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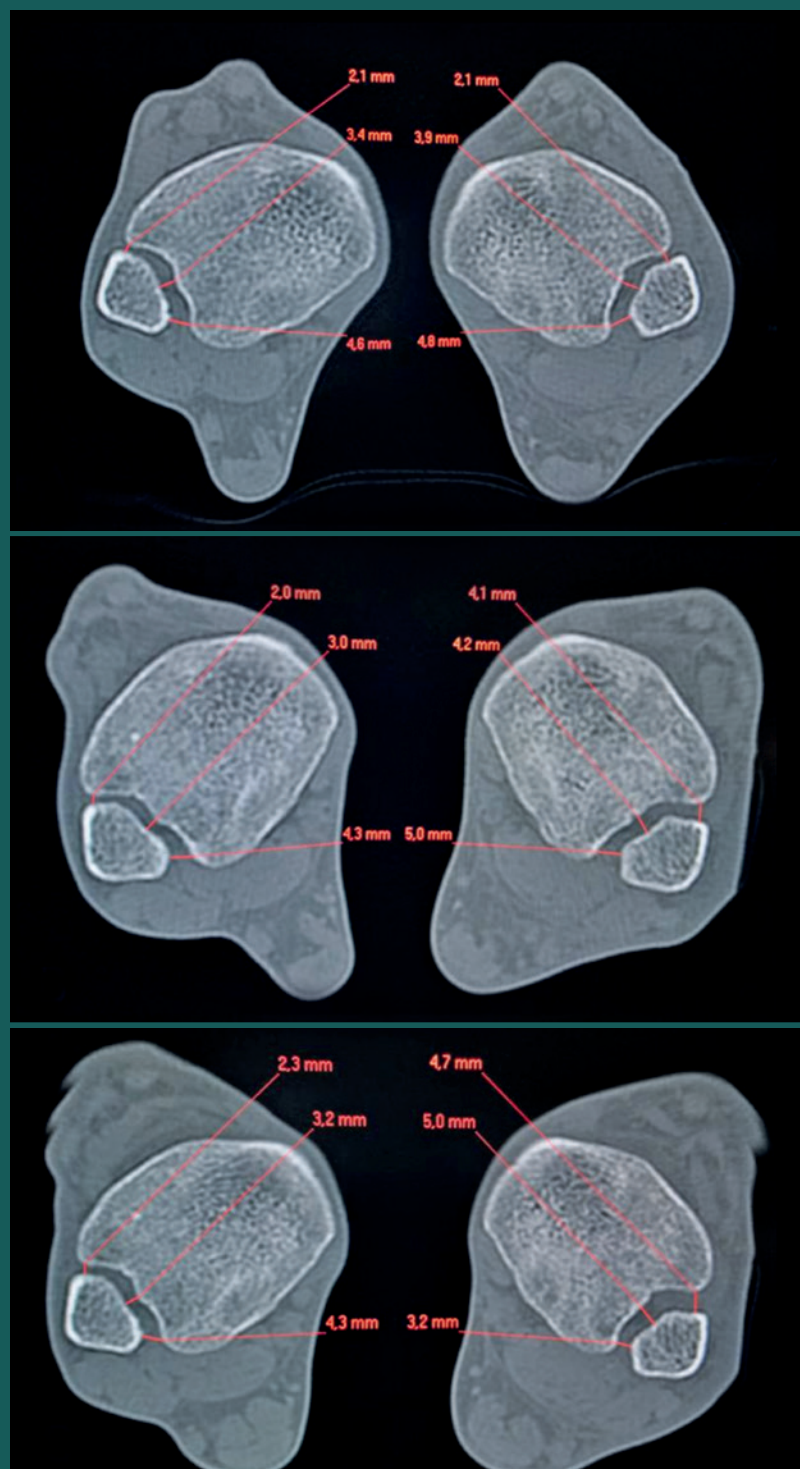

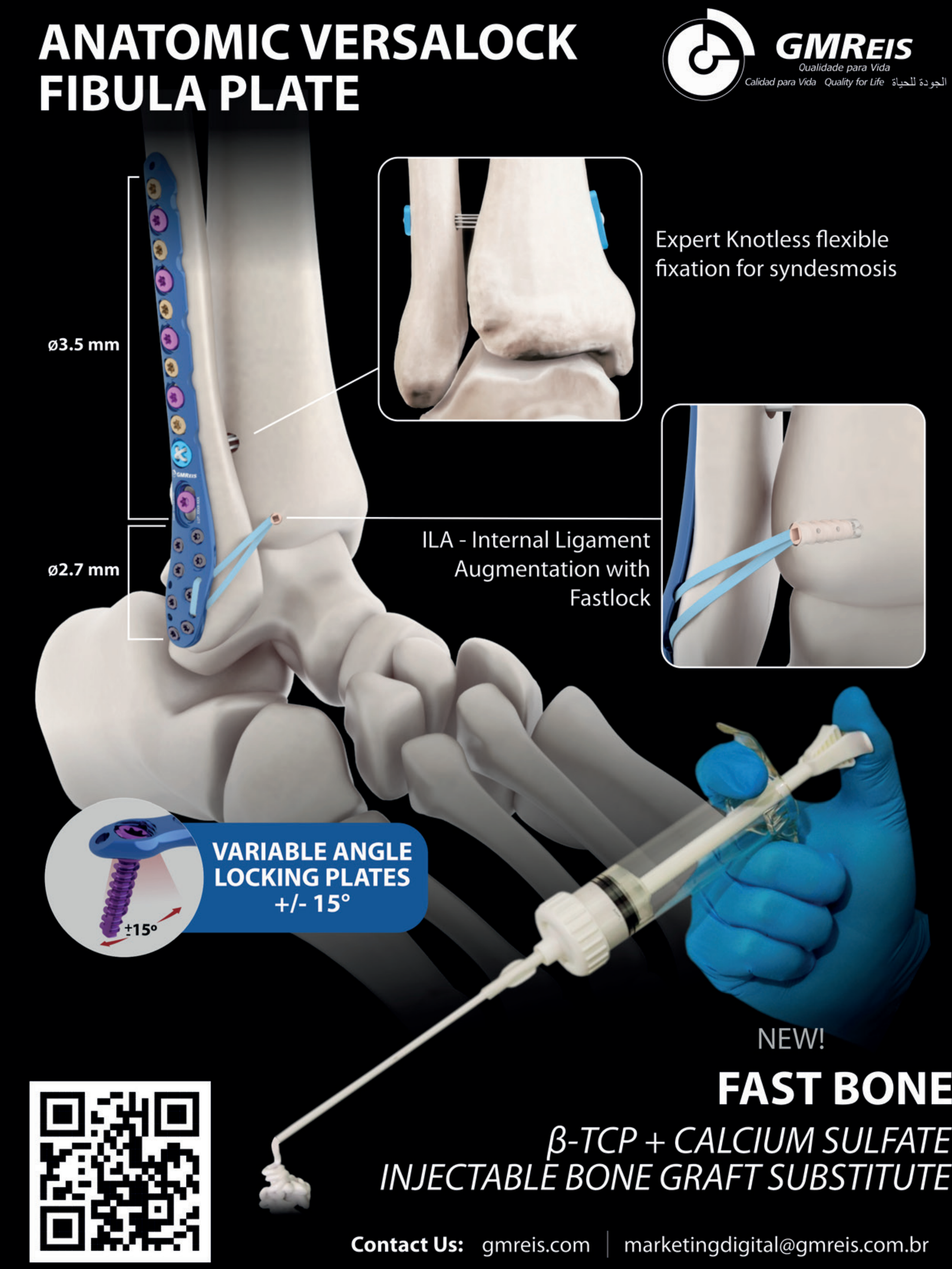
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Editorial

Journal of the Foot & Ankle JFA

A brief perspective of foot and ankle leadership over the decades

MARK MYERSON

EUA

Professor of Orthopedic Surgery, University of Colorado; Past President American Orthopedic Foot and Ankle Society; Editor in Chief Foot and Ankle Clinics North America; Executive Director and Founder, Steps2Walk

I remember so clearly when I first became a member of the American Orthopedic Foot and Ankle Society in the early 1980s. I knew everyone. It was a small organization that facilitated friendships, collegiality as well as academic and professional interaction. Now as then, these incredible friendships that we have all established over the decades define our professional life.

For those of you who have been involved in the education of residents and fellows you will understand how relevant this is to your own personal growth. I have always felt strongly that you cannot be an educator unless you're prepared to listen to your students. In the earlier years of training fellows, it was not much of an age differential, and while there was always a matter of the difference in knowledge and experience, I did not yet have the "seniority". However, over the decades I've learned that some of our closest relationships emanate from these mentoring experiences. Here is a quote from Dr George Quill, a fellow in 1989: "In hindsight, I was doubly fortunate to be only the second surgeon in the world to matriculate with Mark Myerson because, in doing so, I gained a generous mentor and a dear friend for life!" Remember this: as an educator you inevitably give of yourself, but you will also receive something in return. When we share compassion with others, we are all tremendously enriched. Teaching of residents and fellows is a responsibility that we all share. During the formative training particularly of fellows, I want them "to lose their GPS". Residents learn by repetition, but this encourages sterility without analysis. And by following the acquisition of knowledge blindly without questioning and analyzing the process does not help one grow. This is what I mean about losing your GPS, since sooner or later our fellows need to break away from the mentality of being guided by their mentor's thinking and develop strategies of their own.

I have never been afraid to push the envelope of experiences, and I have always embraced intellectual, personal, academic, and professional challenges. Many of you may have heard me saying that life begins at the edge of your comfort zone. In my practice of medicine, I've never felt any room for complacency. To accept everything as given, whether we read it in a prominent journal, or hear it from a colleague is meaningless until we can prove it for ourselves. This I learned from my mentor, Dr. Melvin Jahss who insisted in the early 1980's that very few things were actually new ideas. He maintained that if one read the literature in depth, particularly in other languages, it was all there. I was reminded this many years later when I "rediscovered" what we know as today as the Ludloff osteotomy. I was sure that I had performed a new procedure. However, sure enough, my fellow at the time Dr. Hans Trnka found this technique referred to in the German literature, and although my technique was completely different since Ludloff did not use any fixation, the rest is history.

Where do new ideas come from? I'm sure that all of you have said to yourselves at one point in time or another "oh, why did I not think of that?" As long as I can remember I have derived immense satisfaction and enrichment from research and investigation, and this passion has never diminished. It has been part of my life and continues to be an integral source of stimulation for me. Many of you do not have the resources nor access to research, but I am sure that all of you wonder about outcomes and results pertaining to your own innovative thinking. Try to share these ideas with others and find like-minded individuals who want to explore new ideas. Some of the most productive times for me have been when I am sitting quietly listening to music. When I go to the symphony orchestra, I scribble research notes and ideas onto the program. Multitasking it's something that for surgeons comes naturally. Find a quiet time for yourselves and just think, don't do!

As many of you know, I've devoted these past years to humanitarian service through an organization which I founded, Steps2Walk (www.steps2walk.org). This has been an extraordinary journey, and I and the others who have supported us either on our medical advisory board, or as surgeon volunteers have all been touched and blessed by this opportunity. The spectrum of deformities which we treat is indeed challenging, but by performing humanitarian service, one experiences the deep fulfillment that can only come from improving the lives of others. I truly believe that you cannot experience your practice of orthopedic surgery nor reach your potential until you do something for someone who can never repay you.

Steve Jobs said that "the people who are crazy enough to think that they can change the world are the ones who do".

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Special Article

What do we know about hallux valgus pathogenesis? Review of the different theories

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Abstract

Objective: This work performs a critical review of the different causes described to explain the etiopathogenesis of hallux valgus.

Methods: The authors divide the causal factors into two groups: extrinsic and intrinsic factors. In the first group, footwear and mechanical overload caused by different causes such as ballet, trauma, long walks, obesity, etc., should be considered. In the second group we include a series of factors: constitutional ones, such as heredity, sex and age; anatomical aspects, among which we must highlight the morphology and obliquity of the metatarsocuneiform joint; hypermobility of the first ray; metatarsus primus varus; muscle function; and atavism.

Results: Hallux valgus probably has a multifactorial etiology whose triggering factor is unknown at the moment.

Conclusion: If we know the etiopathogenesis of a deformity, in this case hallux valgus, we can perform a treatment as early and effective as possible.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Hallux valgus/etiology; Intrinsic factor; Extrinsic factor.

"I have no special talents. I am only passionately curious"

Albert Einstein. Nobel Prize in Physics

Introduction

Hallux valgus (HV) is the most frequent deformity of the locomotor system, being present in more than 35% of people over 65 years old[(1)].

It is defined as a three-dimension deformity[(2)], in which the three spatial planes should be considered: transverse, sagittal, and coronal. In the transverse plane, the following variables are assessed: angles between the 1st and 2nd metatarsals, the metatarsophalangeal joint, PASA (Proximal Articular Set Angle), DASA (Distal Articular Set Angle), location of the sesamoid bones and of the CORA (Center of Rotation of Angulation), metatarsocuneiform joint obliquity, and presence of arthrosis in metatarsophalangeal and metatarsocuneiform joints. In the sagittal plane, elevation and descent of the first metatarsal head are observed. Finally, in the coronal plane, hallux pronation is found in more than 80% of the cases, as well as the status of sesamoid bones.

Our aim is to perform a critical analysis of the different causes to explain the etiopathogenesis of HV.

Pathogenesis

HV pathogenesis is a complex topic that evokes different opinions, which explains the emergence of many controversies.

In a lecture delivered at the Royal College of Surgeons of England in 1956, Lake[(3)] (Consulting Surgeon, Charing Cross Hospital) commented: *"[...] yet there is still controversy about*

Study performed at the Instituto Oulton, Córdoba, Argentina; Hospital Virgen del Mar, Madrid, Spain and Clínica Tres Torres, Barcelona, Spain.

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the etiology of such a simple and common condition as hallux valgus, for, despite the large amount of anatomical, statistical and sociological study which has recently been carried out, the problem remains unsolved.”. In their paper “*The pathogenesis of Hallux Valgus*”, Perera et al.[4] (University Hospital of Wales, Cardiff, United Kingdom) state: *“A century of debate has failed to settle the importance of intrinsic versus extrinsic causes in the etiology of HV”* (Figure 1 A and B).

Extrinsic factors

Inadequate footwear

Durlacher[5], a surgeon-chiropodist that served Queen Victoria, published one of the first treatises on diseases of the foot in 1845 *(“A treatise on corns, bunions, the diseases of nails and the general management of the feet”)*, in which he states: *“One of the most certain causes of a “bunion” is the wearing of shoes made too short, and with a narrow sole”.*

It is noteworthy that, both in England and in France, health authorities were interested in controlling the characteristics of footwear. In France, Charles V (1338-1380) issued an edict establishing the length of footwear, and, in England, Queen Elizabeth I (1533-1603) restricted its width. However, as mentioned by Lake[3], the historian Viollet le Duc commented: *“as always happens, fashion proved stronger than all the edicts of kings and councils”.*

For many authors, improper footwear acts as a potential cause for the onset of HV[6,7]. It is also important to mention cases of congenital HV that are isolated or part of a generalized disease, juvenile HV in adolescents who have never worn narrow shoes and, finally, HV in individuals who have never worn any type of footwear or who wear very different shoes from those of the western world[8,9]. Studies conducted with primitive peoples found a low number of cases in Solomon islands and in Belgian Congo[10,11].

In our opinion, the most probable reason for these findings may be the fact that footwear is likely to favor the progression of deformity instead of being the initial cause of the structural anomaly.

Ballet

Within HV pathogenesis, one should assess the scenarios in which feet will maintain a constant posture and be subjected to constant overload. These situations may include classical dance, in which dancers often suffer from metatarsalgia and hallux deviations resulting from joint and muscle overload.

Seki et al.[12] conducted investigations to develop appropriate training methods to prevent the progression of HV. A study with female classical ballet dancers at the advanced college-level concluded that the degree of HV is correlated with basic techniques of classical ballet such as the first position.

In their studies, Pérez and Massó[13] state that classical positions, especially first positions, often leads to the onset of HV, due to the muscular effort demanded by these positions (Figure 2).

In a study conducted with 106 dancers, these authors concluded that HV and hammer toes are often observed in classical dance. In their series, there was a percentage of 67% of square feet, 26% of Egyptian feet, and 8% of Greek forefeet. The highest percentage of HV was found in Egyptian feet.

In the pointe position of ballet, a longer hallux tends to deviate towards the second toe, in order to equal the length of both toes and increase contact with the ground. On the other hand, muscle control over the position of the hallux by the abductor hallucis muscle is reduced in the *“en dehors”* position. Dancers with joint laxity show an increased number of cases of HV. Metatarsalgia and craw toes are more frequent in Greek feet, and less frequent in square feet.

There is not enough evidence to conclusively show that dance, specifically the pointe technique and physical preparation, increases the prevalence or the severity of HV. Most authors think that “permanent aggression” to the first metatarsocuneiform joint may be a factor to consider in the presentation of HV when this joint is not able to withstand the overload to which is permanently subjected.

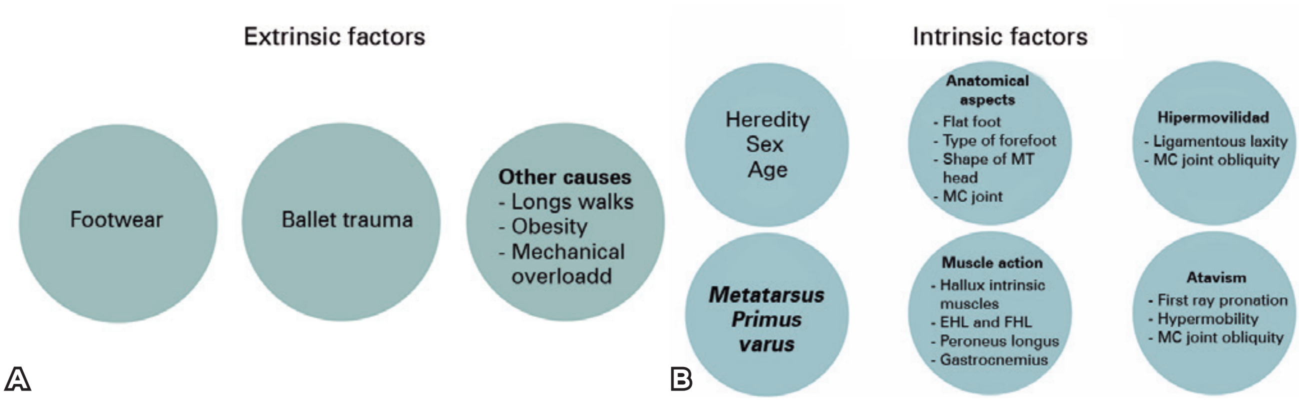

Figure 1. A. Extrinsic factors. B. Intrinsic factors.

Trauma

Low-energy trauma affecting the Lisfranc ligament may cause a Lisfranc fracture-dislocation that is radiologically manifested by diastasis between the first and the second cuneiform bones (subtle injury), sometimes accompanied by bone fragments resulting from avulsion of the Lisfranc ligament insertion on the second metatarsal base (fleck sign).

It is worth remembering that the Lisfranc ligament connects the first cuneiform bone to the second metatarsal base in an oblique, lateral, distal direction (Figure 3). The first metatarsocuneiform joint is located in front of the Lisfranc ligament, and its stability is achieved by the action of intrinsic and extrinsic muscles, especially peroneus longus, ligaments, and articular capsule. Therefore, this joint represents a “weak point”, which Klaue[14] attributes to the fact that the foot is at a “young stage”, from a phylogenetic point of view, and is subjected to mechanical overloads. This may cause metatarsocuneiform joint instability, favored by the unbalance of muscles inserted into the phalangeal base, therefore leading to the development of metatarsal varus.

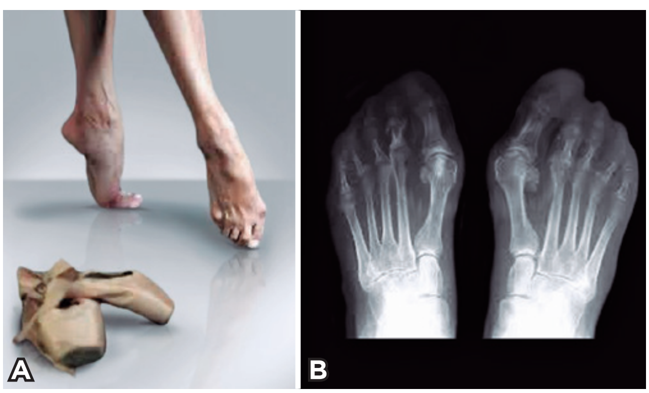

Figure 2. A. First position and pointe technique may favor the development of hallux valgus. B. Hallux valgus, more prominent on the right foot, corresponding to the dancer shown in the previous image.

Direct trauma would cause minor or major fracture-dislocation of the Lisfranc joint, whereas mechanical overload may favor the onset of HV. Post-traumatic HV following direct injury is little frequent. It may be observed among athletes experiencing a strong impact on the forefoot. Most studies were conducted with soccer players with internal lateral ligament injuries of the first metatarsophalangeal joint. Lui[15] also mentions other possible causes, such as sequel of Lisfranc joint trauma, first metatarsocuneiform trauma, first metatarsal fractures, and entrapment of the internal plantar nerve in distal tibial fractures.

Other possible factors

The presence of HV was also related with other possible causes that imply overload, such as: long walks, carrying excessive load, obesity, etc. However, there are no significant statistical studies confirming these supposed associations.

Intrinsic factors

Heredity and race

Genetic probably plays an important role in the development of the deformity. This is possibly due to a dominant autosomal inheritance pattern with incomplete dominance. Piqué-Vidal et al.[16] studied a group of 350 individuals across three generations, confirming such hypothesis.

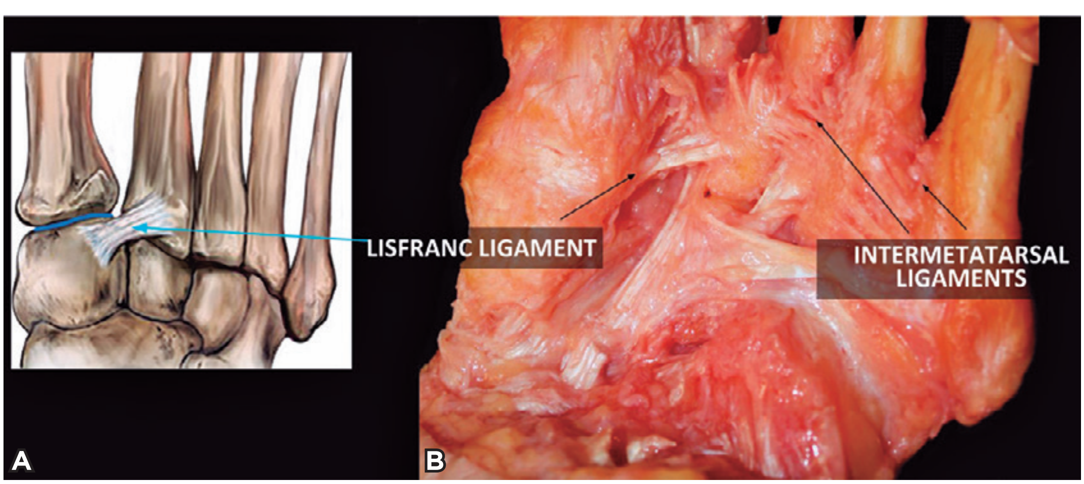

Figure 3. A. The first metatarsocuneiform joint is located in front of the Lisfranc ligament and is stable due to intrinsic and extrinsic muscles, especially peroneus longus, ligaments, and articular capsule. According to some authors, mechanical overload at this level may favor the development of HV. B. Anatomical preparation. Courtesy of Dr. X. Martín Oliva.

There is an accepted maternally inherited predisposition to HV, especially in juvenile HV and that affecting young adults. In a meta-analysis with 5925 Caucasian individuals, Arbeeva et al.[17] identified a new locus (COL. 24A_1) on chromosome 1 that partly encodes collagen and would be related to the onset or to the higher frequency of HV.

The presence of HV is two-fold higher in the white than in the black population[18].

Sex

The clear predominance of women compared to men with HV, in a 10:1 ratio, probably has a genetic cause. Published investigations revealed that the hallux metatarsal head is more rounded and smaller in women than in men, which could favor the onset of HV[19], as well as ligament hyperlaxity and hypermobility, which are more frequent among females. Footwear may also exert an influence.

Age

In a meta-analysis published by Shere et al.[20], the estimated grouped prevalence of HV was 23% in women aged 18-65 years old, reaching 35.7% in elderly people aged over 65 years. It means that one out of three elderly women had HV. In another study, Roddy et al.[21] found that this deformity had an incidence of 26.4% in the population over 35 years old.

Anatomical aspects

Some authors state that flat foot favors the presence of HV[22], whereas others think there is no such relationship[23]. According to our criterion, flat feet with flattening of the medial arch secondarily results in abducted, pronated forefoot, which is often associated with HV.

Núñez-Samper observed that adult-acquired flat foot due to posterior tibial dysfunction (stages III and IV) was associated with moderate or severe HV in most treated cases (Figure 4).

HV may present in any type of forefoot, regardless of metatarsal and digital formula. This is observed in daily practice. However, an Egyptian digital formula, together with an *index minus* metatarsal formula, would favor the onset of HV.

Mann and Coughlin[24] studied the shape of the metatarsal head, concluding that rounded heads would favor the onset of HV. At the level of the metatarsal cuneiform joint, we believe that joint surface obliquity has a significant role in HV with major deformity (Figure 5).

Hypermobility of the first ray

Lapidus[25] states that hypermobility of the first ray has a major role in the development of deformity in HV. In investigations with cadaveric foot specimens with HV, Coughlin et al.[26] observed that joint mobility decreased when first ray realignment was performed with crescentic osteotomy.

When manually exploring hypermobility in the sagittal plane, it is important that the knee remain in the neutral position during examination, since dorsiflexion tensions the plantar fascia and reduces the range of motion in the sagittal plane. Conversely, plantar flexion relaxes the fascia and increases mobility. It is recommended that the knee flexed during examination.

