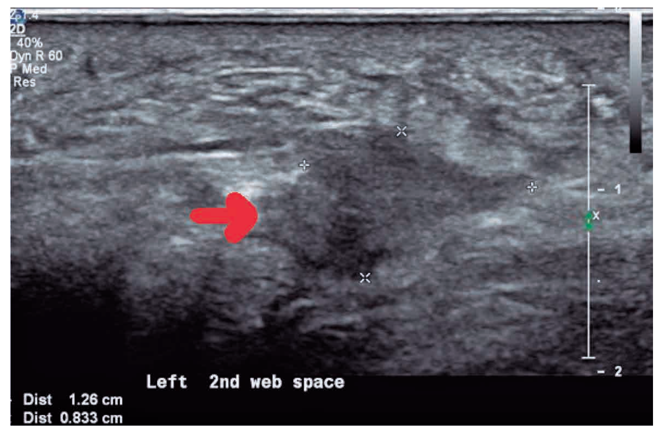

Figure 1. Red arrow shows a hypoechoic mass seen on ultrasound suggestive of interdigital neuroma.

Figure 2. Image shows interdigital neuroma post excision from the third web space.

All patients were contacted independently by one of the authors, who was not involved with the surgeries. Patients were asked to complete the validated Self-Reported Foot and Ankle Score (SEFAS). The SEFAS questionnaire has good psychometric properties for evaluation of patients with different disorders and operative procedures around the forefoot, hindfoot, and ankle joint[19,20]. If a patient had bilateral operations, the worst foot was scored. A total SEFAS score of 0 represents the most severe disability while a score of 48 represents normal function. A score less than 20 was graded as poor, 20-29 as average, 30-39 as good, and 40-48 as excellent. The results were grouped categorically based on whether the scores were poor, average, good, or excellent. An analysis of variance (ANOVA) test was then carried out to assess significance in the variation seen between the two groups of patients. Statistical significance was defined at 5% ($p \leq 0.05$).

Results

The total number of neuromas was 114 in 62 patients. Thirty-one patients had adjacent second and third web-space neuromas in the same foot, with 12 patients having bilateral foot involvement. Of the 31 patients with a single neuroma, three had bilateral foot involvement (Table 1). Twenty-eight patients had unilateral involvement, 20 of whom had third web-space neuromas and 8 had second web-space neuromas. The follow-up time for single neuromas ranged from 0.6 to 13.6 years, with a mean follow-up of 6.2 years. For adjacent web-space neuromas, follow-up ranged from 0.5 to 11.2 years, with a mean follow-up of 4.6 years.

In patients with adjacent web-space neuromas, 23 (74.2%) had excellent or good outcome scores. Of these, 18 (58%) had excellent outcome scores and 5 (16%) had good outcome scores. Four (12.9%) had average outcomes, and four (12.9%) had poor outcomes. Of those with poor outcomes, one patient reported moderate pain while the other three reported severe pain affecting them most days and limiting their activities of daily living. Of the 31 patients, 24 (77.4%) said they would have surgery again. One patient, despite a poor functional score, said he would still have surgery again (Table 2).

For the patients with single neuromas, 28 (90%) had excellent or good outcome scores. Twenty-one (67.7%) of these patients had excellent outcome scores while seven (22.6%) had good scores. Two (6.4%) patients had average scores while only one (3.2%) patient had a poor outcome score. The patient with the poor outcome complained of persistent pain and swelling in the foot, which felt similar to the neuroma pain he had prior to surgery (Table 2). Twenty-seven (87%) patients said they would have the procedure done again. Surprisingly, three of the four patients who said they would not repeat the procedure had either good or excellent scores. The reason for declining a repeat operation included pain felt in the immediate postoperative period and bothersome numbness of the foot postoperatively.

Table 1. Patient demographics stratified according to whether they had single or adjacent neuromas (n=62). The table further shows the proportion of patients who would repeat the procedure in the single vs. double adjacent neuroma groups

	Single (n=31)	Adjacent (n=31)
Female (n=50)	23	27
Male (n=12)	8	4
Mean age	58.4 years (34-74)	55.1 years (41-71)
Unilateral	28	19
Left	13	4
Right	15	15
Bilateral	3	12
Number of patients who would have surgery again		
Yes	27 (87%)	24 (77%)
No	4 (13%)	7 (23%)

Table 2. Results stratified according to the Self-Reported Foot and Ankle Score (SEFAS): scores less than 20 were regarded as poor, 20-29 as average, 30-39 as good, and 40-48 as excellent (n=62)

Groups	Single neuroma (n=31)	Adjacent neuroma (n=31)	Differences between (p=0.05)
Excellent	21 (67.7%)	18 (58.1%)	0.473
Good	7 (22.6%)	5 (16.1%)	0.866
Average	2 (6.5%)	4 (12.9%)	0.448
Poor	1 (3.2%)	4 (12.9%)	0.814

Among the patients with bilateral operations but single neuromas on either side, two (66.7%) of the three had excellent outcomes while one (33.3%) reported good function. However, among the patients with bilateral surgery and adjacent neuromas, only five (56%) of the nine had excellent or good results while two (22%) had average outcomes and two (22%) had poor outcomes.

The mean outcome score was 41 (excellent) for the patients with single neuromas and 37 (good) for those with adjacent neuromas. However, this difference was not statistically significant ($p=0.13$). While there was no statistical difference between groups for patients who had poor outcomes in either group, there was only one patient from the single neuroma group versus four from the adjacent neuroma group ($p=0.81$). In subgroup analyses, the mean score for patients who had excellent scores was 46 in the single neuroma group and 45 in the adjacent neuroma group, with no statistically significant difference ($p=0.47$). Overall, there was no difference between involvement of the right, left, or both feet in the single neuroma group ($p=0.600$)) or the adjacent neuroma group ($p=0.153$). In addition, there was no difference in outcomes between men and women within each group (single group $p=0.829$, adjacent group $p=0.879$).

Discussion

An interdigital neuroma is a common affliction with well-documented clinical presentation, diagnostic work-up, and management. Operative management is a well-recognized treatment option, and thus a study to evaluate outcomes of this common procedure is warranted. This study showed comparably good outcomes post excision of the interdigital neuroma(s) and no difference between patients with single or adjacent neuromas. Of the patients who reported poorer outcomes, the majority complained of troublesome numbness and difficulty with uneven surfaces as the causes of their dissatisfaction. In addition, some patients reported unbearable pain in the early postoperative period. Nonetheless, most patients in either group said they would repeat the procedure. In addition, our study has shown that the existence of simultaneous adjacent neuromas is more common than previously reported.

As far as we know, this study is one of the very few outcome studies addressing adjacent interdigital neuromas. Despite the well-documented demographics and management options, long-term outcomes post excision of the interdigital neuroma have rarely been reported[3,18,21-23]. Coughlin et al.[3] reported 85% excellent or good results in their patients post excision. They also reported that adjacent neuromas or bilateralism did confer lower scores. Kasparek and Schneider[21] reported 75% good or excellent results in their review of patients post excision of interdigital neuromas. However, they reported a significantly worse outcome in patients who had multiple neuromas excised (p=0.038). Bucknall et al.[22] also reported no statistical significance between single and adjacent neuroma excision using clinical scores. Their follow-up was only 6 months, patient-reported outcomes were not compared, and patients with concomitant foot surgery were not excluded. In contrast, Reichert et al.[23] reported that patients who had single neuroma excision did significantly better than those who had adjacent neuroma excision. However, the adjacent neuroma group only had 8 patients compared to 33 patients in the single neuroma group. Our cohort had 31 patients in both the single and adjacent neuroma groups.

In a smaller series (n=19), Benedetti et al.[18] reviewed clinical results of patients with simultaneous adjacent interdigital neuromas and reported outcomes comparable to those of the single interdigital neuroma literature. They reported that 84% of their patients had acceptable results. In our case series, 74% of patients with adjacent neuromas had excellent or good outcomes post excision. The existence of adjacent neuromas has been a subject of skepticism. Valero et al.[17] recently reported on the incidence of multiple Morton neuromas in the foot. In 279 feet, they found an incidence of 65.2% for adjacent neuromas. They concluded that multiple neuromas in the same foot should not be regarded as a rare condition and in fact suggested that the presence of one neuroma should prompt the search for another. All our patients underwent US examination prior to surgery to assess adjacent neuromas, and all specimens taken at the time of surgery were sent for histology. In all cases, the histological examination confirmed the diagnosis of interdigital neuroma. Our study confirms that the existence of simultaneous adjacent neuromas is more common than previously reported. The authors recommend preoperative US examination by a musculoskeletal sonographer in suspected interdigital neuroma cases to confirm the diagnosis, identify the affected web space, and look for adjacent neuromas.

This study was a prospective analysis of retrospective data, which is a potential limitation. We used a well-documented, validated SEFAS questionnaire to assess patient satisfaction. In addition, we excluded patients with concomitant foot disorders or those who had additional procedures done at the time of surgery to remove any potential confounders. Our hypothesis was disproved, as there was no statistical difference in patient-reported outcomes between single versus adjacent neuroma excision.

Conclusion

This study was a long-term follow-up of patient outcomes following excision of either single or adjacent neuromas. Our review of 62 patients demonstrated no statistical difference in outcomes between groups. In our case series, patients with single interdigital neuromas had excellent or good outcomes post excision. Similar to the previously mentioned studies, patients with adjacent neuromas had lower outcome scores in our study. Despite the difference not being statistically significant, we suggest advising patients with adjacent neuromas of a slightly lower success rate post excision. In addition, gender, side of lesion, and bilateral foot involvement showed no difference in outcomes. Dissatisfaction was generally derived from postoperative pain or long-term numbness post excision, which made navigating uneven surfaces difficult. Overall, most patients had excellent or good results and would recommend the surgery. More studies, particularly prospective randomized controlled studies, are required to further elucidate this area of interest.

Authors' contributions: Each author contributed individually and significantly to the development of this article: KBB* (https://orcid.org/0000-0003-0283-1329) Collected data, interpreted results, wrote the paper and reviewed successive versions; NS* (https://orcid.org/0000-0002-5566-7588) Conceived and planned the activities that led to the study, reviewed successive versions, and approved the final version; PF* (https://orcid.org/0000-0003-4639-0326) Participated in the interpretation of results, review process, and made significant contributions and approval of the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Civinni F. Su di um ganglionari rigonfiamento della piñata del piede. Mem Chir Archiespedale Pistoia 1835;4:4-17.
2. Durlacher L. A treatise on corns, bunions, the disease of nails, and the general management of the feet. London: Simpkin, Marshall; 1845.
3. Coughlin MJ, Pinsonneault T. Operative treatment of interdigital neuroma. A long-term follow-up study. J Bone Joint Surg Am. 2001;83(9):1321-8.
4. Morton TG. A peculiar and painful affection of the fourth metatarso-phalengeal articulation. Am J Med Sci 1876;71:37-45.
5. Pastides P, El-Sallakh S, Charalambides C. Morton's neuroma: A clinical versus radiological diagnosis. Foot Ankle Surg. 2012; 18(1):22-4.
6. Valente M, Crucil M, Alecci V. Operative treatment of interdigital Morton's neuroma. Chir Organi Mov. 2008;92(1):39-43.
7. Wu KK. Morton's interdigital neuroma: a clinical review of its etiology, treatment, and results. J Foot Ankle Surg. 1996;35(2):112-9.
8. Zanetti M, Strehle JK, Kundert HP, Zollinger H, Hodler J. Morton neuroma: effect of MR imaging findings on diagnostic thinking and therapeutic decisions. Radiology. 1999;213(2):583-8.
9. Gurdezi S, White T, Ramesh P. Alcohol injection for Morton's neuroma: a five-year follow-up. Foot Ankle Int. 2013;34(8):1064-7.
10. Ha'Eri GB, Fornasier VL, Schatzker J. Morton's neuroma--pathogenesis and ultrastructure. Clin Orthop Relat Res. 1979;(141): 256-9.
11. Biasca N, Zanetti M, Zollinger H. Outcomes after partial neurectomy of Morton's neuroma related to preoperative case histories, clinical findings, and findings on magnetic resonance imaging scans. Foot Ankle Int. 1999;20(9):568-75.
12. Sobiesk GA, Wertheimer SJ, Schulz R, Dalfovo M. Sonographic evaluation of interdigital neuromas. J Foot Ankle Surg. 1997; 36(5):364-6.
13. Grice J, Marsland D, Smith G, Calder J. Efficacy of Foot and Ankle Corticosteroid Injections. Foot Ankle Int. 2017;38(1):8-13.
14. Makki D, Haddad BZ, Mahmood Z, Shahid MS, Pathak S, Garnham I. Efficacy of corticosteroid injection versus size of plantar interdigital neuroma. Foot Ankle Int. 2012;33(9):722-6.
15. Thomson CE, Gibson JN, Martin D. Interventions for the treatment of Morton's neuroma. Cochrane Database Syst Rev. 2004;2004(3):CD003118.
16. Dereymaeker G, Schroven I, Steenwerckx A, Stuer P. Results of excision of the interdigital nerve in the treatment of Morton's metatarsalgia. Acta Orthop Belg. 1996;62(1):22-5.
17. Valero J, Gallart J, González D, Deus J, Lahoz M. Multiple interdigital neuromas: a retrospective study of 279 feet with 462 neuromas. J Foot Ankle Surg. 2015;54(3):320-2.
18. Benedetti RS, Baxter DE, Davis PF. Clinical results of simultaneous adjacent interdigital neurectomy in the foot. Foot Ankle Int. 1996;17(5):264-8.
19. Cöster MC, Bremander A, Rosengren BE, Magnusson H, Carlsson A, Karlsson MK. Validity, reliability, and responsiveness of the Self-reported Foot and Ankle Score (SEFAS) in forefoot, hindfoot, and ankle disorders. Acta Orthop. 2014;85(2):187-94.
20. Cöster M, Karlsson MK, Nilsson JÅ, Carlsson A. Validity, reliability, and responsiveness of a self-reported foot and ankle score (SEFAS). Acta Orthop. 2012;83(2):197-203.
21. Kasparek M, Schneider W. Surgical treatment of Morton's neuroma: clinical results after open excision. Int Orthop. 2013;37(9):1857-61.
22. Bucknall V, Rutherford D, MacDonald D, Shalaby H, McKinley J, Breusch SJ. Outcomes following excision of Morton's interdigital neuroma: a prospective study. Bone Joint J. 2016;98-B(10):1376-81.
23. Reichert P, Zimmer K, Witkowski J, Wnukiewicz W, Kuliński S, Gosk J. Long-Term Results of Neurectomy Through a Dorsal Approach in the Treatment of Morton's Neuroma. Adv Clin Exp Med. 2016;25(2):295-302.

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Original Article

Hallux valgus: a three-dimensional pathology. New therapeutic focus

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Abstract

Objectives: To propose hallux valgus as a three-dimension disease and develop a surgical algorithm for each deformity pattern, incorporating the metatarsal rotation component.

Methods: We prospective evaluated a series of 89 cases from February 2020 to February 2021, of which 80 were women and 9 were men. Mean age was 39 years and mean follow-up duration was 11.3 months. We used the Hardy-Clapham classification system and separated the patients into 2 groups: those with no rotational component (types 1 to 3), and those with a rotational component (type 4 to 7).

Results: Of the cases, 59% belonged to the first group and underwent distal chevron osteotomy, according to deformity degree on the frontal plane. The remaining 41% had a rotational component and underwent distal rotational chevron osteotomy, basal crescentic osteotomy, or modified Lapidus procedure, according to the degree of deformity in the frontal plane or associated instability. Union was achieved in all patients. Furthermore, mean American Orthopaedic Foot and Ankle Society score was 94.5 points, mean visual analog scale was 0.71, and level of satisfaction was 100%.

Conclusion: By considering hallux valgus as a three-dimensional disease, we proposed a treatment protocol appropriate for each patient.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus/pathology; Hallux valgus/diagnostic imaging; Metatarsal bones; Three-dimensional imaging.

Introduction

Hallux valgus is the most frequent musculoskeletal deformity, affecting nearly 23% of adult patients and 35% of older patients[1]. The physiological angle of the metatarsophalangeal joint is from 12.0 to 15.7 degrees, whereas the reference intermetatarsal (IMTT) angle is from 7.0 to 8.5 degrees[2,3]. Tarsometatarsal laxity and hypermobility of first ray are factors that favor the development of hallux valgus[4]. The first concepts on the role of first metatarsal rotation component in the onset of hallux valgus were introduced in 1956 by Mizuno et al.[5], who developed detorsion osteotomy for its treatment. Subsequently, the relationship between flat foot and first metatarsal rotation was described as a triggering factor of hallux valgus[6].

The metatarsocuneiform joint makes small movements that cause dorsal elevation and pronation during the takeoff phase of the gait. Over time, these small movements may lead to changes in extrinsic muscles and generate tarsometatarsal hypermobility. Instability of this joint results from excessive or abnormal mobility of the first metatarsal head[7].

There is onset of progressive metatarsus primus varus, with an increase both in the first-second IMTT and in metatarsophalangeal angles, often with evident metatarsophalangeal pronation. Lateral sesamoid displacement is actually related to the effect of metatarsal head rotation, with an apparent increase in distal metatarsal articular angle[8]. Radiographically, it is manifested as morphological changes in the first metatarsal head, which is found to have a more rounded appearance[9] and leads to changes in its relation to sesamoid position[10].

Study performed at the Sanatorio de la Trinidad Ramos Mejía, Ramos Mejía, Buenos Aires, Argentina.

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Classically, the severity of hallux valgus is evaluated considering the first-second IMTT, metatarsophalangeal, and distal diaphyseal-epiphyseal angles, all of them measured using front and profile weight-bearing radiographs. None of these incidences take first metatarsal rotation into account. However, if hallux valgus is considered in a three-dimensional manner, one will find that the coronal plane should be studied in another radiological view, such as that proposed by Mortier[11] (Figure 1), or through weight-bearing computed tomography.

Pronation has been mentioned in several publications, but the difficulty in quantifying it has minimized its importance. With the aforementioned radiological incidences, it was possible to incorporate the rotational component as an additional factor in the development of the hallux valgus rather than as a factor of its severity[12]. There is a direct relationship between severity of IMTT angle and metatarsal head rotation. Plane rotation of the first metatarsal is an integral component of hallux valgus and defines the third plane of the deformity[13].

More than 100 surgical techniques have been published for the treatment of hallux valgus[14]. Despite the number of studies and the amount of evidence with regard to the first metatarsal rotation component as part of the disease, the literature does not present clear protocols that incorporate rotation into already standardized treatment algorithms on the best surgical decision for each patient, and what is the influence of the rotational component on the decision towards one technique or another. We aim to present a treatment protocol considering hallux valgus in a three-dimensional manner and proposing a different type of surgery for each deformity pattern, taking the 3 possible planes into account.

Methods

This study was approved by the institutional Research Ethics Committee and was conducted by our team of experts in hallux valgus with specific selection criteria and predefined algorithms, following identical guidelines.

The project was performed in compliance with the ethical standards that regulate human research, according to the National Law of Personal Data Protection Number 25326 (*Ley de Habeas Data*) and to the latest version of Declaration of Helsinki.

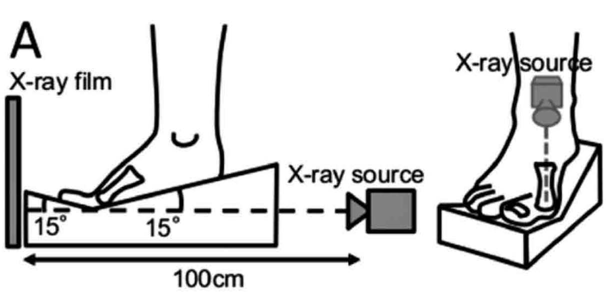

Figure 1. Weight-bearing sesamoid axial view as proposed by Mortier.

We prospectively assessed a case series with a level of evidence IV.

We operated on 89 patients with hallux valgus from February 2020 to February 2021.

Inclusion criteria:

a) Age from 18 to 70 years
b) Painful hallux valgus deformity
c) Preserved metatarsophalangeal mobility (65°-75°)
d) Preoperative American Orthopaedic Foot and Ankle Society (AOFAS) score below 49 points, which ensures that the metatarsophalangeal joint is a painful and/or the patient presents with a mechanical limitation of the forefoot.

Exclusion criteria:

a) Patients with rheumatic disease
b) Hallux metatarsophalangeal arthritis diagnosed in simple radiographs.
c) Previous hallux valgus surgery

Of the patients, 89.8% were women (80 patients) and 11.2% were man (9 patients). Mean age was 39 years (range, 18-70). Mean postoperative follow-up duration was 11.3 months (range 16.2-6 months).

All cases were studied with weight-bearing frontal and profile radiographs associated with axial sesamoid view as proposed by Mortier. In the frontal radiograph, we used the Hardy and Clapham classification system[2] (Figure 2), which is based on tibial sesamoid position in relation to a diaphyseal line of the first metatarsal.

In this incidence, the tibial sesamoid has 7 possible positions, and they were assessed together with sesamoid axial view. When comparing the semiological study of the foot with both views to determine a surgical criterion, we observed that radiological sesamoid positions 1 to 3 do not present with an evident rotational component of the first metatarsal, whereas positions 4 to 7 do present with this component. In the sesamoid axial radiograph, we traced a reference line from the center of the metatarsal head tangential to the horizontal plane (floor) and another from the center metatarsal head to the metatarsal ridge. In this way, we measured the degree of first metatarsal rotation and the degree of required correction; furthermore, we recorded whether medial sesamoid position surpassed (types 5 to 7) or did not surpass (type 1-3) the ridge.

We designed a treatment protocol that divided patients participating in this study into 2 groups (Figure 3), according to medial sesamoid position in the described radiological incidences.

1. Position 1 to 3: there is no significant rotational component. Osteotomy was performed according to angle values shown in frontal radiographs. Distal chevron osteotomy.
2. Position 4 to 7: the deformity has a rotational component. These patients underwent rotational osteotomy, which we selected according to deformity values in the frontal plane, or metatarsocuneiform arthrodesis in case of metatar-

socuneiform joint instability. The procedure of choice will be rotational distal chevron osteotomy, crescentic osteotomy if required according to angular values and in case of stable metatarsocuneiform joint, or modified Lapidus procedure[15] in case of unstable metatarsocuneiform joint. Instability was defined as sagittal mobility of 1 cm on clinical examination[16] or correction of 8° in the coronal plane on tapping radiographs[17].

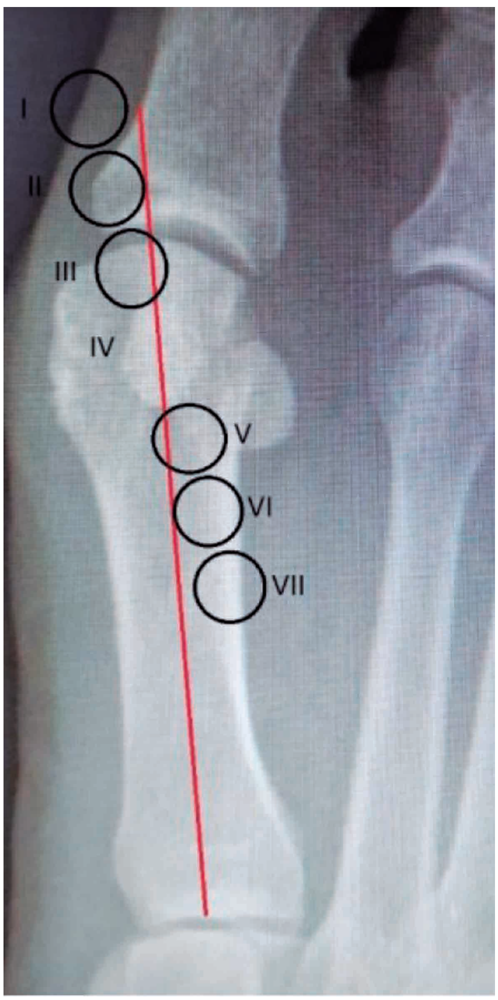

Figure 2. The Hardy and Clapham classification system.