For many years, the concept of hypermobility of the first metatarsal cuneiform joint was centered on the sagittal plane; however, in our opinion, transverse and coronal (pronation) planes should also be assessed, since they contribute for the development of HV.

Some factors should be considered when investigating first metatarsal hypermobility. Moderate ligament laxity is common in patients with HV. Conversely, hypermobility of the first ray is a factor that favors relapses[27]. Morphology and inclination of the first metatarsal-cuneiform joint is closely related to hypermobility of the first metatarsal.

In conclusion, hypermobility of the first ray is related to several factors leading to the persistence of mobility of the first metatarsal cuneiform joint, as occurring in primates.

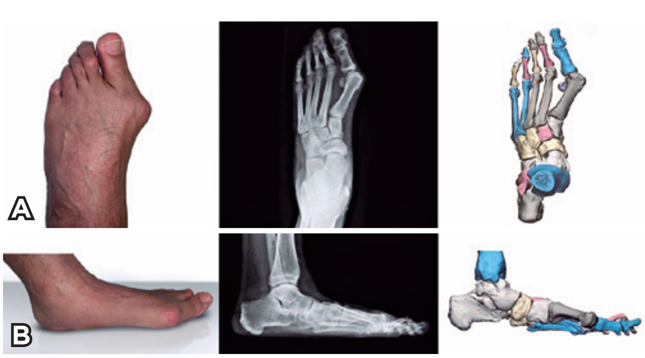

Figure 4. Hallux valgus associated with adult-acquired flat foot due to posterior tibial dysfunction. A. Hallux valgus. Clinical aspect, radiographic image, and 3D reconstruction. B. Flat foot. Clinical aspect, radiographic image, and 3D reconstruction.

Figure 5. First metatarsocuneiform joint obliquity. A. Clinical image and B. Radiographic image of the same case.

Metatarsus primus varus

Some studies give the same meaning to the expressions HV and *metatarsus primus varus*. HV is defined, incorrectly in our opinion, as a deformity involving a first metatarsal varum deviation with an intermetatarsal angle greater than 9º and a hallux valgus deviation with a metatarsophalangeal angle greater than 15º. Strictly speaking, *metatarsus primus varus* would correspond to medial first metatarsal deviation, whereas HV would be a lateral hallux deviation. However, the expression HV usually covers first metatarsal and hallux deviation.

Some authors, such as Kilmartin(29) and Klaue(14), believe that *metatarsus primus varus* is a specific forefoot morphotype, and compare it with other foot types, such as Egyptian, square, or Greek foot. In the case of *metatarsus primus varus*, it is characterized by a clear separation between the first metatarsal and the second and the varus hallux.

This arrangement is observed in the fetus up to the ninth week of intrauterine life and persists in a great number of individuals at birth. It is known as "fan-shaped foot".

Truslow(30) was the first to relate HV to *metatarsus primus varus* and interpreted it as an anatomical variant.

Currently, it is accepted that *metatarsus primus varus* favors the onset of HV, especially its juvenile cases.

Muscle action

The five muscles inserted into the hallux have a great importance in the development of HV deformity, since they tend to displace the toe outwards. In 1887 Wyeth(31) wrote: *"The action of the muscles inserted into the hallux should not be ignored in the etiology of hallux valgus"*.

In 1978, Iida and Basmajian(32) published an electromyography study that compared the electromyography responses of adductor and abductor hallucis muscles and flexor hallucis brevis muscle in normal feet and those with HV. Feet with HV had a relatively weak medial flexion force, a strong lateral flexion force, weak adduction, and no abductive force at the level of the metatarsophalangeal joint. According to the authors, these changes in muscle balance around the joint may favor the presentation of HV.

Muscle imbalance in adductor and abductor muscles is evident in HV deformity. However, the study did not determine whether changes in muscle action are a cause or a consequence of HV.

As Lelievre(33) states in the book "Patología del Pie": *"The action of muscles tends to accentuate deformity"*. In HV the extensor hallucis muscle form the cord of an arch, together with the flexor longus muscle. Both muscles are functionally converted to abductor hallucis muscles. The external portion of the flexor hallucis brevis acts the same way. There are no antagonists, since the adductor muscle is situated at the sole of the foot.

This anatomical and functional change at the level of the muscles leads the toe to become internally rotated or pronated. In turn, the cause of metatarsal pronation should be more proximal, as occurring with primates in which internal rotation or pronation is produced in the tarsometatarsal joint.

How musculotendinous aspects act on the first metatarsal-cuneiform joint?

Bohne et al.(34) state that peroneus longus plays an important role in maintaining stability both in the sagittal and in transverse planes of the first metatarsocuneiform joint, with a most notable action in the sagittal plane.

Gastrocnemius shortening is an important point to consider. It is found in 40% of the population, according to Kowalski et al.(35), and is a frequent cause favoring the onset of HV. In our opinion(36) this shortening has an atavic nature. When human gain started, our ancestors walked on tiptoes, in a valgus position, and the heel was distant from the ground. Achilles tendon retraction leads to joint overload at the end of the 2nd rocker. It is important the assess the retraction of the gemelli muscles through the Silfverskiöld test(37) and proceed with their enlargement in case of failure of rehabilitation treatment.

Atavism

We understand atavism as "the reappearance, in living beings, of regressive characters typical of their ancestors within the evolutionary line".

The foot of our relatives in the phylogenetic scale had a three-dimension structure very similar to that of our hands, in which the first ray was separated from the others and was pronated.

At the knee level, mobility of primates is greater than that of humans. Due to its anatomical configuration and to the role played by intra-articular soft tissues(38), the knee behaves as a ball and socket joint, from a biomechanical point of view.

The subtalar joint of primates has a much greater mobility compared to that of humans, since the axis of motion of anterior y posterior joints does not limit rotation capacity at this level.

These characteristics of the subtalar joint and of the knee facilitate the passage from pronation to supination in the foot without losing joint stability.

Primates also show a greater mobility in the tarsometatarsal, since the embedment of the second metatarsal base within the mortise created by the three cuneiform bones, provide humans with greater foot stability, which is required for remaining in the standing position, but reduces mobility and thus prehensile capacity of foot.

The metatarsocuneiform joint has evolved throughout history(28). Between the Triassic and Jurassic periods (215 Ma) the bone named *os tarsale* or 1st cuneiform bone appeared for the first time. A small divergence was observed between the 1st ray and the lateral rays. During the Eocene period (53 Ma), there is the emergence of modern-prosimian primates. They live an arboreal life, due to the prehensile capacity of their hands and feet. Plantar dermatoglyphics emerge; moreover, fingers and toes terminate in nails rather than in claws. The metatarsocuneiform joint acquires a saddle shape, reinforced in the insertion area of the peroneus longus.

In the Oligocene period (35 Ma), there is the emergence of anthropoid primates. A desertification of the landscape occurs, with the formation of steppes, savannas, and large open spaces on the earth's surface.

Primates come down from the trees and lose part of prehensile capacity of foot.

In primates, both the extinct and the living ones, the three-dimension shape of the metatarsocuneiform joint is essential for the abduction-rotation movement and for prehensile capacity; moreover, morphologically speaking, this is a spherical joint. When humans become bipeds, this joint is nearly flat. It changes from a moveable joint to a buffering joint, which is crucial for the standing posture.

Many characteristics of primate forefoot, such as first metatarsal pronation, indispensable for prehensile capacity of the foot and arboreal displacement, hypermobility of the first ray, increased angle between first and second metatarsals, and obliquity of the metatarsocuneiform surface, are observed in patients with HV, usually at a severe stage (Figure 6). Therefore, we believe that atavism is a hypothesis to consider in HV pathogenesis.

The development of phalangeal may be influenced by the muscles attached to the hallux. However, first metatarsal pronation arises from the metatarsocuneiform joint, as occurring with apes, and first metatarsal pronation is present in most cases of HV.

It was observed that Neanderthal man have a short first metatarsal, with the characteristics observed in Morton's ancestry toe[39], which changes after *homo sapiens sapiens,* with the presentation of Greek, square, and Egyptian feet.

Current men present with slight variants in the metatarsocuneiform joint. Some of these variants have been related to *metatarsus primus varus* and HV, which favor an atavic regression in first ray morphology.

In the book "Patología del antepié", Viladot[40] studies changes of metatarsal in the pathological anatomy of forefoot in HV and says: *"the metatarsal presents with shortening, varus deviation, and pronation, all of which characterizing atavism".*

Not all authors agree with atavic pathogenesis. Klaue[14] believes that HV cannot be considered an atavism and is actually related with ligamentous failure at the level of the tarsometatarsal joint between the first and the second metatarsals, which may secondarily lead to mechanical overload.

Kilmartin and Wallace[41] asked: Why do not primates have HV? We believe that this is because they have never worn any type of footwear. However, there are some cases of congenital HV in the human species, which does not occur with primates. These authors[41] conclude that atavic pathogenesis can be neither confirmed nor refused. This opinion is shared by Perera et al.[4].

However, most authors believe that atavism should be considered in the pathogenesis of HV. In a conference on *"The problem of Hallux Valgus"* held in 1956, which has already been mentioned, Lake[3] approaches the theme of atavism: "[...] *divergence of the metatarsal with the associated rotation of the toe brings it into a position reminiscent of the prehensile digit of the anthropoid apes* [...]"*,* and says as follows: *"*[...] *in the apes rotation occurs at the tarsometatarsal and not the metatarsophalangeal joint".*

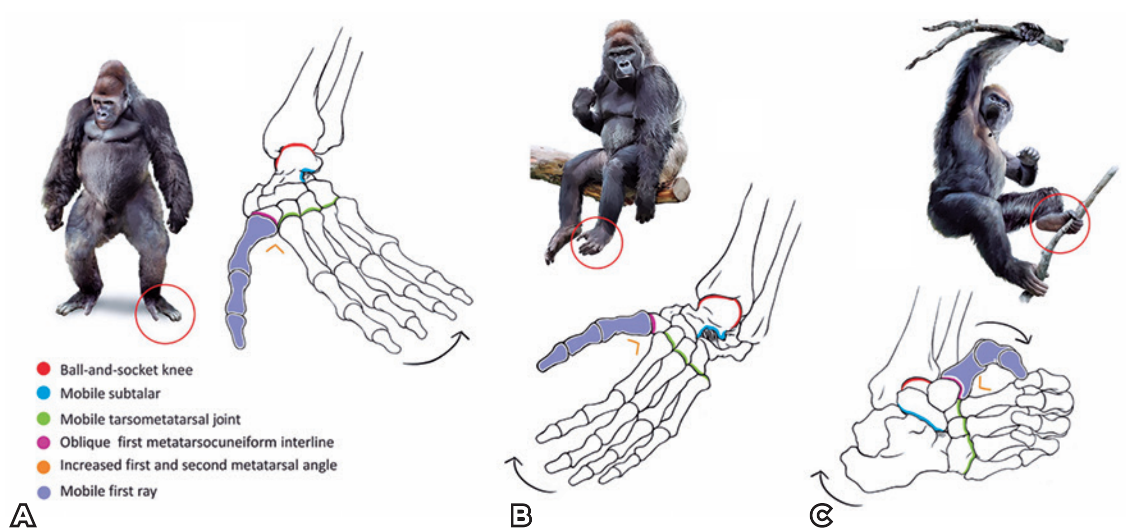

Figure 6. A. When in the standing position, the feet of primates are flat; B. Increased mobility of the knee and of the subtalar joint facilitates the passage from pronation to supination; C. The characteristics of the tarsometatarsal joint, especially first metatarsocuneiform obliquity, are required for the first ray to perform a movement of pronation to grasp the branches of the trees ("grasping foot"*)* and thus to move through the trees (brachiation).

Discussion

Humankind has been presenting with HV for thousands of years, and science has been searching for its specific cause in order to achieve a solution for this condition. Currently, it is possible to say that HV is a three-dimension deformity with a multifactorial pathogenesis. Literature accepts that there is familial sex-linked predisposition to this condition. Constitutional, static, and dynamic factors may lead to the development of HV and be triggered by a "cascade" mechanism, but the initial cause leading to this deformity is still unknown.

First metatarsal pronation, metatarsocuneiform joint obliquity, and first ray hypermobility are key aspects in the development of HV. As previously mentioned, the forefoot of primates exhibits a variety of typical characteristics of HV; thus, we believe that atavism is present in many cases of moderate or severe HV.

Muscular function and changes are highly debatable, and it is often not possible to ascertain whether they are a cause or a consequence of HV. It is logical to think that the treatment of HV would be initiated earlier and be more effective if the etiology of this condition were known. However, it is worth remembering that we are dealing with the world of hypotheses. In our opinion, adopting dogmatic positions on the theme with current knowledge is a serious mistake.

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Special Article

Medium-term results of the HINTEGRA total ankle arthroplasty

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Abstract

Objective: The aim of this study was to determine patient satisfaction, survivorship, and revision rate of the HINTEGRA total ankle arthroplasty (TAA). Our secondary objective was to assess hindfoot function.

Methods: All patients who underwent a HINTEGRA TAA between 2007 and 2014 were evaluated. We included a total of 69 patients (69 ankles), who were subjected to clinical and radiological examination and completed a visual analogue scale (VAS) for pain, the American Orthopaedic Foot and Ankle Society (AOFAS) ankle score, and the self-reported foot and ankle score (SEFAS). Hindfoot function was assessed using the AOFAS hindfoot score. Mean follow-up was 62 (57-101) months.

Results: The mean VAS score was 2 (0-3) and the SEFAS was 37 (26-48) at the most recent follow-up, while the AOFAS ankle score improved from 57 (52-62) to 87 (82-93). The AOFAS hindfoot score improved from 82 to 92 postoperatively. Eight patients had periprosthetic osteolysis and 5 underwent bone grafting of cysts. We detected polyethylene and hydroxyapatite particles in specimens obtained from the cysts. Eight patients had their procedures converted to an ankle arthrodesis.

Conclusion: In select patients, TAA improved quality of life. Our medium-term follow-up of the HINTEGRA TAA observed a survivorship of 89% at 5 years with an improvement in the AOFAS score and a mean SEFAS score of 37. We recommend that large periprosthetic cysts, which may be caused by the hydroxyapatite coating and polyethylene particles, be bone grafted prophylactically. We found hindfoot function to be preserved.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Arthroplasty; Osteolysis; Arthroplasty, Replacement, Ankle.

Introduction

The occurrence of primary osteoarthritis (OA) is not as common as post-traumatic OA of the ankle. The Canadian Orthopaedic Foot and Ankle Society classification for ankle arthritis includes deformities and the involvement of the neighboring joints in conjunction with ankle arthritis. This classification is currently widely used and has substituted previous classifications[1,2]. Secondary OA of the hip and knee joints accounts for only 9.8% and 1.6% of OA cases, respectively, whereas in the ankle it is reported to be as high as 65%-80%[3-6]. This progressive destructive joint disease leads to severe pain, decreased quality of life, and limits the performance of activities of daily living. The impact and severity of ankle OA is reported to be equivalent to those of end-stage renal disease or congestive cardiac failure[7-10].

The management of end-stage ankle arthritis includes fusion and total ankle arthroplasty (TAA). Following the abysmal failures of first-generation TAA designs, there has been a resurgence of TAA in the orthopaedic foot and ankle community using third-generation implants[1]. The HINTEGRA TAA, in particular, was designed to allow for less bone resection and a better surgical technique with a potentially longer survivorship. As is commonly seen in the literature, majority of the published data regarding TAA comes from the designing surgeons, the Hintegra TAA is no different[1,2,4-6,11]. These publications often report better survivorship than that reported by general surgeons. Medium-term results of the HINTEGRA TAA, as reported by the designers, included an 84% patient satisfaction[9]. Outcomes from non-designer surgeons also needs to be reported. It is necessary to report the clinical outcome of TAA as a quality measure and not only by revision rates[11].

Study performed at the University of the Witwatersrand, Johannesburg, Gauteng, South Africa.

Correspondence: Mohammadali Khademi. 24 12th Av., Orange Grove, Johannesburg, South Africa, Zip Code: 2192. **Conflict of Interest:** none. **Date received:** September 15, 2020. **Date accepted:** October 31, 2020. **Online:** December 21, 2020

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The aim of this retrospective study was to determine patient satisfaction, survivorship, and revision rate of the HINTEGRA TAA in the medium-term. Our secondary objective was to assess hindfoot function following TAA using the HINTEGRA prosthesis.

Methods

This study was approved by the Human Research Ethics Committee under the Clearance Certificate number: M170862.

All TAA procedures performed by a sole surgeon (NPS) using the HINTEGRA TAA prosthesis between 2007 and 2014 were identified. This research project was approved by the institution's ethics and research committee. Exclusion criteria included incomplete patient records and patients who were unavailable for follow up or who received protheses other than the HINTEGRA. A total of 93 TAA procedures using the HINTEGRA prothesis were performed during this period. Eight patients had passed away with a mean implant retention of 76 (72-80) months and 16 patients were untraceable. Sixty-nine patients (69 ankles) - 28 women (40.58%) and 41 men (59.42%) were included in the study (Figure 1).

Patient age ranged from 42 to 77 years, with a mean of 65 years. Patient demographics and indications for TAA are outlined in table 1. All patients were followed up on an annual basis after the first year. The mean follow-up time was 62 (57-101) months.

All patients underwent clinical and radiological assessments. Radiological assessment consisted of standard weight-bearing foot and ankle views, and radiographic alignment was measured on all X-ray images (Figure 2). The American Orthopaedic Foot and Ankle Society (AOFAS) ankle score, visual analogue scale (VAS), and self-reported foot and ankle score (SEFAS) were recorded for all patients. For evaluating hindfoot function, preoperative and postoperative AOFAS hindfoot scores were compared. Clinical examinations were performed, and data were collected by the author (MK). Preoperative data was obtained from medical records.

All data were assembled on a Microsoft Excel spreadsheet prior to analysis using STATA version 14. For continuous demographic variables, the Shapiro-Wilk test was used to check for the normality of the data and for deciding on whether to report them as means and standard deviations (SDs) or medians and interquartile ranges (IQR). For categorical variables, frequency tables were computed to determine the proportions for each demographic/clinical category. Differences between preoperative and postoperative AOFAS ankle scores were calculated and checked for normality. They were found to be normally distributed - hence a paired t-test was used to analyze the differences between preoperative and postoperative scores. AOFAS hindfoot scores were compared pre- and postoperatively, and the differences were found to be normally distributed; a paired t-test was also used analyze these results.

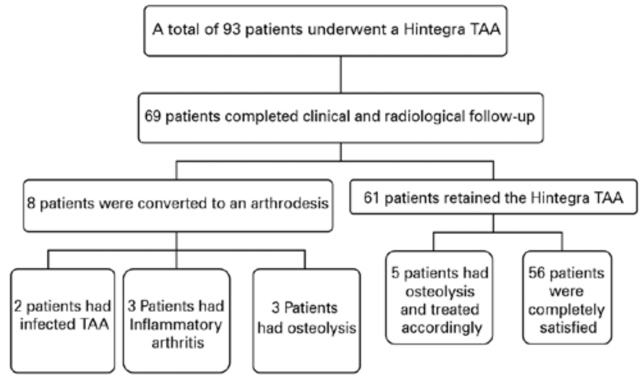

Figure 1. Flowchart of study outcomes.

Table 1. Patient demographics and indications for TAA

Characteristics	Number (N=69)
Sex	
Female	28
Male	41
Side	
Left	34
Right	35
Diagnosis	
Post-traumatic OA	60
Primary OA	6
Inflammatory arthritis	3

TAA: total ankle arthroplasty; OA: osteoarthritis.

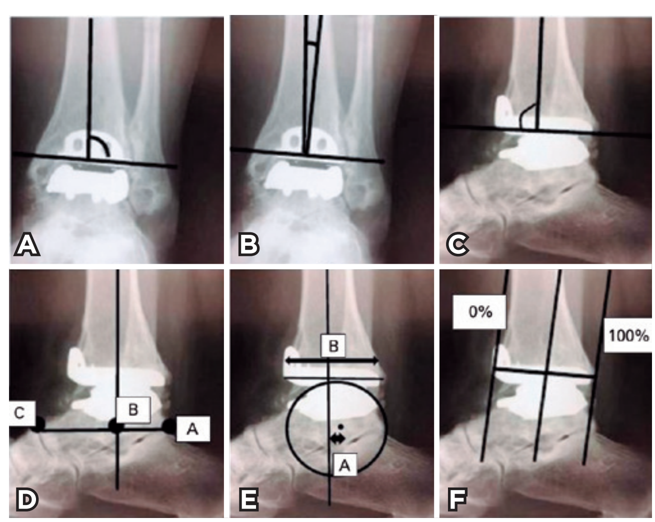

Figure 2. Methods of measurement of postoperative implant sagittal and coronal alignment: A. anatomic lateral distal tibial angle; B. tibiotalar angle; C. anatomic anterior distal tibial angle; D. tibial axis–talus ratio (tibiotalar ratio: AB/AC); E. anteroposterior offset ratio measurement (A/B); F. contact point ratio.

Results

Post-traumatic OA of the ankle joint was found to be the most common indication for TAA in our series. Three patients had inflammatory arthritis, of which 1 had systemic lupus erythematosus (SLE) and the other 2 had rheumatoid arthritis. These patients were on appropriate medical treatment, including biologic agents, in the perioperative period; a biologics-free window of three dosing cycles was strictly adhered to before surgery.

The mean AOFAS ankle score was 57 (range: 52.18-61.99) preoperatively, and 87 (range: 82.25-92.31) postoperatively; there was significant improvement after surgery (p-value <0.0001). The mean SEFAS score, representing patient satisfaction, was 37 (range: 26-48). A SEFAS score of 0 indicates severe disability and a score of 48 indicates normal function. According to these scores, 88% of the patients reported excellent or good outcomes (results are summarized in table 2). The median visual analogue pain score was 2 (0-4). The AOFAS hindfoot score improved significantly from 82 (range: 80-84) preoperatively to 92 (range: 90-94) post-surgery (p-value <0.0001). Patients had a mean ankle range of motion (ROM) of 37° before surgery and 32º after the procedure; ankle ROM thus did not improve after TAA in our series. Ankle instability was clinically checked through anterior drawer and varus stress tests and was not observed in any of the patients.

The radiographic alignment of the implant is summarized in Table 3. Two cases presented talar component subsidence, but with no clinical sequelae. At radiographic evaluation, 1 patient showed midfoot arthritis, 1 presented posterior subluxation of the ankle joint (clinically stable), and 1 had a worn polyethylene (PE) liner. These patients did not require additional surgery as they were asymptomatic and fully functional.

Table 2. SEFAS scores

SEFAS score	Outcome	Number of patients (N=69)
>40	Excellent	56
30-39	Good	5
20-29	Average	8
>20	Poor	**0**

SEFAS: self- reported foot and ankle score.

Table 3. Radiographic measurements of preoperative and postoperative ankle alignment

X-ray measurement	Preoperative	Postoperative	Normal value[8]
Anatomic lateral distal tibial angle	86-94° (mean: 90°)	85-93° (mean: 94°)	85-95°
Tibiotalar angle	-10-10 ° (mean: 0°)	0-6° (mean: 3°)	-5-+5°
Anatomic anterior distal tibial angle	78-92° (mean: 90°)	85-93° (mean: 89°)	80-90°
Tibial axis–talus ratio	28-46 (mean: 42)	34-50 (mean: 42)	27-42%
Anteroposterior offset ratio	-2-+3 (mean: 1)	0.1-0.2 (mean: 0.15)	0
Contact point ratio		35-50 (mean: 42.5)	40-45%

Eight patients were found to have developed large cysts (10mm² or larger) around their implants on postoperative follow-up X-ray imaging. These cysts were classified according to the Gruen zones (Figure 3). Three patients refused any further interventions, as they were asymptomatic. The other 5 patients underwent bone grafting of the cysts using a combination of allograft bone chips and demineralized bone matrix. A CT Scan was obtained for all patients prior to surgery, for planning purposes. Specimens from all five cases were sent for histology requesting Hematoxylin and Eosin (H&E) staining, Von Kossa staining, polarized light microscopy and Oil Red O (ORO) staining.

At H&E staining, serial sections showed synovium with aggregated clusters of pigmented crystalline-like material associated with a foreign body granulomatous response (Figure 4A). These clusters were found to be positive in Von Kossa staining, indicating the presence of of hydroxyapatite (Figure 4B). We identified PE particles in 3 out of the 5 specimens using ORO and polarized microscopy (Figure 4C and D).

Three patients had superficial wound infections. These occurred within the first 2 weeks, were treated topically and with oral antibiotics, and subsequently healed. A total of 8 patients had failure of the TAA and were converted to a fusion. Two cases developed deep infections within 1 year of the index surgery. These were referred to the sepsis unit for management and, once cleared of the infection (6-8 weeks), were converted to an allograft bone block arthrodesis by the primary surgeon. All 3 patients with inflammatory arthritis had their TAA procedures converted to ankle arthrodesis due to aseptic loosening within 2-5 years after index TAA surgery. Other 3 patients developed aseptic loosening with bone loss and required conversion to a fusion. The complications encountered in our case series were classified according to Glazebrook et al.[2] were summarized in table 4.

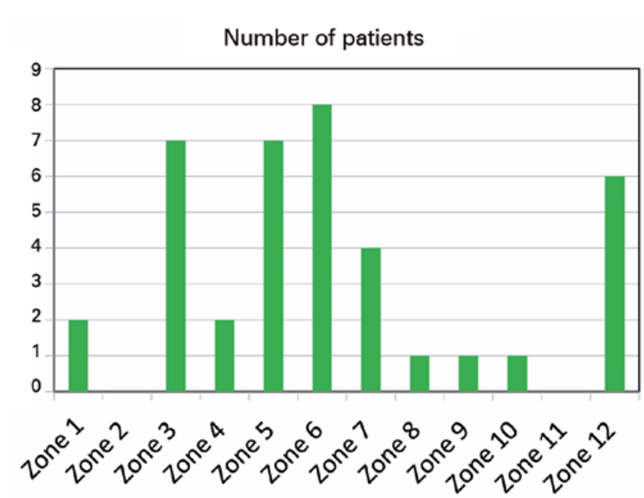

Figure 3. Distribution of cysts according to Gruen zones in the 8 patients who presented with osteolysis.

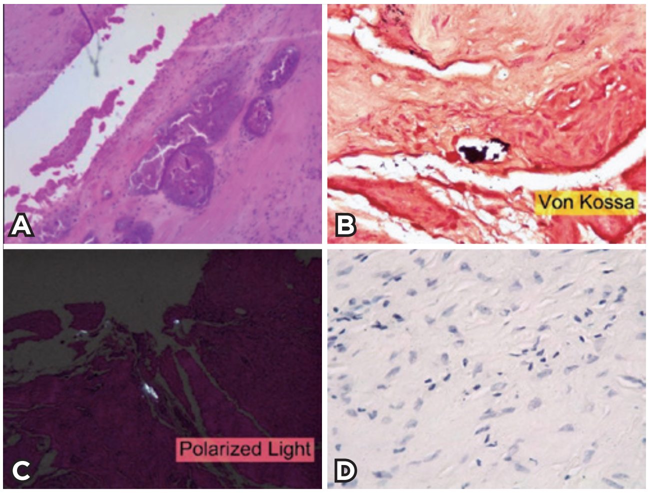

Figure 4. A. Hematoxylin and eosin (H&E) staining of the periprosthetic cysts reveals clusters of pigmented crystalline-like material associated with a foreign body granulomatous response. B. Von Kossa staining of periprosthetic osteolytic cysts showed multiple calcified layers. C. Birefringent particles under polarized microscopy of the periprosthetic osteolytic cysts showed polyethylene particles. D. Oil red O (ORO) staining of specimen taken from a patient with periprosthetic osteolysis around the HINTEGRA prosthesis.

Table 4. Complications according to Glazebrook's classification[2]

Complications	Number
High-grade complications	
Deep infection	2
Aseptic loosening	6
Implant failure	8
Medium-grade complications	
Technical error	0
Subsidence	2
Postoperative fracture	0
Low-grade complications	
Intraoperative fracture	0
Wound healing problems	3

Survivorship of the HINTEGRA implant at 62 months was 89% and the reoperation rate was 7%. No revisions of the implant components have been performed at this stage. Out of all TAAs, 11.4% failed and needed to be converted to ankle fusion. Fifty-six (90.80%) patients would strongly recommend a TAA to another patient. Five patients (8.20%) would not recommend this surgery, mainly due to a long perceived recovery.

Discussion

Fuchs and colleagues, in their 20-year follow-up study on ankle arthrodesis, found a significant negative impact not only on activities of daily living but also on patients' emotional aspects[7]. Total ankle arthroplasty is expected to improve quality of life, decrease pain, and improve gait[11]. The first TAA was performed by Lord and Marotte in 1970 using an inverted hip prosthesis, with disappointing results[7,9,11-13]. Dedicated first-generation TAA implants had constrained designs; these cemented prosthesis with constrained bearings did not have great medium- to long-term outcomes, with a high failure rate due to loosening[11,13-15]. Since then, designers have developed new implants, with different geometries and new technologies such as cementless interfaces and mobile bearings. Semi-constrained and non-constrained implants allow for additional axial rotation[14]. The Agility Total Ankle system, Salto Talaris, and Inbone are two-component prostheses as they have a fixed bearing surface. The Scandinavian Total Ankle Replacement (STAR) and HINTEGRA are three-component prostheses with a mobile bearing. It is important to note that medium-term follow-up of fixed-bearing and mobile-bearing implants revealed no differences in functional tests or outcomes[5,6,16-19]. Patient satisfaction increased from 10% and 65% (in patients with first- and second-generation implants, respectively) to almost 90% with third-generation implants such as the HINTEGRA TAA[3,13,18,20-24].

The ideal candidate for TAA is a mobile, middle-aged, or older patient with no significant comorbidities, good bone stock, and a stable and well-aligned arthritic ankle[14-17,25-29]. Total hip arthroplasty has a good outcome in patients younger than 30 years old, and total knee arthroplasty indications have been extended for patients younger than 55 years old. Kofoed and colleagues believe that TAA in the younger patient presents similar longevity and clinical outcomes as that performed in older patients. TAA has a good reported survivorship and longevity in patients as young as 42 years old[30-32]. The authors feel that the improved function, sparing of the hindfoot joints, and possibility of converting the TAA to an arthrodesis later, if required, render age a relative contraindication for TAA. This has also been reported by Latham and colleagues[23].

Minimal bone resection is a primary requirement for a good ankle prosthesis together with proper soft tissue balancing and alignment for a successful outcome[5]. The HINTEGRA total ankle replacement has one of the least constrained three-component prosthesis designs. Biomechanically, this implant provides axial rotation, as well as flexion and extension. It has been shown to be stable with eversion and inversion. The prosthesis involves minimal bone resection with stable fixation, which does not require cementing or intramedullary fixation, thus making the surgery technically easier[1,9,12,17,33-36].

Patients with arthritis in the neighboring joints (subtalar or midtarsal), in the knee, hip, or contralateral ankle will benefit more from TAA than from an arthrodesis procedure[1,4,22]. The HINTEGRA total ankle replacement is a good alternative to ankle arthrodesis. Preserving motion in the ankle joint with a TAA decreases the strain on neighboring joints. Although the published literature suggests that the ROM of the ankle joint can increase after TAA, our study found no significant postoperative increase in ankle ROM. The first audit of the HINTEGRA TAA by the designers also reported limited dorsiflexion[1,5,12-13]. This procedure can also preserve the biomechanics of the hindfoot and generally help patients improve their function, decrease pain, and discomfort, overall improving quality of life[7,11,37-38]. In our study, the AOFAS hindfoot score improved from 82 to 92 after TAA, thus confirming that hindfoot function was preserved and even suggesting that it improved.

Early failure of TAA is commonly due to infection or surgical errors, whereas late failure is due to aseptic loosening[13,27,28]. In a study done by Braito et al., 15% of TAA failures were found to be due to aseptic loosening; researchers concluded that this was the most common cause of TAA failure[37]. Hintermann and colleagues described radiographic criteria for loosening of the implant: The tibial component should be considered loose if either its position has changed by more than 2° relative to the long axis of the tibia, or a progressive radiolucency of more than 2mm is detected around the implant on anteroposterior or lateral views. The criteria for a loose talar component are: subsidence greater than 5 mm or a change in position of more than 5° relative to the hindfoot axis[3,13,21]. Other studies have suggested possible implant loosening when components moved more than 5° or 5 mm in serial X-ray imaging[27-28,33]. In our series, we had 6 cases of aseptic loosening that required conversion to fusion. Interestingly, the 3 patients in our cohort who had inflammatory arthritis all developed aseptic loosening. This is in contrast with Doets et al., who reported that the results of TAA in patients with rheumatoid arthritis were similar to those in patients with osteoarthritis[20]. We had 2 cases with talar component subsidence; both were asymptomatic patients with normal ankle function.

Periprosthetic cysts have been correlated with TAA failure, especially in mobile-bearing prostheses. Although the exact pathophysiology of this cyst formation is not fully understood, several hypotheses have been described[25]. From a mechanical point of view, osteolysis starts with the mechanical wear of the articulating surfaces and progresses with a cell-mediated immunological response to the wear particles. Particle disease, which is due to a reaction to the PE component, has been reported. According to this theory, cytokines are released by activated macrophages (histiocytes) after phagocytosing PE particles. The cytokines activate osteoclasts and inhibit osteoblast activity, leading to periprosthetic bone lysis[3,21,25,35-36]. The biological response by the host depends on particle size and concentration[3,21]. A gradual increase in fluid pressure occurs due to the inflammatory process, which leads to more bone loss[3,36]. Singh et al. used the term "ballooning osteolysis" to describe large periarticular cystic lesions found during revision TAA. They believe that the osteolysis mechanism in TAA is different than that in other joint arthroplasty procedures due to the difference in biomechanics[36].

Gruen and colleagues described radiographic zones for easier assessment and research of osteolysis after TAA[3,21,35] (Figure 5). In our study, zone 6 followed by zones 3 and 5, were the most commonly affected by osteolysis. Osteolytic cysts around the implant are more difficult to diagnose on plain X-ray images as they can be obscured by the tibial and talar components. Hanna and colleagues observed that CT scans with metal artefact suppression were more sensitive and accurate than plain radiography and should be used for assessing osteolysis in all cases[15]. Jensen and colleagues advocated using 3D multiplanar reconstructed images instead of CT scans to address the issue of scattering related to the CT scan[26]. We identified 8 patients with large periprosthetic cysts on X-ray imaging, of which 5 had had a CT scan.

Singh and colleagues reported on the histomorphometric, immunohistochemical, and elemental analyses of tissues from failed TAA procedures due to osteolysis. Von Kossa staining was used instead of H&E staining. They concluded that the implant's hydroxyapatite coating contributed to cyst formation[36]. All five specimens collected in our study yielded positive Von Kossa staining results, supporting the theory that hydroxyapatite plays a causative role in periprosthetic osteolysis and cyst formation.

Another similar histologic study on osteolytic cysts and periarticular tissue when using the Ankle Evolutive System (AES) prosthesis showed that Al_2O_3 particles released from sand blasting may cause cracks in the titanium/titanium oxide coating, thereby producing stress concentrations that lead to osteolysis[4,17,35]. Dalat et al., in their study on osteolysis around the AES, found metal debris and PE particles within the obtained samples[16].

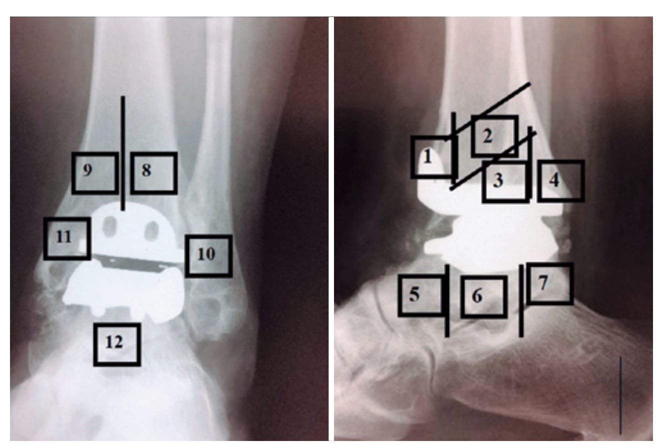

Figure 5. Osteolytic zones in the tibia and talus, according to Gruen and colleagues. Zones 2 and 5 were recommended for screw insertion by the initial HINTEGRA TAA surgical technique. Due to a high rate of osteolysis around these screws, these optional fixation screws were abandoned.

Histiocytes and giant cells are the most common cells observed in these cysts. Histologic studies have shown PE and metal particles in the samples[3,36]. Schmalzried et al. observed that ORO staining had a similar sensitivity to polarized microscopy but was less specific for identifying PE particles; they recommended that the ORO staining should not be used as an isolated method for identifying PE particles. However, Schipper et al. reported that this staining technique was very specific (96.4%) and sensitive (100%)[8,27-28]. Van Wijngaarden et al. also detected PE particles in all their samples using the ORO staining method[10]. Our experience regarding the ORO staining method, used in isolation, differs from that of Schipper et al., as we observed PE particles in only 3 specimens. We found the combination of ORO and polarized microscopy to be more sensitive and specific for identifying PE particles.

Prosthetic design and surgical technique have been shown to influence the development of osteolysis[13,17,22]. We assessed implant alignment using radiographs of the 8 patients who developed osteolysis and found no obvious malalignment that could have contributed to cyst formation. Various studies confirmed that most of the periprosthetic osteolytic cysts related to the HINTEGRA TAA were asymptomatic. However, these cysts should still be identified and treated accordingly. Patient age, weight, and activity level have been reported as risk factors for progression.

Treatment of osteolytic cysts after TAA is challenging. Options can be broadly divided into monitoring, bone grafting, revision, or conversion of the TAA to arthrodesis. If the defect is contained, then bone grafting is the preferred option. A segmental defect, on the other hand, might require revision of the implant. Implants needed for revising a TAA are technically challenging[21,33-34]. Hintermann et al. published a revision protocol for the HINTEGRA TAA in 2013[12]. Gross and colleagues reported that grafting of periprosthetic bone cysts without revision of the prosthesis was effective and increased implant survivorship[33]. In our study, we bone grafted 5 of the 8 periprosthetic cysts with good early results.

In our series, the AOFAS ankle score significantly improved from 57 preoperatively to 84 postoperatively. This is comparable to several other designer and non-designer studies[4,24]. Our results are similar to those of Jung et al., who reported 90.5% of satisfaction in their medium-term follow-up[3,14]. Our postoperative AOFAS ankle scores and survival rates were similar to those of previous studies on the HINTEGRA TAA (Table 5).

Survivorship of a TAA is defined as metallic component failure requiring prosthesis removal and conversion to an arthrodesis, while revision of a TAA is defined as the exchange of one or more components (including the plastic component) without any known trauma[38]. Good short- to medium-term results were reported by European surgeons using the STAR TAA: Wood and Deakin reported a survival rate of 80.3% and Karantana et al. reported a survival rate of 84% with a minimum follow-up of 10 years[39]. A non-designer short-term follow-up study in South Africa showed very satisfactory results for the STAR prosthesis, with survival rates of 95.6%[40]. The survivorship of the HINTEGRA prosthesis in our study was 89% at 62 months, with a 95% confidence interval (Kaplan-Meier curve, Figure 6). Overall survivorship reported in designer studies was 78%-94% and 77%-84% after 5 and 10 years, respectively[1,41]. Survival rates for modern TAA range from 69% to 79% after 10 years; in comparison, total hip and knee arthroplasties present a 95% survivorship[19,21].

Table 5. Comparison of survival rates and postoperative AOFAS ankle scores between the literature and the current study

Study	Year of publication	Type of study	Survival rate	Postoperative AOFAS score	Sample size
Hintermann et al.[26]	2004	Short-term	94%	85	122
Nery et al.[48]	2010	Short-term	94%	76	10
Bai et al.[3]	2010	Short-term	97%	86	65
Choi et al.[35]	2013	Short-term	87.5%	82	21
Barg et al.[4]	2013	Medium-term	94%		684
Hintermann et al.[27]	2013	Medium-term	83%		117
Current study	2020	Medium-term	89%	92	69

AOFAS: American Orthopaedic Foot and Ankle Society.

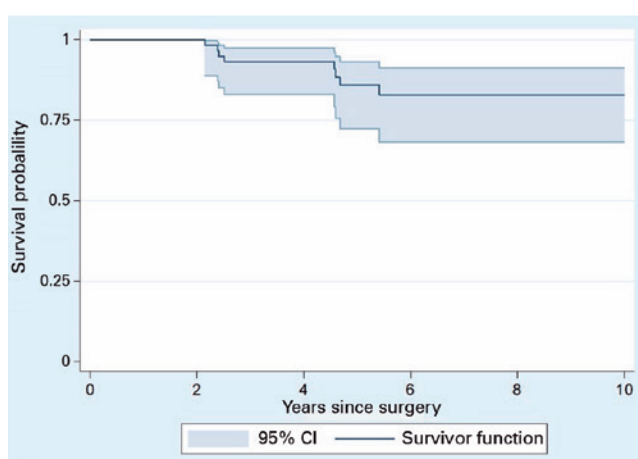

Figure 6. Kaplan-Meier curve showing 89% survivorship in our case series, with a 95% confidence interval (CI).

Conclusion

In select patients, TAA improved quality of life and had good longevity. Our medium-term follow-up of the HINTEGRA TAA showed that the prosthesis had a survivorship of 89% at 5 years, with significant improvement in the AOFAS ankle score (57 to 84) and 88% of patients reporting excellent or good outcomes. We recommend that large periprosthetic cysts (>10 mm^2) be bone grafted prophylactically when identified. Although the pathophysiology of aseptic loosening is still not fully understood, we believe that hydroxyapatite coating and PE wear particles could be causative factors. As a secondary aim of our study, we found hindfoot function to be preserved, with significant improvement in the follow-up AOFAS hindfoot scores.

Authors' Contributions: Each author contributed individually and significantly to the development of this article: KM *(https://orcid.org/0000-0003-3167-7797) collected data; interpreted the results; wrote the paper; participated in the reviewing process; approved the final version; NPS *(https://orcid.org/0000-0002-5566-7588) conceived and planned the activities that led to the study; participated in the reviewing process; approved the final version; PNFF *(https://orcid.org/0000-0003-4639-0326) conceived and planned the activities that led to the study; participated in the reviewing process; approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Special Article

Hindfoot alignment using weight-bearing computed tomography: a new measurement for pes cavovarus

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Abstract

Measurement of hindfoot malalignment and flexibility is essential for treatment decision-making in cavovarus foot deformity. Weight-bearing computed tomography (WBCT) shows greater diagnostic accuracy and allows the study of osteoarticular alignment in the physiological upright position. The most commonly used method for measurements on WBCT scans is the foot and ankle offset (FAO), which is based on the structural tripod of the foot: the calcaneus and the first and fifth metatarsal heads. During the Coleman block test, the first metatarsal head is not resting on the ground and, therefore, does not represent the physiological support of the tripod. We describe a new measurement, the forefoot/hindfoot offset (FHO), for assessing hindfoot alignment on WBCT scans.

Level of Evidence V; Diagnostic Studies; Expert Opinion.

Keywords: Talipes Cavus/diagnostic imaging; Weight-Bearing/physiology; Tomography, X-Ray computed/methods; Bone malalignment.

Introduction

Hindfoot malalignment is a common finding that can result from different etiological factors. The accepted physiological alignment is defined as a hindfoot valgus angle of 0° to 5°, while malalignment is defined as a hindfoot valgus angle greater than 10° or any degree of hindfoot varus[1].

Measurement of hindfoot alignment is essential for surgical planning and treatment decision-making: soft tissue procedures, osteotomy, arthrodesis, or arthroplasty[2]. Cavovarus foot deformity is associated with extensive clinical variability, from subtle and flexible to severe and rigid. Although the term "pes cavus" refers only to an abnormal elevation of the medial longitudinal arch, this deformity is associated with varying degrees of hindfoot varus, ankle equinus, and forefoot adduction[3].

Traditionally, hindfoot alignment has been measured with conventional weight-bearing radiographs in the coronal plane using a long axial view that allows tibiocalcaneal angle measurement[4,5]. Conventional computed tomography (CT) allows better assessment of joint congruity and three-dimensional (3D) images, but it does not allow the assessment of the physiological joint behavior when the foot is loaded[6]. In addition, this technology allows the generation of digitally reconstructed radiographs (DRRs) with no rotation bias[7].

Several studies have compared weight-bearing computed tomography (WBCT) to other imaging modalities and reported greater accuracy of WBCT due to its 3D nature, which avoids bone overlap and allows the assessment of osteoarticular alignments in the physiological upright position[6]. The most commonly used method to measure hindfoot alignment on WBCT scans is the foot and ankle offset (FAO), a semiautomatic 3D biometry that considers the forefoot that interacts with the ground as a reference instead of the tibia[8].

This article describes a new hindfoot alignment measurement that is easy to perform, can assist in the assessment of foot deformities and can quantify the alignment of the forefoot in relation to the hindfoot.

Study performed at the Lab. Prof Manlio Mario Marco Napoli, Hospital das Clinicas HCFMUSP, Faculdade de Medicina, Universidade de Sao Paulo, SP, Brazil.

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Description of the forefoot/hindfoot offset (FHO) measurement

Weight-bearing computed tomography (WBCT) scans are obtained with the patient in an upright position, standing barefoot with the feet and ankles parallel to one another while facing forward in the direction of the longitudinal axis of the feet. The WBCT scanner allows imaging of the foot and ankle simultaneously. The parameters used for image acquisition are as follows: tube voltage, 120 kVp; tube current, 5.0mA; CT dose index (CTDI), 2.171 mGy; field of view (FOV), 20 cm high x 35 cm wide; and slice thickness, 0.3mm. After image acquisition (LineUp®; CurveBeam, Philadelphia, PA, USA), the WBCT scans are assessed with Cubevue® software (CurveBeam, Warrington, PA, USA).

According to a preestablished research protocol approved by the ethics committee of the institution where the study was conducted, 3 sequential WBCT images are acquired in feet clinically diagnosed as flexible cavovarus feet: the first with the patient standing upright, and the other 2 with the patient performing the Coleman block test. At this stage, each image is acquired with one foot resting on a block, while only the first ray of the other foot is not touching the block, keeping the lateral rays resting on it (Figure 1).

After image acquisition, DRRs are examined to confirm the deformity under study using the following radiographic parameters: Meary angle (Figure 2A), calcaneal pitch angle (Figure 2B), and Saltzman view (Figure 2C). Among WBCT measurements, hindfoot angle measured on the inferior point of the calcaneus (HA_{IC}) and FAO can also confirm a hindfoot varus (Figure 3).

To perform the measurement proposed in this study, configuration of sagittal plane alignment is not necessary, as the rotation of the limb does not affect its measurement. Sagittal reconstruction of the foot and ankle is performed with thicker slices so that the metatarsals can be assessed in 3D in the axial plane.

Figure 2. Digitally reconstructed radiographs (DRR). A. Lateral DRR – Meary angle. B. Lateral DRR – Calcaneal pitch. C. DRR measurements of the hindfoot alignment – Saltzman view.

Figure 1. Clinical assessment of flexible cavovarus feet. A. Note the bilateral hindfoot varus. B. Note the elevation of the longitudinal arch of the right foot. C and D. Coleman block test showing right hindfoot flexibility.

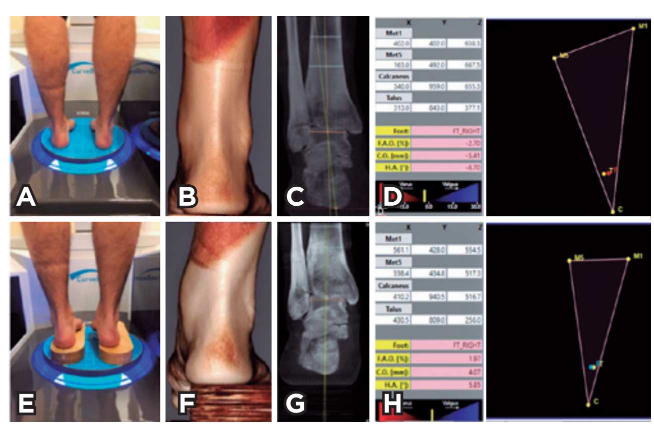

Figure 3. A and B. Protocol for weight-bearing computed tomography (WBCT) scanning in an upright position. C. Hindfoot angle measured on the inferior point of the calcaneus (HA_{IC}) in an upright weight-bearing position showing varus. D. Foot and ankle offset (FAO) in an upright weight-bearing position. E and F. WBCT scanning during the Coleman block test. G. HA_{IC} during the Coleman block test showing hindfoot valgus. H. FAO during the Coleman block test

A line is drawn running along the long axis of the second metatarsal, equidistant from the 2 diaphyseal cortices of the second metatarsal. The line is drawn through the midpoint of 2 lines that connect 2 cortices in the diaphyseal region of the second metatarsal (Figure 4A). After defining the axis of the second metatarsal, the slices that were thickened during sagittal reconstruction are returned to the original minimum thickness of image acquisition (0.3mm). In the axial plane, the shortest distance from this line to the weight-bearing point of the calcaneus is then measured. The weight-bearing point of the calcaneus is determined as the lowest point of the heel in the 3 available planes (axial, sagittal, and coronal). Measurements passing laterally to the weight-bearing point are considered positive, while those passing medially are considered negative (Figure 4B and 4C) (Table 1).

Table 1. Assessment of hindfoot alignment

	Regular	Coleman block test
Calcaneal pitch	31°****	
Meary angle	11°	
Saltzman view	9.5°	
FAO*	-2.7	1.9
HA**	-8.5°	-1.7°
FHO***	21.9mm*****	7.4mm

*Foot and ankle offset
**Hindfoot alignment
***Forefoot/hindfoot offset
****degrees
*****millimeters

Figure 4. Forefoot/hindfoot offset (FHO). A. DDR – long axis of the second metatarsal. B. FHO – regular cavovarus foot. C. FHO – cavovarus foot, Coleman block test.

Discussion

Cavus foot deformity has been studied for decades. It is known that its pathophysiology is mainly due to a muscle imbalance in the feet[9]. In 1977, Coleman described the first test to assess hindfoot flexibility in cavovarus feet. This test is used worldwide to evaluate the behavior of the hindfoot when the first metatarsal is unloaded, which is responsible for hindfoot varus – the “tripod” effect[10]. In 1995, Saltzman described a radiographic view for measuring hindfoot alignment in relation to the tibia with the patient standing upright[4]. To this end, the second toe (forefoot axis) was standardized as a reference for the positioning of the foot during the test. Although widely used, it is known that this radiographic assessment of hindfoot alignment can change depending on the positioning of the forefoot[11].

In 2012, Lintz et al. published a mathematical model to calculate hindfoot alignment on radiographs using the forefoot as a radiographic parameter, regardless of the tibial axis. With the development of WBCT, this measurement was transformed into a software called Torque Ankle Lever Arm System (TALAS). Through a semiautomatic measurement, the software produces a 3D biometric measurement called FAO[8]. Although WBCT has tools capable of repositioning the foot on its sagittal axis, thus eliminating the positioning bias of radiographs, the assessment of hindfoot alignment in relation to the forefoot is already well established in the literature[7].

Although numerous radiographic measurements have been described for the assessment of foot alignment, only Graham et al. described a measurement to assess the behavior of the forefoot in relation to the hindfoot in standing position, called the talar-second metatarsal angle. The authors advocate the use of the second metatarsal axis because it is the most stable structure in the forefoot[12]. Measurement of the forefoot/hindfoot offset uses the same parameter as the forefoot – long axis of the second metatarsal – differing only in the parameter of the hindfoot.

Studies have shown that osteotomy to elevate the first metatarsal alone is not able to reproduce the hindfoot valgus observed during the Coleman block test in all patients[13]. Myerson and Myerson reported only 38% of satisfactory results in the correction of flexible cavovarus feet according to the Coleman block test. The authors believe that, because of its subjective nature, the Coleman block test creates a false impression of the real flexibility of the cavovarus foot[14].