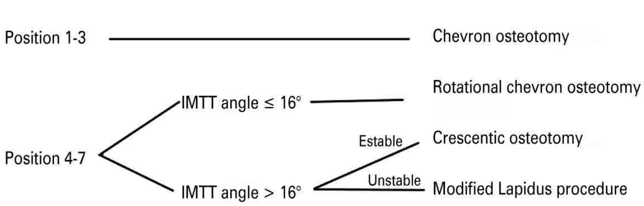

Figure 3. Integrated algorithm for the treatment of hallux valgus.

a. IMTT angle smaller than 16°: rotational Chevron osteotomy
b. IMTT angle greater than 16°.
   1. with no instability: crescentic osteotomy
   2. with instability: modified Lapidus procedure

Rotational chevron osteotomy was performed as described by Prado et al.[18], consisting of a chevron osteotomy with a 90° angle between vertical and horizontal branches. According to the first metatarsal rotation angle, a second osteotomy was performed parallel to the horizontal branch with an internal base wedge (Figure 4). Detorsion osteotomy was performed in all patients through medial approach with bunion resection, chevron osteotomy with medial wage resection and fixation with a 3.0 mm double-thread Herbert or Barouk screw. Lateral capsular and tendon releases were conducted jointly through the same medial approach. First phalangeal Akin osteotomy was performed and then fixed with screw or suture (according to surgeon's preference). Patients used postoperative sandals within the first 24 to 48 hours, according to tolerance, and then used them for up to 30 days.

The parameter for correction is the first metatarsal rotation degree obtained in the weight-bearing axial view, in which a line is traced tangential to the center of the metatarsal head at the horizontal plane (floor), and another line is traced from the center of metatarsal head to metatarsal ridge. Correction was performed with 2-mm base wedges and was systematically reviewed with intraoperative control radioscopy to corroborate final sesamoid position and metatarsal head shape on frontal radioscopy.

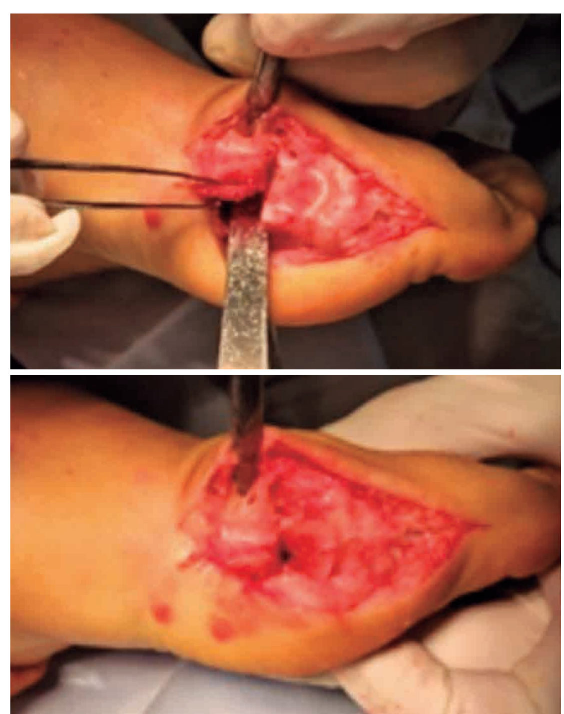

Figure 4. Rotational distal chevron osteotomy. Internal base wedge.

Crescentic osteotomy was performed using a single medial wide approach, bunion resection, transarticular release of the lateral capsule and of the conjoint tendon. The procedure was performed at 1.5 cm from the joint, involved displacing and rotating the metatarsal head, and was monitored with radiographs. We measured IMTT angle correction and sesamoid position under the metatarsal head. Osteotomy was fixed with 1 compression screw and a 2.7 neutralization plate with 2 proximal screws and 2 distal screws. Akin osteotomy was also performed. Preoperative sandals were used according to patient tolerance for 30 days.

Regardless of the surgical technique used in the first metatarsal, the 89 operated patients underwent associated first phalangeal Akin osteotomy, which was stabilized with a cannulated screw or with suture, depending on surgeon's preference.

Postoperative controls radiographs were performed at 7, 30, 45, 60 and 90 days, considering medial sesamoid position and first metatarsal rotation (weight-bearing axial view).

Results

Eighty-nine patients with hallux valgus underwent surgery, all of which had a preoperative AOFAS score below 49 points. On frontal radiographs, 53 patients (59.5%) had their sesamoid position classified as 1-3 and underwent traditional distal chevron osteotomy, whereas the remaining 36 patients (40.4%) had their sesamoid classified as 4-7, thus showing a rotational component. Of the latter group, 33 patients (37 %) had an IMTT angle smaller than 16 degrees and were subjected to detorsion chevron osteotomy (Figure 5). Of the other patients, 2 (2.2 %) had an angle greater than 16° with stable tarsometatarsal joint and underwent crescentic osteotomy. Only 1 patient (1.1%) presented with arthrosis and tarsometatarsal instability, which was resolved with a modified Lapidus procedure.

We observed 2 constant semiological characteristics in hallux valgus with a rotational component. One of them is evident hallux nail rotation compared with the other toes. The other one is medial hyperkeratosis at the level of the hallux interphalangeal joint (Figure 6).

All patients showed signs of radiological osteotomy union at 45 days in the cases subjected to chevron osteotomy and to crescentic osteotomy (Figure 7) and at 60 days in the case subjected to modified Lapidus procedure, and union was followed-up on control radiographs obtained during the postoperative period.

There were no immediate postoperative complications. Although postoperative time for this type of disease is short, no recurrences were reported so far.

Mean postoperative AOFAS score was 94.5 points (range, 77-100). Mean visual analog scale (VAS) was 0.71. When asked whether they would undergo surgery again and whether they were fully satisfied with the procedure, patients expressed a level of satisfaction of 100%.

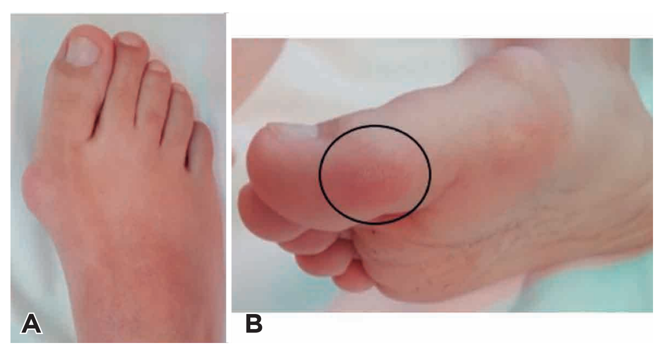

Figure 6. Clinical characteristics of the rotational component.

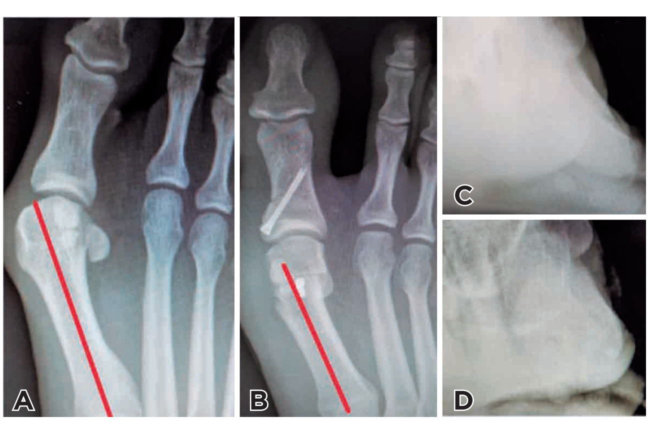

Figure 5. A) Preoperative frontal radiograph showing sesamoid in position 7. B) Postoperative radiograph after rotational chevron osteotomy to correct sesamoid position 3. C and D) Pre-and postoperative weight-bearing sesamoid axial view, respectively.

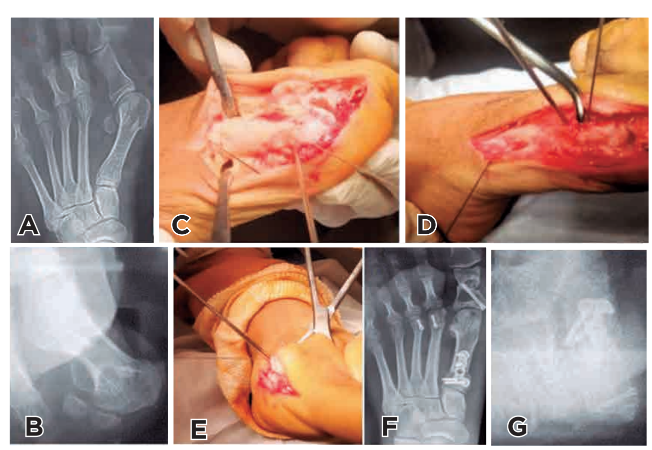

Figure 7. Crescentic osteotomy. Pre- and postoperative radiographs. Images of the surgical technique.

Discussion

In 1980, Scranton and Rutkowski[19] described radiographic axial images of sesamoids in cadavers. Years later (1996), Saltzman et al.[20] analyzed weight-bearing tangential radiographs of sesamoids, in order to assess first metatarsal rotation. In 1998, Talbot and Saltzman[21] investigated whether weight-bearing frontal and tangential radiographs of sesamoids would be sufficient to measure sesamoid subluxation. During decades, sesamoid luxation or subluxation were considered as triggering factors for the rotational component. It has been demonstrated that rotation is produced in the first metatarsal, whereas the sesamoid ligament – second metatarsal maintains the sesamoid complex in position, despite first metatarsal rotation and metatarsus primus varus[10], with the re-emergence of concepts involving first metatarsal rotation, as observed in recent publications[9,10,18,22,23]. Currently there is no doubt that first metatarsal displacement is the origin of sesamoid "subluxation". We analyzed frontal standing radiographs of the foot and sesamoid axial radiographs, both weight-bearing, paying special attention to medial sesamoid position in relation to the first metatarsal medial line (according to the Hardy and Clapham classification system). As it usually occurs when a new concept is incorporated, this concept tends to gain prominence minimize other variables that have already shown to participate in disease onset. Many recent studies[24,25] describe a trend of treating most patients with base osteotomies or metatarsocuneiform arthrodesis rather than with distal osteotomies, which have been performed for many years with excellent outcomes.

In our series, it was observed that 40.4% of cases of hallux valgus presented with first metatarsal rotation before surgery, which was objectively shown both clinically and radiologically. The importance of this percentage mainly lies in 2 concepts. The first of them is the rate of recurrence and poor outcomes[22], due to lack of correction of tibial sesamoid position and of first metatarsal pronation, which is why these 2 elements should be considered in hallux valgus correction. There are no studies in the literature evaluating the association between the Hardy and Clapham classification system and sesamoid measures. The second concept is that the remaining 59% of cases do not have a significant rotational component and thus may be treated with corrective osteotomies that do not involve the rotational component.

The literature did not show any assessment on the potential for rotational correction with horizontal and medial base subtraction wedge in distal osteotomy. We analyzed 5 cadaver bones and measured the correction according to the width of the base subtraction wedge. Each 1 mm of base led to a 2° to 3° of correction.

Relapse or recurrence is usually interpreted based on technical errors, such as insufficient capsular closure force, undercorrection with the osteotomy, or errors in the indication of the type of osteotomy, among other causes. We found that many patients with clinical and/or radiologic recurrence of hallux valgus present with first metatarsal rotation, a fact that is consistent with tibial sesamoid position 4 or greater[4]. The study published by Wagner and Wagner[9] assessed the variables that are associated with deformity recurrence and demonstrated that the most important variable is tibial sesamoid position. Another study found that recurrence rates increase when sesamoid position is 4 or greater (position 4: 50% of recurrence; position 5 or greater: 60% of recurrence)[23].

Although postoperative time of these patients is short and it is not possible to state that none of them will present with recurrence, there were no reports of recurrence of hallux valgus so far. We have investigated whether weight-bearing frontal radiographs and sesamoid axial radiographs are sufficient and appropriate to plan hallux valgus surgery by comparing these radiographs with weight-bearing computed tomography, which has been increasingly used nowadays.

Conclusion

Concepts on rotational deformity are essential to plan hallux valgus correction in a three-dimensional manner; thus, we designed an algorithm that contemplates them in the treatment of this disease. This algorithm provides a specific treatment for each degree of displacement and rotation, which may lead to successful results in all variables of this very frequent disease.

Authors' contributions: Each author contributed individually and significantly to the development of this article: DY *(https://orcid.org/0000-0002-9542-6914) Conceived and planned the activities that led to the study, performed the surgeries and bibliographic review; IM *(https://orcid.org/0000-0002-9452-0175) Performed the surgeries, interpreted the results of the studies and data collection; FA *(https://orcid.org/0000-0001-6577-8911) Participated in the review process, bibliographic review and formatting of the article; SS *(https://orcid.org/0000-0003-0432-8102) Clinical examination, interpreted the results of the study and approved the final version; JD *(https://orcid.org/0000-0002-5733-6766) Performed the surgeries, clinical examination and statistical analysis. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Skweres J, Chhabra A, Hummel J, Heineman N, Dessouky R, Xi Y, et al. Sesamoid malalignment in hallux valgus: Radiographic and MRI measurements and their correlation with internal derangement findings of the first metatarsophalangeal joint. Br J Radiol. 2019;92(1100):20190038.
2. Hardy RH, Clapham JC. Observations on hallux valgus; based on a controlled series. J Bone Joint Surg Br. 1951;33-B(3):376-91.
3. Steel MW 3rd, Johnson KA, DeWitz MA, Ilstrup DM. Radiographic measurements of the normal adult foot. Foot Ankle. 1980;1(3):151-8.
4. Wong DW, Wang Y, Chen TL, Yan F, Peng Y, Tan Q, et al. Finite Element Analysis of Generalized Ligament Laxity on the Deterioration of Hallux Valgus Deformity (Bunion). Front Bioeng Biotechnol. 2020;8:571192.
5. Mizuno S, Sima Y, Yamaxaki K. Detorsion osteotomy of the first metatarsal bone in hallux valgus. J Jpn Orthop Assoc. 1956;30;813-9.
6. Eustace S, Byrne JO, Beausang O, Codd M, Stack J, Stephens MM. Hallux valgus, first metatarsal pronation and collapse of the medial longitudinal arch--a radiological correlation. Skeletal Radiol. 1994;23(3):191-4.
7. Biz C, Maso G, Malgarini E, Tagliapietra J, Ruggieri P. Hypermobility of the First Ray: the Cinderella of the measurements conventionally assessed for correction of Hallux Valgus. Acta Biomed. 2020;91 (4-S):47-59.
8. Tanaka Y, Takakura Y, Sugimoto K, Kumai T, Sakamoto T, Kadono K. Precise anatomic configuration changes in the first ray of the hallux valgus foot. Foot Ankle Int. 2000;21(8):651-6.
9. Wagner E, Wagner P. Metatarsal Pronation in Hallux Valgus Deformity: A Review. J Am Acad Orthop Surg Glob Res Rev. 2020 15;4(6):e20.00091. Erratum in: J Am Acad Orthop Surg Glob Res Rev. 2020;4(8):e20.00144-1.
10. Kim JS, Young KW. Sesamoid Position in Hallux Valgus in Relation to the Coronal Rotation of the First Metatarsal. FootAnkle Clin. 2018;23(2):219-30.
11. Sadamasu A, Yamaguchi S, Kimura S, Ono Y, Sato Y, Akagi R, et al. Influence of foot position on the measurement of first metatarsal axial rotation using the first metatarsal axial radiographs. J Orthop Sci. 2020;25(4):664-70.
12. Gómez Galván M, Constantino JA, Bernáldez MJ, Quiles M. Hallux Pronation in Hallux Valgus: Experimental and Radiographic Study. J Foot Ankle Surg. 2019;58(5):886-92.
13. Dayton P, Feilmeier M, Hirschi J, Kauwe M, Kauwe JS. Observed changes in radiographic measurements of the first ray after frontal plane rotation of the first metatarsal in a cadaveric foot model. J Foot Ankle Surg. 2014;53(3):274-8.
14. Easley ME, Trnka HJ. Current concepts review: hallux valgus part II: operative treatment. Foot Ankle Int. 2007;28(6):748-58.
15. Ornig M, Tschauner S, Holweg PL, Hohenberger GM, Bratschitsch G, Leithner A, et al. A novel method of clinical first tarsometatarsal joint hypermobility testing and radiologic verification. Wien Klin Wochenschr. 2021;133(5-6):209-15.
16. Doty JF, Coughlin MJ. Hallux valgus and hypermobility of the first ray: facts and fiction. Int Orthop. 2013;37(9):1655-60.
17. Myerson MS, Badekas A. Hypermobility of the first ray. Foot Ankle Clin. 2000;5(3):469-84.
18. Prado M, Baumfeld T, Nery C, Mendes A, Baumfeld D. Rotational biplanar Chevron osteotomy. Foot Ankle Surg. 2020;26(4):473-6.
19. Scranton PE Jr, Rutkowski R. Anatomic variations in the first ray: Part I. Anatomic aspects related to bunion surgery. Clin Orthop Relat Res. 1980;(151):244-55.
20. Saltzman CL, Brandser EA, Anderson CM, Berbaum KS, Brown TD. Coronal plane rotation of the first metatarsal. Foot Ankle Int. 1996;17(3):157-61.
21. Talbot KD, Saltzman CL. Assessing sesamoid subluxation: how good is the AP radiograph? Foot Ankle Int. 1998;19(8):547-54.
22. Wagner P, Wagner E. Is the Rotational Deformity Important in Our Decision-Making Process for Correction of Hallux Valgus Deformity? Foot Ankle Clin. 2018;23(2):205-205-17.
23. Shibuya N, Kyprios EM, Panchani PN, Martin LR, Thorud JC, Jupiter DC. Factors Associated With Early Loss of Hallux Valgus Correction. J Foot Ankle Surg. 2018;57(2):236-40.
24. Ferreyra M, Viladot Pericé R, Nuñez-Samper M, Ibáñez L, Ibarra M, Vilá-Rico J. Can we correct first metatarsal rotation and sesamoid position with the 3D Lapidus procedure? Foot Ankle Surg. 2021:S1268-7731(21)00079-5.
25. Seng C, Chunyin Ho D, Chong KW. Restoring Sesamoid Position in Scarf Osteotomy: A Learning Curve. J Foot Ankle Surg. 2015; 54(6):1089-92.

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Original Article

Access to the talar dome through the posteromedial approach: an anatomical study

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Abstract

Objective: To determine the posteromedial area of the talus that can be reached without malleolar osteotomy through the posteromedial approach.

Methods: Fifteen human cadaveric ankles were dissected in standard fashion to expose the posteromedial talar dome. Seven of the approaches (46.7%) were done on the left ankle. We did not observe any significant difference between sides (chi-square test, p=0.715).

Results: On average, 2.09 cm^2 (range, 1.72-2.69) of the posteromedial talus dome or 15.27% (range, 12-20) of the total talus dome can be accessed without osteotomy.

Conclusion: Osteochondral lesions within the area accessible through the posteromedial approach (mean 2 cm^2), as seen on magnetic resonance imaging, may be treated without a medial malleolus osteotomy.

Level of Evidence IV; Descriptive Study.

Keywords: Talus/injuries; Talus/surgery; Osteochondritis; Osteotomy.

Introduction

Osteochondral lesions (OCLs) of the talar dome have different characteristics. Lateral lesions are mainly located on the anterior half of the talus, while medial lesions are usually located on the posterior half.

According to Flick and Gould[1], a history of trauma was observed in approximately 98% of patients with lateral dome OCLs and in 70% of those with medial dome OCLs.

The term transchondral fracture of the dome of the talus was described by Berndt and Harty[2] to reflect this possible traumatic origin. These authors were able to reproduce the lesion at two sites in a cadaver study. Inversion, plantarflexion, and lateral rotation of the tibia at the talus resulted in damage to the medial surface, while inversion of the foot combined with dorsiflexion of the ankle resulted in damage to the lateral part of the talar dome.

There are conflicting findings in the literature regarding the association between type of ankle fracture and the incidence of OCLs. Nosewicz et al.[3] found no significant association with fracture types; on the other hand, Hintermann et al.[4] reported that the frequency and severity of lesions increased significantly from type B to type C fractures, using the classification proposed by Danis-Weber and Müller[5]. Regier et al.[6] reported substantially higher risks of developing OCLs in patients with trimalleolar fractures or dislocated ankle fractures compared to patients with type B unimalleolar fractures.

Burns and Rosenbach[7], in a cadaver study of ankle joints, found that the maximum pressure on the lateral edge of the talus occurred during valgus and pronation, while trauma sustained during supination stressed the medial half of the ankle joint. Verhagen et al.[8] reported a 61% incidence of medial-dome OCLs after ankle trauma. The high incidence in this region can be explained because many OCLs can be attributed to an inversion mechanism and can, therefore, result in impaction of the medial talar dome.

Elias et al.[9] and Asaumi et al.[10] confirmed this in magnetic resonance imaging (MRI) studies; among 424 patients in the first study and 100 patients in the latter, 63% and 61%, respectively, showed involvement of the medial region. In a series of

Study performed at the Hospital do Servidor Público Estadual – IAMSPE, São Paulo, SP, Brazil.

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4 cases describing an en bloc chondral autograft technique by Souza et al.[11], all lesions were located in Raikin's zones 4 and 7 (Figure 1).

Most lateral OCLs can be reached through a standard anterolateral approach; however, the surgical approach to medial lesions usually requires a medial malleolar osteotomy, especially for those involving a larger area and a more posterior region[12].

Medial malleolar osteotomy is associated with some degree of morbidity and further impairment of an already compromised joint, and several factors involved can have an adverse impact on patient recovery: pain and tenderness at the osteotomy site are common; prolonged immobilization may be required, which makes early mobilization of the joint impossible; and several potential technical difficulties are involved. Oblique osteotomy can reach the area of the tibial pilon, while chevron-type osteotomy may not allow adequate access; meticulous preoperative planning is required to avoid causing additional injury to an already damaged area[13,14]. These challenges notwithstanding, it bears stressing that poor outcomes generally result from the underlying condition, although, as noted above, osteotomy can cause additional morbidity.

Access through a posteromedial (PM) approach without osteotomy can allow visualization of approximately 33% of the PM talar dome in the anteroposterior plane, and about 30% in the mediolateral plane[12].

The aim of this study was to determine the area of the PM region of the talus that can be reached via the PM approach without malleolar osteotomy.

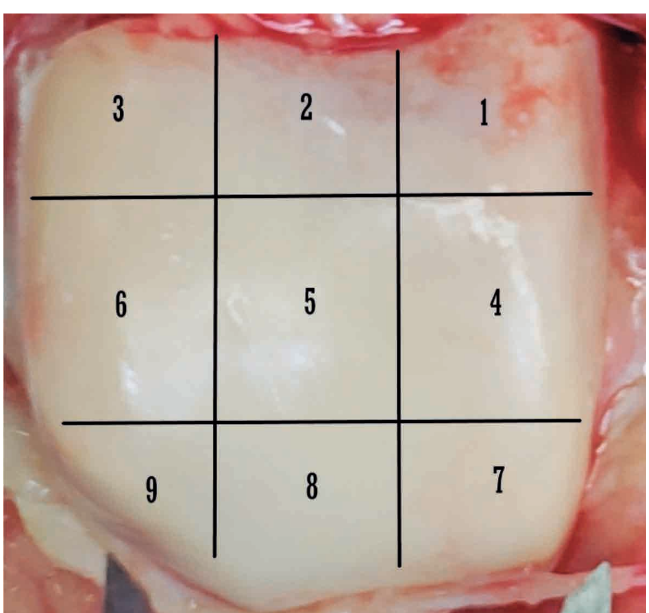

Figure 1. Raikin's nine zones of the talar dome, with 1, 2, and 3 corresponding to the anterior area and 1, 4, and 7 to the medial area.

Methods

This study was approved by the local research ethics committee and was conducted in accordance with the principles of the 1964 Declaration of Helsinki. Fifteen ankle joints from 15 fresh cadavers, all in good condition, with no evidence of trauma or scarring, were dissected. The cadavers were placed in prone position.

PM access was performed with a 6 cm longitudinal incision over the tibial neurovascular bundle. The incision was started 4 cm proximal to the tip of the medial malleolus and extended 2 cm distally. Dissection over the neurovascular bundle must be performed cautiously; the flexor hallucis longus tendon is displaced laterally and the bundle is retracted medially. The arthrotomy is then performed longitudinally, just posterior to the medial malleolus, exposing the PM articular surface of the talus (Figures 2 and 3).

The ankle was then placed in maximal extension to enlarge the view of the talar joint. The exposed height and base were then measured with digital calipers (Mitutoyo® ABSOLUTE, resolution 0.01 mm). Subsequently, we dislocated the tibiotalar joint and measured the total articular surface of the talus with the aid of a measuring tape (heights) and caliper (bases); we then applied the formula of a scalene trapezoid to calculate its area in cm^2 (Figures 4 and 5).

Figure 2. Access window over the neurovascular bundle.

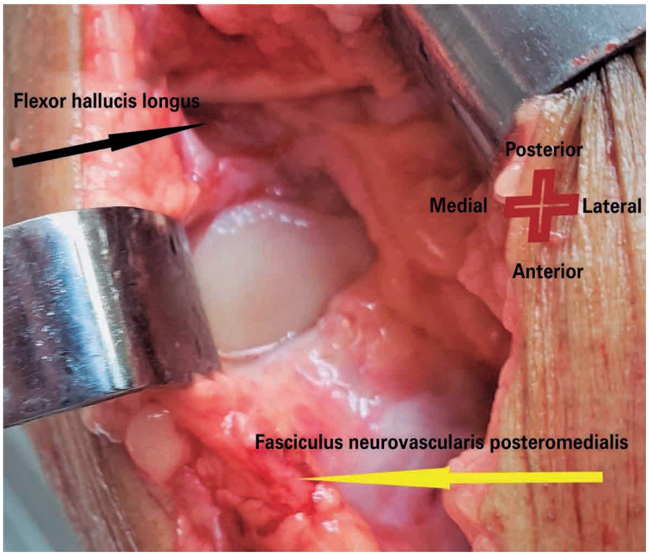

Figure 3. Exposed area of the posteromedial talar surface after arthrotomy with direct visualization. The black arrow indicates the flexor hallucis longus tendon, and the yellow arrow, the neurovascular bundle containing the posterior tibial artery and vein and tibial nerve.

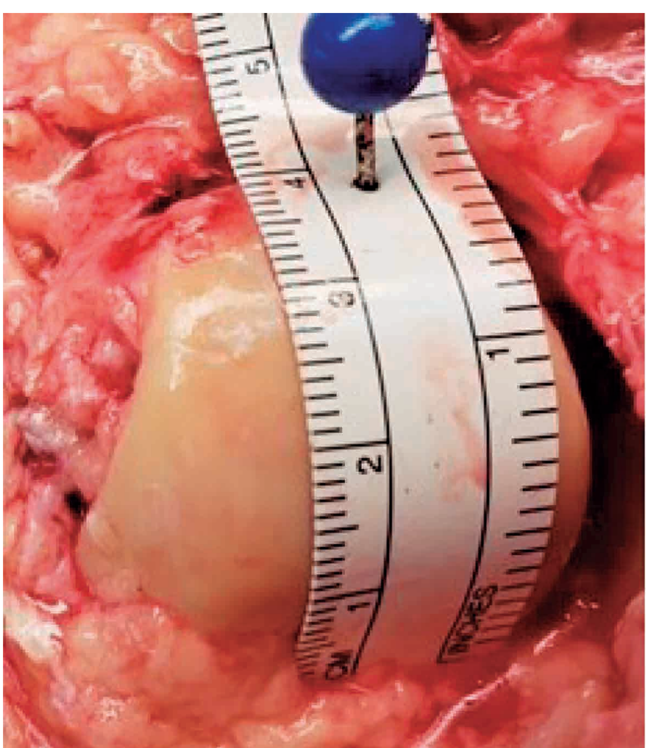

Figure 4. Articular surface of the talus, measured with the aid of a measuring tape.

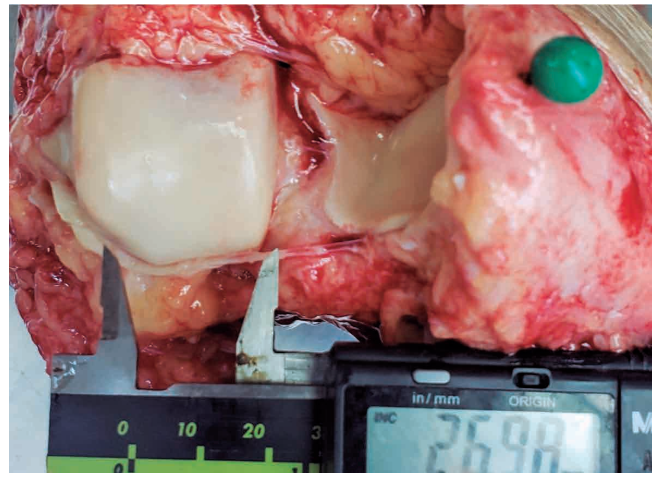

Figure 5. Articular surface of the talus, measured with the aid of a caliper.

For statistical analysis, all variables were first analyzed descriptively. For quantitative variables, this analysis was performed using minimum and maximum values, means, standard deviations, and medians as appropriate. Qualitative variables were described as absolute and relative frequencies.

The Shapiro-Wilk test was used to test for normality of data distribution[15].

When the assumption of normality was confirmed, Student's *t*-test was used to compare means between groups[15]; when the assumption of normality was rejected, the nonparametric Mann-Whitney *U* test was used instead[15].

The chi-square method was used to test for homogeneity of proportions[15].

Spearman's coefficient was used to test for correlation between variables[15]. All calculations were performed in SPSS 17.0 for Windows®, and the significance level was set at 5%.

Results

Fifteen cadavers were examined. Age at the time of death ranged from 24 to 77 years (mean, 51.73 years; standard deviation, 16.20 years; median, 55 years). Eleven (73.3%) were male, and four (26.7%) were female. BMI ranged from 18.67 to 35.14 kg/m^2 (mean, 25.20 kg/m^2; standard deviation, 4.39 kg/m^2; median, 25.59 kg/m^2). Eight (53.3%) were white and seven (46.7%) were black.

PM access was performed on the left side in seven cadavers (46.7%). There was no significant difference between sides (chi-square test, p=0.715).

Area values are described (as percent area and cm^2) in table 1. Figure 6 shows Raikin's zones of the talar dome and the areas visualized under PM access.

Spearman's coefficients showed no significant correlation of age or BMI with differences between measurements.

Table 1. Descriptive statistics of the posteromedial access parameters of interest (degree of exposure of the talar dome in cm, cm^2, and percentage). Standard deviation (SD).

Variable	n	Mean	SD	Minimum	Maximum
Coronal plane	15	1.12	0.09	0.98	1.30
Sagittal plane	15	1.86	0.22	1.47	2.21
Area (cm^2)	15	2.09	0.30	1.72	2.69
Percent exposed area	15	15.27	2.40	12.47	20.38

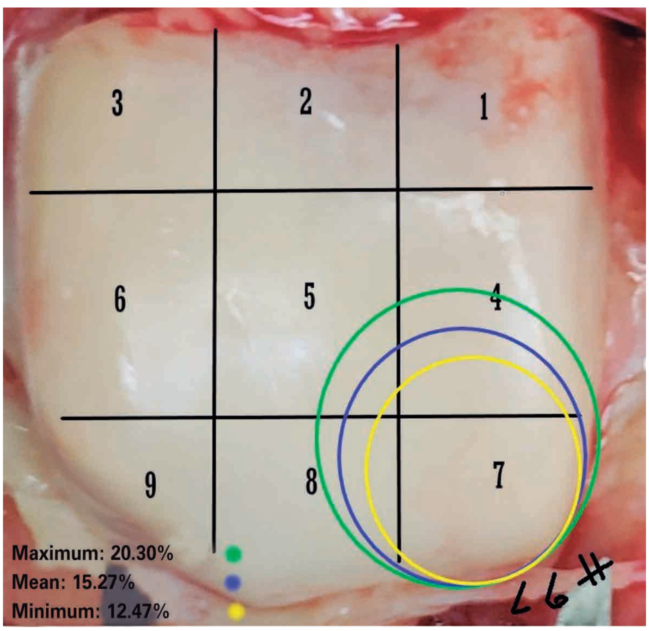

Figure 6. Exposed area of the talar surface. Yellow circle shows the minimum exposure, blue circle shows the average exposure, and green circle shows the maximum exposure achieved, within their respective Raikin's zones.

Discussion

Medial malleolar osteotomies are not without complications. These can be divided into three major types: intraoperative (injuries to adjacent structures, more specifically in the posteromedial region, such as the posterior tibial tendon and artery and the tibial nerve, or chondral lesions of the tibia at the time of osteotomy); intermediate (nonunion and malunion); and late complications, which induce or worsen chondral lesions or cause osteoarthritis[16].

The extent of the OCL itself, as well as inadequate repositioning of the osteotomized segment forming empty spaces or a stepped defect on the joint, can lead to late complications. Gaurapp et al.[17] reported a 50% rate of osteoarthritis after treating OCLs with medial malleolar osteotomy. Baltzer and Arnold[18] observed a decrease in tibiotalar plantarflexion and a 5% nonunion rate after medial malleolar osteotomy, with no such complications after anterior arthrotomy without osteotomy.

In a study of 62 patients who underwent chevron-type osteotomy of the medial malleolus, with a mean postoperative follow-up of 34.5 months, Lamb et al.[19] found that 6% were symptomatic at the osteotomy site. Furthermore, quantitative T2-mapping MRI analysis showed that relaxation times in the deep half of repair tissues at the osteotomy interface were restored to normal values in relation to those in the tibial cartilage, while those in the superficial half were prolonged, indicating a more fibrocartilaginous repair.

In a case series published by Jarde et al.[20], in which 13 patients underwent malleolar osteotomy for the treatment of OCLs with a minimum follow-up of 2 years, no case had any complications attributable to osteotomy.

Leumann et al.[16] reported that 59% of patients had to undergo arthroscopy of the ankle joint to remove osteotomy hardware and anteromedial capsular adhesions.

If an OCL is within the area accessible via a PM approach as seen on MRI, it is treatable without medial malleolar osteotomy. Muir et al.[12] evaluated methods of access to OCLs of the talus (a combination of approaches with and without malleolar osteotomies) in 9 cadaver ankles. They achieved access perpendicular to, on average, 35% of the talar dome when using the PM approach without osteotomy. Their findings showed that more than 75% of the entire dome of the talus can be accessed without osteotomy. Young et al.[21], in a study with five cadaver ankles, managed to expose 33% of the anteroposterior length and 30% of the mediolateral length of the dome through the PM approach.

These results are slightly better than those found in our study. We were able to expose an average area of 2.09 cm^2 of the PM region and an average of 15.27% of the total area of the talar dome, as shown in Figure 6. It is noteworthy that both studies were performed on cadaver ankles, in which the gastrocnemius-soleus complex was lacking, which can result in excessive ankle dorsiflexion and exposure of a larger area. Muir tried to minimize this bias by limiting dorsiflexion to 20° in each of the examined specimens. Furthermore, since this study was performed on intact fresh cadavers and not isolated anatomical specimens, we were able to perform a wider and more aggressive dissection than is sometimes possible *in vivo*. It would therefore be interesting to carry out clinical trials, preferably randomized, to reduce the biased inherent to anatomical studies and translate our results to clinical practice.

In studies by Asuami et al.[10], 22% of lesions were in the PM region (zone 7). Raikin et al. apud Asaumi et al.[10] reported 6.8% of lesions in this area; in both studies, zone 4 was most affected, accounting for 33% and 53% of lesions, respectively.

Sagittal radiographs with the tibiotalar joint in maximum dorsiflexion are extremely important preoperatively, as they allow the operator to determine whether exposure of the OCL in the talar dome through the PM approach will be possible. If the lesion is in Raikin's zone 4, it is important to keep osteotomy as a surgical option, as the OCL may not be adequately exposed.

We believe that access to the medial talar dome without osteotomy causes less morbidity and is associated with more favorable outcomes. Clinical trials comparing the two approaches are needed to test this hypothesis. Nevertheless, it is essential that the surgeon be prepared to use both techniques as appropriate according to the location of the lesion.

Conclusion

If an OCL is within the approximately 2-cm^2 area accessible via a PM approach as seen on preoperative imaging, it should be treatable without medial malleolar osteotomy.

Authors' contributions: Each author contributed individually and significantly to the development of this article: WFM *(https://orcid.org/0000-0002-1007-9539) Conceived and planned the activity that led to the study, wrote the article, participated in the review process; LGH *(https://orcid.org/0000-0003-4345-7222) Data collection, bibliographic review; GBM *(https://orcid.org/0000-0003-0735-8999) Formatting of the article, bibliographic review; LSMP *(https://orcid.org/0000-0002-7087-5852) interpreted the results of the study, participated in the review process; GRF *(https://orcid.org/0000-0002-0225-2004) performed the surgeries; data collection, statistical analysis; IAF *(https://orcid.org/0000-0003-0655-3258) Conceived and planned the activity that led to the study, wrote the article, participated in the review process All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Flick AB, Gould N. Osteochondritis dissecans of the talus (transchondral fractures of the talus): review of the literature and new surgical approach for medial dome lesions. Foot Ankle. 1985;5(4):165-85.
2. Berndt AL, Harty M. Transchondral fractures (osteochondritis dissecans) of the talus. J Bone Joint Surg Am. 1959 41-A:988-1020.
3. Nosewicz TL, Beerekamp MS, De Muinck Keizer RJ, Schepers T, Maas M, Niek van Dijk C, et al. Prospective Computed Tomographic Analysis of Osteochondral Lesions of the Ankle Joint Associated With Ankle Fractures. Foot Ankle Int. 2016;37(8):829-34.
4. Hintermann B, Regazzoni P, Lampert C, Stutz G, Gächter A. Arthroscopic findings in acute fractures of the ankle. J Bone Joint Surg Br. 2000;82(3):345-51.
5. Danis-Weber BG, Müller ME. Lesiones Traumaticas de la Articulacion del Tobillo. Barcelona: Editorial Cientifico-Médica; 1948.
6. Regier M, Petersen JP, Hamurcu A, Vettorazzi E, Behzadi C, Hoffmann M, et al. High incidence of osteochondral lesions after open reduction and internal fixation of displaced ankle fractures: Medium-term follow-up of 100 cases. Injury. 2016;47(3):757-61.
7. Burns J, Rosenbach B. [Osteochondrosis dissecans of the talus. Results of a follow-up study]. Z Orthop Ihre Grenzgeb. 1989; 127(5):549-55.
8. Verhagen RA, Struijs PA, Bossuyt PM, van Dijk CN. Systematic review of treatment strategies for osteochondral defects of the talar dome. Foot Ankle Clin. 2003;8(2):233-42.
9. Elias I, Zoga AC, Morrison WB, Besser MP, Schweitzer ME, Raikin SM. Osteochondral lesions of the talus: localization and morphologic data from 424 patients using a novel anatomical grid scheme. Foot Ankle Int. 2007;28(2):154-61.
10. Asaumi ID, Apostólico NA, Macedo RR, Ferreira TG, Oliveira HC, Guercia RF, et al. Osteochondral lesions of the talus: location and morphological features in a Brazilian sample. Rev ABTPé. 2013;7(2):79-84.
11. Souza BBB, Nery CAS, Prado MP, Alloza JFM, Godoy-Santos AL. En bloc osteochondral autograft in the treatment of osteochondral lesions of the talus: a report of 4 cases. Sci J Foot Ankle. 2019;13(3):217-22.
12. Muir D, Saltzman CL, Tochigi Y, Amendola N. Talar dome access for osteochondral lesions. Am J Sports Med. 2006;34(9):1457-63.
13. Alexander IJ, Watson JT. Step-cut osteotomy of the medial malleolus for exposure of the medial ankle joint space. Foot Ankle. 1991;11(4):242-3.
14. O'Farrell TA, Costello BG. Osteochondritis dissecans of the talus. The late results of surgical treatment. J Bone Joint Surg Br. 1982; 64(4):494-7.
15. Rosner B. Fundamentals of Biostatistics. 2nd ed. Boston: PWS Publishers; 1986.
16. Leumann A, Horisberger M, Buettner O, Mueller-Gerbl M, Valderrabano V. Medial malleolar osteotomy for the treatment of talar osteochondral lesions: anatomical and morbidity considerations. Knee Surg Sports Traumatol Arthrosc. 2016;24(7):2133-9.
17. Gaulrapp H, Hagena FW, Wasmer G. [Postoperative evaluation of osteochondrosis dissecans of the talus with special reference to medial malleolar osteotomy]. Z Orthop Ihre Grenzgeb. 1996; 134(4):346-53.
18. Baltzer AW, Arnold JP. Bone-cartilage transplantation from the ipsilateral knee for chondral lesions of the talus. Arthroscopy. 2005;21(2):159-66.
19. Lamb J, Murawski CD, Deyer TW, Kennedy JG. Chevron-type medial malleolar osteotomy: a functional, radiographic and quantitative T2-mapping MRI analysis. Knee Surg Sports Traumatol Arthrosc. 2013;21(6):1283-8.
20. Jarde O, Trinquier-Lautard JL, Garate F, de Lestang M, Vives P. [Osteochondral lesions of the talar dome: surgical treatment in a series of 30 cases]. Rev Chir Orthop Reparatrice Appar Mot. 2000;86(6):608-15.
21. Young KW, Deland JT, Lee KT, Lee YK. Medial approaches to osteochondral lesion of the talus without medial malleolar osteotomy. Knee Surg Sports Traumatol Arthrosc. 2010;18(5):634-7.

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Original Article

Reliability of coronal plane rotation measurements in the medial column of the foot: a cadaveric study

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Abstract

Objective: To assess interobserver reliability of previously described coronal plane rotation measurements of medial column bones and to assess their ability to accurately quantify changes in rotational profile.

Methods: Two cadaveric below-knee specimens were implanted with pins in each bone of the medial column. Weight-bearing computed tomography (CT) scans were acquired in a simulated standing position under neutral, supinated, and pronated conditions. For each specimen and condition, 2 observers measured the coronal plane rotation of the navicular, medial cuneiform, first metatarsal base, shaft, and head, and proximal phalanx of the hallux as previously described. The rotation of each pin was measured relative to the ground in the coronal plane for each condition. These measurements were defined as benchmarks for the rotational profile of each bone. The correlation between these benchmarks and direct bone measurements was then assessed. Intraclass correlation coefficient was used to assess interobserver reliability. Pearson's coefficient was used to evaluate correlations.

Results: The interobserver reliability of direct bone measurements ranged from 0.98 to 0.99. Correlations between pin rotation and direct measurements ranged from ρ=0.87 to 0.99 across the neutral, supinated, and pronated conditions.

Conclusion: Coronal plane rotation measurements of medial column bones described in this study are reliable tools.

Level of Evidence III; Case-Control Study.

Keywords: Cadaver; Hallux valgus; Metatarsal bones; Pronation; Weight-bearing.

Introduction

The coronal plane rotational profile of medial column bones in the foot is a recent focus of attention(1-6). Previously, understanding of foot pathologies was limited by conventional 2-dimensional radiographs and bone superimpositions(7-9). Therefore, alignment of the tarsal bones in the coronal plane has been largely disregarded. Recently, several weight-bearing computed tomography (WBCT) studies have identified the presence of hyperpronation of the first ray relative to the ground in hallux valgus(1,2,6,10-12). Subsequently, Conti et al.(13) showed that surgical correction of this hyperpronation in hallux valgus decreased recurrence and improved patient-reported outcomes. Beyond hallux valgus deformity, assessing the tarsal bones in the coronal plane in other foot conditions, such as progressive collapsing foot deformity, cavovarus, and clubfoot, has shown promise for improving understanding and treatment(14-17).

Most of the measurements described to assess the rotational profile of the medial column in the coronal plane only assess rotation at the level of the first metatarsal head(1,2). Saltzman et al.(18) on conventional radiographs and later Kim et al.(6) on WBCT scans described measurements to assess coronal plane rotation of the first metatarsal head relative to the ground. However, these measurements assess not only the rotational profile of the first metatarsal but also the aggregate rotation of each bone in the medial column(5). There-

Study performed at the University of Iowa, Carver College of Medicine, Department of Orthopedics and Rehabilitation, Iowa City, IA, USA.

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fore, hyperpronation present in hallux valgus deformity could originate from anywhere in the entire medial column, from the navicular to the first metatarsal. Understanding the origin of this hyperpronation could both improve comprehension of pathogenesis and guide surgical treatment.

Schmidt et al.[19] were the first to describe coronal plane rotation measurements for each bone in the medial column. However, neither the interobserver reliability of these measurements nor their ability to quantify real changes in bone rotation in the coronal plane (pronation or supination) has been evaluated.

The primary objective of our study was to assess the interobserver reliability of these measurements along the medial column. The secondary objective was to assess the accuracy of these measurements in quantifying coronal plane rotation.

Methods

Institutional Review Board approval was obtained (IRB# 201904825).

Two fresh frozen below-knee specimens without deformity or disease were obtained. The proximal 5 centimeters of the leg were prepared by removing the surrounding soft tissue to enable potting of the tibial plateau with bone cement. This apparatus provided the support to hold the specimens in a vertical plantigrade position in a radiolucent loading frame. These same specimens had been used in a previous study of instability of the distal tibiofibular syndesmosis, but the hindfoot, midfoot, and forefoot remained intact. The potted specimens were placed in the frame where a vertical load of 80 lbs. (356 N) was applied to simulate a double-legged stance with the tibia perpendicular to the floor (Figure 1). The frame holder was placed in a WBCT scanner (Hi-Rise, CurveBeam®) and foot acquisitions were obtained using a metal artifact reduction algorithm. Specimens were thawed for more than 24 hours before the acquisitions.

We implanted a 2-mm diameter pin in each bone of the medial column (one in the navicular, one in the medial cuneiform, one in the first metatarsal, and one in the proximal phalanx of the hallux) and ensured they were not torqued to remain straight for each specimen. After pin placement, each bone underwent 3 WBCT scans, one in each of the neutral, supinated, and pronated conditions (Figure 2).

The following measurements were performed using a dedicated software (CubeVue™, CurveBeam, LLC, Warrington, PA, USA) and after having aligned our sagittal plane on the longitudinal axis of the first metatarsal in the axial view. Navicular, medial cuneiform, first metatarsal base, and proximal phalanx of the hallux rotations were measured in accordance with the techniques described by Schmidt et al.[19]. First metatarsal head rotation was additionally measured in accordance with the definitions proposed by Steadman et al.[4], Kim et al.[6], and Saltzman et al.[18]. We additionally proposed a new definition to assess first metatarsal rotation in the coronal plane at the midshaft level.

Navicular rotation

The navicular rotation was measured as the angle between the floor and the widest mediolateral distance of the bone, at a level just distal to the talonavicular joint[19] (Figure 3A).

Medial cuneiform rotation

The medial cuneiform rotation was measured just proximal to the most proximal aspect of the first tarsometatarsal joint and was defined as the angulation between the vertical line and a bisecting line of an angle formed by tangent lines to the medial and lateral surfaces of the medial cuneiform[19] (Figure 3B).

First metatarsal base rotation

The first metatarsal base coronal rotation was measured at a level just distal to the most distal aspect of the first tarsometatarsal joint. The rotation was defined as the angle between the floor and a bisecting line of the angle formed by tangent lines to the medial and lateral surfaces of the proximal first metatarsal[19] (Figure 3C).

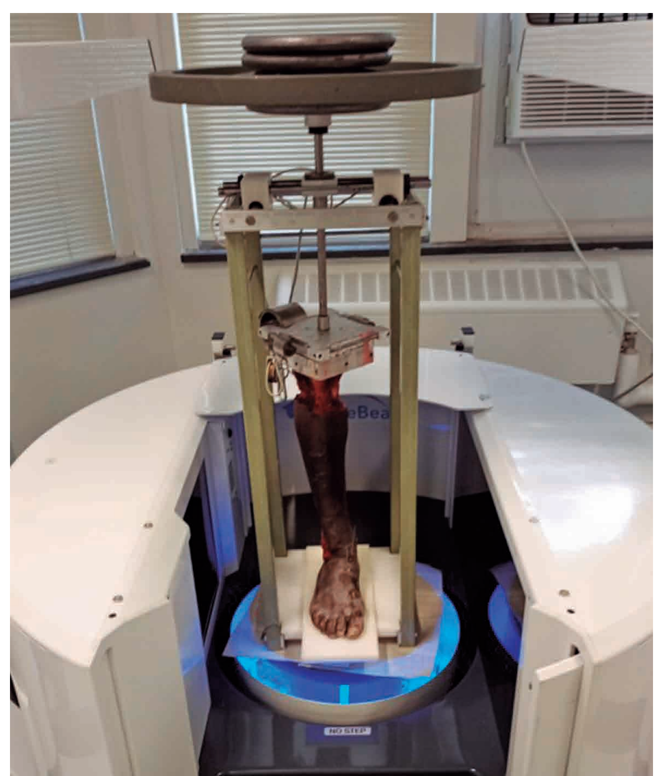

Figure 1. Overall view of the radiolucent frame, holding a leg in a simulated weight-bearing position.