There has been discussion among experts as to the validity of the FAO associated with the Coleman test, since, during the test, the first metatarsal head is not resting on the ground and, therefore, does not represent the physiological support of the tripod. The measurement proposed here allows to quantitatively measure forefoot alignment in relation to the weight-bearing point of the hindfoot in cavovarus feet, which can be useful in the surgical planning for correction of these feet. In addition, low radiation exposure along with high-speed acquisition of high-resolution 3D images by the WBCT scanner makes it possible to assess the real flexibility of cavovarus feet using only 2 image captures, with the patient standing upright and performing the Coleman block test.

The evident globalization of this technology and the development of new measurements, such as the one described here, will produce more reliable data and, consequently, better biomechanical compression of the foot, thus contributing to the reduction of unsatisfactory surgical results. We believe that future studies may also use this measurement to assess foot deformities such as metatarsus adductus and valgus flatfoot, among others[6].

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Special Article

Computed tomography with stress maneuvers for diagnosing syndesmotic instability: a summarized research protocol for a new examination

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Abstract

Syndesmotic instability is a fundamental question that guides treatment; despite the currently available diagnostic imaging tests, its determination is still challenging. Knowledge of the instability degree assists the physician in the decision-making process regarding surgical or nonsurgical treatments. The authors are currently conducting a prospective diagnostic accuracy study by consecutively selecting individuals aged 18 years and older with an orthopaedic clinical examination indicating suspected acute syndesmotic injury. Magnetic resonance imaging is the reference standard used for evaluating the diagnostic accuracy of 3 computed tomography index tests. These tests include the neutral position and 2 ankle stress maneuvers: external rotation and dorsiflexion. Comparative measurements between the injured syndesmosis and the uninjured contralateral side of the same individual evaluate the tibiofibular relationship and investigate syndesmotic instability. This study aims to describe a summarized research protocol for a new technique using computed tomography with stress maneuvers and to show a didactic example of syndesmotic instability diagnosis.

Level of Evidence V; Diagnostic Studies; Expert Opinion.

Keywords: Tomography, X-Ray Computed/methods; Ankle joint/diagnostic imaging; Magnetic resonance imaging.

Introduction

Ligament damage to the distal tibiofibular syndesmosis is a specific type of sprain commonly recognized as a high ankle sprain. Persistent disability and chronic pain are the leading causes of unfavorable outcomes concerning syndesmotic lesions, which frequently demand a significantly more intense treatment and longer recovery times than low lateral ankle sprains[1,2].

In case of syndesmotic disruption, the degree of instability guides decision-making on whether to operate or treat conservatively[3]. The diagnostic tools available to define the correct treatment option include clinical examinations, routine radiographs, stress radiographs, computed tomography in the neutral position (CTNP), weight-bearing computed tomography (WB-CT), and magnetic resonance imaging (MRI). The best current practice considers that clinical diagnosis is supported by limited evidence and that few clinical tests have any validity in recognizing syndesmotic disruption[4]. Identifying the wider articular space on the injured side relative to the contralateral unaffected side may immediately allow the diagnosis of severe syndesmotic instability (SI) on mortise or anteroposterior radiographic views. However, routine radiography may underdiagnose SI when this test demonstrates a normal tibiofibular relationship and it cannot reliably estimate syndesmotic injuries[5]. Stress radiographs are inaccurate for evaluating syndesmotic injuries, as shown in a cadaveric model[6]. Recently, the use of WB-CT (a new imaging test mo-

Study performed at the Hospital Israelita Albert Einstein, São Paulo, SP, Brazil and Hospital das Clínicas HCFMUSP, Faculdade de Medicina, Universidade de São Paulo, SP, Brazil.

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dality) has emerged in syndesmosis examination; however, a study showed that WB-CT was not superior to CTNP[7], and axial loading did not improve the diagnosis of instability[8]. Although MRI tests have a high accuracy in visualizing and diagnosing syndesmotic injuries[9], they are expensive and not widely accessible. CTNP is more sensitive than radiography for identifying syndesmotic widening[10]; even so, the anterior tibiofibular distance obtained using CTNP has an undesirable area under the receiver operating characteristic (ROC) curve (AUC) performance of 0.56 for diagnosing SI[11].

Despite the utility of all these tests, the correct diagnosis of SI is still difficult to achieve, and syndesmotic disruption and real SI should be differentiated.

Comparative ankle CT with stress maneuvers (CTSM) is an alternative test that might advance SI diagnosis, and to the best of our knowledge, its implementation has not yet been reported. This study is currently in progress, recruiting participants, and for transparency purposes, the authors registered the complete research protocol on *ClinicalTrials.gov* (NCT04095598, pre-results). The authors have also published the complete research protocol, without results, in another medical journal[12]. This article is a summarized version of the entire research protocol, emphasizing the description of the examination technique and adding a didactic example.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 62100016.5.1001.0071.

This prospective study of diagnostic test accuracy follows the Standards for Reporting of Diagnostic Accuracy Studies (STARD) guidelines[13]. The Radiology Department of a tertiary hospital is conducting this study in partnership with the Orthopaedics Department. A consecutive sample of participants with suspected syndesmotic disruption visiting the foot and ankle outpatient clinic is being referred to the Radiology Department of the same institution for CT and MRI examinations. Researchers are including participants aged 18 years and older with an episode of ankle sprain having occurred up to 3 weeks before imaging. Patients should also have a positive orthopaedic evaluation for unilateral syndesmotic injury determined as the presence of at least one of the following symptoms: pain during palpation of the distal tibiofibular syndesmosis, pain during manual compression of the tibia and fibula in the middle third of the leg (squeeze test), pain in the external rotation examination, and an inability to stand on the toes of the affected foot. Researchers are excluding participants with bilateral ankle sprains, previous ankle surgery, ankle fractures or dislocations, acquired or congenital ankle deformities, as well as infection, inflammatory, or neuropathic ankle arthropathies. Participants are required to sign an informed consent form, provide demographic data, and complete preexamination forms before undergoing imaging examinations.

Technical parameters for CT image acquisition

An Aquilion ONE CT scanner (Toshiba Medical Systems, Tochigi, Japan) with 320 channels uses the following technical parameters in the examinations: volumetric acquisition, 320-detector rows, medium or large field of view, a high-resolution bone filter, 120 kV, 150 mA, 0.5 s rotation time, 0.5mm slice thickness, and 0.25mm interpolation. The lowest possible irradiation dose produces images of diagnostic quality. The same field of view simultaneously examines the feet of the participants.

Existing index test: CTNP

In this test, one foot is parallel to the other in the neutral phase, and both feet are perpendicular to the long axis of the legs. The knees are in the extended position. Figure 1 (A and B) illustrates the position of the feet during CTNP.

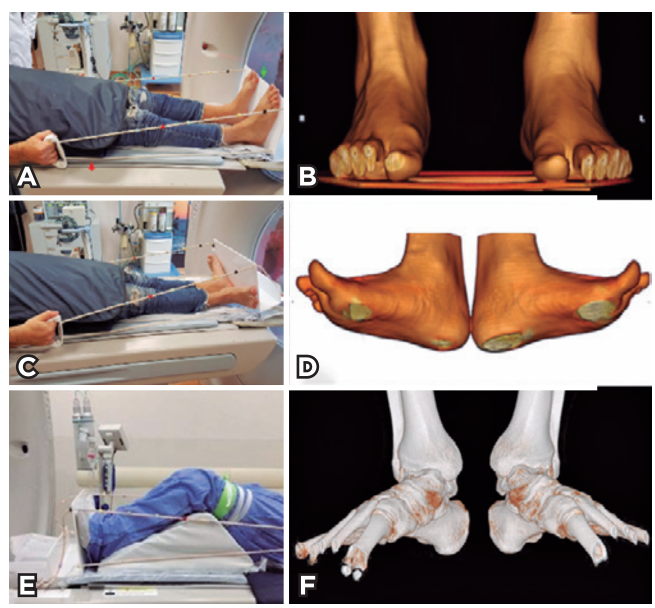

Figure 1. Position of feet during the CT examination. Photograph of a patient undergoing CT in the neutral position (A). A three-dimensional skin surface reconstruction CT image showing the feet in the neutral position (B). Photograph of a patient undergoing CT with ankle stress maneuvers and extended knees (C). A three-dimensional skin surface reconstruction CT image showing the feet with stress maneuvers and extended knees (D). Photograph of a patient undergoing CT with ankle stress maneuvers and semi-flexed knees (E). A three-dimensional bone reconstruction CT image showing the feet with stress maneuvers and semi-flexed knees (F).

New index test: CTSM and extended knees (CTSM-EK)

In the first stress phase, the researchers control external rotation by placing the feet at 45 degrees using an angle meter and a vertical line as reference. Voice commands instruct the participant to maintain maximum dorsiflexion to the limit of tolerable pain during image acquisition. The knees are maintained in the extended position. Figure 1 (C and D) shows the position of the feet during CTSM-EK.

New index test: CTSM and semi-flexed knees (CTSM-FK)

In the second stress phase, the researchers control external rotation by placing the feet at 45 degrees using an angle meter and a vertical line as reference. Voice commands instruct the participant to maintain maximum dorsiflexion to the limit of tolerable pain during image acquisition. A support pad maintains the knees in a flexed position at 45 degrees. Figure 1 (E and F) shows the position of the feet during CTSM-FK.

Acrylic board

Investigators perform the CTNP, CTSM-EK, and CTSM-FK tests in a standardized manner. All participants are placed in the supine position, and an acrylic board (Medintec, Mogi das Cruzes, Brazil) connected to a pair of side strings of adjustable length supports the feet during examinations. The researchers ask the participants to hold the proximal ends of the strings and provide verbal instructions to pull strings and perform dorsiflexion at proper times through the room's speakers.

Feasibility assessment of stress maneuvers

Technicians guide participants to train dorsiflexion by simulating the movement of the feet, pulling strings just before image acquisition. Difficulties in performing stress maneuvers, including pain exacerbation, motion artifacts, image repetition, total examination duration, and dropouts are used to assess the feasibility of the new index test.

CTNP, CTSM-EK, and CTSM-FK reading parameters

Syndesmotic injury is a multiplanar instability, and reading parameters should examine the rotational, anteroposterior, and lateral translation of the fibula to the tibia. Measurements comprising 6 distances, 2 ratios, and 2 angles as proposed by Nault et al[14] are a complete evaluation of the multiplanar tibiofibular relationship. A reference line placed 1 cm above the tibial plafond establishes the correct plane for all measurements except for the second angle, which is measured in the plane of the tibial plafond. All measurements are performed in a standardized manner for the CTNP, CTSM-EK, and CTSM-FK examinations.

MRI technical parameters

A 1.5-T magnet HDX (GE Healthcare, Milwaukee, USA) with a dedicated phased-array coil is being used in all examinations with the following sequence parameters: sagittal T2-weighted fat-suppressed (repetition time/echo time [TR/TE] = 3000/39; number of excitations [NEX] = 2; matrix = 384 x 224; thickness = 4mm; field of view [FOV] = 10cm); sagittal T1-weighted (TR/TE = 542/9; NEX = 1; matrix = 320 x 256; thickness = 4mm; FOV = 10cm); and axial T2-weighted fat-suppressed (TR/TE = 3483/48; NEX = 2; matrix = 384 x 224; thickness = 4mm; FOV = 10 cm). Two optimized sequences with a 3-mm slice thickness are also being performed: coronal T2-weighted fat-suppressed (TR/TE = 3000/39; NEX = 2; matrix = 384 x 224; thickness = 3 mm; FOV = 10cm) and coronal oblique PD-weighted (TR/TE = 2840/35; NEX = 2; matrix = 384 x 224; thickness = 3; FOV = 10cm).

Reference test (MRI)

The standard protocol acquires MRIs of all participants' ankles suspected to have a syndesmotic injury. Participants are scanned with their ankles in the neutral position and their knees in extension. Two studies compared the accuracy of MRI to that of arthroscopy and showed that MRI is highly sensitive and specific for evaluating syndesmotic injury[9,15]. The best reference standard for syndesmotic injuries is the arthroscopic examination, which enables correct diagnosis and treatment[16]. However, in this study, the inclusion criteria are based on the ankle sprain context and physical examination, which have limited accuracy[4]. A significant proportion of uninjured syndesmosis is selected with the alternative diagnosis of lateral collateral ligament injury. The use of arthroscopy would have been difficult to justify ethically because patients with alternative diagnoses would presumably show negative results in the index and reference tests. Although the arthroscopic examination is a minimally invasive procedure, it may lead to complications and is not risk-free[17,18].

MRI reading parameters

During MRI reading, investigators are classifying the syndesmotic ligaments (anterior inferior tibiofibular, posterior inferior tibiofibular, and interosseous), lateral collateral ligaments (anterior talofibular, calcaneofibular, and posterior talofibular), and deltoid ligaments (deep and superficial layer) as grade 0 (normal ligament), grade I (ligament sprain with soft tissue edema around the ligament, which is still intact), grade II (partial tear with high signal intensity and thickening), and grade III (complete ligament tear with avulsion or discontinuity)[19].

Statistical analysis

Descriptive analyses

Absolute frequencies and percentages describe categorical variables. Means, standard deviations, and minimum and maximum values describe numerical variables.

Inference analyses of diagnostic accuracy

The ROC curve and the AUC indicate the diagnostic accuracy of the 3 index tests. The absolute difference in AUC compares the performance of the tests. The CTSM-EK or CTSM-FK tests will have superior diagnostic accuracy if the ROC curves shift to the left when compared to the CTNP test. The CTSM-EK or

CTSM-FK tests will have the best diagnostic accuracy if their AUC values are greater than that of the CTNP test.

Analysis of variability

A subgroup analysis assesses sources of variability in the accuracy of the index tests. The reference standard test determines the degree of severity of the ankle sprain by prespecifying 3 subgroups based on the number of damaged syndesmotic ligaments. Isolated tears of the anterior inferior tibiofibular ligament define a mild sprain. Injuries involving the anterior inferior tibiofibular and interosseous ligaments define a moderate sprain. Lesions involving the anterior inferior tibiofibular, interosseous, and posterior inferior tibiofibular ligaments indicate a severe sprain. Higher degrees of ankle sprain produce higher degrees of instability that may be easier to diagnose, and lower sprain degrees act in the opposite direction. The index test is expected to be more accurate in higher than in lower sprain degrees. Another source of variability is the control of dorsiflexion by the participants during the stress maneuver. The current acrylic board setting does not enable researchers to control dorsiflexion, but they do register this measurement and investigate its influence on result accuracy. The pain reported by the participant may be another source of variability. Pain aggravation defines a subgroup, while no aggravation characterizes the other subgroup. The pain aggravation subgroup may have difficulties during dorsiflexion, and lower accuracy results are expected in comparison to the subgroup with no pain aggravation. The ROC curve and the AUC will compare the subgroups' diagnostic accuracy for all variability sources.

Inter-rater analysis

Two observers will independently read the index tests and, after a 3-month washout interval, the reference standard test. The intraclass correlation coefficient will verify the agreement between observers regarding the data extracted from the index test, and the Kappa coefficient will confirm the agreement concerning reference standard data. A second consensus reading will solve discordant cases.

Sample size calculation

A previous study found an AUC performance of 0.56 regarding CTNP[11]. Considering the null hypothesis that the existing CTNP test has an AUC of 0.56, researchers propose the alternative hypothesis that the new CTSM test will display superior accuracy with an AUC of 0.80. The full sample size needed to observe a difference between these outcomes is estimated as 39, considering a 1:2 proportion between the groups (13 and 26 participants per group, respectively).

Software and thresholds

The MedCalc Statistical Software (MedCalc Software Ltd, Ostend, Belgium), version 19.4.0, will be used for the analyses, considering a power of 80% for finding differences between groups, a significance level of 5%, and 95% confidence intervals.

Didactic Case Example

A 47-year-old male patient suffered a high ankle sprain. He complained of persistent pain and swelling in the left ankle since the sprain episode 3 weeks earlier. The orthopaedic clinical examination was positive for syndesmotic injury. A painful syndesmosis on palpation inspection and difficulty to stand on the toes of the affected foot were the main positive clinical signs. Anteroposterior, mortise, and lateral radiographic views of the ankle were unremarkable. The patient was referred to the Radiology Department for CT and MRI. In the first phase of the examination (CTNP), the left anterior, central, and posterior tibiofibular distances were similar to those of the unaffected contralateral side, representing a false-negative result (Figure 2A). In the second phase, where external

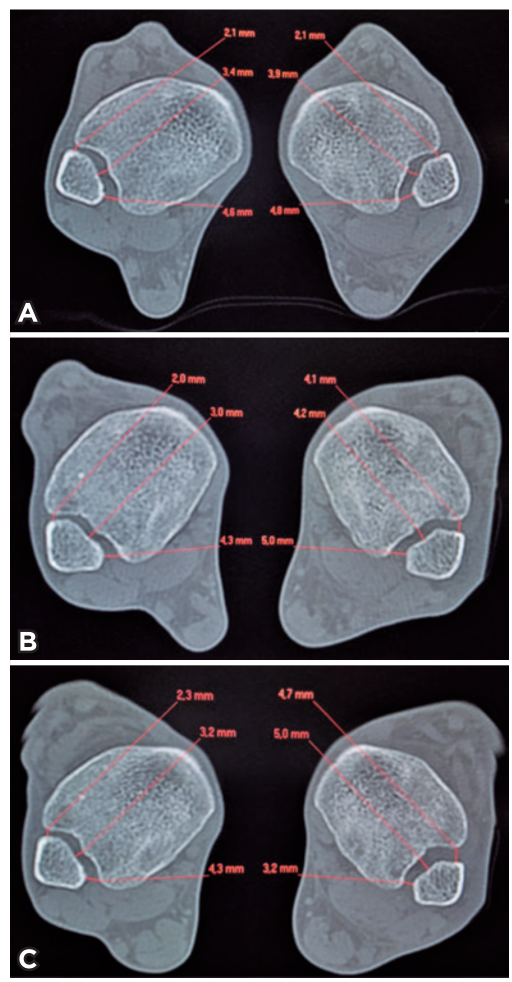

Figure 2. CT images in the axial plane 1 cm above the tibial plafond during the three phases of the examination. CT in the neutral position (A). CT with ankle stress maneuvers and extended knees (B). CT with ankle stress maneuvers and semi-flexed knees (C).

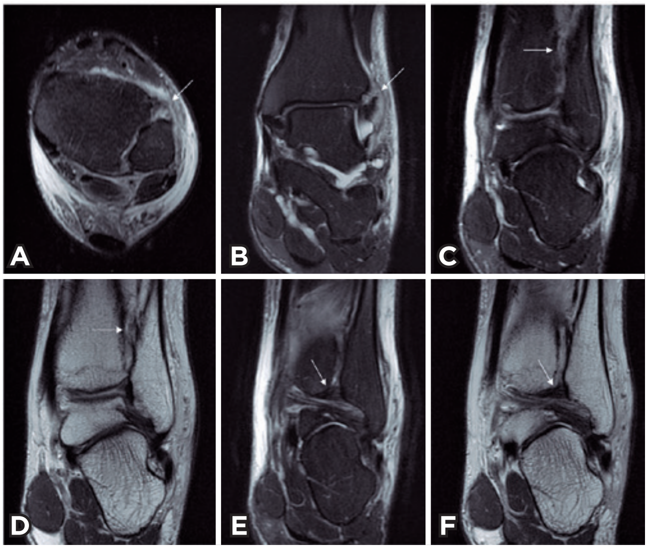

Figure 3. MRI of the left ankle. An axial T2-weighted fat-suppressed image shows complete tear of the anterior inferior tibiofibular ligament (A – white arrow). A coronal T2-weighted fat-suppressed image shows complete tear of the anterior inferior tibiofibular ligament (B – white arrow). A coronal T2-weighted fat-suppressed image shows complete tear of the interosseous ligament (C – white arrow). A coronal DP-weighted image shows complete tear of the interosseous ligament (D – white arrow). A coronal T2-weighted fat-suppressed image shows an intact posterior inferior tibiofibular ligament (E – white arrow). A coronal DP-weighted image shows an intact posterior inferior tibiofibular ligament (F – white arrow).

Table 1. Anterior, central, and posterior tibiofibular syndesmosis distances in both ankles.

	Distance (mm)					
	Anterior		Central		Posterior	
	Right	Left	Right	Left	Right	Left
CTNP*	2.1	2.1	3.4	3.9	4.6	4.8
CTSM-EK**	2.0	4.1	3.0	4.2	4.3	5.0
CTSM-FK***	2.3	4.7	3.2	5.0	4.3	3.2

*CTNP: CT in the neutral position. **CTSM-EK: CT with ankle stress maneuvers and extended knees. ***CTSM-FK: CT with ankle stress maneuvers and semi-flexed knees.

rotation and ankle dorsiflexion were performed (CTSM-EK), the left anterior and central tibiofibular distances were wider than those of the unaffected contralateral side (Figure 2B). In the third phase, using external rotation, ankle dorsiflexion, and semi-flexed knees (CTSM-FK), the left anterior and central tibiofibular distances were wider than those of the unaffected contralateral side, confirming syndesmotic instability (Figure 2C). Table 1 shows the anterior, central, and posterior tibiofibular syndesmosis distances in both ankles. The left ankle MRI depicted a complete tear of the anterior inferior tibiofibular (Figure 3, A and B) and interosseous (Figure 3, C and D) ligaments. The posterior inferior tibiofibular ligament was intact (Figure 3, E and F).

Discussion

Various imaging tests are available for the diagnostic of syndesmotic injuries; however, a fundamental question guiding treatment remains partially answered. Current imaging tests readily diagnose severe syndesmotic instability but have difficulty in confirming mild and moderate cases. Undoubtedly, the correct treatment is not being offered to a significant proportion of individuals. Undiagnosed and untreated mild and moderate cases of syndesmotic instability are the primary sources of inappropriate outcomes. If this study endorses CTSM as an accurate test for diagnosing syndesmotic instability, a novel approach for investigating demanding cases may become available and more individuals may benefit from correct treatment, thus reducing the burden of unfavorable outcomes. An algorithm matching clinical suspicion, MRI findings, and the CTSM protocol may be the most correct and precise method to diagnose SI. To the best of our knowledge, this is the first study to test the accuracy of CTSM in diagnosing syndesmotic instability and to evaluate the feasibility of stress maneuvers; this represents the main strength of our protocol. Our limitation is related to the use of MRI as the reference standard test, which, although not perfect, has a high estimated accuracy when compared to the gold-standard arthroscopy(15). Other potential limitations are the fact that the participants themselves control dorsiflexion, which introduces an inherent degree of imprecision and variability, and the absence of follow-up imaging for recording the evolution of the instability, producing long-term outcomes, and estimating the strength of the initial imaging data.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JCR *(https://orcid.org/0000-0002-7107-2621) conceived and planned the activities that led to the study, wrote the paper, participated in the reviewing process, approved the final version; ALGS *(https://orcid.org/0000-0002-6672-1869) interpreted the results of the study, participated in the reviewing process, approved the final version; MPP *(https://orcid.org/0000-0003-0325-8050) interpreted the results of the study, participated in the reviewing process, approved the final version; JFMA *(https://orcid.org/0000-0002-7664-2064) interpreted the results of the study, participated in the reviewing process, approved the final version; AAC *(https://orcid.org/0000-0003-0649-3662) interpreted the results of the study, participated in the reviewing process, approved the final version; RAM *(https://orcid.org/0000-0002-7830-8318) interpreted the results of the study, participated in the reviewing process, approved the final version; DCSB *(https://orcid.org/0000-0002-5210-3605) interpreted the results of the study, participated in the reviewing process, approved the final version; CASN *(https://orcid.org/0000-0002-9286-1750) interpreted the results of the study, participated in the reviewing process, approved the final version; LAR *(https://orcid.org/0000-0003-4395-1159) interpreted the results of the study, participated in the reviewing process, approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

The interobserver reliability of first metatarsal rotational component of axial sesamoid radiographs in hallux valgus

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Abstract

Objective: Hallux valgus is a progressive triplanar deformity of the forefoot with an important rotational component (RC) in the first metatarsal, which has been associated with recurrence. There is controversy about using weight-bearing vs. non-weight-bearing radiographs in RC measurement. This study aims to assess interobserver reliability for RC of the first metatarsal using a non-weight-bearing sesamoid view, as well as to correlate the hallux valgus angle, intermetatarsal angle, distal metatarsal articular angle (DMAA) and sesamoid position regarding RC.

Methods: An observational, cross-sectional and descriptive study was conducted with 81 feet from 48 patients (66.6% female). RC was evaluated regarding the first metatarsal proximal shaft in non-weight-bearing axial metatarsal radiographs and weight-bearing anteroposterior radiographs. Measurements were taken independently by two foot and ankle subspecialists and an orthopedic resident, all of whom were blinded.

Results: Statistically significant intraclass correlations (p=0.02) were obtained for first metatarsal RC assessment among the three observers (95%CI 0.01–0.65; Cronbach's α=0.41) in non-weight-bearing axial metatarsal views. Significant correlations (Spearman ρ) were also found for hallux valgus angle (p=0.04) and DMAA (p=0.01), and non-significant correlations were found for intermetatarsal angle and sesamoid position (p>0.05).

Conclusion: The significant correlations between hallux valgus angle and DMAA for RC suggest that RC is isolated from the first metatarsal bone structure. This practical assessment method may isolate the first metatarsal head RC regarding the proximal metatarsal in the metaphyseal region and could be useful in centers where weight-bearing CT scans are not available.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Bunion; Metatarsal bones; Foot deformities; Pronation; Rotation.

Introduction

Hallux valgus is a progressive triplanar deformity of the forefoot, characterized by a lateral deviation of the hallux towards the medial side of the foot and a rotational component (RC) with pronation of the head corresponding to the first metatarsal[1-3] regarding its diaphysis or proximal metaphysis. It has been described that more than a third of the population over 65 years of age suffer from this deformity[4].

In addition to conservative management, operative treatment of hallux valgus includes more than 200 procedures[5].

Study performed at the Hospital Christus Muguerza, Monterrey, Nuevo León, Mexico.

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This high number can be interpreted to reflect an incomplete understanding of the pathophysiology[4]. Historically, and especially recently, there has been an interest in RC, which can lead to better understanding and resolution in an effort to improve functionality and decrease recurrences[6,7]. Currently, there is controversy about RC assessment due to the technical heterogeneity and load quantity variance involved in both weight-bearing[3,8] and partial weight-bearing radiographic projections[9]. Likewise, transurgical non-weight-bearing projections have been considered to have practical utility[10,11], although without taking RC into account.

To our knowledge, there is no current well-accepted method for assessing RC in plain radiographs[9,12-15]. This study aimed to assess the inter-rater reliability of the RC of the first metatarsal from a non-weight-bearing sesamoid view, as well as to correlate hallux valgus angle (HVA), intermetatarsal angle (IMA), distal-metatarsal articular angle (DMAA) and sesamoid position regarding RC.

Methods

This study was approved by the research ethics committee of our university and hospital (number 22052020-ENM-1-CM-CI). All the radiographs were reviewed under the local law NOM-004-SSA3-2012 regarding medical file management, privacy rights and the ethical standards laid down in the 1964 Declaration of Helsinki. This study was conducted with resources from our institution and hospital. Since no financial profit was obtained through this study, no financial biases exist for any author and, thus, the authors declare no conflicts of interest.

This descriptive, cross-sectional observational study evaluated radiographs of 58 subjects. The study included patients over 16 years of age diagnosed with hallux valgus. Patients with previous forefoot surgeries were excluded, as were patients who did not comply with the weight-bearing anteroposterior foot and non-weight-bearing axial metatarsal views (10 patients). The RC of the first metatarsal head was evaluated in 48 patients (81 feet) according to the method of Mortier et al. (2012)[14], in which a line representing the rotation of the plantar aspect is measured according to the line of the diaphysis of the first metatarsal or proximal metaphysis. We consider this measurement technique relevant in axial projections of the hallux sesamoids with 45 degrees of plantar flexion, since it considers a single bone structure, isolating to some extent the configuration and effect of other bone structures. The measurements were performed independently by two foot and ankle orthopedic subspecialists and one trauma and orthopedic resident, all of whom were blinded. For RC assessment in sesamoid views, as well as HVA, IMA, DMAA and sesamoid position assessment in anteroposterior projections, ImageJ digital Goniometer software was used (version 1.52q, National Institutes of Health, Bethesda, MD, USA) (Figure 1).

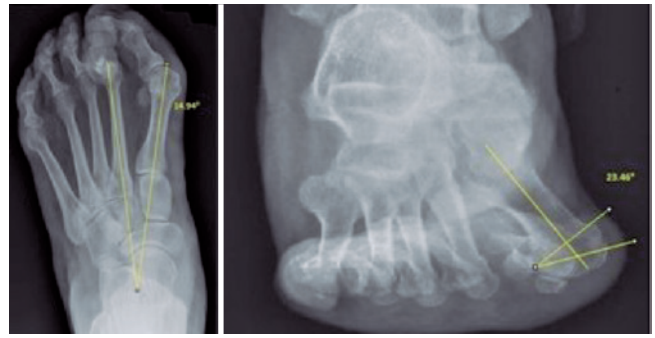

Figure 1. Weight-bearing anteroposterior and non-weight-bearing axial sesamoid view using the assessment method employed in this study.

Statistical analysis

Numerical variables are summarized as measures of central tendency and dispersion, and categorical variables as frequencies and percentages. The Kolmogorov-Smirnov test was performed to evaluate the distribution of the numerical variables. Numerical variables were compared using the Mann-Whitney U test. To assess interobserver agreement, the intraclass correlation test was used with a two-way random model for absolute agreement. In addition to the Spearman correlation coefficient (Spearman's ρ), scatter diagrams were made to graphically visualize the correlation of measurements between observers. $P<0.05$ was considered statistically significant. SPSS version 25 for Mac (IBM, Armonk, NY, USA) was used for the analyses.

A priori sample size calculation was not performed because the entire available population was to be included in the databases. However, it was decided to estimate the power of the included sample. Using a sample estimation formula for agreement studies, the included sample size was determined to have a 90% confidence level and a 95% power to find an inter-observer agreement of 0.80 with an accuracy of 15%.

Results

Weight-bearing anteroposterior radiographs and non--weight-bearing axial sesamoid projections were evaluated in 48 patients (81 feet), whose mean age was 47.85 ± 14.75 years; 66.6% (32/48) were female and 33.3% (16/48) male.

The demographic characteristics of the sample, as well as the mean and standard deviation of the angles reported by the three observers are shown in tables 1 and 2. Statistically significant intraclass correlations (95%CI 0.01-0.65; $p=0.02$) were obtained for RC of the first metatarsal (Figure 2) among the three observers (Cronbach's $\alpha=0.41$).

We also found statistically significant correlations when evaluating HVA (p=0.04) and DMAA ($p=0.01$), as well as non-significant correlations when evaluating IMA and PS ($p>0.05$) (Table 3).

Table 1. Descriptive Statistics with average measures. Hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMAA) and rotational component (RC)

n=48 (81 feet)	Mean ± SD (degrees)
HVA observer 1	22.92 ± 11.38
IMA observer 1	12.38 ± 2.87
DMAA observer 1	15.81 ± 6.74
RC observer 1	18.07 ± 8.09
HVA observer 2	23.12 ±11.29
IMA observer 2	12.54 ± 3.03
DMAA observer 2	16.00 ± 6.57
RC observer 2	13.31 ± 4.3
HVA observer 3	23.45 ± 12.65
IMA observer 3	13.11 ± 3.13
DMAA observer 3	15.39 ± 6.13
RC observer 3	21.98 ± 13.74

Table 2. Frequencies and percentages reported for sesamoid position by three observers

Sesamoid position	Grade 0	Grade 1	Grade 2	Grade 3
Observer 1	12 (14.8%)	31 (38.3%)	19 (23.5%)	19 (23.5%)
Observer 2	13 (16.0%)	31 (38.3%)	17 (21.0%)	20 (24.7%)
Observer 3	6 (7.4%)	31 (38.3%)	28 (34.6%)	16 (19.8%)

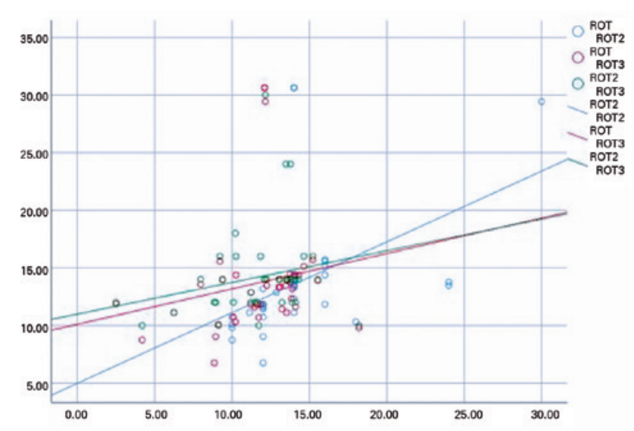

Figure 2. Scatter diagram of the correlation trend of the measurements between three observers for the rotational component.

Table 3. Non-parametric rotational component (RC) Spearman rank correlation coefficient (Spearman's ρ; SCC) regarding hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMAA) and sesamoid position (SP)

	HVA	IMA	DMAA	SP
RC SCC	-0.22	-0.11	-0.27	-0.01
p	**0.04**	0.33	**0.01**	0.87

Discussion

There were significant intraclass correlations (p=0.02) among the three observers when assessing RC of the first metatarsal in axial projections of non-weight-bearing metatarsals using the method of Mortier et al.[14] We consider this measurement technique relevant for axial projections of the hallux sesamoids since it considers the first metatarsal diaphysis, as well as another line that intersects the plantar cortices of the medial and lateral sesamoid grooves. We specifically selected this assessment technique since it considers the morphology of a single bone structure (first metatarsal) and its center of rotation[16] (the head of the first metatarsal regarding the proximal diaphysis or epiphysis). Although it has been described that the morphology and relation of bony structures of the forefoot changes with the axial load[17,18], these changes could be minimized by evaluating a single anatomical structure without considering the rest.

Although the clinical use of non-weight-bearing radiographic projections has been widely questioned in the literature[17,19], most of these studies assessed RC using different techniques that involve technical differences[9,12-15]. Furthermore, there is increased interest in RC assessment using weight-bearing CT[4,7,20]. A practical method for assessing RC in plain radiographs could be clinically relevant, since it would allow it to be performed in a transurgical setting, as well as in centers in which no weight-bearing CT scans are available or where it is difficult to recreate the properties of the axial load[10,11] in the operating room.

Regarding pathophysiology, interest has been expressed in the literature about the role of RC in first metatarsal hallux valgus deformity[7,16], as well as dynamic factors[18], such as muscle strength or ligament resistance, that could have a biomechanical effect on the global architecture of a weight-bearing foot[17] in addition to an isolated bone structure. Our results are relevant in morphological terms because they describe the rotation by trying to isolate the first metatarsal deformity. They are also relevant in clinical and methodological terms by establishing good inter-observer agreement.

There is also controversy in the literature regarding the morphometric relationship between HVA, IMA, the position of the sesamoids[9,15,21] and their relationship with RC[12]. This relationship was not significant in some studies[20] but significant in others[9,12,15] mainly regarding the correlation between DMAA and RC[12]. In this study we found significant correlations when evaluating HVA (p=0.04) and DMAA (p=0.01), as well as non-significant correlations when evaluating IMA and PS (p>0.05) in relation to RC.

It is important to point out that due to the method of radiological evaluation used in the present study, which included the use of weight-bearing anteroposterior projections, some biomechanically dependent variables (HVA, IMA, and sesamoid position, i.e., which involve more than one bone structure in the forefoot) could not correlate due to the effect of load distribution when evaluating RC in non-weight-bearing axial projection. Despite a *p*-value of 0.04, the correlation between HVA and RC could be dependent on factors such as the DMAA in relation to the proximal phalanx and the HVA.

Likewise, the statistically significant correlation for DMAA (p=0.01) regarding RC could be explained as being partially independent of weight load. These findings could be due the fact that the progression of RC is related to the progression of DMAA and not to the correlation of weight-bearing angles (HVA, IMA, sesamoid position). Thus, evaluation and preoperative planning in patients for whom RC must be reduced could be clinically relevant.

Limitations

To our knowledge, this is the first study to evaluate morphological characteristics of first metatarsal rotation in a Mexican sample, as well as to standardize a method of RC evaluation with practical and clinical utility.

However, this study has important limitations. It was performed with axial radiographs of non-weight-bearing sesamoids to evaluate RC, while HVA, IMA, DMAA and the position of the sesamoids were measured using weight-bearing radiographs. We are aware of the controversy surrounding the use of non-weight-bearing projections in clinical practice[17,19]. However, studying RC in non-weight-bearing projections could help clarify the pathophysiological or morphological mechanism of hallux valgus, which could translate into future improvements in medical/surgical management, with better functional results in centers located in low- and middle-income countries that have limited resources.

Future studies on RC assessment should include different techniques with plain radiographs, comparing and adding these evaluations to weight-bearing CT. Although this is a retrospective study, the power of the sample size was calculated post-hoc, not prior to the study. However, our results will be useful when conducting secondary research about RC assessment and its morphological relationship with other clinically relevant anatomical structures.

Conclusion

Significant intraclass correlations (p=0.02) were obtained in the evaluation of first metatarsal rotation by three observers (α=0.41) in axial radiographs of non-weight-bearing metatarsals. We also found significant correlations when evaluating HVA (p=0.04) and DMAA (p=0.01), as well as non-significant correlations when evaluating IMA and PS (p>0.05) regarding RC. This practical method of assessment may isolate the RC of the first metatarsal head regarding the proximal metatarsal in the metaphyseal region and could be useful in centers where weight-bearing CT scans are not available.

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Original Article

Posterior malleolar fractures. New classification and treatment algorithm

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Abstract

Objective: This study proposes a new classification of posterolateral malleolar fractures and a treatment algorithm.

Methods: We divided the posterolateral malleolus, which we considered as the posterior malleolus, from the posteromedial one, which we considered as being part of the medial malleolus fracture. The experience with 77 patients treated from February 2017 to February 2020 was assessed. All of them were assessed by frontal and profile radiographies and computed tomography (CT). Among the parameters to classify these fractures, we believe the most determining ones are fracture size, followed by presence of fracture displacement.

Results: Fractures were divided into those whose posterior fragment was 25% smaller than the tibial joint surface and those that compromised more than 25% of this joint. The first group underwent syndesmotic opening and was subclassified into 1A (stable fractures), which do not require surgical treatment, and 1B (unstable), which require syndesmotic stabilization. The second group, which comprised the larger fractures, was subclassified into 2 A (non-displaced fractures, or with a displacement below 2 mm), which underwent percutaneous osteosynthesis, 2B (displaced fractures), and 2C (comminuted fractures), which underwent open reduction and internal fixation using a posterior approach.

Conclusion: The classifications published so far are anatomic or descriptive, but none of them proposes a therapeutic algorithm for each type of fracture. We believe it will be helpful for its interpretation and decision-making on the need to perform a posterior approach, prioritizing the anatomical reduction of the joint fragment and resolution of syndesmotic instability linked to each fracture pattern using the most simple and effective method.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Ankle fractures/classification; Algorithms; Treatment outcomes.

Introduction

The treatment of posterior malleolar fractures of the ankle has been changing throughout time, especially in the last 10 years. According to worldwide statistics, posterior malleolar fractures are associated with ankle fractures in 7 to 44% of the cases and usually worsen the prognosis of these fractures(1).

The scarce relevance historically given to the association between these two injuries made that concerns to identify a specific pattern for malleolar fractures were raised only a few years ago, to classify and improve their post-treatment clinical outcomes.

Initially, these fractures were underestimated and did not receive surgical treatment(2). Later, patients began to undergo anterior compression screw osteosynthesis(3) with indirect reduction without approaching the fracture focus; finally, in the last decade, the prevailing idea has been to approach the fracture posteriorly and thus to perform open reduction and internal fixation. Good initial outcomes lead to the indication of posterior reduction to practically all posterior malleoli, with no actual parameters to standardize this intervention. Placing patients in the prone position and adding a new approach should be justified, to provide the patient with an actual benefit and not bringing an additional element of morbidity.

The main research question is to investigate whether a posterior approach is required in all cases(4), which implies in pre-operative planning.

Study performed at the Trinidad Ramos Mejia, Ramos Mejia, Buenos Aires, Argentina.

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Methods

This study was approved by the Institutional Review Board, and a level IV retrospective study was conducted.

All patients with AO 44B and 44C fractures who had a posterior malleolus were included in the research. Seventy-seven patients treated from February 2017 to February 2020 were selected for inclusion in the study. Thirty-four were men (44.15%), and 43 were women (55.85%). Patients' mean age was 40.5 years, ranging from 23 to 75 years.

Patients underwent frontal and profile radiographs of the ankle[5] and then computed tomography (CT)[6] with axial, sagittal, and coronal planes and 3D reconstruction[7,8]. Patients presenting with ankle dislocation or sub-dislocation were underwent reduction by the on-call team at the time of consultation, and osteosyntesis was scheduled for a later date.

This study was approved by the institution's ethical committee.

Inclusion criteria:

- 44B ankle fractures with posterior malleolus
- 44C ankle fractures with posterior malleolus
- Age above 18 years old

Exclusion criteria:

- Exposed fractures
- Previous surgeries on the same ankle
- Age below 18 years old

Data were collected through a review of clinical histories and analysis of pre-and post-operative radiographies, along with CT[9]. Data were interpreted as a lesion pattern contemplating items considered essential in these injuries: the size of the posterior fragment, syndesmotic stability, and joint congruence.

The 2 planes used to classify fractures were:

Sagittal. On radiological images, the site of the greatest joint involvement is identified. A straight line is drawn from the most anterior point on the cartilage to its most posterior point and divided into 4 parts (Figure 1). If the fracture compromises at least 25% of the joint at this level, a posterior approach will be required.

Axial: A section running through 0.5 cm proximally to the tibial joint cartilage is randomly selected, a measure similar to that presented by Bartoníček et al., in 2019 (0.4cm)[10]. A straight line is drawn from the most anterior point on the notch to its most posterior point and divided into 4 parts (Figure 1). If the fracture compromises at least 25% of this line, posterior open reduction and internal fixation of this fragment are required.

The size of the fracture fragment is a determining factor to perform the classification. Cadaveric studies confirm that fractures lower than 25% do not compromise joint stability per se[11] and reduce the tibioastragalar contact area by only 4%. Fragments greater than 25% do generate a major change in the distribution of ankle loads and thus may lead to arthrosis in the medium or long term[12,13]. The 2015 series by Drijfhout van Hooff et al. with 131 patients is the most extensive published and is consistent with this statement[14].

Intra-operative findings were compared with these patterns, and based on the study, the 77 operated patients were regrouped in a novel classification as defined by the therapeutic algorithm.

In terms of surgical approach, the most frequently used was the classical posterolateral one[15-17]. The incision was equidistant to 2 lines running through the lateral edge of the Achilles heel and the posterior edge of the fibula. The muscle belly of the flexor hallux longus is medially retracted, allowing for the directing visualization of the fracture fragment in the posterior malleolus. It is important to consider the route of the external saphenous nerve.

Another approach used was the modified posteromedial one. It das performed only in patients whose posterolateral malleolar fracture was associated with a posteromedial mass. This approach is performed between the posterior edge of the medial malleolus and the internal edge of the Achilles heel. It is crucial to identify the flexor hallux longus and always take it as a reference so as to protect the posterior tibial neurovascular bundle.

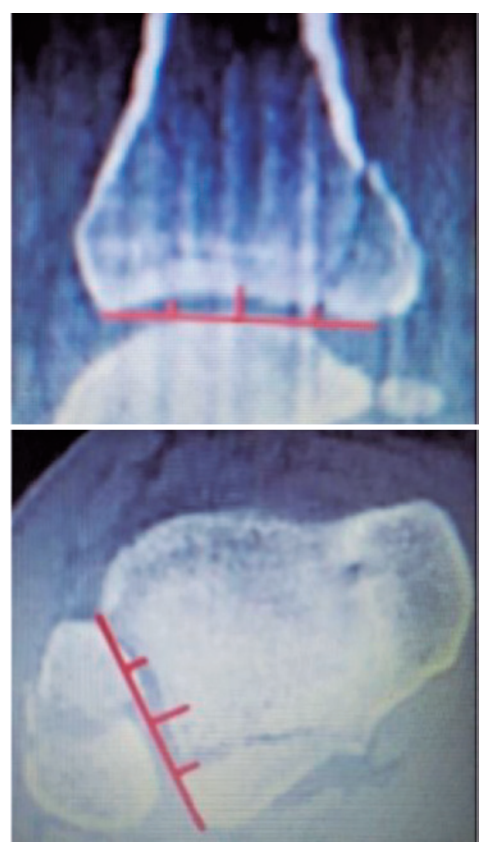

Figure 1. Coronal plane (above) and axial plane (below) to classify each fracture as larger or smaller than 25%.

Results

We analyzed the CT scans of all study patients and anatomically recognized two fracture groups, based on the sagittal plane of the ankle and/or axial plane of the syndesmosis, according to the tibial involvement on the joint surface:

1. Fractures affecting less than 25%
2. Fractures affecting more than 25%

Based on the obtained results, we propose a classification with a treatment algorithm.

- **Type 1**. Fragments compromising less than 25% of the joint surface on the CT sagittal plane and/or axial plane of the syndesmosis. This fracture pattern always requires investigating syndesmotic stability. We conducted the stress maneuver with external rotation and dorsal ankle flexion. The result may be:

A. Stable fractures: do not require reduction or syndesmotic stabilization (Figure 2). We identified 6 patients (7.79%) in this group.

B. Unstable fractures: If instability is diagnosed, it should be treated using suprasyndesmotic screws(18) or syndesmotic button, according to the surgeon's preference (Figure 3). 26 patients (33.76%) of our sample belonged to this group.

There is no indication of a posterior approach or direct reduction for posterior malleolar fractures affecting less than 25% of the joint.

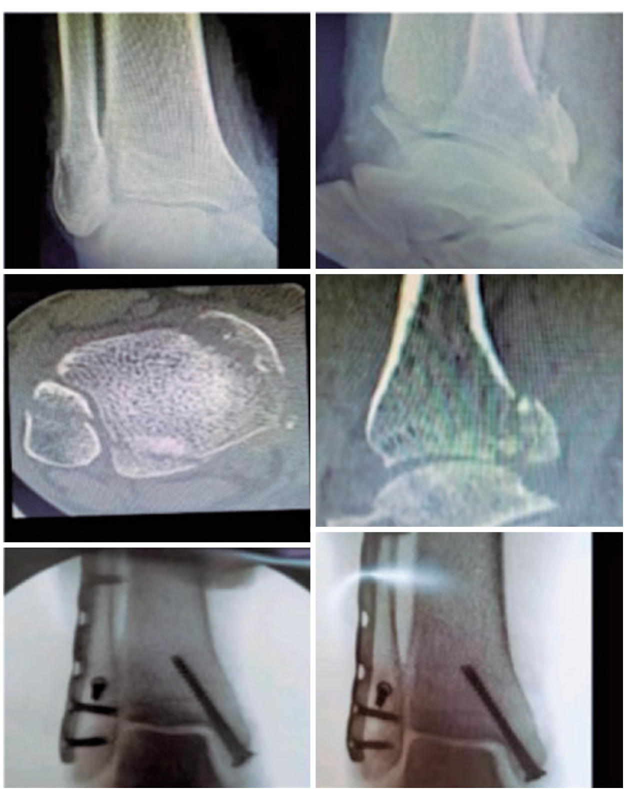

Figure 2. Type 1A fracture with untreated syndesmosis. Below is the intraoperative control of syndesmotic opening.

- **Type 2.** The fracture fragment compromises the joint in at least 25% on the sagittal plane of the ankle or axial plane of the syndesmosis.

Within this group, we recognize 3 fracture patterns: a) Non-displaced fractures; b) Displaced fractures; and c) Comminuted fractures:

A. These fractures consist of large non-displaced fragments on TC scans. Fixation with 2 percutaneous screws from posterolateral to anteromedial with the patient in the lateral position (Figure 4), similarly to the way we treat non-displaced talar neck fractures. The stability provided by the 2 screws in the fragment is significantly similar to that provided by an anti glide plate[19,20], which means that it is unnecessary to perform a fixation approach.

There were 4 patients (5.19%).

B. Displaced fractures always require a posterior approach and stabilization with a postero-external anti glide plate[21] (Figure 5). This group comprised 46 patients (59.74%), thus being the more frequent pattern of posterior malleolar fractures.

C. Comminuted fractures compromising more than 25% of the joint should always be fixed by a posterolateral approach and placement of anti-glide plate. This group included 5 patients (6.49%). The difference from group 2B is that these fractures did not present with intermediate fragments, which should often be approached since they are found to be interposed and may hamper the reduction of the main fragment.

It is important to assess 3 topics that may be presented in displaced fractures:

Figure 3. Type 1B fracture stabilized with a syndesmotic button.

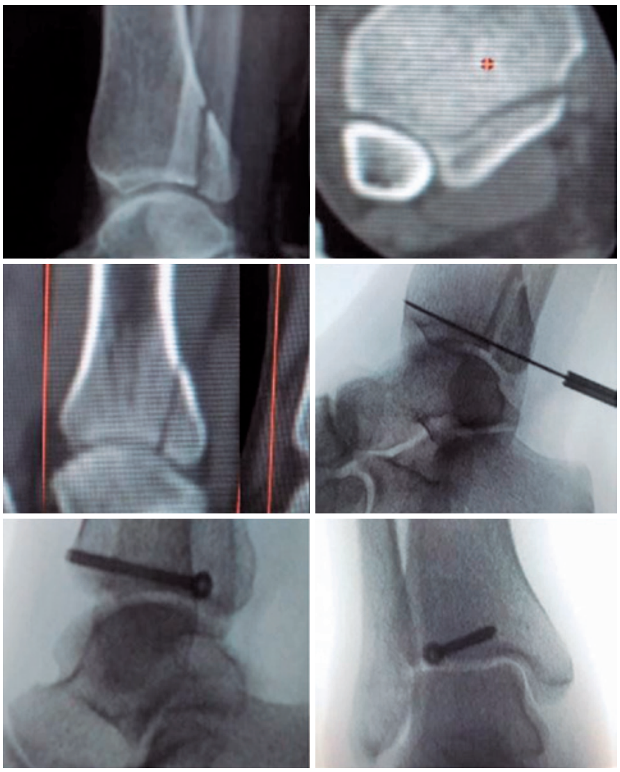

Figure 4. Type 2A fracture treated percutaneously.

Figure 5. Type 2B fracture treated with an antiglide plate.

1. The existence of an interposed fragment;
2. Syndesmotic instability;
3. Incongruence on CT scan.

None of these 3 subtypes leads to changes in the therapeutic focus, but they should be considered when scheduling osteosynthesis and evaluating intra and post-operative radiographic controls.

Discussion

Posterior malleolar fractures have gained importance and prominence with regard to definite outcomes of ankle fractures. Their contribution to the reduction and stability of fractures is directly related to their long-term prognosis.

It is crucial to classify posterior malleolar fractures into posteromedial and posterolateral, according to their anatomical position, since the first has different behavior and a different approach. We established the lateral edge of the posterior tibial tendon groove as the boundary between the two types of fractures.

They follow different fracture patterns.

The posteromedial fragment usually extends up to the medial malleolus (posterior colliculus) and is closely related to the posterior tibial tendon and its sheath[22]. One of these characteristics that differs these fractures from that of the posterolateral malleolus is the fact that their reduction is impossible to be performed through ligamentotaxis[23]. We believe that posteromedial fractures should be classified as a subtype of medial malleolar fractures and not as part of posterior malleolar fractures. When these fractures are associated with syndesmotic instability, they display a lesion association with anterior and interosseous syndesmotic ligaments. In the context of a complex ankle fracture, this type of associated syndesmotic instability would require fixation with suprasyndesmotic screws or suprasyndesmotic suture button, according to surgeon practice and experience[24].

Conversely, posterolateral malleolar fractures exhibit a different pattern. They consist of those from the lateral edge of the malleolar groove to the external malleolus. These fractures may be reduced through ligamentotaxis. The posterior-inferior and transverse ligaments of the tibiofibular syndesmosis are inserted at the level of the lateral edge of the posterolateral malleolus; therefore, an adequate reduction and stable fixation of fractures affecting this site usually leads to syndesmotic stability.