First metatarsal shaft rotation

The first metatarsal shaft coronal rotation was measured at the middle of the first metatarsal after having measured the length of the first metatarsal in the axial plane. The rotation was defined as the angle between the floor and a bisecting line of the angle formed by tangent lines to the medial and lateral surfaces of the midshaft of the first metatarsal[19] (Figure 3D).

First metatarsal head coronal rotation, α angle

To measure the α angle, a plantar line was drawn between the lateral edge of the lateral sulcus and the medial edge of the medial sulcus. A second line was drawn between the medial and lateral dorsal corners of the first metatarsal head. A third line was drawn connecting the midpoints of these 2 lines and the α angle was measured between this line and the vertical line[6] (Figure 3E).

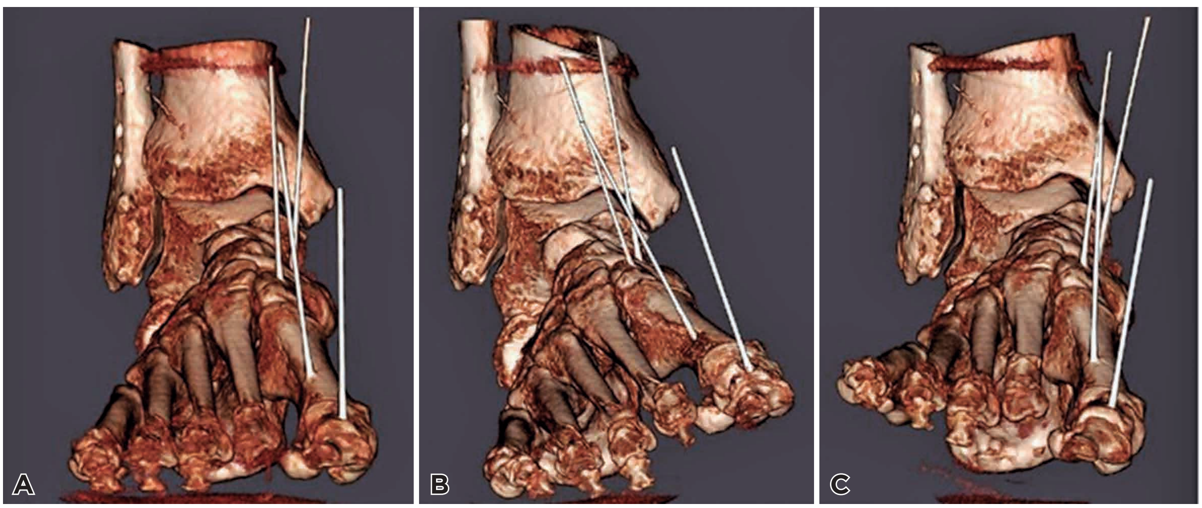

Figure 2. Three-dimensional reconstruction of weight-bearing CT acquisitions. A) Neutral condition. B) Supinated condition. C) Pronated condition.

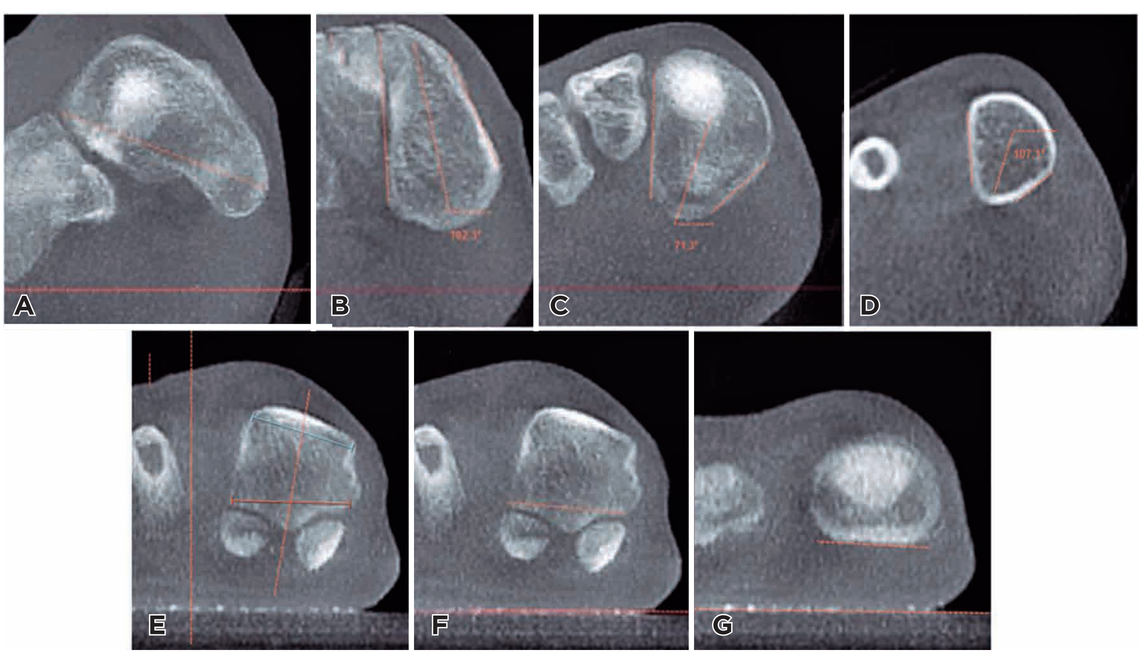

Figure 3. Illustrations of coronal plane rotation measurements of medial column bones. A) Navicular. B) Medial cuneiform. C) First metatarsal base. D) First metatarsal shaft. E) Alpha angle. F) Saltzman angle. G) Proximal phalanx of the hallux.

First metatarsal head coronal rotation, Saltzman angle

To measure the Saltzman angle, a line was drawn touching the outer profile of the tibial and fibular sesamoid sulci at their most inferior edges. The Saltzman angle was measured between this line and the floor[4,18] (Figure 3F).

Proximal phalanx of the hallux rotation

The proximal phalanx of the hallux rotation was measured at a level just distal to the most distal aspect of the first metatarsophalangeal joint by the angulation between the floor and a tangent line to the plantar aspect of the proximal phalanx[19] (Figure 3G).

Primary assessment criteria

Two independent observers performed these 7 measurements on each specimen under each condition (neutral, supinated, and pronated), based on which we assessed interobserver reliability.

Secondary assessment criteria

To define rotational position benchmarks for each bone, the 2 observers measured the position of each pin (navicular, medial cuneiform, first metatarsal, and proximal phalanx of the hallux) relative to the vertical line in the coronal plane for each specimen under each condition (neutral, supinated, and pronated) (Figure 4A). We also assessed the interobserver reliability of these measurements. Then, the mean value of the 2 observers' measurements was taken into consideration for each pin to define the rotational position benchmarks of each bone in each condition.

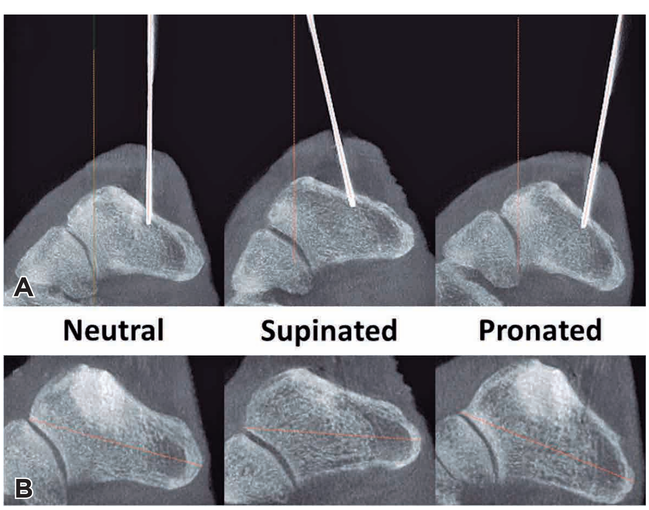

Figure 4. Assessment of the correlation between the benchmark pin and direct bone rotational measurements in the coronal plane: Example of the navicular. A) Measurements of the benchmark navicular pin rotation under neutral, supinated, and pronated conditions. B) Measurements of the navicular rotation under neutral, supinated, and pronated conditions.

We then assessed the correlation between these benchmarks and the 7 direct bone measurements performed by the 2 observers in order to assess the ability of these measurements to accurately quantify changes in bone rotation in the coronal plane (Figure 4B).

Statistical analysis

The interobserver reliability of the measurements was determined using intraclass correlation coefficients (ICCs)[20]. Pearson product-moment correlation coefficient was used to assess linear dependence between parameters. Correlation was judged to be very strong from 1 to 0.9, strong from 0.9 to 0.7, moderate from 0.7 to 0.5, low from 0.5 to 0.3, and poor from 0.3 to 0. The α risk was set to 0.05. Statistical analysis was performed with EasyMedStat (version 3.12; www.easymedstat.com).

Results

Navicular rotation

The interobserver reliability of the navicular rotation measurement was 0.99 (95% confidence interval [CI], 0.97 to 1).

The interobserver reliability of the benchmark navicular pin measurement was 1 (95% CI, 0.99 to 1). The correlations between changes in benchmark navicular pin and changes in navicular rotation direct measurement across neutral, supinated, and pronated conditions were very strong for observer 1 (ρ=0.95; r^2=0.899; p=0.004) and observer 2 (ρ=0.96; r^2=0.914; p=0.003) (Figure 5A).

Medial cuneiform rotation

The interobserver reliability of the medial cuneiform rotation measurement was 0.99 (95% CI, 0.99 to 1).

The interobserver reliability of the benchmark medial cuneiform pin measurement was 1 (95% CI, 0.99 to 1). The correlations between changes in benchmark medial cuneiform pin and changes in medial cuneiform rotation direct measurement across neutral, supinated, and pronated conditions were very strong for observer 1 (ρ=0.98; r^2=0.97; p<0.001) and observer 2 (ρ=0.98; r^2=0.96; p<0.001) (Figure 5B).

First metatarsal base rotation

The interobserver reliability of the first metatarsal base rotation measurement was 0.99 (95% CI, 0.97 to 0.99).

The interobserver reliability of the benchmark first metatarsal pin measurement was 1 (95% CI, 0.99 to 1). This was also used as a benchmark for the first metatarsal shaft and head rotation measurements. The correlations between changes in benchmark first metatarsal pin and changes in first metatarsal base rotation direct measurement across neutral, supinated, and pronated conditions were very strong for observer 1 (ρ=0.98; r^2=0.959; p<0.001) and observer 2 (ρ=0.98; r^2=0.97; p<0.001) (Figure 5C).

First metatarsal shaft rotation

The interobserver reliability of the first metatarsal shaft rotation measurement was 0.99 (95% CI, 0.99 to 1).

The correlations between changes in benchmark first metatarsal pin and changes in first metatarsal shaft rotation direct measurement across neutral, supinated, and pronated conditions were very strong for observer 1 (ρ=0.99; r^2=0.974; p<0.001) and observer 2 (ρ=0.99; r^2=0.981; p<0.001) (Figure 5D).

First metatarsal head coronal rotation, α angle

The interobserver reliability of the α angle measurement was 0.99 (95% CI, 0.97 to 1).

The correlations between changes in benchmark first metatarsal pin and changes in α angle across neutral, supinated, and pronated conditions were strong for observer 1 (ρ=0.87; r^2=0.754; p=0.025) and observer 2 (ρ=0.88; r^2=0.778; p=0.02) (Figure 5E).

First metatarsal head coronal rotation, Saltzman angle

The interobserver reliability of the Saltzman angle measurement was 0.99 (95% CI, 0.98 to 1).

The correlations between changes in benchmark first metatarsal pin and changes in Saltzman angle across neutral, supinated, and pronated conditions were very strong for observer 1 (ρ=0.95; r^2=0.909; p=0.003) and observer 2 (ρ=0.95; r^2=0.91; p=0.003) (Figure 5F).

Proximal phalanx of the hallux rotation

The interobserver reliability of the proximal phalanx of the hallux rotation measurement was 0.98 (95% CI, 0.92 to 0.99).

The interobserver reliability of the benchmark proximal phalanx pin measurement was 1 (95% CI, 0.99 to 1). The correlations between changes in benchmark proximal phalanx pin and changes in proximal phalanx of the hallux rotation direct measurement across neutral, supinated, and pronated conditions were very strong for observer 1 (ρ=0.99; r^2=0.992; p<0.001) and observer 2 (ρ=0.99; r^2=0.988; p<0.001) (Figure 5G).

Discussion

Interobserver reliability was excellent for the navicular, medial cuneiform, first metatarsal base and shaft, and proximal phalanx of the hallux rotation measurements in the coronal plane as well as for the α angle and the Saltzman angle. These measurements were able to accurately quantify changes in bone rotation (pronation or supination) in the coronal plane.

The reliability of the α angle and the Saltzman angle has already been reported as good in the literature, and our study confirmed these previous findings[3,4,6]. On the other hand, the reliability of navicular, medial cuneiform, first metatarsal base and shaft, and proximal phalanx of the hallux rotations had not been previously assessed. Najefi et al.[3] and Steadman et al.[4] went further and defined the normative values of the α and Saltzman angles. Considering the excellent reliability

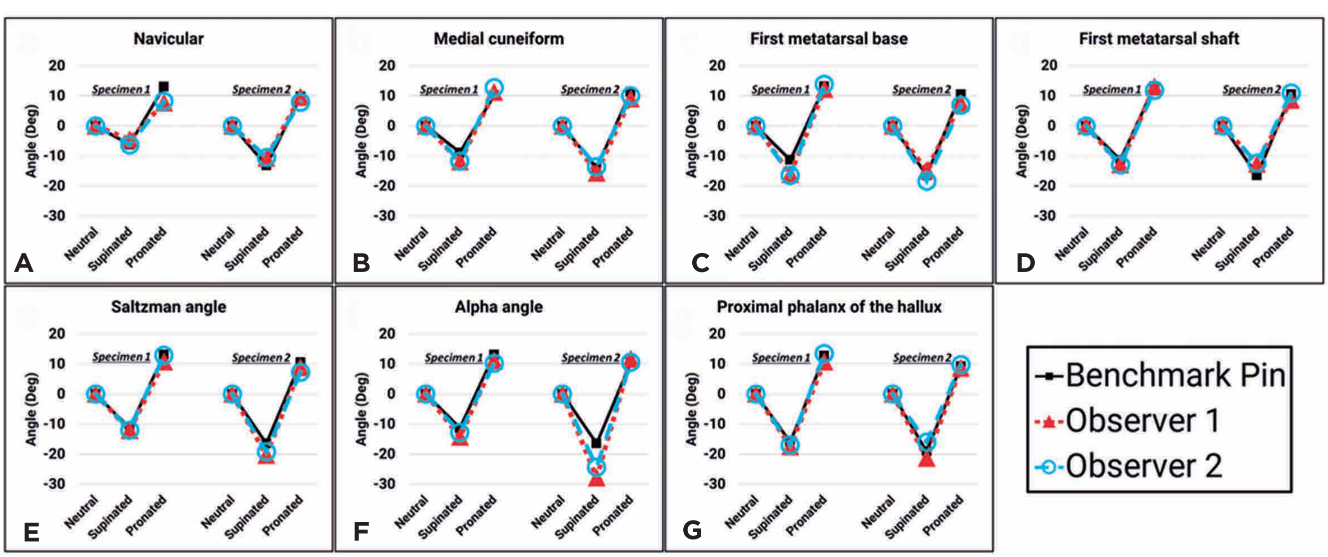

Figure 5. Charts representing the changes in rotation in the coronal plane of the benchmark pin and of the 2 observers' measurements. A) Navicular. B) Medial cuneiform. C) First metatarsal base. D) First metatarsal shaft. E) Alpha angle. F) Saltzman angle. G) Proximal phalanx of the hallux.

of the other measurements that were performed along the medial column in our study, it would be interesting to define their normative values to serve as a reference for future studies and for the management of foot deformities. Although interobserver reliability has already been validated in the literature for the α and Saltzman angles, it remained uncertain whether these measurements would be able to accurately quantify changes in the rotation of the first metatarsal in the coronal plane. Saltzman et al.[18] had previously validated the ability of the Saltzman angle to quantify rotational changes on conventional radiographs in a cadaveric study, and our study confirmed their results on WBCT acquisitions. The results of the present study showed that these measurements, together with the other measurements that were performed along the medial column, are able to accurately quantify a motion or deformity in pronation or supination in the coronal plane.

Randich et al.[21] performed similar measurements along the medial column in the coronal plane, comparing hallux valgus and controls, but their description of some measurements lacked clarity and they did not assess the position of the navicular or perform a reliability assessment. In this context, it is challenging to evaluate the accuracy of their results. In contrast, Schmidt et al.[19] described several measurements along the medial column in greater detail and included the navicular. Given the similarity of their intentions to ours and this contrast, we decided to perform a validation study using the descriptions provided by Schmidt et al.[19]. As described by Conti et al.[5], the results reporting hyperpronation in hallux valgus, based on measurements performed at the level of the first metatarsal head, are an indirect reflection of an aggregate in pronation of all bones along the medial column. Therefore, using the measurements validated in the present study to compare hallux valgus and controls could reveal the exact location of this hyperpronation in the medial column in hallux valgus.

This study has several limitations. A primary limitation is that it only evaluated 2 specimens. This small sample size could not assess the impact of anatomic variability in the medial column on the measurements. Therefore, reliability values reported in this study likely represent an upper bound of the true reliability. As these specimens were selected for having no deformity, further research is needed to establish a lower bound of reliability resulting from anatomic variation. To control for these potential biases, 2 independent observers performed the measurements under 3 different conditions, and a benchmark pin was used as a control.

Conclusion

Coronal plane rotation measurements of medial column bones described in this study are reliable. These measurements can accurately quantify changes in bone rotation in the coronal plane.

Authors' contributions: Each author contributed individually and significantly to the development of this article: KD *(https://orcid.org/0000-0002-8061-4453) Wrote the paper, participated in the reviewing process, approved the final version; HB *(https://orcid.org/0000-0001-6917-1519) Performed acquisitions, participated in the reviewing process, approved the final version; AB *(https://orcid.org/0000-0002-4588-9291) Participated in the reviewing process, approved the final version; LMG *(https://orcid.org/0000-0001-8440-1335) Participated in the reviewing process, approved the final version; KAMC *(https://orcid.org/0000-0003-1082-6490) Participated in the reviewing process, approved the final version; NDBM *(https://orcid.org/0000-0003-1067-727X) Participated in the reviewing process, approved the final version; ML *(https://orcid.org/0000-0001-5058-8867) Performed acquisitions, participated in the reviewing process, approved the final version; CCN *(https://orcid.org/0000-0001-6037-0685) Conceived and planned the activities that led to the study, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Steadman J, Barg A, Saltzman CL. First metatarsal rotation in hallux valgus deformity. Foot Ankle Int. 2021;42(4):510–22.
2. Najefi AA, Malhotra K, Patel S, Cullen N, Welck M. Assessing the Rotation of the First Metatarsal on Computed Tomography Scans: A Systematic Literature Review. Foot Ankle Int. 2021; 107110072110206.
3. Najefi AA, Zaveri A, Alsafi MK, Malhotra K, Patel S, Cullen N, et al. The Assessment of First Metatarsal Rotation in the Normal Adult Population Using Weightbearing Computed Tomography. Foot Ankle Int. 2021;107110072110151.
4. Steadman J, Bakshi N, Arena C, Leake R, Barg A, Saltzman CL. Normative Distribution of First Metatarsal Axial Rotation. Foot Ankle Int. 2021;10711007211001016.
5. Conti MS, Patel TJ, Caolo KC, Amadio JM, Miller MC, Costigliola SV, et al. Correlation of Different Methods of Measuring Pronation of the First Metatarsal on Weightbearing CT Scans. Foot Ankle Int. 2021;10711007211003090.
6. Kim Y, Kim JS, Young KW, Naraghi R, Cho HK, Lee SY. A New Measure of Tibial Sesamoid Position in Hallux Valgus in Relation to the Coronal Rotation of the First Metatarsal in CT Scans. Foot Ankle Int. 2015;36(8):944–52.
7. Johnson KA, Strom DE. Tibialis posterior tendon dysfunction. Clin Orthop Relat Res. 1989;(239):196-206
8. Hardy RH, Clapham JCR. Hallux valgus; predisposing anatomical causes. Lancet. 1952;1(6720):1180–3.
9. Hardy RH, Clapham JCR. Observations on hallux valgus; based on a controlled series. J Bone Joint Surg Br. 1951;33-B(3):376–91.
10. Mansur NSB, Lalevee M, Schmidt E, Dibbern K, Wagner P, Wagner E, et al. Correlation between indirect radiographic parameters of first metatarsal rotation in hallux valgus and values on weight-bearing computed tomography. Int Orthop. 2021;45(12):3111-8.
11. Lee HY, Lalevee M, Mansur NSB, Vandelune CA, Dibbern KN, Barg A, et al. Multiplanar instability of the first tarsometatarsal joint in

hallux valgus and hallux rigidus patients: a case-control study. Int Orthop. 2021. doi: 10.1007/s00264-021-05198-9.

12. Lalevée M, Barbachan Mansur NS, Lee HY, Maly CJ, Iehl CJ, Nery C, et al. Distal Metatarsal Articular Angle in Hallux Valgus Deformity. Fact or Fiction? A 3-Dimensional Weightbearing CT Assessment. Foot Ankle Int. 2021:10711007211051642.
13. Conti MS, Patel TJ, Zhu J, Elliott AJ, Conti SF, Ellis SJ. Association of First Metatarsal Pronation Correction With Patient-Reported Outcomes and Recurrence Rates in Hallux Valgus. Foot Ankle Int. 2021;107110072110469.
14. de Cesar Netto C, Godoy-Santos AL, Saito GH, Lintz F, Siegler S, O'Malley MJ, et al. Subluxation of the Middle Facet of the Subtalar Joint as a Marker of Peritalar Subluxation in Adult Acquired Flatfoot Deformity: A Case-Control Study. J Bone Joint Surg. 2019;101(20):1838–44.
15. Probasco W, Haleem AM, Yu J, Sangeorzan BJ, Deland JT, Ellis SJ. Assessment of Coronal Plane Subtalar Joint Alignment in Peritalar Subluxation via Weight-Bearing Multiplanar Imaging. Foot Ankle Int. 2015;36(3):302–9.
16. Barbachan Mansur NS, Lalevee M, Maly C, Dibbern K, Lee HY, Godoy-Santos AL, et al. Association Between Middle Facet Subluxation and Foot and Ankle Offset in Progressive Collapsing Foot Deformity. Foot Ankle Int. 2021;10711007211040820.
17. Lalevée M, Barbachan Mansur NS, Rojas EO, Lee HY, Ahrenholz SJ, Dibbern KN, et al. Prevalence and pattern of lateral impingements in the progressive collapsing foot deformity. Arch Orthop Trauma Surg. 2021. doi: 10.1007/s00402-021-04015-7.
18. Saltzman CL, Brandser EA, Anderson CM, Berbaum KS, Brown TD. Coronal Plane Rotation of the First Metatarsal. Foot Ankle Int. 1996;17(3):157–61.
19. Schmidt E, Silva T, Baumfeld D, Dibbern K, Lee HY, Femino JE, et al. The Rotational Positioning of the Bone in the Medial Column of the Foot: A Weightbearing CT Analysis. Iowa Orthop J. 2021; 41(1):103.
20. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159–74.
21. Randich JR, John KJ, Gomez K, Bush W. Frontal Plane Rotation of the First Ray in Hallux Valgus using Standing Computerized Tomography (CT). J Foot Ankle Surg. 2021;60(3):489–93.

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Original Article

Hallux valgus measurements using weight-bearing computed tomography: what changes?

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Abstract

Objective: To assess whether traditional hallux valgus (HV) measurements obtained with conventional radiography (CR) correspond to those obtained with weight-bearing computed tomography (WBCT).

Methods: In this retrospective case-control study, 26 HV feet and 20 control feet were analyzed with CR and WBCT. Hallux valgus angle (HVA), intermetatarsal angle (IMA), interphalangeal angle (IPA), distal metatarsal articular angle (DMAA), sesamoid station (SS), and first metatarsal head shape were measured. Chi-square tests were used to compare hallux valgus and control patients. T-tests were used to compare CR and WBCT. P-values less than 0.05 were considered significant.