The most relevant classification was those proposed by Bartonicek et al. in 2014, consisting of 5 types of fragments[25,26]: type 1, extraincisural fragment; type 2, posterolateral fragment; type 3, two-part fragment, posteromedial and posterolateral; type 4, large posterolateral triangular fragment; and type 5, osteoporotic fragments. Mason et al. presented another classification in 2017[27], which dividing fractures into 3 types: type 1, extra-articular; type 2, posterolateral triangular fragment; and type 3, a fragment characterized by a coronal plane fracture line involving the whole posterior plafond.

These classifications are more descriptive and anatomical, but do not present a treatment protocol; hence, we believe it is important not only to describe each fracture but also to standardize treatment for each of their types.

The present study is based on the interpretation of radiographic and tomographic images of posterior malleolar fractures to develop an anatomical classification and report a related therapeutic algorithm and thus achieve anatomical reduction and syndesmotic stability (Figure 6).

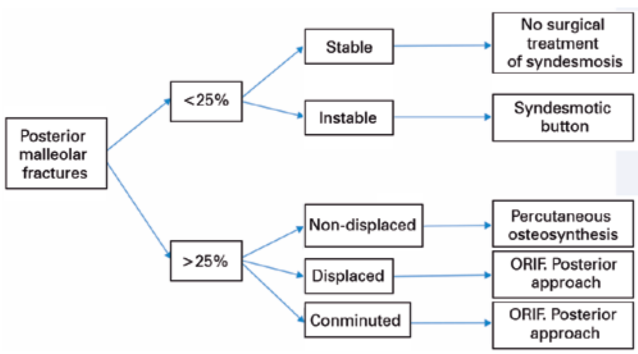

Figure 6. Classification of posterior malleolar fractures

The limitation of this study relies on its retrospective design. Although the sample is important, the study is based on the authors' interpretation of radiographic and tomographic images for the identification of lesion patterns.

Conclusion

This study proposes a classification and a treatment algorithm for posterior malleolar fractures that we believe will be helpful for its interpretation and decision-making on the need to perform a posterior approach, prioritizing the anatomical reduction of the joint fragment and resolution of syndesmotic instability linked to each fracture pattern using the most simple and effective method.

Each fracture pattern is associated with a surgical approach that we consider necessary, with the most convenient type of osteosynthesis for each case, and with the resolution of syndesmotic instability simply and algorithmically.

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 activity that led to the study, and approved the final version; IM *(https://orcid.org/0000-0002-9452-0175) = bibliographic review, interpreted result of study, and approved the final version; FA *(https://orcid.org/0000-0001-6577-8911) = participated in the review processand and clinical examination, and approved the final version; SS *(https://orcid.org/0000-0003-0432-8102) = data collection, biographic review, and approved the final version; JD*(https://orcid.org/0000-0002-5733-6766) = performed the surgeries; data collection, formatting of the article, and approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Arthroscopic treatment of anteromedial ankle impingement

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Abstract

Objective: Impingement syndromes are recognized as an important cause of chronic ankle pain, which results from the entrapment of an inflamed soft-tissue component between the osteophytes. The predominant site of occurrence is the anterolateral aspect of the ankle for soft-tissue impingement, and anteromedial aspect for bony impingement. Symptoms related to the physical impact of bone or soft-tissue pain often result in limited ankle range of motion.

Methods: We conducted a retrospective study of 34 patients (34 ankles) with anteromedial bony impingement. All patients underwent arthroscopy, with a mean follow-up of 34 months.

Results: All osteophytes were removed, and the ankle range of motion improved. The AOFAS score improved from 73 preoperatively to 95 postoperatively.

Conclusion: The arthroscopic removal of the anteromedial osteophytes of the ankle had excellent functional results. It is an effective procedure that allows rapid patient recovery.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Ankle injuries/complications; Exostoses/surgery; Ankle injuries; osteophytes; Arthroscopy; Sports.

Introduction

Impingement syndromes, recognized as a significant cause of chronic ankle pain, have been described in the anterior, posterior, anterolateral, and anteromedial region of the ankle. While these conditions are relatively rare, their diagnosis is considered important as they can lead to chronic ankle pain. Murawski and Kennedy explain in their article that the pain is secondary to the entrapment of an inflamed soft tissue component between the osteophytes[1]. Moreover, the predominant site of occurrence is the anterolateral aspect of the ankle for soft-tissue impingement, and anteromedial aspect for bony impingement[2].

In 1943, Morris called this impingement "athlete's ankle". Later, in 1950, McMurray preferred to call it "footballer's ankle" and published good results in athletes after surgical resection. Thereafter, the term "anterior ankle impingement syndrome" has been widely cited. Nowadays, this condition is recognized as 2 different entities, anteromedial impingement syndrome and anterolateral impingement syndrome[1].

Symptoms related to the physical impact of bone or soft-tissue pain often result in limited ankle range of motion. Massada found that as many as 60% of professional soccer players have osteophytes located anteriorly within the ankle joint[3].

It is a condition that almost exclusively affects athletes as they routinely submit the talocrural joint to repetitive dorsiflexion movements, although there are some cases of patients with no sports activities but who perform repetitive dorsiflexion movements, such as people who work in a squat position or who frequently go up and down stairs. As Manoli mentions in his article, it can also appear after nonsporting injuries, especially fractures about the ankle and foot. Therefore, there could be an association with a subtle cavus foot and ankle instability[4].

McMurray hypothesized 3 primary theories, since he thought that there was no clear explanation for the cause of anteromedial impingement (AMI). First, he hypothesized that the talotibial osteophytes were formed by repetitive capsular traction during kicking movements. This has since become

Study performed at the Institution Dupuytren, Autonomous City of Buenos Aires; Buenos Aires, Argentina.

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known as the ‘‘traction spurs’’ theory. The second theory relates to direct and recurrent microtrauma to the joint capsule, and he believes that the impact forces of a soccer ball are of a great enough magnitude to incur damage to the anatomy of the anterior ankle region[5]. Spur formation and symptoms of AMI can also be a result of repetitive dorsiflexion of the ankle joint; this may be particularly relevant in dancers[1]. Open or arthroscopic surgery are a treatment option in cases in which the medial impingement lesion is sufficiently symptomatic.

The aim of the present study was to retrospectively report the outcomes of our patients with anteromedial ankle impingement operated on by arthroscopy.

Methods

This study was approved by the Institutional Review Board. We conducted a retrospective study of 34 patients (34 ankles) with anteromedial bony impingement; patients with only soft-tissue impingement were excluded. All patients underwent arthroscopy between January 2014 and July 2019, with a mean follow-up of 34 months (minimum, 24 months; maximum, 40 months). Mean patient age was 32.1 years (minimum, 22 years; maximum, 42 years); 30 were men and 4 were women. Seven patients were high-performance athletes, 24 participated in amateur sports, and 3 patients reported low physical activity. Clinically, all patients had pain at the medial ankle joint and limited dorsiflexion.

For all patients, radiographs of the ankle (anteroposterior, lateral, and 45° oblique) were taken and graded according to the van Dijk scale (Figure 1). The obtained images revealed the presence of osteophytes at the tibial and talar levels in all patients.

Initial treatment was conservative and consisted of administration of nonsteroidal anti-inflammatory drugs (NSAIDs) and physical therapy, which lasted for an average of 4.9 months (minimum, 2 months; maximum, 12 months). Surgery was proposed when there was persistence of symptoms despite conservative treatment. Surgical treatment consisted of arthroscopy of the ankle and removal of the osteophytes shown on the diagnostic radiographs.

Arthroscopy was performed through anteromedial and anterolateral portals with the patient under general anesthesia or spinal block. Prophylactic antibiotic therapy was administered, and a tourniquet was applied to the lower limb in all patients. The joint was visualized and debrided through the arthroscope using associated instruments (Shaver). Presence of exostoses of the talus and tibia was confirmed (Figures 2 and 3).

Spurs were removed with an osteotome or a burr-type device. Fluoroscopic support was performed (Figures 4 and 5).

Results

Tibial and talar osteophytes were surgically resected in all patients. Radiographs were taken postoperatively to control for exostoses (Figure 6).

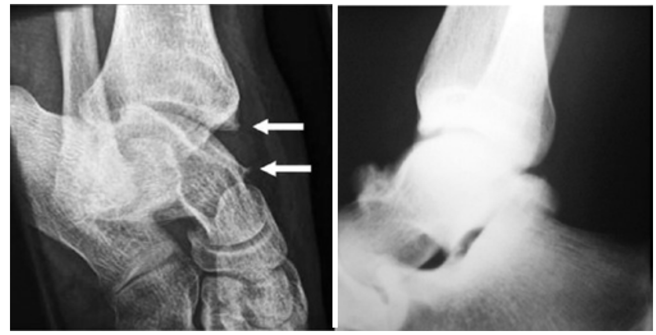

Figure 1. Oblique and lateral radiographs of the ankle. Tibial and talar osteophytes

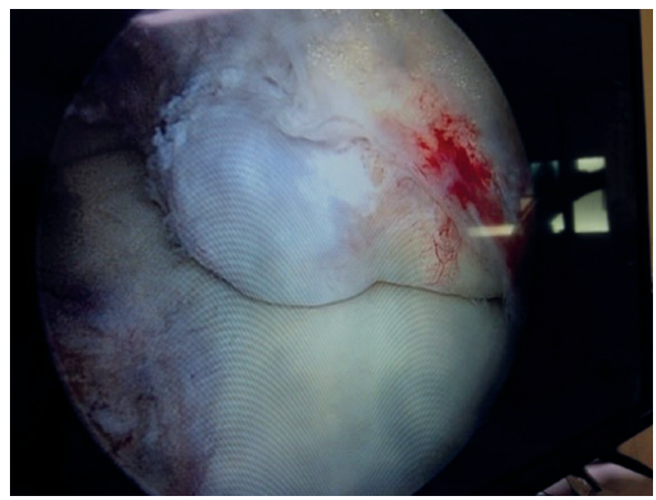

Figure 2. Arthroscopy. Tibial osteophyte.

Figure 3. Arthroscopy. Talar osteophyte.

Figure 4. Removal of talar osteophyte.

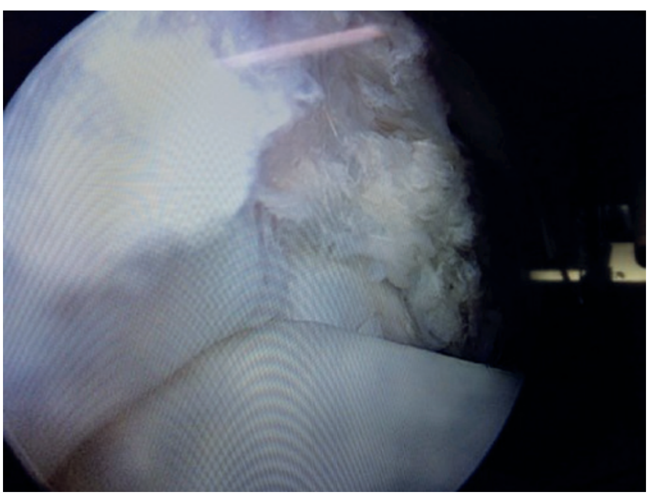

Figure 5. Removal of tibial osteophyte

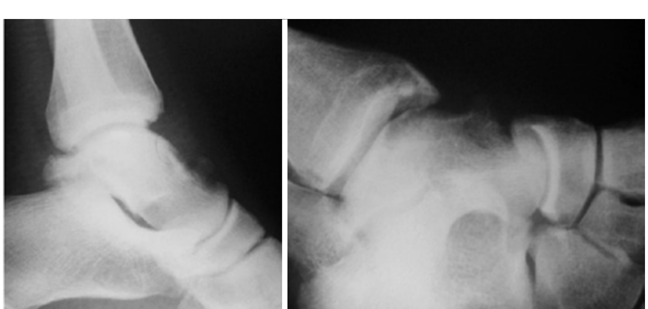

Figure 6. Postoperative lateral and oblique radiographs of the ankle.

Patients started weight-bearing on postoperative day 2. Sutures were removed on day 10. Rehabilitation was performed for 2 months. All patients returned to their daily activities at a mean of 3.8 weeks after surgery. Athletes returned to sport-specific training at a mean of 2.1 months after surgery. The American Orthopaedic Foot and Ankle Society (AOFAS) score improved from 73 preoperatively to 95 postoperatively. All patients had relief of symptoms, were satisfied with the surgical procedure and were willing to recommend it to others. No complications were reported.

Discussion

Anteromedial ankle impingement is a frequently misdiagnosed pathology that affects athletes and, consequently, their quality of play. The diagnosis is purely clinical, and pain of the ankle joint line is often present along with limited dorsiflexion. Because forced hyperdorsiflexion may produce pain, diagnostic confirmation is needed[6].

In 2000, Scranton et al. found that 57% of patients with chronic instability have impingement spurs, against 17% of 200 randomly selected individuals. They hypothesized that ankle instability is associated with arthritic changes; therefore, impingement spurs occur as a consequence of instability and are the expression of joint degeneration, thereby differing from localized spurs in case of local microtrauma. In fact, chronic ankle instability is associated with osteophytic formation in cases with medial and lateral ankle compartment[7].

The first complementary study for the imaging diagnosis of AMI should be a routine weight-bearing radiograph in anteroposterior and lateral directions. An oblique AMI radiograph is recommended[6]. The anterolateral aspect of the tibia is the most prominent aspect on standard lateral radiographs, thereby appreciating anterolateral osteophytes. On the other hand, anteromedial osteophytes are often misdiagnosed on standard lateral projections[1].

Tol and van Dijk cited an interesting cadaver study describing that anteromedial tibial osteophytes up to 7.3 mm in size and originating from the anteromedial border could be undetected on a standard lateral radiograph because of the prominent aspect of the anterolateral border of the distal tibia[8]. As a complement, the sensitivity of lateral radiographs for detecting anterior tibial and talar osteophytes was 40% and 32%, respectively (specificity 70% and 82%). Also, when the lateral radiograph was combined with an oblique AMI radiograph (craniocaudal radiograph with 30º external rotation of the leg), sensitivity increased to 85% and 73%, respectively. This increase was due to the high sensitivity of the oblique AMI radiographs for detecting anteromedial osteophytes (93% for tibial and 67% for talar osteophytes)[8].

Another complementary study is magnetic resonance imaging (MRI). MRI is useful to detect injuries in the anterior deltoid thickening, synovitis, and ossifications. In the coronal view, one can identify injury to the anterior tibiotalar band of the deltoid, typically seen as ligament thickening and edema. Therefore, with MRI, one can make a differential diagnosis with soft-tissue diagnoses, including osteochondral lesions, loose bodies, and stress fractures[6].

Van Dijk et al. were the first to differ between the affected sites in 62 arthroscopic procedures for treatment of anterior ankle impingement[9]. They compared AMI resection vs anterolateral impingement (ALI) resection and found that the former was statistically superior at 4 months, 1 year, and 2 years postoperatively. Two years after surgery, 66% of ALI patients and 87% of AMI patients had a good to excellent result. Visual analog scale (VAS) results also showed improvement in pain postoperatively. At 2 years, VAS scores in the AMI group had decreased from 6.9 preoperatively to 4.3 postoperatively[6].

Murawski and Kennedy[1] demonstrated the results of the arthroscopic treatment of 41 patients with AMI, with a mean patient age of 31.12 years; 34 patients (83%) were competing at some level of athletic sport. At a minimum of 2 years of follow-up, 93% were satisfied with the procedure. The results of both AOFAS (62.83 to 91.17) and Short Form-36 version 2 (61.54 to 92.21) improved significantly, and all but 1 patient returned to their pre-injury level of sporting activity. Ten patients also had a concomitant lateral ligament reconstruction or arthroscopic bone marrow stimulation of an osteochondral lesion. The possibility to return to play in the athletic patients undergoing only AMI resection was 7 weeks. The difference was observed in the patients who had concomitant lateral ligament reconstruction, as they returned to sport at an average of 15 weeks, and in those who underwent concomitant bone marrow stimulation, as they returned to sports at an average of 14 weeks. Patients who were not involved in sports (17%) returned to daily activities without pain at an average of 9 weeks after AMI resection[6]. No high dorsiflexion range of motion was observed in the ankle; it was slightly limited in all cases before surgery by a mean of 3.2º (range 2-5º) compared to the contralateral side, as explained by the authors. Postoperative results showed a normal range of motion (<2° of the contralateral side) in all patients. In fact, complications occurred in 3 cases after arthroscopy, accounting for 7% of the overall cohort. A single patient had neurapraxia of the superficial peroneal nerve, which resolved 6 weeks postoperatively. Another patient developed arthrofibrosis after surgery requiring further manipulation under anesthesia and an injection of triamcinolone. Only 1 patient developed complex regional pain syndrome.

In our patients, all impingement was resected. All patients returned to their daily activities at 3.8 weeks, with a better ankle range of motion. The AOFAS score improved from 73 to 95. All symptoms were relieved, and all patients were satisfied with the treatment. There were no complications.

Conclusion

The arthroscopic removal of the anteromedial osteophytes of the ankle produces excellent functional results. It is an effective procedure that allows rapid patient recovery, including early return to sports activities with minimal morbidity associated with the procedure, compared to arthrotomy. In athletes who participate in jumping or kicking sports, the impingement may require removal.

Authors' contributions: Each author contributed individually and significantly to the development of this article: AG *(https://orcid.org/0000-0003-4767-5489) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version; DNG *(https://orcid.org/0000-0002-7870-5882) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version; GJ *(https://orcid.org/0000-0001-9998-190X) bibliographic review, interpreted the results of the study, clinical evaluation of the patients and performed the surgeries; XMO *(https://orcid.org/0000-0003-2231-0678) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version; MI *(https://orcid.org/0000-0002-6336-6080) bibliographic review and approved the final version; LC *(https://orcid.org/0000-0003-1187-0864) bibliographic review and clinical evaluation of the patients. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Minimally invasive Chevron-Akin osteotomy: clinical and radiographic results

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Abstract

Objective: To present the clinical and radiographic results of surgical treatment of patients with moderate to severe hallux valgus (HV) by minimally invasive Chevron - Akin osteotomy (MICA).

Methods: The case series comprises 25 patients (30 feet) with diagnoses of moderate to severe HV treated surgically with the MICA technique. All patients answered the American Orthopedic Foot and Ankle Score (AOFAS) and rated pain on visual analogue scale (VAS) at preoperative assessment and at the last follow-up consultation. Radiological assessment included measurement of the valgus angles of the hallux (HVA) and the 1st and 2nd ray intermetatarsal angle (IMA). Complications and satisfaction ratings were also documented.

Results: Mean follow-up was 14.6 months. Mean AOFAS increased from 42.8 to 90 and VAS reduced from 8.6 to 1.7. Mean HVA reduced from 31.7° to 8.4° and IMA from 14° to 5°. All these improvements were statistically significant ($p<0.001$). The most common complication observed was discomfort caused by hardware, affecting five feet (16.6%). Two patients (6.6%) had transitory neurapraxia and one patient (3.3%) developed reflex sympathetic dystrophy. There were no cases of infection, relapse, pseudarthrosis, or malunion of osteotomies. Subjective satisfaction ratings classified 93.3% of results as good or excellent.

Conclusion: Minimally invasive Chevron-Akin osteotomy is a safe and reproducible technique that achieves good clinical and radiographic results for treatment of moderate to severe hallux valgus.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus; Minimally invasive surgical procedures; Metatarsal bones/surgery; Osteotomy/methods; Forefoot, human/surgery.

Introduction

Hallux valgus (HV) is a very common pathology that affects approximately 2 to 4% of the population. Painful cases that do not improve after changing footwear and adaptation to the deformity are indicated for surgical intervention[1]. A range of different procedures are described in the literature and nowadays minimally invasive techniques exist that can be used to correct deformities via smaller incisions, causing less surgical trauma and postoperative pain[2].

Development of percutaneous techniques to treat HV was initiated by Isham[3], who developed the first generation method, with a distal metatarsal osteotomy accomplished via a percutaneous access without internal fixation[4]. This was followed by second-generation osteotomies fixed with Kirschner wires[5,6], which were associated with a range of serious complications such as pseudarthrosis and malunion[7-9]. This situation prompted two surgeons to further develop the technique, describing a third-generation method. This is a chevron osteotomy of the first metatarsal combined with an Akin osteotomy of the proximal phalanx of the great toe (MICA - minimally invasive Chevron - Akin osteotomy) conducted via a percutaneous approach using specific burrs and combined with a stable internal fixation of the metatarsal fragment using two cortical screws[10].

The combination of a stable and rigid internal fixation combined with a minimally invasive approach revolutionized percutaneous HV treatment[10,11] and, as a result, has become very

Study performed at the Hospital Belo Horizonte, Belo Horizonte, MG, Brazil.

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popular with foot and ankle surgeons for HV repair[11]. While there are some studies demonstrating the promising results of the MICA technique[12-14], there is still a lack of scientific evidence proving its superiority over traditional procedures[11]. Moreover, some authors still question the procedure's advantages and reproducibility[15]. It is also important to point out that although there are some case reports using the technique in the literature[12-14] the majority of authors, including those who have criticized the technique in their papers[15], included modified versions of the procedure and did not reproduce the technique as originally described by Redfern and Vernois[10].

The objective of this study is to present a case series and evaluate the clinical and radiographic outcomes in patients with moderate to severe HV who underwent surgical treatment using the original MICA technique.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 16213319.8.0000.5122. All of the patients included in this study signed free and informed consent forms.

This study presents a retrospective assessment of a series of 25 patients (30 feet) diagnosed with HV and treated surgically using the MICA technique from November 2017 to January 2019 by the same surgeon. Patients were included who had been diagnosed with moderate or severe HV that had not improved after conservative treatment, which consisted of adapted footwear and symptomatic medication.

Hallux valgus was defined as moderate if deformities had a hallux valgus angle (HVA) exceeding 20° and/or an intermetatarsal angle between the first and second rays (IMA) exceeding 12°, while severe HV was defined as deformities with HVA exceeding 40° and/or IMA exceeding 16°. Exclusion criteria were prior history of surgery, arthritis of the metatarsal phalangeal joint of the hallux, concurrent deformities of the hindfoot and midfoot, and rheumatological and neurological diseases.

Preoperative assessment included administration of the American Orthopedic Foot and Ankle Score (AOFAS)[16] and a visual analogue pain scale (VAS) to all patients. Supplementary examinations comprised anteroposterior (AP) and lateral X-rays, both with support. The HVA and IMA were measured[17].

At the last follow-up appointment, patients answered the AOFAS, rated pain on the VAS once more, and underwent radiographic assessment. The following variables were also noted: radiographic union (defined as osseous consolidation of three or more cortexes on orthogonal X-rays), complications, and patient satisfaction rated on the Coughlin scale (excellent, good, fair, poor, or very poor)[18].

Statistical analysis was conducted using GRETL software (2017c). Student's *t* test was used to compare measures before and after intervention. In this study, we adopted a value of 0.05 for alpha error and consequent rejection of the null hypothesis.

Surgical technique

The operation was performed according to the original technique described by Redfern and Vernois[10].

Patients underwent the surgical procedure with administration of spinal anesthesia and sedation. They were placed in dorsal decubitus with the feet hanging over the operating table edge, supported on the image intensifier tube. Specialized minimally intensive surgery instruments were used: electric motor with a high torque, low speed hand piece, beaver blade, percutaneous burrs, and manual retractor and rasps.

The first step was to insert a 2x20mm Shannon burr at the center of rotation of the metatarsal (Figure 1A), via an extracapsular portal of approximately 3 millimeters at the distal diaphysis-metaphysis transition in the medial region of the first metatarsal. The osteotomy displacement plane was determined according to the orientation of the burr in the transverse and coronal planes. A chevron osteotomy was made in a "V" shape with an angle of approximately 130°, with a dorsal cut parallel to the axis of the first metatarsal and a plantar cut in the proximal direction.

The second step was to insert a dorsomedial guidewire at the base of the first metatarsal until it penetrated the lateral cortex. After introduction of the guidewire, the head of the metatarsal was displaced laterally, using a retractor or a Kirschner wire inserted into the medullary canal, until the deformity was corrected (Figure 1B). The guidewire was then advanced until the head of the metatarsal was fixed. A 3.5 millimeter full-thread, headless cannulated screw was then inserted, perforating the medial and lateral cortexes before fixing the metatarsal head

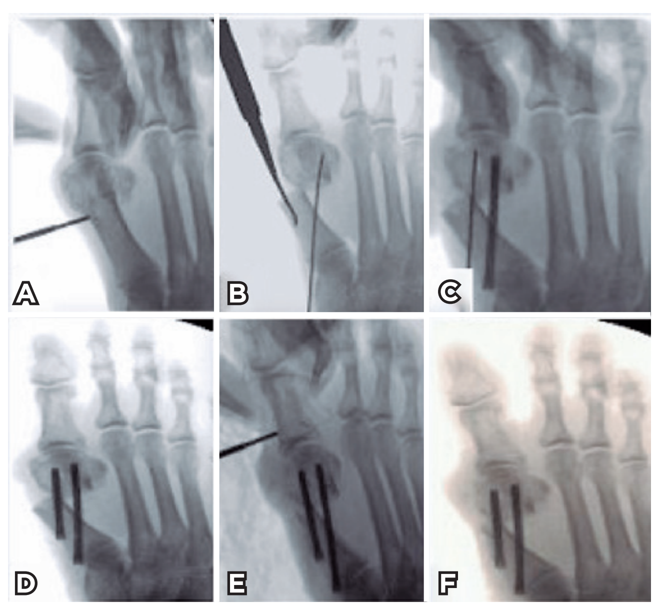

Figure 1. Intraoperative sequence showing surgical technique; A) Insertion of the Shannon burr. B) Displacement of the metatarsal head and fixation with the first guidewire. C) Fixation with the first screw and second guidewire D) Fixation with second screw. E) Akin osteotomy F) Final appearance.

(Figure 1C). A second, anti-rotational, screw was then inserted in the same plane, slightly distal of the first screw (Figure 1D). We then proceed with resection of the medial diaphyseal eminence with a 2 x 12 mm Shannon burr and a 3.1mm wedge burr via the proximal screw access portal.

If, after fixation of the osteotomy, there was any misalignment of the metatarsal-phalangeal joint of the hallux or if the lateral sesamoid was uncovered, medial soft tissues were released (freeing the adductor). The next step was to proceed with the Akin osteotomy, performed at the proximal metaphyseal region of the proximal phalanx without internal fixation. (Figure 1E). Bone fragments were removed and the area washed by abundant immersion in saline. Once the procedure was finalized, with final fluoroscopic assessment (Figure 1F), surgical incisions were sutured, padded dressing applied, and the foot bandaged, maintaining correct alignment of the hallux.

Postoperative care

Patients' dressings were applied and changed by the medical team weekly for 4 weeks. After the fourth week, a toe spacer was worn for a further 2 weeks. Immediate weight bearing was enabled by a Barouk sandal, worn for 6 weeks. Control X-rays were taken 2, 6, and 12 weeks after surgery.

Results

In this study, 25 patients (30 feet) with diagnoses of moderate (63%) and severe HV (37%) were assessed. Mean age of the participants was 53.6 years (32 to 79 years) and just 1 participant (4%) was male. Mean follow-up time was 14.6 months, varying from 12 to 18 months.

As shown in table 1, mean AOFAS increased from 42.8 to 90 points and VAS dropped from 8.6 to 1.7 points. With regard to angles, it was observed that mean HVA reduced from 31.7° to 8.4° and mean IMA reduced from 14° to 5°. All of these improvements were statistically significant (p <0.001). Twelve feet (40%) had concurrent pathologies of smaller toes, which were operated on using minimally invasive techniques during the same operation (Table 2).

Eight patients (26.6%) had complications. The most common complication was discomfort caused by hardware, observed in five feet (16.6%). After union of osteotomies, these devices were removed, with complete resolution of the complaints. Two patients (6.6%) had neurapraxia of medial dorsal cutaneous nerves, with complete recovery in response to clinical treatment. One patient (3.3%) developed reflex sympathetic dystrophy with partial improvement after 6 months of drug treatment. There were no cases of infection, wound dehiscence, or relapse of deformities. There were also no cases of delayed union, pseudarthrosis, or malunion of osteotomies (Figure 2).

All patients returned to their normal activities and none had footwear limitations. The subjective satisfaction ratings classified 93.3% results as good or excellent. One patient classified the result as poor because of reflex sympathetic dystrophy that could not be controlled clinically and improved partially in response to clinical treatment.

Table 1. Comparative analysis of the study variables

Variables	Mean value		p
	Preoperative	Postoperative	
AOFAS	42.8	90.0	<0.001
VAS	8.6	1.7	<0.001
HVA	31.7°	8.4°	<0.001
IMA	14.0°	5.0°	<0.001

AOFAS (American Orthopedic Foot and Ankle Score); VAS (visual analog pain scale); HVA (hallux valgus angle); IMA (intermetatarsal angle between first and second metatarsals).
Source: the author

Table 2. Concurrent pathologies and procedures

Associations	Number of patients	Procedures
Hammer toe	1	PP Ost + FCB tenotomy
Metatarsalgia	5	DMMO
Bunionette	6	Oblique osteotomy of 5th mtt

PP Ost (proximal phalanx osteotomy); FCB (flexor hallucis brevis); DMMO (distal metatarsal minimally invasive osteotomy); mtt (metatarsal).

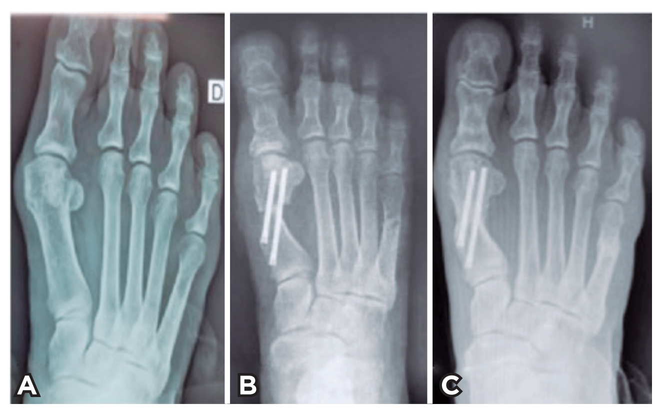

Figure 2. A) Preoperative X-ray. B) Postoperative control X-rays at week 6 and, C) at week 12, showing osseous consolidation.

Discussion

This study presents the clinical and radiographic outcomes of a case series of patients with moderate to severe HV who underwent surgical treatment with the MICA technique. There was considerable radiographic improvement, with reduced HVA and IMA and favorable clinical outcomes with significant improvement in pain and increased quality of life, according to VAS, AOFAS, and patient satisfaction ratings. The most common complication was discomfort caused by hardware. There were no serious complications and none of the osteotomies had to be revisited.

The MICA technique is capable of achieving considerable radiographic correction to treat HV. Silva et al. described a series of 26 cases of patients with moderate to severe HV treated using a third generation minimally invasive techniques in which they obtained improvement in mean HVA of 29.7° to 12.8 and in mean IMA of 14.2°to 8.2[19]. Holme et al. presented a case series of 40 patients treated using this technique with mean improvement in HVA and IMA of 20° and 6°, respectively[14]. In this study, the MICA technique achieved very powerful radiographic correction in terms of improved HVA and IMA with mean reductions of 23.3° and 9°, respectively. Since the osteotomy is extracapsular, with minimal biological aggression, it is possible to perform large displacements of the metatarsal head without compromising its vascularization, achieving sufficient radiographic correction to treat more severe deformities.

With regard to the clinical results, several studies have reported significant improvement in patient quality of life. Holme et al. reported preoperative and postoperative AOFAS of 48 and 93, respectively[14] and Jowett and Bedi achieved AOFAS improvement from 56 to 87 points in postoperative assessment of 106 patients[21]. In this series, patients had significantly improved function, with improvement from a preoperative AOFAS of 42.8 to 90 postoperatively.

The results of the MICA technique are also similar to those of the open technique when assessed over the medium and long term[20,22]. Lee et al. conducted a randomized prospective study of 50 patients comparing clinical and radiographic results of surgical treatment of hallux valgus with percutaneous Chevron osteotomy to conventional open osteotomy. They observed that pain during the acute postoperative phase was statistically lower in the subset treated with percutaneous surgery[20]. Conventional open surgery for hallux valgus demands extensive dissection of soft tissues and this can result in painful and slow postoperative recovery. A major advantage of minimally invasive surgery is the less painful and more comfortable postoperative course[23,24]. This series adds weight to findings in the literature, with improvement in mean VAS from 8.6 to 1.7 points.

Some complications have been associated with this technique, but it is important to emphasize that the majority are related to hardware and that serious complications such as avascular necrosis, pseudarthrosis, malunion, and problems related to healing of soft tissues are infrequent[12-14].

Some surgeons considered experienced and pioneers of minimally invasive surgery have presented cases series with low rates of complications[10,13]. Jowett and Bedi state that the occurrence of complications is related to the surgeon's learning curve. They reported a case series of 106 patients distributed into 2 similar groups and operated on by the same surgeon, observing that the group that comprised the first 53 cases had worse results and the screws had to be removed in 19% of cases. They emphasize the importance of conducting preoperative fluoroscopic assessment in internal oblique view to determine the correct positioning for screws in the medial cortex of the metatarsal[21]. The complication rate in the present series was 26.6% (eight patients), the majority related to discomfort caused by hardware. After removal of screws, all patients exhibited complete remission of symptoms. It is hypothesized that the high rate of hardware removal in those series may be related to the surgeon's learning curve and to the square shaped proximal extremity of the screws used in the series. Some authors point out that screws manufactured specifically for this surgery, with an oblique chamfered design at the proximal extremity, achieve a better fit in the metatarsal and reduce the likelihood of irritation of soft tissues[10,14]. Despite a high rate of implant removal, use of a rigid and stable internal fixing achieved excellent radiographic results and no delayed union, pseudoarthritis, or malunion was observed. Some studies of percutaneous osteotomies with no fixation or only fixed using Kirschner wires reported higher rates of this type of complication[9,25,26]. Two patients in the study had neurapraxia and one patient had sympathetic reflex dystrophy that was resistant to clinical control. It should be noted that, although we consider 26.6% to be a high rate of complications, there were no serious complications, all osteotomies were consolidated within 3 months, there were no problems related to soft tissue healing, and none of the osteotomies needed to be revisited. Moreover, more than 90% of the patients were satisfied with their treatment.

There has been criticism of minimally invasive surgery related to excessive shortening that can be caused by burrs[27]. The decision on whether or not to shorten the first metatarsal is taken on the basis of the radiographic characteristics of each patient. In some severe deformities, shortening is desirable and essential to achieve good correction. In order to compensate for the shortening caused and reduce the likelihood of transference metatarsalgia, the osteotomy cut can be made at angle of more than 10° from dorsal to plantar in the coronal plane, provoking plantar displacement of the head of the metatarsal. It is worthy of note that none of the patients in this study suffered from this complication.

This study is subject to several limitations, such as the small number of participants, inclusion of the learning curve of the surgeon responsible for the cases, the presence of additional procedures in some of the cases, and use of the AOFAS score. The AOFAS score is a tool that has certain limitations for assessing the pathology in question, but it is the most widely-used score for evaluating the results of HV surgery and therefore enables direct comparison with earlier publications. Edema was not assessed in the study because of the difficulties involved in measuring it objectively. The distal metatarsal joint angle was not used as a radiographic outcome in this study because it has been shown to have weak interobserver reliability and is not generally used in other studies[28]. Although there are few studies of percutaneous techniques for treatment of severe and moderate HV, the results reported in this study are consistent with the current literature.

Conclusion

It can be concluded that the MICA technique is safe and reproducible and can achieve good clinical and radiographic results for treatment of moderate and severe HV and that to obtain these the learning curve should be respected and prior training should be conducted on practical courses with cadavers. Comparative studies with higher level scientific evidence and larger numbers of participants are needed to support these findings.

Authors' contributions: Each author contributed individually and significantly to the development of this article: GAN *(https://orcid.org/0000-0003-4431-5576) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; approved the final version; JMM *(https://orcid.org/0000-0002-4224-8149) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; TB *(https://orcid.org/0000-0001-9244-5194) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; RZ *(https://orcid.org/0000-0001-9692-5283) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Achilles tendon repair by a minimally invasive technique using Tenolig®

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Abstract

Objective: To assess the degree of postoperative satisfaction of patients with acute Achilles tendon rupture who underwent surgical reconstruction by a minimally invasive technique using Tenolig®.

Methods: A retrospective observational study was conducted with 18 patients with acute Achilles tendon rupture diagnosed by a positive Thompson test who underwent surgery. Outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score and the Foot Function Index (FFI). Furthermore, quantitative variables were descriptively treated, and patients' age was correlated with FII and AOFAS score using Spearman's correlation coefficient at a significance level of 5%.

Results: Patients underwent surgery from one to six days after injury and were discharged one day later. Only one patient had a superficial postoperative infection. Patients' AOFAS scores ranged from 75 to 100 points, and FFI ranged from 0 to 20%. The patient with superficial postoperative infection had an AOFAS score and a FFI of 75 points and 20%, respectively.

Conclusion: Percutaneous repair of complete Achilles tendon rupture with Tenolig® resulted in high functional scores and a low rate of complications.

Level of Evidence IV; Therapeutic Studies; Case Series.

Descriptors: Achilles tendon; Rupture; Orthopedic procedures; Patient satisfaction.

Introduction

Achilles tendon rupture is the third most frequent tendon injury in the human body and the most frequent in the lower limb[1].

The Achilles tendon, the longest (15cm) and strongest tendon in the body, originates in the gastrocnemius and soleus muscles and is inserted in the posterior portion of the calcaneus; it is also has the highest rates of rupture.

In 1990, G. T. Kuwada published a classification system of Achilles tendon rupture to guide treatment options. Type 1 injuries are partial ruptures that should be treated by immobilization with cast. Type 2 injuries consist of those with complete rupture and a tendinous gap smaller than 3cm between the stumps with the ankle at 90 degrees, and their recommended treatment is end-to-end tenodesis. Type 3 injuries, which have a tendinous gap from 3 to 6cm, may be treated with V-Y advancement, tend transfer, Bosworth turndown, or a combination of the three. Injuries measuring more than 6cm require gastrocnemius elongation, free tendon graft, synthetic graft, or a combination of these methods[2].

The treatment of this problem is controversial among the professionals, since some of them advocate for conservative methods and others prefer surgery. Conservative treatment requires prolonged immobilization, does not pose risks for complications or skin infection, but has high rates of rerupture, tendon elongation, and muscle mass loss. Conversely, open surgery restores tendon continuity, but poses risk for adherences and skin complications (profound infection and tendon adherence), in addition to neurologic injury. Several percutaneous techniques have been described since 1977, such as the Tenolig® (FH Orthopaedics, Heimsbrunn, France), a device developed to maintain the tendon in contact with each other. The Tenolig® kit consists of two wires with anchors at one end and needles at the other end; two washers and two poliethylene disks for securing the distal end of the wire[3,4].

Study performed at the Hospital Santa Marcelina, São Paulo, SP, Brazil.

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This type of injury is often treated by the foot and ankle team of the referral service in Orthopedics and Trauma at a hospital located in the east region of the city of São Paulo, Brazil. Surgical tendon repair may be performed by the following techniques: open and minimally invasive with percutaneous approach, a simple and rapid procedure, with early return to daily activities[1,5].

The standard percutaneous technique consists of: (1) union of the ruptured ends without using a large surgical approach, thus also avoiding the drainage of the local hematoma and rushing the repair; (2) avoiding damaging of the tendon's vascular supply. This technique leads to a rapid transformation of the collagen fibers into elastic fibers, which are mechanically effective. Complications include: sural nerve injury, infection, rerupture, deep vein thrombosis, and hypertrophic scars. Thus, the procedure may not be appropriate for patients with diabetes mellitus or peripheral vascular disease[4,6].

The importance of the present study relies on analyzing the outcome of the minimally invasive technique for the percutaneous repair of the tendon injury using Tenolig® and assess the degree of patients' postoperative satisfaction, based on pain level, functionality, and ankle and hindfoot mobility. Therefore, our study will contribute for the planning of future procedures and for the management of individuals with this type of injury and have a surgical indication.

The aim of this study is to assess the degree of postoperative satisfaction of patients who underwent a minimally invasive technique for repair of acute Achilles tendon rupture.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 98291018.3.0000.0066.

A retrospective observational study was conducted with 18 patients who underwent Achilles tendon repair with a percutaneous suture from September 2017 to October 2019 and were followed up by the Orthopedics and Trauma service of a hospital located in the east region of the city of São Paulo, Brazil.

Exclusion criteria were patients who underwent other surgical techniques or who received conservative treatment, patients with other associated diseases, and those refused to answer the questionnaires and/or did not sign the Informed Consent Form (ICF).

Initially, the researchers assessed the electronic medical records of the 18 patients who underwent the minimally invasive technique during the study period, who were contacted by phone and invited to participate in the research. Next, those who agree to participate were evaluated using the following instruments: the American Orthopaedic Foot and Ankle Society (AOFAS) scale[7], which analyzes pain, functionality, maximum walking distance in blocks, walking surfaces, gain abnormality, sagittal mobility (flexion and extension), hindfoot mobility (inversion and eversion), ankle-hindfoot stability, and alignment; and the Foot Function Index (FFI) questionnaire[8], initially developed in English and subsequently translated into Portuguese and revised, in order to assess foot functionality in patients with musculoskeletal injuries.

That said, the diagnosis of Achilles tendon was clinical in all patients, consisting of a positive Thompson test for the injury and of the presence of a gap in the topographic region of the injury. The test was applied with the patient placed in the horizontal prone position with the knee flexed at 90 degrees, and the examiner then squeezes the calf muscle. In normal conditions, this procedure should result in plantar flexion of the ankle, but it is not observed in the presence of a complete Achilles tendon injury. An important sign of injury is the presence of a gap detected by physical examination.

Moreover, the collected data were referred to statistical analysis, in which all variables were initially subjected to descriptive analysis. Then the analysis proceeded with the identification of minimum and maximum values and the calculation of means, standard deviations, and medians, for quantitative variables, and with the calculation of absolute and relative frequencies for qualitative variables. Correlation between scores and age was assessed using the Spearman correlation coefficient[9]. The SPSS 17.0 for Windows software was used for calculations. The level of significance for the tests was set at 5%.

Surgical description

The patient is placed in the prone position under spinal anesthesia; asepsis and antisepsis of the affected lower limb are performed; sterile fields are placed; a sterile cushion is positioned in the anterior region of the ankle to maintain it initially at 90 degrees; a surgical pen was used to draw the proximal and distal stumps of the ruptured tendon through simple palpation; proximal entry points were demarcated 5cm above the injured region on the posteromedial and posterolateral surfaces of the tendon; distal exit points were demarcated 5cm below the injured region on the posteromedial and posterolateral surfaces of the tendon; a small incision was made on the entry site; the first Tenolig® is inserted using strong tweezers, the needle penetrates the tendon perpendicularly, and the surgeon feels the knee crossing the gap site under his/her finger; then the needle penetrates the distal stump and exits at the previously established point; the needle is pulled outwards until the anchor n is positioned at the level of the proximal entry point; the second Tenolig® is inserted in the same manner, on opposite sides; for the tightening, the pad is removed to position the ankle in a maximum equinus position, the two straps are pulled tight simultaneously, thus making sure that the anchors are properly anchored; the plastic disks are threaded on, with convex surface against the skin; washers were inserted fixed using pliers; the implant is tested after having relaxed the tension of the straps; the distal ends of the straps are cut 3cm from the washers; proximal sutures are made; a shaped compress is slipped under the discs; a sterile dressing is made; a resin boot holding the foot in the equinus position is made.

Results

Eighteen patients aged from 29 to 62 years were assessed (mean 45.39 years, standard deviation 9.22 years, and median 42.50 years). Overall, 16 (88.9%) patients were male; 16 (88.9%) injured themselves while playing soccer, one (5.6%) fell from his own height, and one (5.6%) fall of a ladder.

Of the total sample, 16 (88.9%) patients participated in recreational sports activities, two (11.1%) were sedentary, and none was a professional athlete; furthermore, 11 (61.1%) of injuries were located on the right side, and seven (38.9%) on the left side.

The patients underwent surgery from one to six days after injury (mean 1.61 day, standard deviation 1.24 day, and median 1 day) with a postoperative discharge of one day. One patient (5.6%) had postoperative superficial infection. Three patients (16.7%) were smokers.

AOFAS scores ranged from 75 to 100 (mean 93.50 points, standard deviation 6.40 points, and median 93.50 points). The patient with infection had an AOFAS score of 75 points, whereas the other patients scored above 90 points.

FFI ranged from 0 to 20% (mean 5.94%, standard deviation 5.58%, and median 5%). The patient with infection had a FFI of 20%, whereas the other patients scored from 0% to 15%.

Table 1 shows the frequency distribution of patients according to their jobs.

AOFAS score: Table 2 shows the absolute and relative (%) frequencies of the following variables: sex, smoking, affected side, physical activity, and complication, according to the AOFAS score. No significant difference was found in AOFAS scores with regard to sex, smoking, affected side, physical activity, and presence of complication. Spearman's correlation coefficient did not show any significant correlation between age and AOFAS score (r=0.312, p=0.208).

FFI: Table 3 shows absolute and relative (%) frequencies of the variables: sex, smoking, affected side, physical activity, and complication according to the FFI. No significant difference was found in the FFI with regard to sex, smoking, affected side, physical activity, and presence of complication. Spearman's correlation coefficient did not show any significant correlation between age and FFI (r=-0.409, p=0.092).

Table 1. Frequency distribution of the eighteen patients according to their jobs

Job	n	%
Trader	3	16.7
Housekeeper	2	11.1
Driver	2	11.1
Production	2	11.1
Seller	2	11.1
Retired	1	5.6
Joiner	1	5.6
Physician	1	5.6
Doorman	1	5.6
Teacher	1	5.6
Security guard	1	5.6
General services	1	5.6

Table 2. Absolute and relative (%) frequencies for the variables: sex, smoking, affected side, physical activity, and complication according to the AOFAS score

	AOFAS				
	<90 (n=1)	90-94 (n=8)	95-99 (n=5)	100 (n=4)	p*
Sex					0.739
Female	0 (0.0)	1 (12.5)	0 (0.0)	1 (25.0)	
Male	1 (100.0)	7 (87.5)	5 (100.0)	3 (75.0)	
Smoking	0 (0.0)	1 (12.5)	0 (0.0)	2 (50.0)	0.328
Affected side					0.600
Right	0 (0.0)	5 (62.5)	4 (80.0)	2 (50.0)	
Left	1 (100.0)	3 (37.5)	1 (20.0)	2 (50.0)	
Physical activity					0.739
Recreational	1 (100.0)	7 (87.5)	5 (100.0)	3 (75.0)	
Sedentary	0 (0.0)	1 (12.5)	0 (0.0)	1 (25.0)	
Complication	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.056

* Descriptive level of probability in the Fisher's exact test.

Table 3. Absolute and relative (%) frequencies for the variables: sex, smoking, affected side, physical activity, and complication according to the FFI

	FFI				
	0% (n=4)	1-9% (n=9)	10-19% (n=4)	>=20% (n=1)	p*
Sex					1
Female	0 (0.0)	1 (11.1)	1 (25.0)	0 (0.0)	
Male	1 (100.0)	8 (88.9)	3 (75.0)	1 (100.0)	
Smoking	1 (25.0)	2 (22.2)	0 (0.0)	0 (0.0)	1
Affected side					0.715
Right	3 (75.0)	5 (55.6)	3 (75.0)	0 (0.0)	
Left	1 (25.0)	4 (44.4)	1 (25.0)	1 (100.0)	
Physical activity					1
Recreational	4 (100.0)	8 (88.9)	3 (75.0)	1 (100.0)	
Sedentary	0 (0.0)	1 (11.1)	1 (25.0)	0 (0.0)	
Complication	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0.056

* Descriptive level of probability in the Fisher's exact test.

Discussion

Achilles tendon injuries are relatively common in middle-aged athletes. The most frequent mechanisms of rupture are: impulse with the anterior portion of the foot that is bearing the weight during knee extension, sudden unexpected dorsiflexion of the ankle, and violent dorsiflexion of a plantarflexed foot, as it happens when a person falls from a high place[1].

The diagnosis of acute Achilles tendon rupture is mainly based on patient's history, physical examination, and imaging tests. Patients present with sudden inability to walk and acute pain when running or jumping. Some patients describe that they heard a popping sound in the back of the leg in dorsiflexion of the ankle or had the feeling of being kicked in the back of the ankle(10).

The treatment may be conservative or surgical. These are some of the surgical techniques: open repair, with or without reinforcement (tendon transfer, opening of fibrous membrane, allografts) and percutaneous minimally invasive repair. The open approach is associated with greater complications compared to percutaneous or minimally invasive approaches(5,10).

Percutaneous techniques have the following advantages: low rate of complications, reduced surgical time, expedited rehabilitation, reduced cost, and better aesthetic outcomes, but they may lead to a higher rate of recurrence compared to techniques of open surgical repair(11).

The involvement of the sural nerve was a major difficulty in percutaneous minimally invasive techniques, causing damages and inflexibility. Suture needles may easily damage when sural nerves are blindly sutured(12).

It was also observed a lack of consensus among professionals with regard to the best treatment option, because studies did not show significant differences in the outcome after conservative or surgical treatment: some meta-analyses reveal that conservative treatment increases the risk of rerupture, while other studies found that surgery may cause wound-related complications(13).

Jallageas et al. performed a cross-sectional study assessing 31 patients with a mean age of 38 years who presented with a ruptured Achilles tendon that occurred during sports participation. Percutaneous surgery was performed in 16 patients, and open surgery in 15 patients. No patient experienced a rerupture. The return to sports occurred at 130 days after percutaneous surgery and 178 days after open surgery. Percutaneous surgery resulted in less muscle atrophy than open surgery. The average AOFAS score was 94, comparable to published studies. The majority of patients (77%) had returned to their preinjury level of sports activity(14).

Antunes et al. conducted a retrospective study with 30 patients with Achilles tendon rupture during sports (80% soccer and 20% running) who underwent surgery with percutaneous Tenolig® to evaluate the functional outcome and post-rupture and rerupture rate. In relation to activity level, 16.6% of patients of patients had occasional activity, 46.6% had mild activity, and 36.6% had intense activity. During follow-up, 86.6% of patients had an average AOFAS score of good (80 to 100 points). There was a rerupture rate of 10%, on average 4 months after surgery, all of which were surgically intervened by open approach(5).

Lacoste, Féron and Cherrier conducted a prospective study with 75 patients with a mean age of 39.09 years who suffered Achilles tendon rupture. Most injuries (82.8%) were sports-related. All patients underwent Tenolig(®) repair under followed by early rehabilitation therapy started after 3 weeks. Mean follow-up was 20.7 months. Mean time to sports resumption was 8.6 months, with two thirds of satisfied patients returning to their returning to their previous level of sporting activities. The mean AOFAS functional score was 95(3).

A study by Taglialavoro et al. concluded that percutaneous treatment represents the gold standard for acute Achilles ruptures because it is minimally invasive and respectful to the biology of tendon cicatrization and devoid of serious complications. Percutaneous suture guarantees a strong stabilization of the stumps of the ruptured tendon. The patients treated with Tenolig® showed shorter surgical time, hospital permanence and immobilization, and it functionally stimulates the tendon healing in a short time(15).

The percutaneous approach have many advantages, such as: (1) avoiding tendon devascularization and maintaining hematoma after rupture, preserving anatomic and biological factors to stimulate tissue regeneration; (2) reducing immobilization time, which helps align collagen fibers by transforming them into functional elastic fibers; (3) it is a rapid procedure, thus allowing to approximate the stumps of the tendon, causing few skin complications(5).

A follow-up study after percutaneous repair with Tenolig® concluded that this technique has been used for many years and led to more satisfactory outcomes for patients, minimizing complications that occur in open and even mini-open methods, such as healing problems and prolonged immobilization(16).

Conclusion

Percutaneous repair of complete Achilles tendon rupture with Tenolig® resulted in high functional scores and a low rate of complications.