Results: WBCT was capable of discriminating patients with HV from controls, showing higher mean values for HV patients than controls in HVA (35.29 and 9.02, p<0.001), IMA (16.01 and 10.01, p<0.001), and DMAA (18.90 and 4.10, p<0.001). When comparing the two methods, differences were not significant between CR and WBCT measurements in HVA (-0.84, p=0.79), IMA (-0.93, p=0.39), IPA (1.53, p=0.09), or SS (p=0.40), but were significant for DMAA (13.43, p<.0001). CR analysis yielded varied metatarsal head shapes, while all WBCT shape classifications were round.

Conclusion: Unidimensional HV measurements were similar between WBCT and CR, while more three-dimensional findings were not. CR may be used to assess the axial aspects of HV, but multidimensional aspects of the deformity may not be accurately assessed with plain radiographs.

Level of Evidence III; Therapeutic Studies; Retrospective Case-Control Study.

Keywords: Hallux valgus; Radiography; Weight-bearing; Computed tomography; Imaging, three-dimensional; Metatarsal bones.

Introduction

Conventional radiographs (CR) are the standard modality when evaluating patients with hallux valgus (HV)[1,2]. In the course of those evaluations, various angular measurements, including the hallux valgus angle (HVA), intermetatarsal angle (IMA), interphalangeal angle (IPA), and distal metatarsal articular angle (DMAA), are obtained[3,4]. However, such measurements are sometimes unreliable, and DMAA in particular has less than desired interobserver reliability[4-6]. In addition to poor reliability, it is possible these estimates may stray significantly from true values because radiographs only provide images in two dimensions[7].

Many of these radiographic findings and values are used to address possible etiology, grade the deformity, and plan its surgical treatment[8]. The shape of the metatarsal head (round, chevron, or flat) and the presence of an abnormal DMAA are associated with the pathogenesis of hallux valgus[9-11]. The degree of HVA, IMA, and displacement of sesamoids are used in deformity classifications and treatment algorithms[1,12]. Surgical planning is largely based on angular or radiographic unidimensional findings, and deformity recurrence is associated with an inability to correct abnormal angular findings[13]. For example, HVA as measured with plain radiographs has been found to be a major predictor of successful hallux valgus correction[14,15].

Study performed at the University of Iowa Department of Orthopedics and Rehabilitation, Iowa City, Iowa, USA.

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Weight-bearing computed tomography (WBCT) inherently provides images in three dimensions, and so may offer a more complete way to assess patients with HV and other foot and ankle conditions[16,17]. The objective of this study was to compare traditional HV imaging measurements (HVA, IMA, DMMA, head shape, IPA, and sesamoid station [SS]) obtained via CR versus measurements obtained with WBCT. We hypothesized that unidimensional parameters such as HVA, IMA, IPA, and SS would be similar between the two methods, while three-dimensional findings such as DMMA and the shape of the metatarsal head would demonstrate significant differences.

METHODS

Design

This study was approved by the University of Iowa's IRB (#202012422) and complied with the Health Insurance Portability and Accountability Act (HIPAA) and the Declaration of Helsinki. Full weight-bearing radiographs and weight-bearing CTs were taken of HV patients and controls. Patients were enrolled at the University of Iowa's Department of Orthopedics and Rehabilitation from January 2017 to November 2020. Included patients were 18 years of age or older with a diagnosis of HV and matched with control patients. Controls were selected for having HVA <15° and no complaints on the forefoot. Patients were excluded from the control group if they had existing foot deformities or any incidental findings of disease on the forefoot.

Subjects

A total of 19 patients with HV were enrolled (median age 53.79 years, range 18-92, SD 8.09), for a total of 26 feet imaged via radiography and WBCT. The HV patients were 89% female, 11% male, and had a median BMI of 29.60 (SD 5.50). The control group was composed of 16 patients (median age 38.18 years, range 17-71, SD 16.37), for a total of 20 imaged feet. Median control BMI was 30.98 (SD 8.29).

Imaging

Standard bilateral weight-bearing conventional radiographs were taken in anteroposterior, lateral, and oblique views[1]. A cone-beam CT extremity scanner (PedCAT; CurveBeam, LLC, Warrington, PA, USA) was used to take weight-bearing CT images of each foot. Each patient was instructed to stand in the scanner with their feet spaced shoulder-width apart, with even distribution of weight[18].

Radiographic Measurements

Two fellowship-trained, board-certified orthopedic foot and ankle surgeons performed all measurements. HVA, IMA, DMAA, IPA, and sesamoid station (SS) were measured using anteroposterior weight-bearing radiographs (Vue PACS™, Carestream, USA). SS was measured between the medial sesamoid and the metatarsal axis using the Hardy-Clapham system[19]. Metatarsal head shape was classified through observation into 3 categories: flat, round, and chevron[9].

WBCT measurements

The same two fellowship-trained foot and ankle surgeons performed all WBCT measurements. CubeVue™ software (CurveBeam, LLC, Warrington, PA, USA), was used to analyze the images, which were converted from raw multiplanar data into sagittal, coronal, and axial plane images. Head shape, SS, HVA, IMA, IPA, and DMAA were recorded in the axial plane[1,12,16, 19-21].

The metatarsal and phalanx axes were established in the axial plane, and angular measurements were performed using the Cobb method[16,22]. The most medial and the most lateral articular voxel of the metatarsal head were used to establish the DDMA[23] (Figure 1).

Statistical Analysis

Interobserver reliability was calculated with intraclass correlation coefficients (ICCs) for continuous data and Cohen's kappa for categorical data. Descriptive statistics including mean, median, range, interquartile range (IQR), standard deviation and error, and 95% confidence intervals were calculated for each measurement. The Shapiro-Wilk test was used to evaluate normality. One-way ANOVA was used to compare the means of normally distributed variables, while nonparametric Wilcoxon tests were used for non-normally distributed variables. T-tests were used to compare measurements between CR and WBCT. Chi-square tests were used to evaluate differences between HV and control patients. P-values less than 0.05 were considered significant.

Results

Interobserver reliability was generally high. The ICC was 0.91 for HVA measured via CR and 0.98 for HVA measured via WBCT. ICC was 0.89 for IMA as measured by both radiograph and WBCT. For DMAA, the ICC was 0.83 and 0.72 using CR and WBCT, respectively. Additionally, ICC for IPA was 0.80 as measured by plain radiography and 0.77 as measured by WBCT. For sesamoid station, Cohen's kappa was calculated to be 0.70 with CR and 0.75 with WBCT (Figure 2).

Using WBCT scans, readers were able to accurately discern HV patients from controls without HV (Figure 3). Using WBCT, the mean HVA in HV patients was 35.29° compared to 9.02° for control patients ($p<0.001$). IMA was also significantly greater in HV patients compared to controls (mean 16.01° and 10.01° respectively, $p<0.001$). A significant difference was detected for IPA (mean 5.87° for HV patients and 11.19° for controls, $p<0.001$). DMAA was found to be significantly greater in HV patients than controls (mean 18.90° *vs* 4.10°, $p<0.001$). SS was also significantly different in HV patients compared to controls ($p<0.001$).

Comparing CR and WBCT, some angles were similar and others were significantly different (Figure 4). For pooled HV and control patients, similarities were seen between HVA measured by radiography and HVA measured by WBCT (mean difference = -0.84, p=0.79, CL = -6.40, 4.73). For pooled HV and control patients, similarities were also seen in IMA

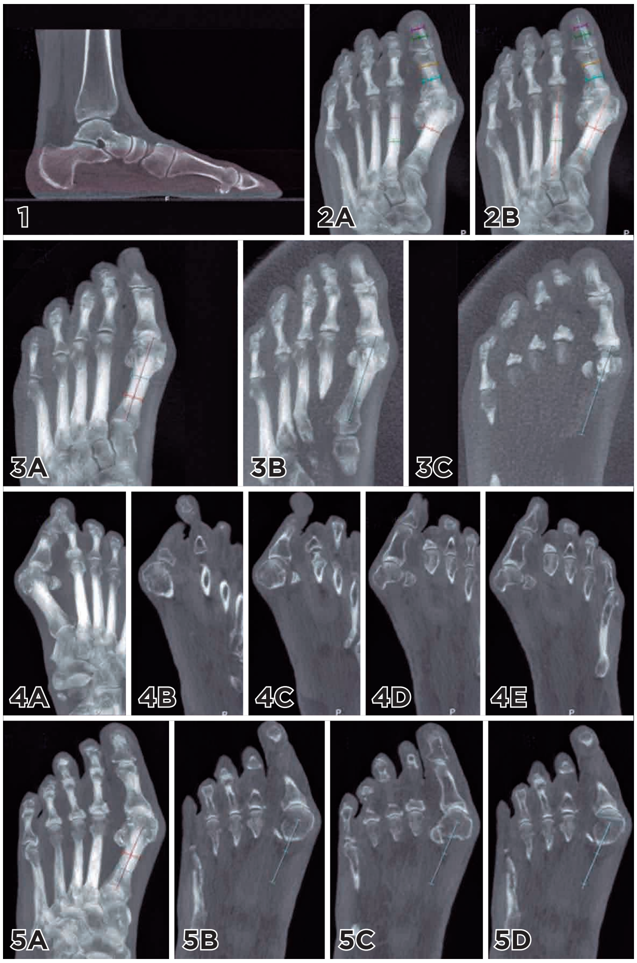

Figure 1. Sequence of hallux valgus angles measurements using weight-bearing computed tomography (WBCT). Panel 1 demonstrates the increase (approximately 29.5 mm) of the slab (cut thickness) used to find bone axes when the visualization is changed to the axial window. Panel 2 shows measurements of traditional hallux valgus angles: intermetatarsal angle (IMA), hallux valgus angle (HVA), and interphalangeal angle (IPA). The thicker slab is used to find the metatarsal and phalanxes (2A) axes, followed by angular calculations (2B). Hardy and Clapham assessment on WBCT is shown on panel 3, where a thicker slab is used the find the first metatarsal axis (3A), and the exact point where this axis crosses the medial sesamoid is observed by moving inferiorly (3B), portraying the amount of dislocation presented (3C). Panel 4 illustrates how the first metatarsal head shape is evaluated under WBCT, decreasing the slab (4A to 4B) to its standard cut thickness (0.37 mm) and observing the entire head diameter from dorsal (4B | 4C) to plantar (4D | 4E). After finding the first metatarsal axis (5A) with the thicker slab, the cut is reduced to its standard value. The distal metatarsal articular angle (DMAA) is obtained, as shown in panel 5. The most medial (5B) and lateral (5C) articular points of the first metatarsal head are attained using all WBCT axial cuts. The complementary angle between the line connecting these two points and the first metatarsal axis represents the DMAA (5D).

Figure 2. Example of the measured variables in a hallux valgus patient using conventional weight-bearing radiographs and weight-bearing computed tomography (WBCT). Traditional hallux valgus angles, such as hallux valgus angle (HVA), intermetatarsal angle (IMA) and interphalangeal angle (IPA) assessed on radiographs (A) and WBCT (B). Shape of the first metatarsal head on radiographic (C) and tomographic (D) analysis. Measurement of the distal metatarsal articular angle (DMAA) using radiographs (E) and WBCT (F). Finally, the sesamoid station calculated under a radiographic view (G) and a weight-bearing computed tomography view (H).

(mean difference = -0.93, p=0.39, CL = -2.89, 1.02) and IPA (mean difference = 1.53, p=0.09, CL = -0.48, 3.53). SS was also similar when using WBCT in comparison to CR (p=0.40). However, DMAA measurements were found to be significantly different in the pooled patient population between WBCT and CR (score mean difference = 13.43, p<.0001, CL = 9.00, 18.30).

For HV patients, 65.4% of metatarsal head shapes were classified as round and 34.6% as chevron. For control patients, 50% of metatarsal head shapes were classified as round, 45% were classified as chevron, and 5% were classified as flat. In contrast, for both patient populations 100% of WBCT classifications of metatarsal head shape were round (Figure 3). Correlation analysis (r) was also performed between angles measured by radiograph and angles by WBCT. The coefficients were r=0.97 for HVA, r=0.88 for IMA, r=0.51 for IPA, and r=0.61 for DMAA.

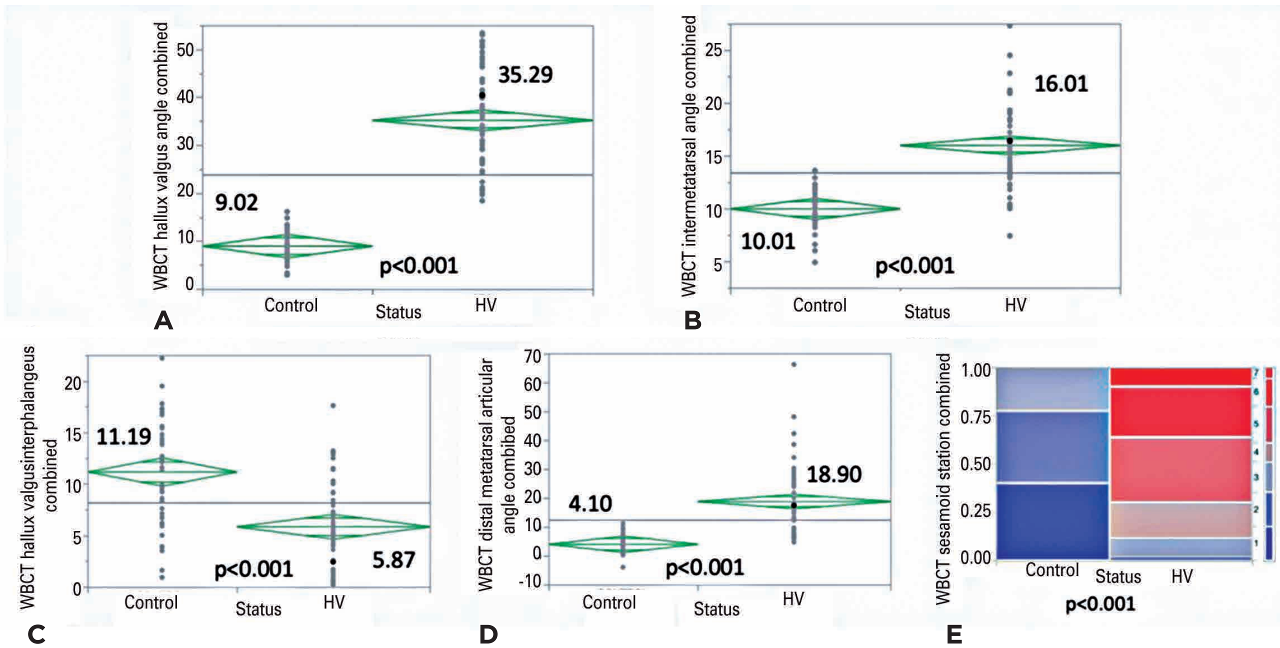

Figure 3. Comparison of hallux valgus patients and control patients using measurements from weight-bearing computed tomography (WBCT). Mean values for each measurement are given. A) Hallux valgus angle (HVA), B) intermetatarsal angle (IMA), C) hallux valgus interphalangeous angle (HVIP or IPA), D) distal metatarsal articular angle (DMAA), and E) sesamoid station (SS).

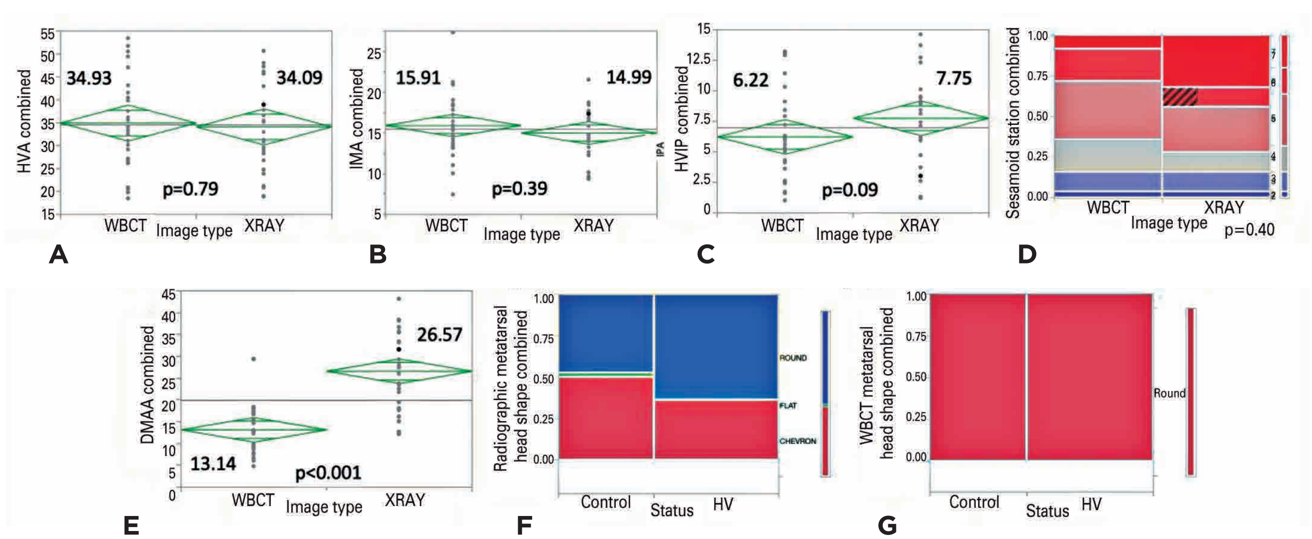

Figure 4. Comparison of hallux valgus measurements obtained from weight-bearing computed tomography (WBCT) and conventional radiography (CR) for the combined hallux valgus and control patient population. Mean values for each measurement are given. A) Hallux valgus angle (HVA), B) intermetatarsal angle (IMA), C) hallux valgus interphalangeal angle (HVIP or IPA), D) sesamoid station (SS), E) distal metatarsal articular angle, F) metatarsal head shape measured by CR, and G) metatarsal head shape measured by WBCT.

Discussion

Hallux valgus is one of the most common problems seen and addressed by foot and ankle surgeons. HVA, IMA, and a number of other important metrics are used in the diagnosis, surgical planning, and postoperative analysis of HV, and so accurate measurement of these parameters is important. Therefore, this retrospective study aimed to compare such parameters as measured by conventional weight-bearing radiographs with those obtained with weight-bearing computed tomography (WBCT).

Reliability was good for both radiography and WBCT across the overall patient population enrolled in the study. WBCT was found to be more reliable than CR between observers for HVA and SS, equivalent in reliability for IMA, and less reliable for DMAA and IPA. Since many clinicians may not have access to WBCT, the solid reliability of CR for most measurements is helpful for the assessment and treatment of HV. Considering that WBCT and CR operate in different dimensions, it is unsurprising that reliabilities varied depending on the specific measurement.

As was hypothesized, for some parameters (HVA, IMA, IPA, and SS), radiographic measurements were comparable to WBCT. This aligned with the findings of Mahmoud et al.[16] Based on this study's findings, and the fact that these measurements assess a unidimensional aspect of the deformity, there should be a high degree of comparability between CR and WBCT measurements. It appears that the two methods can be used interchangeably when evaluating HVA, IMA, IPA, and SS.

However, there was a statistically significant difference between the radiographically derived measurements of DMAA and those obtained from WBCT. This may be explained by the more three-dimensional nature of the DMAA angle, as well as the fact that DMAA varies with first metatarsal axial rotation and inclination[8]. Given the observed discrepancy, use of DMAA in clinical practice may necessitate WBCT imaging rather than CR. Similarly, there was a stark difference between metatarsal head shape as measured with radiography versus WBCT. When measured with radiography, there were a variety of head shape classifications, yet when using WBCT all head shapes were found to be round across both HV patients and controls. WBCT shows the true shape of the metatarsal head more than radiography does, and so this finding implies that head shape may not be a strong etiological factor, in contrast to what some authors have indicated in the past[9-11]. DMAA and head shape are three-dimensional parameters, and as a result may be greatly influenced by factors like the position of the foot, the inclination of the metatarsal, and rotation.

This study has several limitations that must be addressed. First, it was a retrospective analysis, and is thus subject to inherent bias. Functional evaluation was not performed, which hinders the possibility of associating clinical symptoms and radiographic aspects of hallux valgus. Proximal features of the deformity at the tarsometatarsal and naviculocuneiform joints were not tested. Angles assessing the rotation of the metatarsal or the sesamoids were not considered in this study, since the inability of radiographs to estimate true values is already known[24,25]. Although healthy controls with an absence of foot deformities were included, they were not volunteers. Further, although statistical differences were found, no sample size calculation or power analysis was performed.

Conclusion

HV values obtained with WBCT had good reliability. Indirect unidimensional radiographic measurements of HVA and IMA are not significantly different from HVA and IMA measurements obtained with WBCT. This may support the use of CR to address the disease's axial components. However, the measurement of DMAA changed significantly between radiographs and WBCT, which might pose a challenge to providers when assessing this aspect of the deformity.

Authors' contributions: Each author contributed individually and significantly to the development of this article: SB *(https://orcid.org/0000-0001-8381-1455) Interpreted the results of the study, bibliographic review, wrote the paper, formatting of the article, participated in the reviewing process, approved the final version; NSBM *(https://orcid.org/0000-0003-1067-727X) Conceived and planned the activities that led to study, participated in the review process, approved the final version; VM *(https://orcid.org/0000-0002-8612-5941) Participated in the review process, approved the final version; KAMC *(https://orcid.org/0000-0003-1082-6490) Participated in the review process, approved the final version; KD *(https://orcid.org/0000-0001-5404-2132) Bibliographic review, participated in the review process, approved the final version; CASN *(https://orcid.org/0000-0002-9286-1750) Bibliographic review, approved the final version; ML *(https://orcid.org/0000-0001-5058-8867) Participated in the review process, approved the final version; CCN *(https://orcid.org/0000-0002-9286-1750) Conceived and planned the activities that led to the study, performed the surgeries, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Coughlin MJ, Jones CP. Hallux valgus: demographics, etiology, and radiographic assessment. Foot Ankle Int. 2007;28(7):759-77.
2. Coughlin MJ, Kaz A. Correlation of Harris mats, physical exam, pictures, and radiographic measurements in adult flatfoot deformity. Foot Ankle Int. 2009;30(7):604-12.
3. Coughlin MJ, Freund E. The reliability of angular measurements in hallux valgus deformities. Foot Ankle Int. 2001;22(5):369-79.
4. Lee KM, Ahn S, Chung CY, Sung KH, Park MS. Reliability and relationship of radiographic measurements in hallux valgus. Clin Orthop Relat Res 2012;470(9):2613-21.
5. Vittetoe DA, Saltzman CL, Krieg JC, Brown TD. Validity and reliability of the first distal metatarsal articular angle. Foot Ankle Int. 1994;15(10):541-7.
6. Chi TD, Davitt J, Younger A, Holt S, Sangeorzan BJ. Intra-and inter-observer reliability of the distal metatarsal articular angle in adult hallux valgus. Foot Ankle Int. 2002;23(8):722-6.
7. Robinson AH, Cullen NP, Chhaya NC, Sri-Ram K, Lynch A. Variation of the distal metatarsal articular angle with axial rotation and inclination of the first metatarsal. Foot Ankle Int. 2006;27(12):1036-40.

8. Perera AM, Mason L, Stephens MM. The pathogenesis of hallux valgus. J Bone Joint Surg Am 2011;93(17):1650-61.
9. Ferrari J, Malone-Lee J. The shape of the metatarsal head as a cause of hallux abductovalgus. Foot Ankle Int. 2002;23(3):236-42.
10. Piggott H. The natural history of hallux valgus in adolescence and early adult life. J Bone Joint Surg Br 1960;42(4):749-60.
11. van Deventer SJ, Strydom A, Saragas NP, Ferrao PNF. Morphology of the first metatarsal head as a risk factor for hallux valgus interphalangeus. Foot Ankle Surg. 2020;26(1):105-9.
12. Shi GG, Whalen JL, Turner NS 3rd, Kitaoka HB. Operative Approach to Adult Hallux Valgus Deformity: Principles and Techniques. J Am Acad Orthop Surg. 2020;28(10):410-8.
13. Hagio T, Yoshimura I, Kanazawa K, Minokawa S, Ishimatsu T, Nagatomo M, et al. Risk factors for recurrence of hallux valgus deformity after minimally invasive distal linear metatarsal osteotomy. J Orthop Sci. 2021:S0949-2658(20)30379-1.
14. Deenik AR, de Visser E, Louwerens JW, de Waal Malefijt M, Draijer FF, de Bie RA. Hallux valgus angle as main predictor for correction of hallux valgus. BMC Musculoskelet Disord. 2008;9(1):1-6.
15. Okuda R, Kinoshita M, Yasuda T, Jotoku T, Shima H, Takamura M. Hallux valgus angle as a predictor of recurrence following proximal metatarsal osteotomy. J Orthop Sci. 2011;16(6):760-4.
16. Mahmoud K, Metikala S, Mehta SD, Fryhofer GW, Farber DC, Prat D. The role of weightbearing computed tomography scan in hallux valgus. Foot Ankle Int. 2021;42(3):287-93.
17. Lalevée M, Barbachan Mansur NS, Lee HY, Maly CJ, Iehl CJ, Nery C, Lintz F, de Cesar Netto C. Distal Metatarsal Articular Angle in Hallux Valgus Deformity. Fact or Fiction? A 3-Dimensional Weightbearing CT Assessment. Foot Ankle Int. 2021; 13:10711007211051642.
18. Mansur NSB, Lalevee M, Schmidt E, Dibbern K, Wagner P, Wagner E, et al. Correlation between indirect radiographic parameters of first metatarsal rotation in hallux valgus and values on weight-bearing computed tomography. Int Orthop. 2021;45(12):3111-8.
19. Hardy RH, Clapham JC. Observations on hallux valgus; based on a controlled series. J Bone Joint Surg Br. 1951;33-B(3):376-91.
20. Wagner P, Wagner E. Is the Rotational Deformity Important in Our Decision-Making Process for Correction of Hallux Valgus Deformity? Foot Ankle Clin. 2018;23(2):205-17.
21. Coughlin MJ, Saltzman CL, Nunley JA 2nd. Angular measurements in the evaluation of hallux valgus deformities: a report of the ad hoc committee of the American Orthopaedic Foot & Ankle Society on angular measurements. Foot Ankle Int. 2002;23(1):68-74.
22. Apostle KL, Coleman NW, Sangeorzan BJ. Subtalar joint axis in patients with symptomatic peritalar subluxation compared to normal controls. Foot Ankle Int. 2014;35(11):1153-8.
23. Day J, de Cesar Netto C, Richter M, Mansur NS, Fernando C, Deland JT, et al. Evaluation of a Weightbearing CT Artificial Intelligence-Based Automatic Measurement for the M1-M2 Intermetatarsal Angle in Hallux Valgus. Foot Ankle Int. 2021;42(11):1502-9.
24. Sadamasu A, Yamaguchi S, Kimura S, Ono Y, Sato Y, Akagi R, et al. Influence of foot position on the measurement of first metatarsal axial rotation using the first metatarsal axial radiographs. J Orthop Sci. 2020;25(4):664-70.
25. Yildirim Y, Cabukoglu C, Erol B, Esemenli T. Effect of metatarsophalangeal joint position on the reliability of the tangential sesamoid view in determining sesamoid position. Foot Ankle Int. 2005;26(3):247-50.

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Case Report

Tendoscopic treatment of acute posterior tibial tendon dysfunction: case report

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Abstract

We present a case of a rheumatoid patient presenting with acute signs of posterior tibial tendon dysfunction (PTTD). Magnetic resonance imaging (MRI) results were inconclusive regarding the grade of posterior tibial tendon (PTT) tear.

We performed posterior tibial tendoscopy, releasing all tendon adherences, and accomplished complete synovectomy. By the end of the procedure, we observed PTT integrity, normal excursion, and mild tendinosis.

At 24-month follow-up, the Visual Analog Scale for pain (VAS-Pain) decreased from 9 (preoperatively) to 1. The Foot and Ankle Outcome Score (FAOS) increased from 16% (preoperatively) to 94%. Clinically, the patient had a symmetric bilateral heel rise test and no pain over the course of the PTT. A standard radiographic assessment demonstrated a normal foot arch and hindfoot alignment.

This report illustrates how posterior tibial tendoscopy can simultaneously provide accurate diagnosis and surgically address acute PTTD on a rheumatoid patient, relieving symptoms and improving midterm clinical scores.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Posterior tibial tendon dysfunction; Endoscopy; Treatment outcome.

Introduction

The posterior tibial tendon (PTT) is commonly affected in chronic rheumatoid arthritis (RA)[1-3]. Chronic inflammation causes tenosynovitis, chronic tendinosis, and partial or complete rupture, which can lead to flatfoot[1-4]. The diagnosis of posterior tibial tendon dysfunction (PTTD) is based on clinical findings together with a radiographic assessment, initially with standard weight-bearing anteroposterior (AP) and lateral radiographs of the foot and ankle, combined with a long axial view for assessing hindfoot alignment[2-4]. Magnetic resonance imaging (MRI) can provide further information on the severity of PTT damage, but its sensibility is commonly affected by chronic local inflammation, as observed in RA[3,4].

Failure of conservative treatment of acute PTTD in patients with RA prompts surgical treatment, which is classically performed by an open approach, with tendon debridement and direct repair, if necessary[4,5]. Posterior tibial tendoscopy presents a less invasive endoscopic alternative to traditional open surgery or steroid injections, with potential benefits that include decreased postoperative pain and fewer postoperative complications such as wound infection or scar contracture[6-10].

We present a case of a patient with a clinical and radiological suspicion of high-grade partial-thickness tear of the PTT, describing the endoscopic approach for diagnosis and treatment, as well as clinical and radiographic outcomes at 2 years follow-up. The patient provided informed consent for the publication of this report.

Case description

A 68-year-old male patient with long-standing RA was referred to our institution after a gradual onset of pain and swelling of his right ankle over the previous 4 weeks. He did not report prior direct or indirect trauma of his foot or ankle. He had a normal foot arch, no clinical hindfoot valgus, and the bilateral heel rise test demonstrated that he was unable to

Study performed at the Hospital da Prelada, Porto, Portugal.

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invert his right heel. This failure to invert on the heel rise test, on a normally aligned foot and ankle, was an important sign that the PTT was not ruptured and that the intense pain over its course was what probably limited normal foot movement. MRI results demonstrated a large amount of effusion, PTT tenosynovitis, and a suspected high-grade partial-thickness tear (Figure 1). Failure of a 2-week attempt at conservative treatment with oral medication, rest, cryotherapy, and a foot orthosis led to the decision to proceed with surgical treatment.

Posterior tibial tendoscopy was performed with the patient in the supine position under regional anesthesia with a tight tourniquet, as described by van Dijk et al.[8] The distal portal was placed 2 centimeters distal and anterior to the medial malleolar tip, just proximal and above the insertion of the PTT on the navicular bone. After opening the PTT sheath, a 2.7mm 30-degree arthroscope (Dyonics; Smith & Nephew, Memphis, TN) was introduced under 30mmHg fluid pressure. The second portal was placed under direct visual control (Figure 2A). PTT tenosynovitis and adherences to the tendon sheath were documented. We performed thorough debridement, complete synovectomy, and release of tendon adherences with a 2.5mm arthroscopic synovial shaver blade (Smith & Nephew, Memphis, TN) (Figure 2B). By the end of the procedure, we observed a PTT integrity of at least 50% of its thickness, with mild tendinosis and normal excursion (Figure 2C).

After surgery, protected weightbearing with a walking boot and crutches was prescribed for 2 weeks, with analgesics and anticoagulants. At 2 weeks, we proceeded with suture removal and allowed progressive weightbearing, together with a dedicated physiotherapy regimen for 6 weeks.

The pain level was measured using the Visual Analog Scale for pain (VAS-Pain), which ranges from 0 (no pain) to 10 (maximum pain). Functional evaluation was performed using the Foot and Ankle Outcome Score (FAOS), comprising 42 questions and 5 subscales: pain, symptoms, quality of life, daily activities, and sport activities. This score ranges from 0 to 100 and higher scores indicate better clinical outcomes.

At 24-month follow-up, the VAS-Pain decreased from 9 (preoperatively) to 1. The FAOS increased from 16% (preoperatively) to 94%, scoring zero on all items of the quality of life subscale. The patient progressively returned to his normal routine and only reported slight pain over the course of the PTT. No swelling was observed on the medial retromalleolar region of the ankle, the foot had a normal arch, and he had a positive, symmetric bilateral heel rise test (Figures 3A and 3B). Weight-bearing AP and lateral radiographs of the foot and ankle, as well as a long axial view, demonstrated normal foot arch and hindfoot alignment (Figures 4A and B).

Figure 1. Axial proton-density weighted MRI revealing a large amount of effusion, tenosynovitis, and a suspected high-grade partial-thickness tear of the PTT.

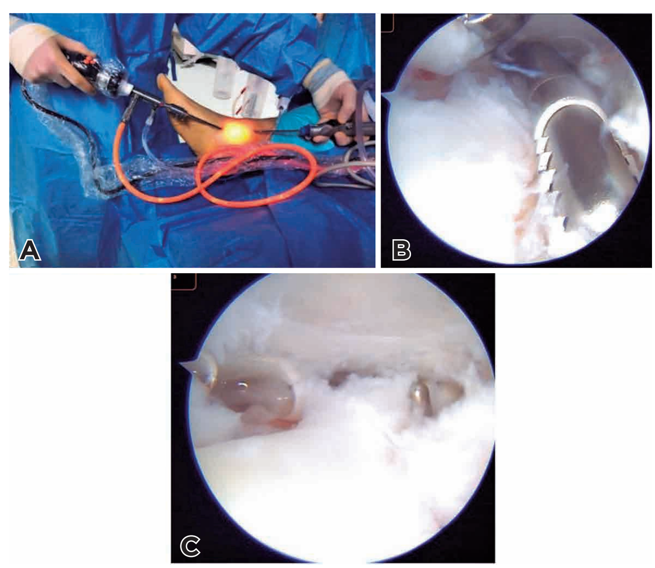

Figure 2. A) Posterior tibial tendoscopy of the right foot with the arthroscope placed in the distal portal and the arthroscopic synovial shaver blade placed in the proximal portal; B) intraoperative image documenting synovectomy and release of tendon adherences with a 2.5mm arthroscopic synovial shaver blade; C) PTT integrity of at least 50% of its thickness, with mild tendinosis and normal excursion with the arthroscopic probe.

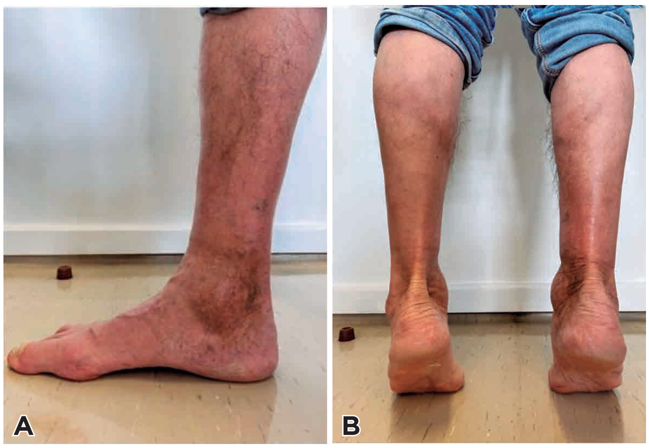

Figure 3. Two-year postoperative images of the right foot and ankle demonstrating A) a normal arch and no swelling on the medial retromalleolar region of the ankle and B) a symmetric bilateral heel rise test.

Figure 4. A) Weightbearing lateral and B) long axial view radiographs of the foot and ankle, demonstrating a normal foot arch and hindfoot alignment.

Discussion

RA is a chronic inflammatory disease that can lead to acute or chronic joint and tendon pathologies[1,2]. PTT is often involved in RA and, in a recent publication by Harman et al., posterior tibial tenosynovitis was demonstrated to be significantly more prevalent in rheumatoid patients than in patients with other rheumatic diseases such as gout or spondyloarthropathies[1].

In our report, we had a strong suspicion of PTT damage due to the patient's history of long-standing RA, together with clinical findings such as pain and swelling over the medial retromalleolar area combined with the patients' inability to perform the bilateral heel rise test. The presence of a normal foot arch and the absence of hindfoot valgus provided a positive outlook regarding the status of the PTT, indicating acute (and possibly revertible) PTTD. It was critical to differentiate this acute PTTD from chronic flatfoot, a condition frequently observed in rheumatoid patients[2,3]. In 1995, Michelson et al.[2] found that the combination of loss of foot arch support, lack of palpable posterior tendon, and inability to perform a single-leg heel rise were the most rigid criteria for the clinical diagnosis of PTTD in a group of 99 patients with RA.

Our initial basic radiographic assessment demonstrated a normally aligned foot and ankle. MRI results were inconclusive regarding the grade of the tear, which is a rare event when considering the high sensitivity of this examination; this was probably due to intense synovial proliferation around the PTT. Accordingly, Bouysset et al.[3] described a series of 67 rheumatoid feet and found that PTT tears were common in rheumatoid patients presenting with flat feet, but most were incomplete tears.

Classic PTT debridement through an open medial approach was proven to be a successful technique according to previous reports[4,5]. Hasler et al.[4] reported on a case of a rheumatoid patient with a high suspicion of complete PTT rupture on MRI and found an intact tendon after open synovectomy. Tokunaga et al.[5] described a series of 3 patients who underwent surgery for PTTD and found that open synovectomy and release of the PTT improved ankle swelling and pain, with an increase in the American Orthopaedic Foot and Ankle Scale (AOFAS) score from a mean 58.3 to a mean 90.3 postoperatively. Despite these good results, it must be kept in mind that rheumatoid patients with a long history of systemic or local steroid application are more likely to suffer from wound healing problems when an open technique is performed, meaning that the endoscopic approach can be a better option on this particular subset of patients[2,3]. Another advantage of posterior tibial tendoscopy is that it advantageously replaces steroid injections, which can lead to tendon rupture since they promote collagen disorganization and present tenocyte toxicity[6].

Posterior tibial tendoscopy was first described by Wertheimer et al.[7] in 1995 in a case report of a tendon sheath opening through a two-incision endoscopic approach. This technique was later supported by the report of a cadaveric study and a clinical prospective study by van Dijk et al.[8] In 2014, a comprehensive review on foot and ankle tendoscopy by Cychosz et al.[9] concluded that PTT debridement and synovectomy by an endoscopic technique was a useful and safe procedure.

Posterior tibial tendoscopy was proven to be a powerful diagnostic tool by Gianakos et al.[10], who found that tendoscopy was more sensitive than MRI in PTTD diagnosis. In 2018, Bernasconi et al.[11] described surgical results of posterior tibial tendoscopy in 16 patients with stage II PTTD and found that, at 2-year follow-up, 80% of the patients were relieved from symptoms. Also in 2018, an update on tendoscopy of the Achilles, peroneal, and tibialis posterior tendons found this procedure reliable and promising for different disorders around the foot and ankle[12]. It must be stressed that, as reported, this technique is limited to cases of no or very little foot and ankle malalignment[10,11]. In presence of mechanical failure, with longitudinal arch collapse and hindfoot valgus, it is imperative to perform a bony realignment procedure. Our case is in line with these previous reports, demonstrating good results in a rheumatoid patient. Future studies with more patients could bring stronger evidence of the use of this technique on this particular set of patients.

Conclusion

This report illustrates how posterior tibial tendoscopy can simultaneously provide accurate diagnosis and surgically address acute PTTD on RA, relieving symptoms and improving midterm clinical scores.

Authors' contributions: Each author contributed individually and significantly to the development of this article: DS *(https://orcid.org/0000-0002-6178-8263) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version, performed the surgery and data collection; MK *(https://orcid.org/0000-0002-8260-9500) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; ASR *(https://orcid.org/0000-0002-9703-5589) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version, performed the surgery and data collection; TMG *(https://orcid.org/0000-0002-7199-5389) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; XMO *(https://orcid.org/0000-0003-0132-2047) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Harman H, Tekeoglu I. Ankle pathologies in patients with inflammatory rheumatic diseases: a clinical and ultrasonographic study. Int J Rheum Dis. 2017;20(6):675-84.
2. Michelson J, Easley M, Wigley FM, Hellmann D. Posterior tibial tendon dysfunction in rheumatoid arthritis. Foot Ankle Int. 1995; 16(3):156-61.
3. Bouysset M, Tebib J, Tavernier T, Noel E, Nemoz C, Bonnin M, et al. Posterior tibial tendon and subtalar joint complex in rheumatoid arthritis: magnetic resonance imaging study. J Rheumatol. 2003; 30(9):1951-4.
4. Hasler P, Hintermann B, Meier M. Posterior tibial tendon dysfunction and MR imaging in rheumatoid arthritis. Rheumatol Int. 2002; 22(1):38-40.
5. Tokunaga D, Hojo T, Takatori R, Ikoma K, Nagasawa K, Takamiya H, et al. Posterior tibial tendon tenosynovectomy for rheumatoid arthritis: a report of three cases. Foot Ankle Int. 2006;27(6):465-8.
6. Dean BJ, Lostis E, Oakley T, Rombach I, Morrey ME, Carr AJ. The risks and benefits of glucocorticoid treatment for tendinopathy: a systematic review of the effects of local glucocorticoid on tendon. Semin Arthritis Rheum. 2014;43(4):570-6.
7. Wertheimer SJ, Weber CA, Loder BG, Calderone DR, Frascone ST. The role of endoscopy in treatment of stenosing posterior tibial tenosynovitis. J Foot Ankle Surg. 1995;34(1):15-22.
8. van Dijk CN, Kort N, Scholten PE. Tendoscopy of the posterior tibial tendon. Arthroscopy. 1997;13(6):692-8.
9. Cychosz CC, Phisitkul P, Barg A, Nickisch F, van Dijk CN, Glazebrook MA. Foot and ankle tendoscopy: evidence-based recommendations. Arthroscopy. 2014;30(6):755-65.
10. Gianakos AL, Ross KA, Hannon CP, Duke GL, Prado MP, Kennedy JG. Functional Outcomes of Tibialis Posterior Tendoscopy With Comparison to Magnetic Resonance Imaging. Foot Ankle Int. 2015;36(7):812-9.
11. Bernasconi A, Sadile F, Welck M, Mehdi N, Laborde J, Lintz F. Role of Tendoscopy in Treating Stage II Posterior Tibial Tendon Dysfunction. Foot Ankle Int. 2018;39(4):433-42.
12. Bernasconi A, Sadile F, Smeraglia F, Mehdi N, Laborde J, Lintz F. Tendoscopy of Achilles, peroneal and tibialis posterior tendons: An evidence-based update. Foot Ankle Surg. 2018;24(5):374-82.

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Case Report

Inveterate adult congenital clubfoot in a patient with myelomeningocele and the Ponseti method as a choice: case report

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Abstract

The Ponseti method is currently considered the gold standard for treating congenital clubfoot, including in syndromic cases such as myelomeningocele. Its indication in neglected cases is well established in children and adolescents but remains uncertain in adult patients. We present a clinical case of a 27-year-old female patient with myelomeningocele and neglected clubfoot who was treated for the first time at this age with the Ponseti method, with good results. In developing countries, we often encounter adult patients with congenital club feet who have not had access to health care. Although the age limit to institute the Ponseti method as a therapeutic option is still unclear, it is an inexpensive, safe, accessible, and plausible option with satisfactory results even in adult, neglected, and syndromic cases.

Level of Evidence V; Diagnostic Studies; Expert Opinion.

Keywords: Clubfoot; Meningomyelocele; Manipulation, orthopedic; Ponseti technique.

Introduction

The Ponseti method[1], characterized by a gradual and progressive correction of the feet based on manipulation, serial casting, and percutaneous Achilles tenotomy, is currently considered the gold standard for treating congenital clubfoot. This method is also described as effective in cases of syndromic clubfeet, such as arthrogryposis and myelomeningocele[2].

The treatment of congenital neglected clubfoot in children and adolescents through the Ponseti method is well described in the literature[3], but the best management strategy in adult patients remains uncertain.

With this report, we aim to demonstrate a unique case of therapeutic success regarding a 27-year-old patient with myelomeningocele and neglected congenital clubfoot who was treated for the first time at this age with the Ponseti method, achieving good results.

Case description

This work was approved by the Research Ethics Committee linked to the institution's Plataforma Brasil.

We report a case of a female patient, aged 27 years, who has lower lumbar myelomeningocele and congenital clubfeet that had never been treated; she reached the health unit complaining of foot deformity, gait difficulty, and chronic cutaneous injuries on her feet that frequently turned acute.

During clinical examination, at inspection, we noticed a severe deformity of the feet characterized by ankle equinus, hindfoot varus, midfoot adductus, and severe forefoot cavus. Moreover, there were 3 pressure ulcers on the right foot, with no signs of infection at the moment. Regarding gait, patient ambulation happened with a walker, using the dorsal region of the feet for support. At palpation, no pain due to neuropathy was observed. As for mobility, important stiffness was noticed in all deformed segments of the feet, where the right

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side was stiffer than the left side. Vascular examination yielded normal results. A neurological examination demonstrated foot insensitivity and M0 motor function in all muscles going through the feet and ankles (Figure 1).

The patient underwent laboratory examinations to exclude inflammatory/infectious activity in the ulcers, with normal blood count, C-reactive protein (CRP), and erythrocyte sedimentation rate (ESR). She was also subjected to radiographs of the feet and ankles, demonstrating alterations that were compatible with bilateral cavus-adductus-varus-equinus feet, bone dysplasia, and no signs of osteomyelitis (Figure 2).

Considering the diagnosis of inveterate adult congenital neurological clubfoot, after a long conversation with the patient we proposed an attempt at a non-surgical treatment based on manipulation, serial casting, and Achilles tenotomy, as proposed by Ponseti[1].

Figure 1. Examination of the feet with and without weight bearing.

Figure 2. Anteroposterior (AP) radiograph of the ankles projecting the feet.

In May 2021, we initiated treatment according to the Ponseti method[1]. After the fifth cast, on the right side, we noticed signs of inflammation and drainage with fetid odor on the pressure ulcers when the patient underwent magnetic resonance on this side, with signs of soft tissue infection but not of bone involvement. We removed the cast and performed thorough debridement of the ulcers; samples sent for culture showed bacterial growth (*Acinetobacter*) on soft tissue fragments but not on the bone biopsy. The antibiogram indicated sensitivity to ciprofloxacin, and the patient used this medication for 2 weeks (intravenously for 1 week, under hospitalization, and orally for 1 week at home). During this period, a new cast was made, with openings around the ulcers for daily dressing changes. The ulcers healed completely in 2 weeks.

The correction of deformities happened progressively: with 12 serial castings on the left side and 15 on the right side, we obtained satisfactory correction of the cavus, adductus, and varus deformities, with bilateral 30-degree abduction and persistence of the equinus deformity; percutaneous Achilles tenotomy was then performed. Tenotomy was performed under local anesthesia, with only 1 cutaneous suture (Figure 3). After tenotomy, the patient remained with the cast for 3 consecutive weeks in maximum ankle dorsiflexion (Figure 4).

At 3-week follow-up after tenotomy, once the cast was removed, we noticed satisfactory correction of deformities and complete healing of the pressure ulcers. The feet were plantigrade and able to adjust to an ankle-foot orthosis (AFO) (Figure 5). At 2-month follow-up, the patient reported she was satisfied with the deformity correction, with satisfactory improvement in gait, healing of the ulcers, and a possibility of using conventional closed-toe shoes with good adjustment to the orthosis. She brought new radiographs of the feet and ankles (Figure 6).

Figure 3. Serial casting: first, third, fifth, seventh, ninth, and eleventh casts.

Figure 4. Maximum dorsiflexion of the right ankle after percutaneous Achilles tenotomy.

Figure 5. Corrected plantigrade feet adjusted to the ankle-foot orthosis (AFO).

Figure 6. AP radiograph of the feet and profile view of the feet and ankles after correction.

Discussion

Recent evidence suggests that the Ponseti method is appropriate for older patients, although the age limit for this technique is still not well established[3]. In neglected cases, the most frequently performed treatment in the present day is surgery, varying from extensive soft tissue release to complex corrections using external fixators, corrective osteotomies, and triple arthrodesis[4]. However, all these techniques are complex, expensive, and have high complication rates.

Lourenço and Morcuende[5] studied 24 neglected clubfeet in patients aged 1–9 years. They used the Ponseti method with minimal modifications. One of them was the duration of manipulation in each session, varying from 5 to 10 min; this differed from the shorter time used with smaller children. This longer manipulation period allowed a more effective stretching of soft tissues, which are less elastic. In our case report, considering an adult patient with no previous treatment, we also used longer manipulation periods in each session for achieving increased stretching of soft tissues.

In the same study by Lourenço and Morcuende[5], casts were changed every 2 weeks, as opposed to the weekly method originally proposed by Ponseti, in order to provide more time for remodeling in neglected cases. In this case report, however, weekly cast changes were maintained because neuropathic feet may present blisters and ulcers, thus a shorter interval between cast changes was defined. Weekly cast changes were also reported by Khan and Kumar[6] and Haje[7].

Due to 2 well-established reasons (neglected and syndromic feet), the number of casts used in this case was larger than that described by Ponseti. In a study by Gerlach et al.[8], which assessed the Ponseti method in clubfeet of patients with myelomeningocele, one of the reported differences was the larger number of casts when compared with idiopathic cases. A study by Sinha et al.[9] also reported a higher number of casts for achieving maximum correction in neglected cases when they treated 30 patients aged 1-10 years. They observed that the older the patient, the larger the number of casts required. These findings are in accordance with our report, where we treated a neglected and syndromic case and required more casts for obtaining maximum correction: 12 for the left foot and 15 for the right foot.

Another noteworthy finding is the maximum abduction achieved by these neglected feet before percutaneous Achilles tenotomy. In studies by Sinha et al.[9] and Lourenço and Morcuende[5], patients achieved up to 40 degrees of foot abduction, unlike the 70 degrees of abduction originally described by Ponseti. This limitation in abduction was also noticed in this report: when patients reached 30 degrees of abduction (maximal value), we performed percutaneous Achilles tenotomy.

Regarding the type of orthosis prescribed after the 3 weeks following Achilles tenotomy, whether a Dennis Browne foot abduction orthosis or a rigid AFO, the literature presents no consensus when considering syndromic and neglected cases. In studies by Sinha et al.[9], Khan and Kumar[6], and a report by Haje[7], the abduction orthosis was chosen in protocols described by Ponseti. In the study by Lourenço and Morcuende[5], however, an AFO was recommended, since although blisters and ulcers may happen in idiopathic and non-idiopathic clubfeet, patients with myelomeningocele have higher chances of problems due to their sensory deficit[9].

According to a systematic review published in 2017 by Digge et al.[3], some aspects should be better elucidated for clearly defining the age limit for successfully applying the Ponseti method: larger studies with longer follow-up, well-established inclusion and exclusion criteria, clarity when describing modifications in the technique, type of cast (long or short), cast duration, tenotomy vs stretching of the Achilles, and type of orthosis used.

Although our follow-up was short, the main goal of this report is to state that an adult with neglected congenital syndromic clubfoot may be treated with a non-surgical alternative such as the Ponseti method, reaching satisfactory results.

Conclusion

In developing countries, we frequently find adult patients with congenital clubfeet that have not had access to treatment. Although the age limit for instituting the Ponseti method as therapeutic option is still obscure, this is an inexpensive, safe, and accessible option that could achieve satisfactory results even in adult, neglected, and syndromic cases.

Author's contributions: The author contributed individually and significantly to the development of this article: EASJ *(https://orcid.org/0000-0002-5054-874X) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version. The author read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Ponseti IV. Treatment of congenital club foot. J Bone Joint Surg Am. 1992;74(3):448-54.
2. Matar HE, Beirne P, Garg NK. Effectiveness of the Ponseti method for treating clubfoot associated with myelomeningocele: 3-9 years follow-up. J Pediatr Orthop B. 2017;26(2):133-6.
3. Digge V, Desai J, Das S. Expanded Age Indication for Ponseti Method for Correction of Congenital Idiopathic Talipes Equinovarus: A Systematic Review. J Foot Ankle Surg 2018;57(1):155-8.
4. Ferreira RC, Costo MT, Frizzo GG, da Fonseca Filho FF. Correction of neglected clubfoot using the Ilizarov external fixator. Foot Ankle Int. 2006;27(4):266-73.
5. Lourenço AF, Morcuende JA. Correction of neglected idiopathic club foot by the Ponseti method. J Bone Joint Surg Br. 2007; 89(3):378-81.
6. Khan SA, Kumar A. Ponseti's manipulation in neglected clubfoot in children more than 7 years of age: a prospective evaluation of 25 feet with long-term follow-up. J Pediatr Orthop B. 2010;19(5):385-9.
7. Haje DP. Neglected Idiopathic Clubfoot Successfully Treated by the Ponseti Method: A Case Report of an Adult Patient who Started Treatment at 26 Years of Age. J Orthop Case Rep. 2020; 10(4):74-7.
8. Gerlach DJ, Gurnett CA, Limpaphayom N, Alaee F, Zhang Z, Porter K, et al. Early results of the Ponseti method for the treatment of clubfoot associated with myelomeningocele. J Bone Joint Surg Am. 2009;91(6):1350-9.
9. Sinha A, Mehtani A, Sud A, Vijay V, Kumar N, Prakash J. Evaluation of Ponseti method in neglected clubfoot. Indian J Orthop. 2016; 50(5):529-35.

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Case Report

Arthroscopic treatment for posteromedial talar process fracture (Cedell fracture): a case report

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Abstract

Fracture of the posteromedial talar process (Cedell fracture) is a rare injury and is easily misdiagnosed as a simple ankle sprain. Suspicion should be heightened if specific mechanisms of injury are present, and, in these cases, a CT scan should be performed. Significant ankle pain and disability can result if these injuries are not identified and treated properly. Few cases have been described in the literature, and the efficacy of surgical techniques and approaches for fractures of the posterior talar process remains controversial. We report a 56-year-old man with an acute posteromedial talar fracture treated arthroscopically. This approach provides good access to the posterior ankle compartment, subtalar joint, and extraarticular structures, which may allow fracture reduction and fixation under arthroscopic visualization.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Talus; Fractures, bone; Arthroscopy; Fracture fixation, internal.

Introduction

Talar fractures constitute only 3%-5% of all reported foot and ankle fractures, and by far the rarest fractures are those of the posterior talar process[1]. The posterior process of the talus consists of lateral and medial tubercles, with the groove for the flexor hallucis longus (FHL) tendon located in the middle between the two tubercles. The inferior surface forms the posterior 25% of the subtalar joint, being essential for normal subtalar movement[2]. Fractures of the posterior process of the talus, and, in particular, those of the posteromedial process are extremely rare, with few cases reported in the literature[1,3,4]. The first descriptions on medial tubercle fractures are attributed to Cedell[5] in 1974. Cedell described the posteromedial tubercle fracture as an avulsion injury when the foot is pronated and is forcibly flexed dorsally, increasing tension in the posterior tibiotalar ligament[3,6]. Certain reports also indicated that this injury might occur when the supinated foot is forcefully plantarflexed[1,7]. Alternative proposed mechanisms include impingement of the sustentaculum tali and direct trauma to the posteromedial facet[3,6]. On physical examination, patients present with pain and swelling in the hindfoot, usually with pain increasing with passive extension of the big toe (positive posterior talar impingement test)[6]. Up to 40% of these fractures may be missed at initial presentation because they are rare and resemble an ankle sprain on standard radiographs[6]. Suspicion should be maintained based on specific mechanisms of injury. A CT scan should be performed to identify the fracture and assess displacement and fragment size[4,6].

Incorrect and delayed diagnosis may be responsible for painful nonunion, posterior ankle impingement, tarsal tunnel syndrome, subtalar arthritis, or FHL entrapment[2]. The choice of optimal treatment method for posteromedial talar process fractures is unclear, and depends on subtalar joint involvement, fragment size, degree of displacement, and comminution[2,6]. Various treatments for this injury are advocated in the literature: conservative treatment of minimally or nondisplaced fractures, with non-weight-bearing cast immobilization for 4 to 6 weeks; fracture excision in painful nonunion, highly comminuted fractures, or malunions causing posteromedial ankle impingement[7,8]; primary open reduction and internal fixation (ORIF), which is recommended for the majority of Cedell fractures that are less than 4 weeks old, with fracture fragments >1cm, displaced (>2mm) and with disruption of the

Study performed at the Orthopedic Surgeon, Department of Orthopedics, Hospital CUF Descobertas, Lisboa, Portugal.

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subtalar joint[6]; arthroscopic approaches for screw fixation or excision of the fragment have also been described[3,8-10]. The purpose of this article is to raise physician suspicion of this uncommon fracture and present a case of arthroscopy-assisted reduction and screw fixation of acute posteromedial talar fracture.

Case description

Ethics Committee approval and written consent from the patient were obtained for this report.

A 56-year-old male presented to our hospital complaining of right ankle pain and swelling after a fall from stairs. To his recollection, the foot was in plantarflexion and supination at the time of injury. The patient's medical and surgical history was unremarkable, and there were no previous injuries to the right lower extremity. Physical examination revealed significant swelling and severe tenderness of the ankle joint. There was no neurovascular compromise. Ecchymosis was present over the posteromedial aspect of the ankle, spreading to the foot, along the path of the FHL (Figure 1), and pain occurred behind the medial malleolus during passive motion of the hallux. Standard radiographs of the ankle raised suspicion of the presence of a small fragment on the posterior aspect of the talus (Figure 2). A CT scan of the right ankle was performed for more detailed examination and evaluation. A fracture of the posteromedial tubercle of the talus was found; the size of the fragment was approximately 2.2x0.9x1.8 cm, with a 3-mm displacement (Figure 3). A posterior hindfoot arthroscopy was performed. The patient was placed in the prone position and a tourniquet was applied to the right thigh. The procedure was performed through the posterolateral and posteromedial portals. The FHL tendon was visualized and retracted laterally to expose the posteromedial talar process and fracture (Figure 4A). The surrounding inflamed synovium was resected. The fracture was reduced and fixed with a guidewire (Figure 4B). The position of the guidewire was checked with fluoroscopy (Figure 4C-D). A cannulated screw of appropriate length was inserted (Figure 4E-F). The ankle was plantarflexed and the hallux dorsiflexed to ensure that ankle motion and sliding of the FHL were not impeded by the screw head. The position of the screw was verified by fluoroscopy (Figure 5). In the postoperative period, the foot was immobilized in a short leg cast for 4 weeks (Figure 6). At this time, the patient began physical therapy but maintained immobilization with a non-weight-bearing walking boot for an additional 6 weeks. The swelling gradually subsided, and the patient reported no pain in the ankle or during hallux dorsiflexion.

Figure 1. Patient's right foot and ankle. Swelling of the ankle joint and bruising over the posteromedial aspect of the ankle spreading to the foot, in the path of the flexor hallucis longus tendon sheath. This bruise trajectory could be a potential diagnostic sign of Cedell fracture.

Discussion

There have been few reports of Cedell fracture in the literature[3]. This fracture is most commonly described as an avulsion injury resulting from a pronation-dorsiflexion force causing tension at the insertion of the posterior talotibial ligament. Most cases have been attributed to this indirect effect[1,3,5]. Nevertheless, the injury may occur as a result of an inversion and a forced plantarflexion mechanism leading to direct compression of the posterior talus, as seems to have occurred in our patient[6,7]. This mechanism of injury on landing may explain the vertical compressive force and splitting

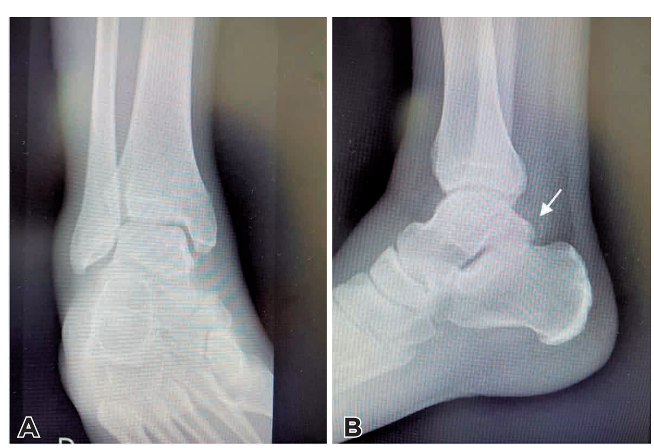

Figure 2. Preoperative A) anteroposterior and B) lateral radiographs of the right ankle, showing suspicious findings on the posteriomedial aspect of the talus (arrow).

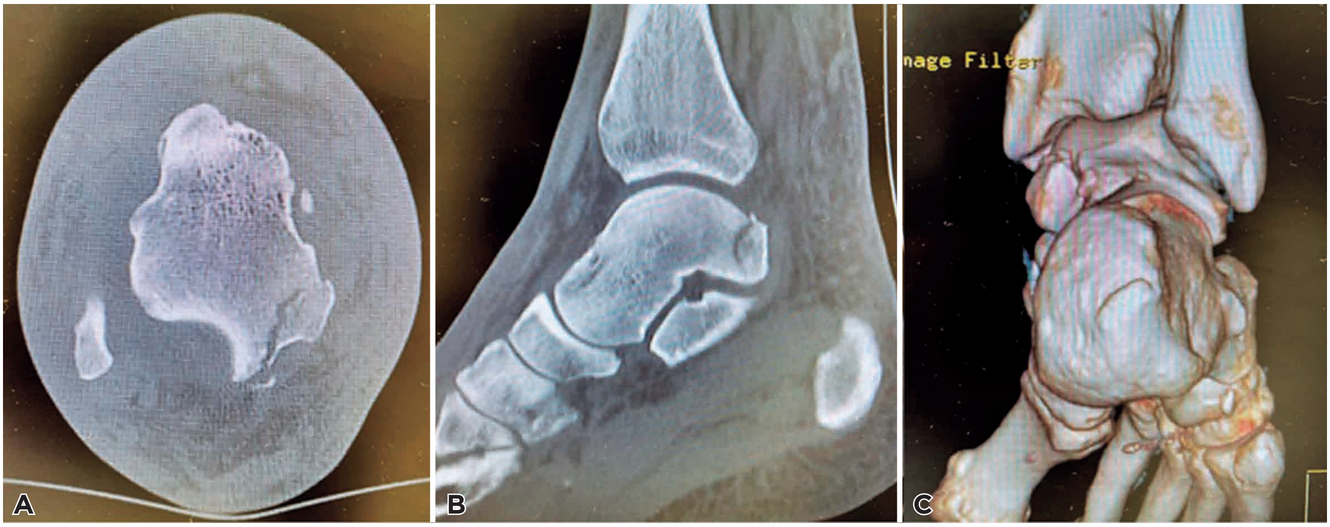

Figure 3. Preoperative computed tomography showing a displaced posteromedial talus fracture (arrow). A) Transverse view; B) sagittal view; C) 3-dimensional reconstruction.

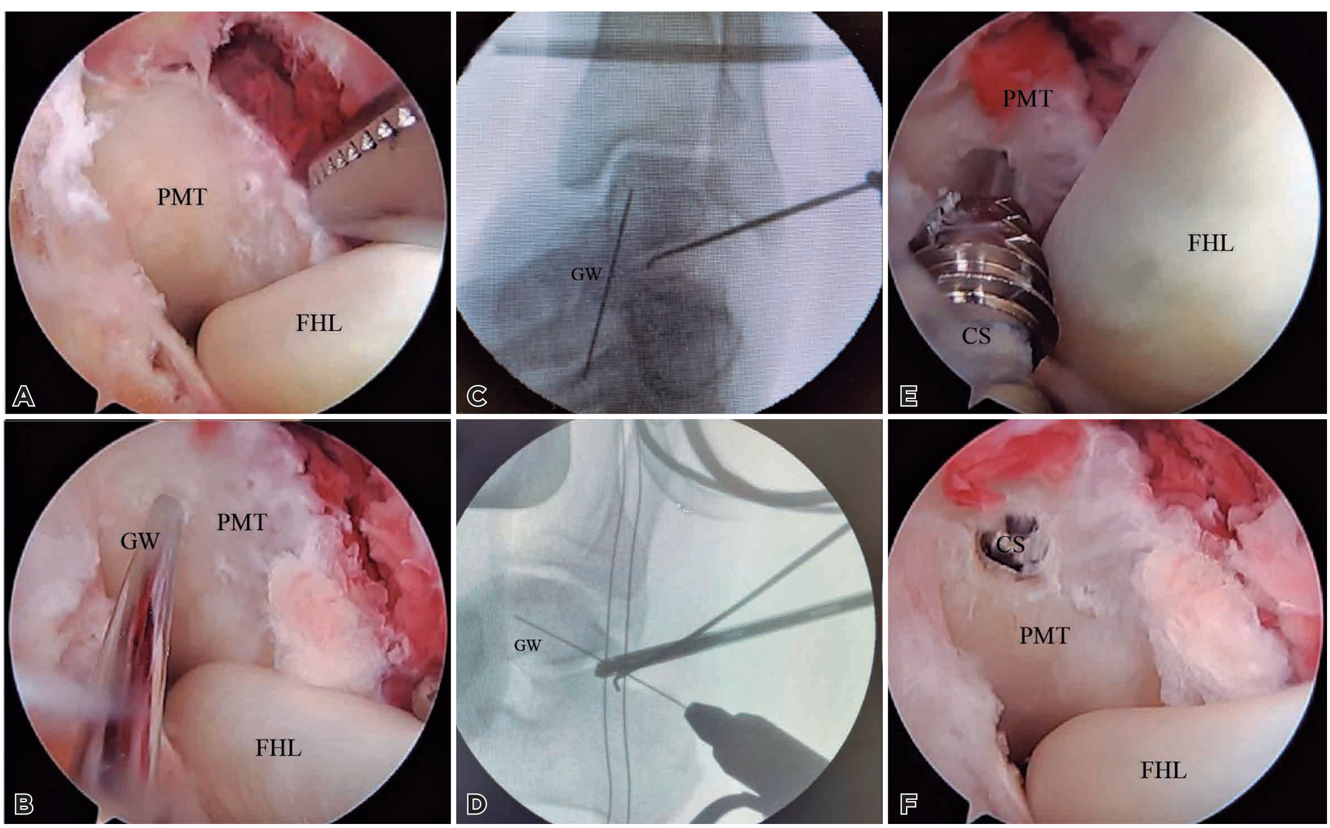

Figure 4. Endoscopically assisted reduction and screw fixation of acute fracture of the posteromedial talar process of right ankle. A) Arthroscopic view of the posteromedial talus fracture from the posterolateral portal. The FHL tendon is retracted laterally for better fracture exposure; B) Fracture reduced and temporarily fixed with a guidewire. The position of the guidewire is checked with fluoroscopy [anteroposterior view C), lateral view D)]; E,F) Placement of cannulated screw. PMT, posteromedial talar process; FHL, flexor hallucis Longus tendon; GW, guidewire; CS, cannulated screw.

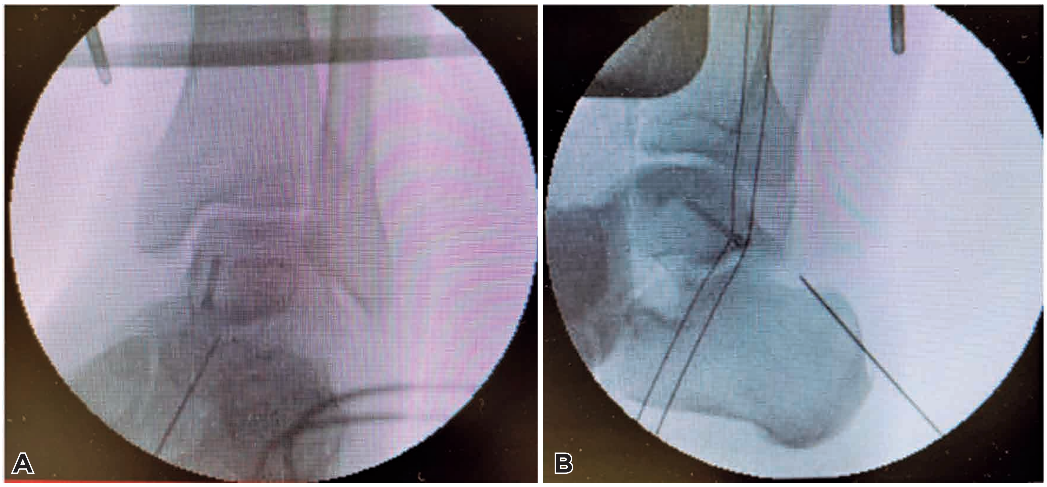

Figure 5. Endoscopically assisted reduction and screw fixation of acute fracture of the posteromedial talar process of right ankle. A) Position of the screw checked with fluoroscopy. Anteroposterior view; B) lateral view.

Figure 6. Postoperative radiographs obtained at 4-week follow-up. A) Anteroposterior and B) lateral radiographs of the right ankle.

of the posterior talar process at the base of the posteromedial tubercle in the present case. These fractures could be misdiagnosed as severe ankle sprains, mostly due to poor visualization on routine radiographs. Timely diagnosis and treatment of such an injury is of great importance in restoring subtalar joint anatomy and function, as minimal displacement can lead to posttraumatic arthritis, painful nonunion, or posterior impingement[2,8,9]. The real challenge is to choose appropriate treatment after recognizing a Cedell fracture. To the author's knowledge, and according to a recent review, there have been few descriptions of surgical techniques for this type of fracture, consisting mainly of case reports[3]. Most of these publications also lack a detailed description of the patients and their management[3,4]. In general, there are three strategies for treatment of Cedell fractures: conservative treatment with immobilization alone; excision of the fragment; or osteosynthesis, which may be performed by open or arthroscopic approaches[3,4,8-10]. The optimal treatment for fractures of the posteromedial talar process is still unclear, and depends on the fracture pattern. Large, displaced fragments with joint involvement and subtalar dislocation often result in significant incongruity of the subtalar joint and require surgical intervention[2]. Some complications, especially wound healing problems, are associated with open surgical approaches to the hindfoot due to poor blood supply in this region[10]. Minimally invasive methods have been developed to reduce surgical trauma. Nevertheless, percutaneous screw fixation can be difficult as a minimally invasive surgical approach. The posterior screw may injure the posterior subtalar joint, the FHL tendon, and the tibial neurovascular bundle[8]. The posterior arthroscopic approach is proving to be an interesting treatment alternative. To our knowledge, only a few cases are known in which a posteromedial talar fracture has been treated arthroscopically, and the majority of these are arthroscopic excision of avulsion fragments[3,8-10]. We demonstrate, in our case, that such fractures can be reduced under arthroscopic visualization and that screw insertion is facilitated by mobilization of the FHL tendon. The procedure provided excellent access to the posterior ankle compartment and a better visualization of the fracture fragments and the subtalar joint, which allowed reduction and screw fixation as well as correction of the posterior ankle impingement. The advantage of this minimally invasive technique is less soft- tissue trauma, fewer wound complications, shorter recovery time, and a better cosmetic outcome[8,9]. In our opinion, internal fixation with hindfoot arthroscopy can be a safe treatment option for posteromedial talar fracture, when performed by an experienced arthroscopist.

Conclusion

This case demonstrates that arthroscopy-assisted reduction and screw fixation is a viable alternative technique for treatment of posteromedial talar fractures.

Authors' contributions: Each author contributed individually and significantly to the development of this article: CFM *(https://orcid.org/0000-0001-8454-3050) Conceived and planned the activities that led to the paper, wrote the paper, participated in the bibliographic review, in the reviewing process, approved the final version; PANG *(https://orcid.org/0000-0002-1681-109X) Conceived and planned the activities that led to the paper, participated in the reviewing process, approved the final version; PJRSF *(https://orcid.org/000-0003-1892-8360) Conceived and planned the activities that led to the paper, performed the surgery, participated in the reviewing process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

References

1. Letonoff EJ, Najarian CB, Suleiman J. The posteromedial process fracture of the talus: a case report. J Foot Ankle Surg. 2002; 41(1):52-6.
2. Hsu AR, Scolaro JA. Posteromedial Approach for Open Reduction and Internal Fixation of Talar Process Fractures. Foot Ankle Int. 2016;37(4):446-52.
3. Zwiers R, de Leeuw PAJ, Wiegerinck EMA, van Dijk CN. Surgical treatment for posteromedial talar process fractures. Foot Ankle Surg. 2020;26(8):911-7.
4. Engelmann EWM, Wijers O, Posthuma JJ, Schepers T. Systematic review: Diagnostics, management and outcome of fractures of the posterior process of the talus. Injury. 2020;51(11):2414-20.
5. Cedell CA. Rupture of the posterior talotibial ligament with the avulsion of a bone fragment from the talus. Acta Orthop Scand. 1974;45(3):454-61.
6. Majeed H, McBride DJ. Talar process fractures: An overview and update of the literature. EFORT Open Rev. 2018;3(3):85-92.
7. Watanabe H, Majima T, Takahashi K, Kawaji H, Takai S. Split Fracture of the Posteromedial Tubercle of the Talus: Case Report and Proposed Classification System. J Foot Ankle Surg. 2017;56(1):187-90.
8. Li CHC, Lui TH. Endoscopically Assisted Reduction and Screw Fixation of Acute Fracture of the Posteromedial Talar Process (Cedell Fracture). Arthrosc Tech. 2020;9(8):e1147-e53.
9. Más Martínez J, Verdú Román C, Martínez Giménez E, Sanz-Reig J, Bustamante Suárez de Puga D, Morales Santías M. Arthroscopic Treatment of a Malunion of a Posteromedial Tubercle Fracture of the Talus. Arthrosc Tech. 2017;6(6):e2107-e10.
10. Ogut T, Seyahi A, Aydingoz O, Bilsel N. A two-portal posterior endoscopic approach in the treatment of a complex talus fracture: a case report. J Am Podiatr Med Assoc. 2009;99(5):443-6.

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Case Report

Hemophilic pseudotumor of the ankle: a case report

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Abstract

Hemophilic pseudotumors are little prevalent lesions associated with coagulation factor VIII or IX deficiency that characterizes hemophilia. Their most frequent location are regions such as hips or iliopsoas, whereas distal joints are rare locations. In the present case, we reported the development of a hemophilic pseudotumor related to a conventional anterolateral ankle arthroscopy in a patient with mild hemophilia A who required surgical management for hemophilic arthropathy.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Hemophilia A; Arthrosis; Ankle/abnormalities.

Introduction

Hemophilia A and B are X-linked inherited congenital hemorrhagic disorders characterized by factor VIII and IX deficiency. In Colombia, the 2019 prevalence was 7.5/100 000 inhabitants for hemophilia A and 1.61/100 000 inhabitants for hemophilia B[(1)].

Patients present with muscular and joint bleeding from an early age, according to disease severity. In some cases, these hemorrhagic events are associated with locally aggressive encapsulated lesions named pseudotumors, whose main control measure is preventing bleeding episodes. The location of pseudotumors is predominantly proximal and axial; thus, it is not often found in acral regions, especially when manifested in a patient with mild deficiency and related to a surgical procedure, like in the case below.

Case report

A 38-year-old patient with history of mild hemophilia A presented with trauma on the right ankle in 2013, subsequent persistent anterolateral pain on the ankle, and feeling of instability. Physical examination revealed pain during tibiotalar mobilization and limited support. Images showed osteoarthritic tibiotalar and subtalar changes and presence of an anterior osteophyte. In view of these findings, the patient underwent arthroscopy for osteophyte resection, synovectomy, and chondroplasty in June 2014, with favorable postoperative outcomes.

In 2018, the patient presented with a progressive enlarging mass at the site of the anterolateral arthroscopy, not related to trauma. Physical examination showed a 3x3cm painless soft mass not adherent to deep planes (Figure 1). Nuclear magnetic resonance imaging (Figure 2) revealed a lesion suggesting hemophilic pseudotumor, which was later resected in 2020 and had its diagnosed confirmed by a subsequent pathological examination (Figure 3).

Pathophysiology

This hematological disorder favors spontaneous bleeding or due to minimum trauma, which is usually is self-limited and is reabsorbed. Of these episodes, 80% occur in the musculoskeletal system[(2)], and the most frequent are hemarthrosis in the knee, ankle, and elbow, whereas hematomas (10% of the cases) occur in iliopsoas and vastus lateralis muscles[(3,4)].

After the first episode of hemarthrosis, the events may become persistent or recurrent, which leads to synovial membrane hypertrophy and progressive cartilage injury and is translated into hemophilic arthropathy, manifested in the second and third decade of life[(4)].

Ankle joint bleeding emerges from the second to the fifth year of life, after children start to walk[(5)], resulting in a cycle of hemarthrosis and early synovitis, which generates pain and functional limitation associated with angular deformities, especially plantar flexion ones and, later, subtalar joint misalignment and ankle valgus.

Study performed at the Hospital de San José, Fundación de Ciencias de la Salud, Bogotá, Colombia.

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Treatment of hemarthrosis

After the first manifestation of hemarthrosis, the treatment of choice is synoviorthesis at any age[5,6], with an estimated failure rate of up to 25%[7]; moreover, arthroscopic synovectomy is considered a useful alternative to reduce bleeding episodes.

Therefore, treatments of joint disease encompass from minimally invasive joint preservation procedures to cases requiring removal of the joint. Compared with other joints, the ankle presents with a higher incidence of postoperative complications after arthroscopic procedures, among which there are infection and neurovascular lesions.

Pseudotumors

Recurrent bleeding episodes occasionally originate encapsulated hematomas that behave as aggressive lesions causing local destruction, which are named hemophilic pseudotumor or hemophilic cyst[2,3].

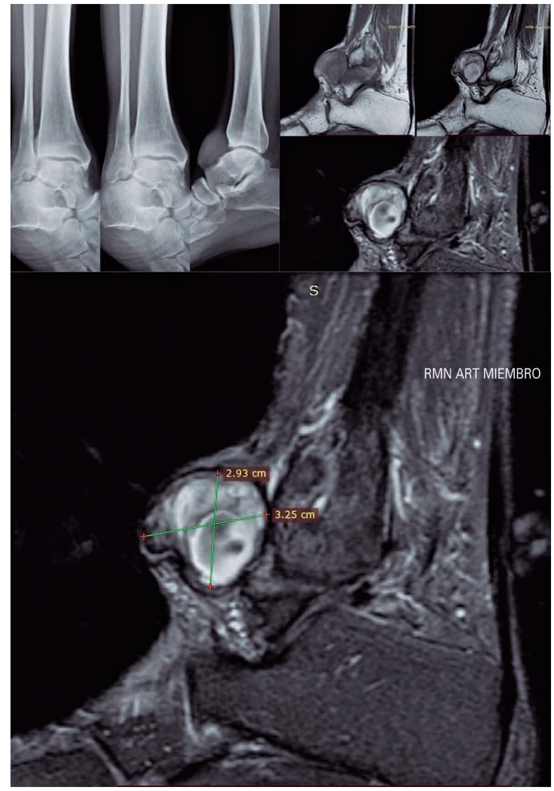

Figure 2. Radiologic images. A) Ankle radiograph showing soft tissue mass in lateral view. A) Nuclear magnetic resonance imaging of the ankle revealing a multilocular, heterogeneous mass.

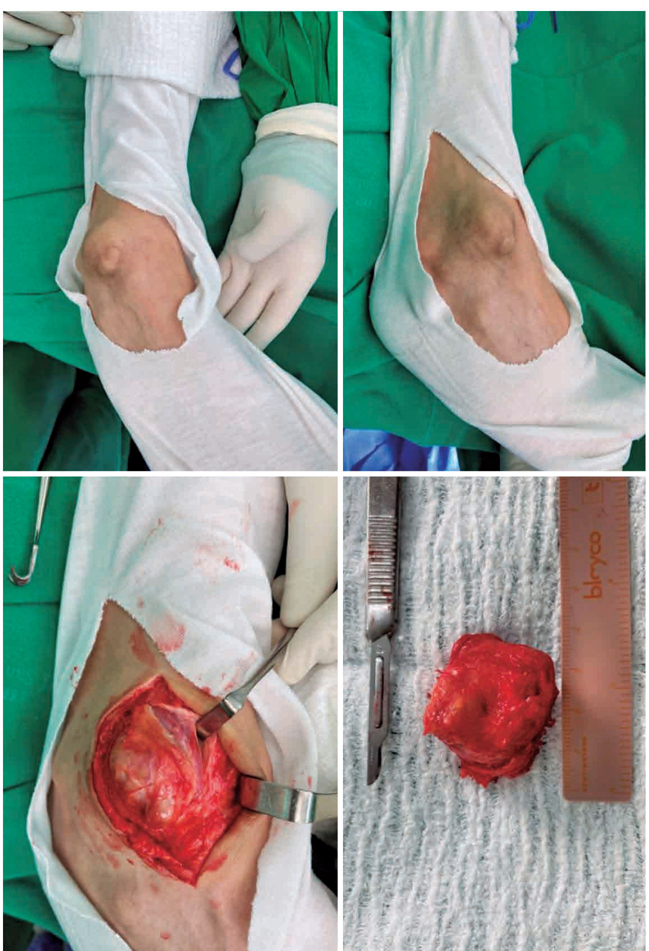

Figure 1. Clinical findings of pseudotumor: 3 x 3 cm mass related to posterolateral arthroscopy.

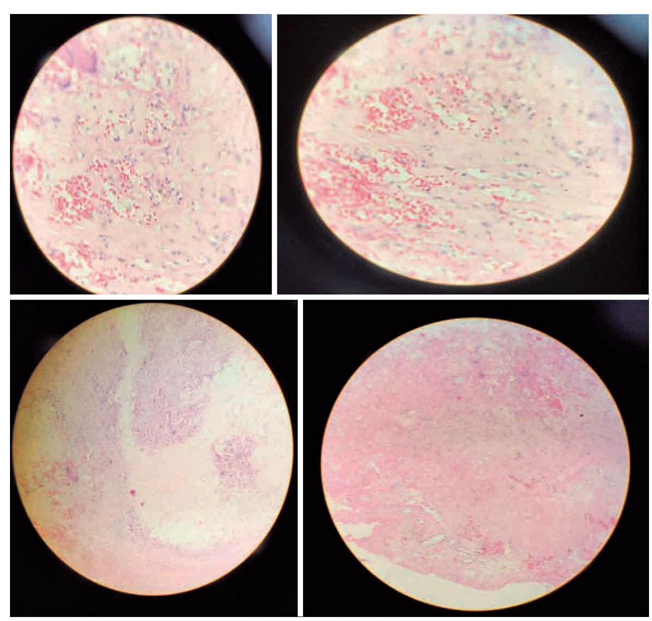

Figure 3. Histopathology of pseudotumor: Red cells with different degrees of lysis, focal hemorrhagic areas, hemosiderin-laden histiocytes, giant cells, and evidence of reaction to foreign body granuloma.

Pseudotumors are manifested as an isolated, unilocular or multilocular lesion[8] that may be secondary to mild, recurrent trauma or trauma, or emerge spontaneously. According to Arnold, they are classified as type A if originated from the soft tissue, type B if originated from the subperiosteal space, and type C when originated from bones. The most frequent location is the femur, followed by pelvis, tibia, and small hand bones, whereas the most frequently affected muscle is the psoas[9].

Pseudotumors have an incidence of 1.14%-2% in patients with severe hemophilia and up to 10% in patients who developed inhibitors[10]; however, no difference was observed in lesion presentation according to coagulation factor deficiency. Most of these lesions are asymptomatic, despite having metabolic activity and progressive growth. Symptoms are derived from compression of underlying structures, bone destruction, and onset of skin fistulas.

Anatomically, pseudotumors are encapsulated hematomas with areas of calcification. Histologically, they contain red cells with different degrees of lysis, subperiosteal bone, and focal hemorrhagic areas with predominantly clotting cells, hemosiderin-laden histiocytes, giant cells, and evidence of reaction to foreign body granuloma. Pseudotumor walls contain a thin inner layer with abundant hemosiderin debris, a thick intermediate layer with fibrous tissue, and an outer layer consisting of muscle fibers, elastin fibers, and blood vessels[2].

Diagnosis is based on clinical findings, whereas imaging assessment determines lesion extent. Computed axial tomography allows for evaluating bone and soft tissue involvement; furthermore, nuclear magnetic resonance imaging shows the specific characteristics of unilocularity or multilocularity and the relationship of the mass with neurovascular structures and joint spaces[6].

Biopsy is not recommended, due to risk of bleeding, in addition to the development of fistula and even of infection[3]. Arteriography may be a diagnostic tool and a therapeutic option if associated with selective embolization.

Treatment of pseudotumors

Currently, there is no consensus on the treatment of pseudotumor; thus, different alternatives are considered, according to patient's findings and resources of each institution. In lesions smaller than 1 cm, intensive replacement therapy has shown good results, and, for larger lesions, associated administration of coagulation factor is considered to reduce lesion size prior to surgical resection.

Radiation therapy provides alternatives in the adjuvant management or definitive treatment, at a total dose of 5-30 Gy, for acral pseudotumors or when surgical resection is contraindicated. Response is observed in the fourth week of treatment, achieving a full cure at 12 weeks. Overall failure rate is 25%, with a lesion recurrence rate of 3.6%, and an increase in size of up to 18%[3].

Although the content of the pseudotumor is mostly solid, the capsule contains the vascular network that is associated with bleeding after its extraction; therefore, embolization of the main vessel for tumors greater than 10cm[3] reduces their size and the risk of bleeding.

Surgical management takes the mass size (<10cm) and consistency into account. In the case of smaller and cystic masses, echography-guided puncture is considered with the benefit of symptom relief, as long as replacement levels are monitored, since this procedure has a recurrence rate of 13%, due to incomplete drainage or bleeding[3].

Solid or mixed masses greater than 10cm with rapid growth and associated with neurovascular involvement, massive and recurrent bleeding, spontaneous perforation, fractures, or failure of symptomatic treatment, require surgical management, including excision of the capsule that contains the feeder vessels, except for the cases in which adherence to underlying tissues may lead to greater postoperative bleeding[3]. If bone involvement is greater than 1/3 of the diameter of the segment or bone defect is >5cm, bone graft or structural allograft should be considered.

Complications of pseudotumors

The most frequent complications are recurrence in 15% of the cases and infection in up to 50% of the patients.

Discussion

The presentation of pseudotumors requires a high level of suspicion, since their manifestation in sites such as the pelvis does not allow for a timely detection. The manifestation of the pseudotumor reported herein had early clinical evidence due to scarcity of soft tissue in the perilesional region.

It bears highlighting that the best treatment is preventing musculoskeletal bleeding, based on prophylaxis with administration of coagulation factor, from 2 years to 18 years of age, especially at a concentration lower than 1%[3]. However, 25%-30% of patients with hemophilia do not receive timely prophylactic treatment, due to its high cost. In Colombia, hemophilia is considered an orphan disease, because of its low prevalence and its high treatment cost, which has allowed for the development of multidisciplinary programs of disease prevention and permanent treatment.

Conclusion

Hemophilia is a rare entity, and early diagnosis and prevention of bleeding play a key role in reducing the incidence of hemophilic pseudotumors. These pseudotumors are mostly located in the pelvis and in the mandible and are infrequently found in the ankle, with only one reported case of a pseudotumor in the talus of a girl; thus, the finding of the present case is relevant, especially because it is related to surgical approach.

With regard to the patient reported in the present study, this is a case of mild deficiency that requires replacement of the deficient coagulation factor under demand, which is why episodes of soft tissue hemarthrosis and hemorrhage require timely management, in order to control the bleeding episode and thus resolve the lesion.

The Hospital de San José de Bogotá has a multidisciplinary team for the treatment of primary and secondary manifestations of hemophilia. Orthopedics and hematology services were able to diagnose and treat different musculoskeletal manifestations, such as those described in this report, where we present a case of pseudotumor associated with arthroscopic procedures, considered rare in the reported literature, in addition to a severe manifestation with a challenging medical and surgical treatment.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RRC *(https://orcid.org/0000-002-3817-0609) Conceived and planned the activities that led to the study; CEPL *(https://orcid.org/0000-0001-8197711X) interpreted the results of the study, participated in the review process and approved the final version; ASGF *(https://orcid.org/0000-0003-0296-5263) interpreted the results of the study, participated in the review process and approved the final version; MHST *(https://orcid.org/0000-0001-8752-7080) Conceived and planned the activities that led to the study; CCD *(https://orcid.org/0000-0002-8049-3903) Interpreted the results of the study, participated in the review process and approved the final version; NHA *(https://orcid.org/0000-0003-2120-2181). All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID iD.

References

1. Cuenta de Alto Costo. [Situation of hemophilia in Colombia] [Internet]. Bogotá; 2019. Available at:www.cuentadealtocosto.org
2. Rodriguez-Merchan EC. Musculoskeletal complications of hemophilia. HSS J. 2010;6(1):37-42.
3. Rodriguez-Merchan EC. Hemophilic Pseudotumors: Diagnosis and Management. Arch Bone Jt Surg. 2020;8(2):121-30.
4. Rodriguez-Merchan EC. Orthopaedic surgery in persons with haemophilia. Thromb Haemost. 2003;89(1):34-42.
5. Rodriguez-Merchan EC. Ankle surgery in haemophilia with special emphasis on arthroscopic debridement. Haemophilia. 2008; 14(5):913-9.
6. Pasta G, Forsyth A, Merchan CR, Mortazavi SM, Silva M, Mulder K, et al. Orthopaedic management of haemophilia arthropathy of the ankle. Haemophilia. 2008;14 Suppl 3:170-6.
7. Buitrago AQ, Pardo CE, Cañón M. Radiosynoviorthesis: current therapeutic option for chronic synovitis. Rev Med Sanitas 2014; 17(3):143-9.
8. Kamal AF, Waryudi A, Kurniawan A, Lubis AM, Gatot D. Various Surgical Treatment of Hemophilic Pseudotumor: A Case Series. Arch Bone Jt Surg. 2019;7(6):514-22.
9. Rodriguez-Merchan EC. Haemophilic cysts (pseudotumours). Haemophilia. 2002;8(3):393-401.
10. Rodríguez-Merchán EC, Goddard NJ. Muscular bleeding, soft-tissue hematomas and pseudotumors. In: Rodríguez-Merchán EC, Goddard NJ, Lee CA, editors. Musculoskeletal aspects of hemophilia. Oxford: Blackwell Science; 2000. p. 85-90

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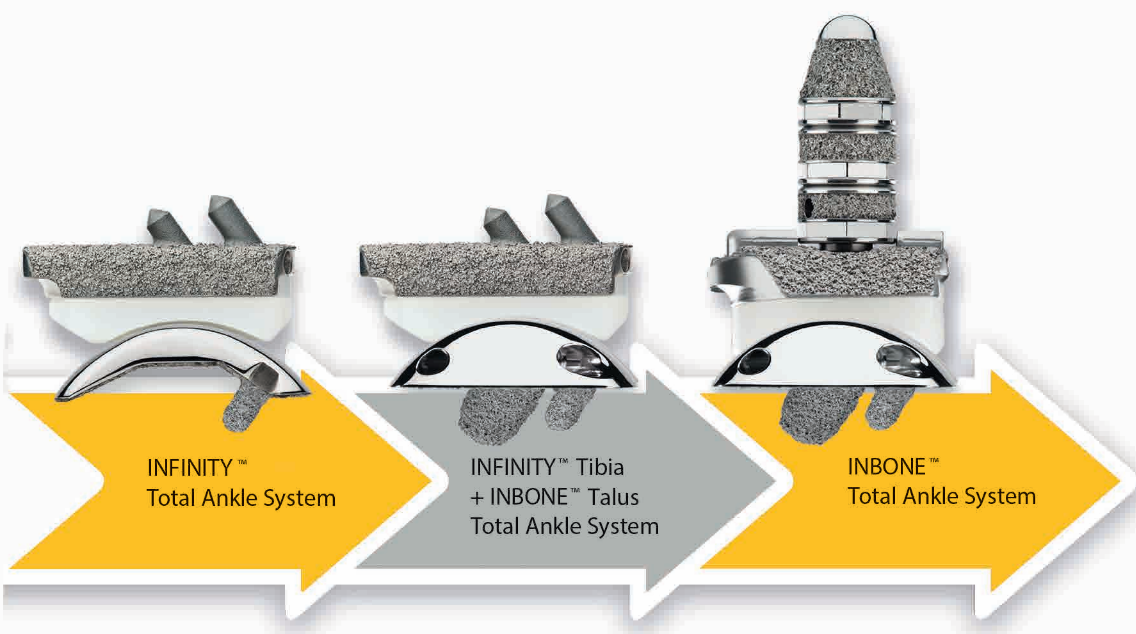

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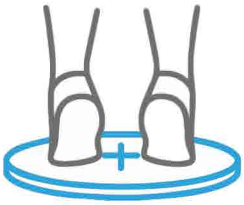

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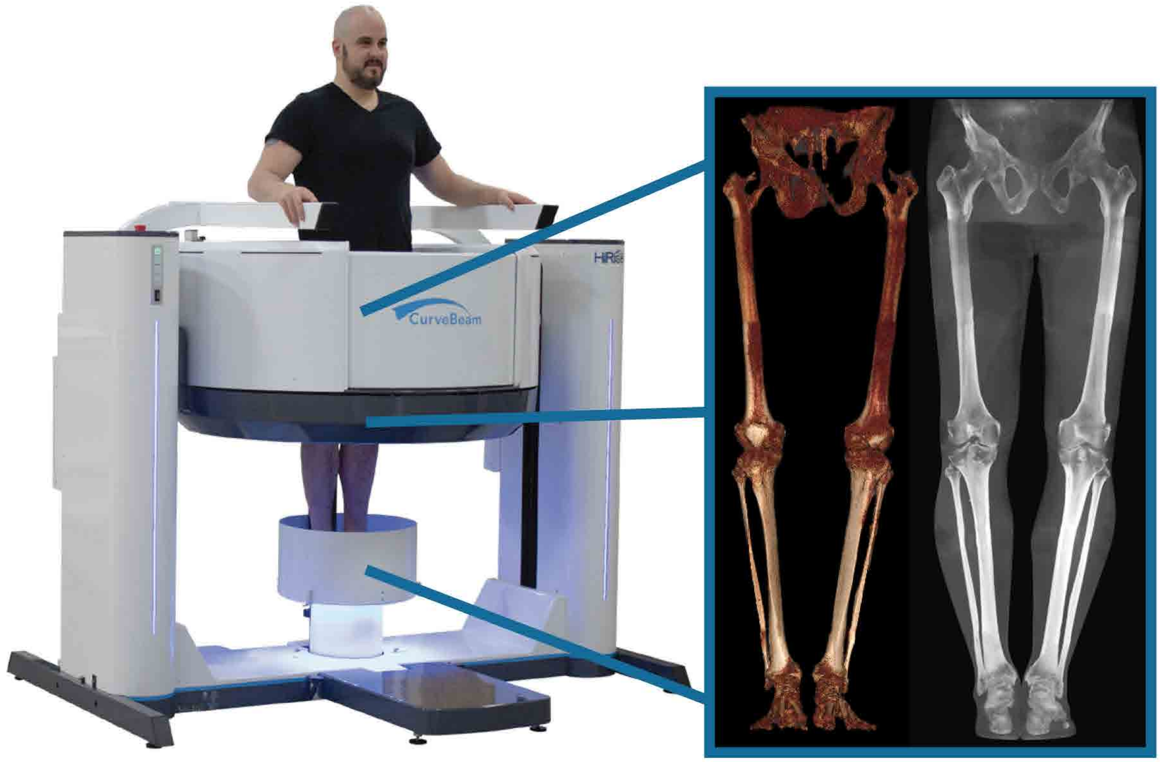

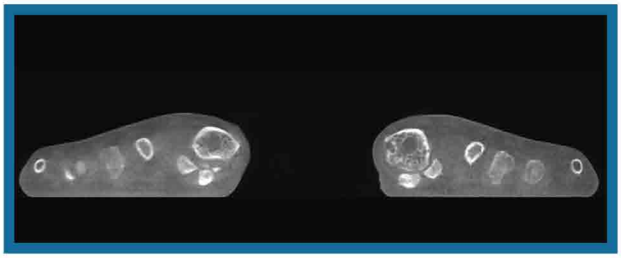

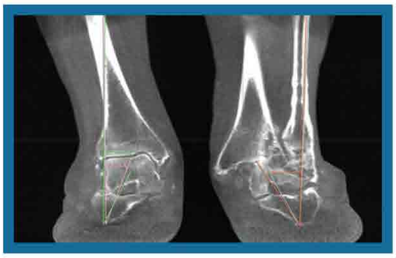

(1) Richter M, Seidl B, Zech S, Hahn S. PedCAT for 3D-imaging in standing position allows for more accurate bone position (angle) measurement than radiographs or CT. Foot Ankle Surg. 2014 Sep;20(3):201-7. doi: 10.1016/j.fas.2014.04.004. Epub 2014 May 9. PMID: 25103709.
(2) Borel C et al. Diagnostic value of cone beam computed tomography (CBCT) in occult scaphoid and wrist fractures. Eur J Radiol. 2017 Dec;97:59-64. doi: 10.1016/j.ejrad.2017.10.010. Epub 2017 Oct 18. PMID: 29153368.

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