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Original Article

Minimally invasive technique for suprasyndesmotic ankle fracture fixation: clinical and radiographic analysis

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Abstract

Objective: To evaluate the clinical and radiographic results of suprasyndesmotic ankle fracture fixation with a minimally invasive technique.

Methods: Retrospective study of 11 patients with suprasyndesmotic fractures of the lateral malleolus who underwent surgery between 2016 and 2018. Retrospective analysis of medical records considered the following: radiographic assessments (preoperative, immediate postoperative, six weeks postoperative), clinical evaluation, and strength scale and movement test results.

Results: Of the 18 patients qualified for inclusion, 7 failed to appear at the follow-up appointment and were excluded. The patients' age varied from 20 to 53 years, and 72.7% were male. The trauma mechanisms included torsion (46% of the cases), automobile accidents (36.4%) and direct trauma (17.6%). The mean time between trauma and definitive surgery was 3.27 days. The mean talocrural angle in the preoperative period was 83.13°, ranging from 80.63° in the immediate postoperative period to 81.27° at 6 months postoperatively. Approximately 90% of the patients did not lose strength. Regarding the range of motion, the mean dorsiflexion and plantar flexion 6 months postoperatively were 10.72° and 34.4°, respectively.

Conclusion: The minimally invasive technique had excellent technical results in patients treated surgically for ankle fractures and required smaller incisions than conventional surgery. Osteolysis or fatigue of the osteosynthesis material is a possibility with this technique, which generally occurred between three and four months postoperatively.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Ankle fractures/diagnostic imaging; Minimally invasive surgical procedures; Fracture fixation, intramedullary; Treatment outcome.

Introduction

Ankle fractures are among the most common injuries treated by orthopedists. Typically, ankle fractures result from injuries caused by a low-energy mechanism, such as torsional trauma. In the United States, about 8.3 of every 1000 patients seen at health services each year have an ankle fracture(1).

Knowledge of the trauma mechanism is significant, since it helps the orthopedist understand the fracture, assess the patient's clinical and soft tissue conditions, and determine the best surgical approach(2).

The criteria for conservative or surgical treatment are well established. In fractures that require surgery, open reduction with internal plate and screw fixation is the gold standard. Despite good results with this technique, patients who smoke, have diabetes or have peripheral vascular diseases are more vulnerable to complications, such as surgical wound dehiscence, skin necrosis and absence of fracture consolidation. Use of a new technique, known as minimally invasive percutaneous plate osteosynthesis (MIPPO), has increased due to its decreased rate of postoperative complications(3) and smaller incisions (3cm vs. approximately 10cm in the conventional technique).

One of the main objectives of ankle fracture treatment is to maintain tibiotalar congruence, which promotes joint stability and allows joint movement and early rehabilitation.

Study performed at the Hospital do Trabalhador, Curitiba, PR, Brazil.

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Lauge-Hansen[3] classified ankle fractures based on the mechanism of injury. Through a cadaveric study, he assessed the position of the foot (supination or pronation) and the deforming force at the time of trauma (external rotation, abduction and adduction) and proposed that understanding the mechanism of injury would facilitate the fracture reduction procedure by recreating the deforming force:

1) Pronation-abduction: the talus is abducted in the mantle, coming into contact with the medial structures and compressing the sides.
2) Pronation and external rotation: injury to the lateral and posterior elements occurs
3) Supination and adduction: this mechanism of injury leads to the following two stages:
   - Stage I: Fracture of the malleolus below the syndesmosis;
   - Stage II: Vertical fracture of the medial malleolus.
4) Supination and external rotation: this is the most common mechanism, which includes about 75% of all ankle injuries

In addition to Lauge-Hansen classification, the Danis-Weber system is used to classify fractures of the lateral malleolus:

- **Type A:** Infrasyndesmotic fracture, which is usually associated with avulsion of the lateral ligament complex.
- **Type B:** Oblique or spiral fracture at the level of the syndesmosis, which may be associated with injuries to the posterior elements.
- **Type C:** Fracture above the level of the syndesmosis, which may include Maisonneuve-type injuries.

Type C fractures are visible radiographically above the level of distal tibiofibular syndesmosis and are associated with loss of joint congruence. These are usually treated with open reduction and internal fixation. In the intraoperative period of these patients, we evaluated the syndesmosis lesion using the Cotton test[3] or the dorsiflexion test; external rotation of the ankle was assessed with fluoroscopy.

These patients are immobilized for 15 days with an orthosis and were followed serially (15, 45, 90,180 days) until their return to normal activities. We indicate physical therapy and partial body-weight support beginning at 15 days postoperatively. At approximately 90 postoperative days, the patient is ready to return to work and resume normal activities.

The aim of the study was to propose a minimally invasive technique for treating suprasyndesmotic lateral malleolus fractures, assessing its results through a retrospective analysis of the medical records of patients who underwent the procedure between 2016 and 2018.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 36477520.1.0000.5225.

The comparative retrospective analysis included medical records and complementary exams (radiography), patient satisfaction results (self-report), strength test results (dynamometry), and range of motion test results (goniometry), as well as measurement of the talocrural angle preoperatively, in the immediate postoperative period and at least six weeks postoperatively.

The medical records were collected through a Unified Health System procedure code ("Surgical treatment of unimalleolar ankle fracture" - 040805057-80).

The inclusion criteria were patients with Danis-Weber type C suprasyndesmotic lateral malleolus fractures with instability of the distal tibiofibular syndesmosis who underwent surgery between 2016 and 2018. The exclusion criteria were bimalleolar fractures, trimalleolar fractures, treatment with conventional osteosynthesis techniques, Danis-Weber type A or B fractures and failure to appear at the post-operative follow-up appointment.

We retrospectively analyzed radiographic images and joint congruence. Clinical evaluation of the medical records included the degree of strength on a scale of 0-5 (compared to the contralateral side), the range of motion, the visual analog pain score, and the trauma mechanism that caused the fracture.

All selected patients provided written informed consent prior to inclusion. In the cases selected for this study (patients with Danis-Weber type C ankle fractures), it was decided to use a minimally invasive technique for syndesmosis fixation.

The data were tabulated in Microsoft Excel 2016 and analyzed in SPSS.

Surgical technique

1. Distal tibiofibular syndesmosis was assessed using fluoroscopy following Koenig et al.[5], including dorsiflexion and external rotation of the ankle, maintaining the true anteroposterior incidence of the ankle.
2. Indirect fracture reduction using traction and countertraction, rotation and fluoroscopy to obtain ankle and distal tibiofibular joint congruence.
3. Joint reduction was maintained with a 2.0mm Kirschner wire that entered the distal region of the fibula and was anchored in the medial cortex of the tibia.
4. A lateral incision of approximately 3cm in the fibula, always below the level of the fracture and slightly suprasyndesmotic.
5. Fixation with a one-third tubular plate with three holes and two transyndesmal screws[6], which stabilized the syndesmosis, indirectly stabilized the proximal fracture and maintained the joint congruence of the ankle (Figure 1).
6. Intraoperative fluoroscopy was performed, keeping the ankle in true anteroposterior incidence during dorsiflexion and external rotation. Distal tibiofibular stability was assessed after fixation.

Figure 1. Minimally invasive surgery results in the immediate postoperative period.

It should be noted that the indirect reduction of syndesmosis and stabilization with the third tubular plate and screws was addressed, and not the suprasyndesmotic fracture.

Results

Although 18 patients met the inclusion criteria, 7 failed to appear at the 6-month follow-up appointment regarding patient satisfaction and were excluded from the study. The 11 included patients had a mean age of 34.7 years (20-53) and 72.7%(8) were male.

The trauma mechanisms included torsional trauma (46%; 5), automobile accidents (36.4%; 4) (we could not determine whether the trauma was direct or indirect), and direct trauma (17.6%; 2). The mean time between trauma and surgical treatment was 3.27 days, with a maximum of 19 days and a minimum of zero.

According to radiographic analysis, the preoperative talocrural angle varied from 79° to 95° with a mean of 83.13°. The angle in the immediate postoperative period ranged from 78° to 83°, with a mean of 80.63°. Finally, at the 6-month postoperative evaluation, the angle varied from 80° to 86°, with a mean of 81.27° (Figure 2).

After 6 months of follow-up, we obtained the following strength values: inversion grade 5 in 90.9% (10) and grade 4 in 9.1% (1), eversion grade 5 in 90.9%(10) and grade 4 in 9.1%(1), dorsiflexion grade 5 in 90.9%(10) and grade 4 in 9.1%(1), and plantar flexion grade 5 in 90.9%(10) and grade 4 in 9.1%(1). Four different patients had a decrease in each type of movement. The analog pain scale was used to assess postoperative pain. Scores ranged from 0 to 6, with a mean of 1.54. Regarding the range of motion of the operated ankle, dorsiflexion varied between 5° and 15°, with a mean of 10.72°, whereas the plantar flexion varied from 35° to 45°, with a mean of 34.4° (Figure 3). There were no complications in any of the cases.

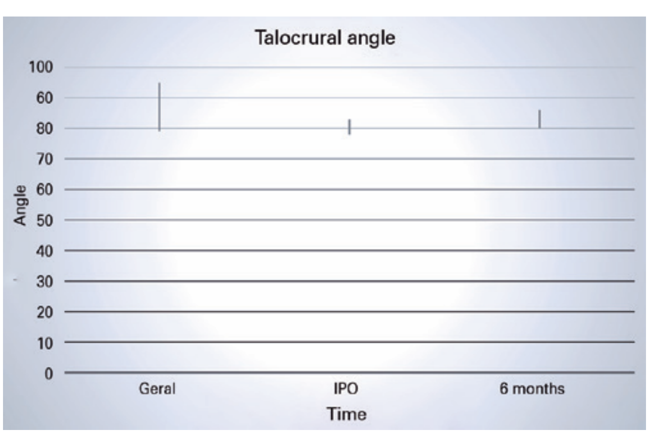

Figure 2. Variation of the talocrural angle in the preoperative period, immediate postoperative (IPO) period and at 6 months of follow-up.

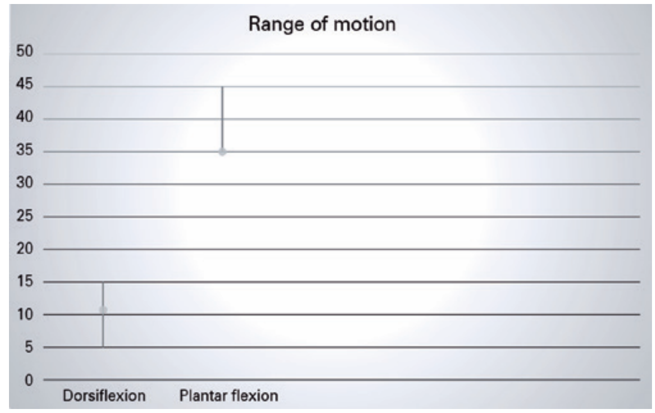

Figure 3. Range of motion assessment.

Discussion

Classically, open reduction and internal fixation with plates and screws is considered the gold standard for correcting fractures of the suprasyndesmotic lateral malleolus. However, due to the increased risk of complications related to wound healing, especially in patients with vasculopathies due to diabetes or vascular insufficiency, minimally invasive approaches are gaining ground.[1]

Although a number of studies have demonstrated the success of minimally invasive surgery, considerably fewer have been carried out on ankle fractures, such Pires et al. (2014). Thus, the aim of our study was to demonstrate the effectiveness of minimally invasive treatment for suprasyndesmotic lateral malleolus fractures (Danis-Weber type C).

Our patients had a lower mean age (34.7 years) than other studies[1,4], as well as a different sex prevalence (more men than women)[1,4]. However, such information was not relevant since the most frequent trauma mechanism in the sample, torsional trauma (45.5%), was the most commonly described mechanism in the literature. The prevalence of trauma due to automobile accidents in our sample was also expressive (36.4%), which is explained by the fact that our Orthopedics and Traumatology Service is a reference center for trauma.

The mean time until surgery (3.27 days) was acceptable given that fractures of the suprasyndesmotic lateral malleolus, in most cases, are not considered emergencies and are likely to receive elective treatment within two weeks of the trauma.

Regarding surgical efficacy in the late postoperative period, the chosen treatment can be considered excellent, both for the minimal pain reported by the patients (a mean of 1.54 on a scale of 0 to 10) and for the degree of muscle strength during inversion, reversal, and plantar and dorsal ankle flexion, which was maximal (grade 5) in almost all cases (90.9%).

In addition, our surgical approach showed mean plantar and dorsiflexion (34.4° and 10.72°, respectively) close to the peak range of motion (45° and 20°, respectively)[4,5].

We used a minimally invasive incision of about 3cm in the lateral portion of the fibula, as described by Pires et al.[1], which is much smaller than the approximately 10 cm incision used in the conventional technique .

In cases where the medial clear space was ≥5mm after fixation, a medial approach involving retensioning of the medial capsule with transosseous sutures or a metallic anchor with high-strength wire was selected[7].

In the radiographic analysis, it was observed that four months postoperatively, all patients had either osteolysis around the osteosynthesis material or implant fatigue (broken screws). This is not surprising, since the distal tibiofibular joint is highly mobile and becomes rigid when stabilized. As it tries to return its natural degree of mobility, lysis or implant breakage can occur[6].

Finally, it is worth mentioning that the minimally invasive technique was applied to Danis-Weber type C fractures, which, according to the literature, require treatment with syndesmosis fixation, unlike the Danis-Weber type B fractures analyzed by Pires et al.[1], who only recommended stabilizing the lateral malleolus.

When performing this type of procedure, we advise removing the surrounding osteosynthesis material approximately four months after the operation to avoid breakage and/or lyse.[6] However, osteolysis or fatigue of the osteosynthesis material did not lead to clinical complications and/or functional deficits in our sample.

We obtained good radiographic and functional results with a minimally invasive surgery technique in this sample of patients. Despite the short follow-up period, the fact that seven patients failed to appear for the final follow-up, and the biases implicit in these factors, the results were promising. Thus, another option for treating these fractures is available in the therapeutic arsenal of the orthopedic surgeon.

Conclusion

In comparison to the traditional technique of open reduction and internal fixation of unimalleolar suprasyndesmotic ankle fractures, minimally invasive surgery is becoming increasingly common as an approach for these injuries due to its excellent functional results, the preservation of strength and mobility, and smaller surgical incisions.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RH *(https://orcid.org/0000-0002-3371-1752) wrote the article; participated in the review process; RG *(https://orcid.org/0000-0001-8099-820X) interpreted the results of the study; conceived and planned the activities that led to the study; JTCF *(https://orcid.org/0000-0001-8274-2195) participated in the review process; approved the final version; LM *(https://orcid.org/0000-0003-3377-7919)) wrote the article; approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Percutaneous surgical treatment of hallux valgus: retrospective study with 6.5-year follow-up

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Abstract

Objective: To analyze outcomes of hallux valgus surgical correction using the Reverdin-Isham technique by means of clinical and radiographic studies.

Methods: We retrospectively assessed 43 feet (38 patients) with moderate to severe hallux valgus treated from June 2009 to July 2014. Mean age at surgery was 59 years; mean postoperative follow-up time was 79 months. Patients were assessed at pre- and postoperative periods both functionally, by the American Orthopaedic Foot and Ankle Society (AOFAS) score, and radiographically, by the hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMAA), and shortening of 1st metatarsal bone.

Results: AOFAS scores had a mean increase of 55 points. Mean HVA decreased 14.5°, whereas IMA and DMAA exhibited a mean decrease of 3.8° and 9.7°, respectively. Mean shortening of the first metatarsal bone was 3mm.

Conclusion: The presented surgical technique showed to be effective to correct mild to moderate hallux valgus, resulting in appropriate angle correction angular and significant increase in AOFAS scores.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus; Minimally invasive surgical procedures/instrumentation; Osteotomy/surgery; Treatment outcome; Patient satisfaction.

Introduction

Hallux valgus, the main deformity of the forefoot, is characterized by a lateral deviation of the hallux and a medial deviation of the first metatarsal, producing a bony protrusion at the metatarsophalangeal joint (MTPJ)[1,2].

Conservative treatment may relieve pain, but it is ineffective in correcting the deformity. Surgery is indicated in symptomatic cases, which are usually associated with difficulty in wearing certain types of shoes. The procedure aims to correct alignment of the first ray, in order to maintain biomechanical functionality of the forefoot[2,3].

Increasingly less invasive techniques have been used for orthopedic treatment. In foot surgery, percutaneous approach stands out due to its potential advantages over open techniques, such as: use of loco-regional anesthesia and of small or punctiform incisions, non routine use of synthesis material, immediate ambulation, low rates of skin complications and of postoperative pain[3-7]. Furthermore, percutaneous approach allows surgeons to intervene on the deformity without directly exposing tissues and anatomical structures, thus reducing trauma to the involved soft parts. Due to the small size of the incision, radiological guidance with fluoroscopy is required[4,6,7].

Percutaneous foot surgery is a recent technique assessed by few studies reporting long-term outcomes in the international literature, which makes it difficult to implement and systematize this technique[5,7].

The aim of this study is to analyze functional and radiological outcomes of percutaneous surgical treatment of hallux valgus using the Reverdin-Isham technique, with a mean follow-up of six and a half years.

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

Correspondence: Luiz Carlos Ribeiro Lara. 1551 Itália Av., Jardim das Nações, Taubaté, SP, Brazil, Zip Code: 12030-212. **Conflicts of interest:** none. **Source of funding:** none. **Date received:** October 18, 2020. **Date accepted:** November 30, 2020. **Online:** December 21, 2020

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Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 36043320.0.0000.5501.

From June 2009 to July 2014, 92 patients with mild to moderate hallux valgus were operated in our Hospital and in the private clinic of one of the authors. The surgical technique employed a percutaneous approach, as proposed by Isham[6,8].

The study included patients with symptomatic hallux valgus classified as mild or moderate[9] and with a postoperative follow-up longer than five years.

Exclusion criteria were patients with severe hallux valgus, rheumatoid arthritis, neurological disorders, arthrosis of hallux metatarsophalangeal joint radiologically visualized (according to Coughlin and Shurmas[1]), history of previous surgeries or fractures of the forefoot, and postoperative follow-up shorter than five years.

Patients were contacted by telephone, and 38 individuals (46.7% of total) returned for outpatient assessment, totaling 43 feet. All participants were informed on study objectives and signed a free informed consent. Weight-bearing radiographs of the foot were taken in the anteroposterior (AP) and profile incidences, according to routine procedures. Angles were manually measured using a goniometer on the pre- and postoperative AP x-rays. Hallux valgus angle (HVA), intermetatarsal angle (IMA), and distal metatarsal articular angle (DMAA) were obtained[10,11]. Length of the first metatarsal was also assessed through a line drawn from the center of joint surface of the first metatarsal head to the center of the metatarsal-cuneiform joint[7]. The x-rays obtained at public services were analog. For calculating postoperative shortening, the length of distal phalanx of the hallux was used as a scale. Images obtained at private services were digital and had a scale, which facilitated proportional calculation.

All measurements were made by orthopedists belonging to the foot and ankle surgical staff at our service.

Clinical assessment was conducted using the translated version of the questionnaire proposed by the American Orthopaedic Foot and Ankle Society (AOFAS) for disorders of the hallux[12] As requested in the questionnaire, range of motion of hallux interphalangeal or metatarsophalangeal joints was assessed using a goniometer, both in the pre- and postoperative periods.

All postoperative complications were registered on medical records. The following events were considered as complications: surgical wound intercurrences, sensory or motor changes in the hallux, residual callosities and deformities affecting the hallux or the small toes, unpredicted displacement of metatarsal osteotomy, delayed consolidation (absence of bony callus after 8 weeks), relapses, or evolution with osteodegenerative changes.

Surgical technique

Procedures were conducted by a team of three orthopedists specialized in foot and ankle surgery. We used the percutaneous Reverdin technique modified by Isham[6,8] on all 43 feet, associated with proximal phalangeal (Akin) osteotomy[13] and with adductor hallucis tenotomy[4,6].

Patients were placed in the supine position, without using tourniquet, and were under loco-regional anesthesia (5-in-1 blocks) at the ankle[14].

The special material used was a MIS 64 beaver blade, a Wedge 4.1-mm roughing burr, a long Shannon osteotomy burr, and manual bone rasps. The burrs were rotated using a drilling motor operating at 6,000 rotations per minute (Figure 1).

1. Exostectomy – it was performed through a 5-to-8-mm incision on the medial and plantar surface of the first metatarsal (Figure 2). Sectioning was started on a single plane and was made towards the end of exostosis. The joint capsule was then detached using a scraper. Removal of exostosis started using a 4.1-mm roughing burr. The resulting bone fragments were removed by manual expression and cleaned with saline.

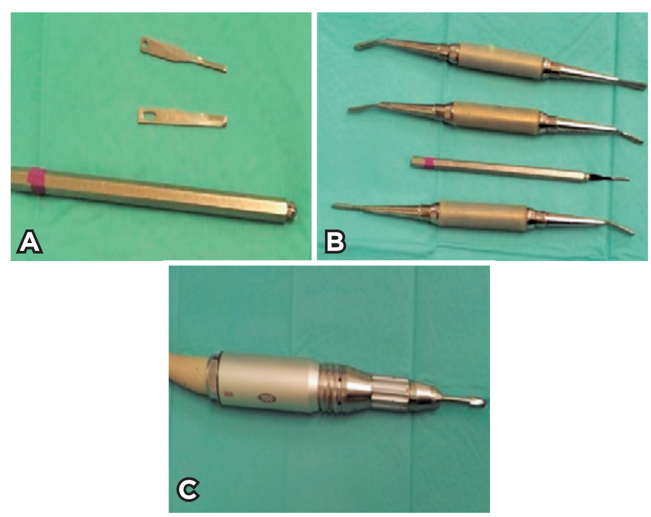

Figure 1. Special materials. A. MIS scalpel handle and its blades B. Manual rasps. C. Handpiece with burr.

Figure 2. Route of surgical access for the conduction of exostectomy and osteotomy.

2. Distal osteotomy of the first metatarsal bone, following the technique described by Reverdin modified by Isham(6,8) – A long Shannon burr (cutting burr) was introduced through the same surgical approach and placed on the medial surface of the metatarsal bone in an oblique direction of 45°. In this position, osteotomy cut was started up to the lateral cortical surface, which was maintained intact to achieve greater stability. By moving the hallux towards a varus alignment, the space generated by the osteotomy cut is closed, leading to osteoclasis of the lateral cortical surface (Figure 3).
3. Adductor hallucis tenotomy and lateral capsulotomy - With a new 2-mm incision at the dorsolateral region of the hallux MTPJ, adductor hallucis tendon and the lateral capsule were sectioned.
4. Proximal phalangeal osteotomy of hallux (Akin)(13) – Through another surgical approach measuring from 3 to 5mm on the dorsal and medial surface of the first phalangeal base, a medial osteotomy was performed using a long Shannon burr without crossing the cortical lateral bone, maintaining a greater stability with osteoclasis after valgus osteotomy of the toe.

Figure 4 shows intraoperative radiological images of the steps described above.

5. Immobilization and postoperative – At the end of the surgery, an elastic bandage was applied, maintaining a slight hypercorrection of the hallux. Bandages were changed weekly during the first four weeks and, in the two subsequent weeks, by the patient. Patients were allowed to walk wearing rigid sole shoes from the first day up to the second postoperative month (Figure 5). Patients were instructed to mobilize the hallux after the first week. Physical therapy was requested after the first postoperative week.

The paired t test was applied to compare pre- and postoperative angle measures and AOFAS scores. This test is based on the assumption of data distribution normality, which was investigated using the Kolmogorov-Smirnov test. Level of significance was set at below 0.05 and represented by "*".

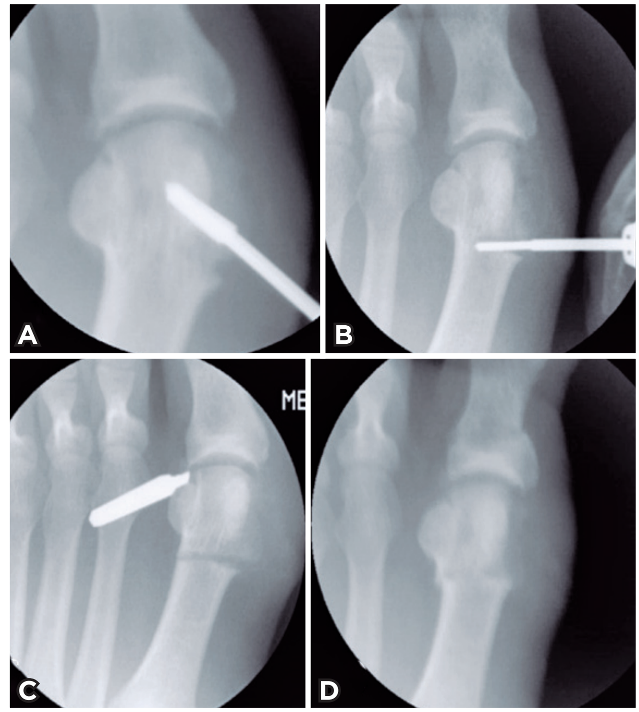

Figure 4. Intraoperative anteroposterior fluoroscopy images used to guide each stage of the procedure. A. Exostectomy B. Distal metatarsal osteotomy C. Adductor hallucis tenotomy D. Proximal phalangeal osteotomy.

Figure 5. A. Postoperative bandage B. Rigid sole shoe.

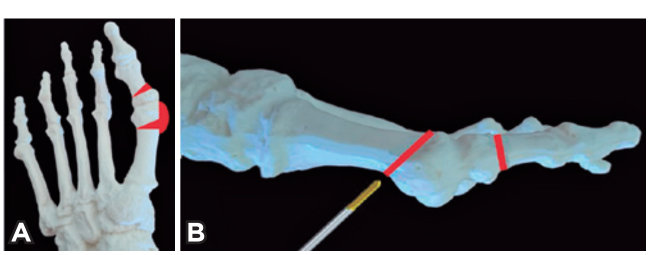

Figure 3. Scheme of the desired result after distal metatarsal osteotomy and phalangeal Akin osteotomy – A. Frontal view, B. Lateral view.

Statistical analyses were performed using the SPSS 20.0 and STATA 12 statistical software.

Results

There was a predominance of women (36 patients, or 94.7%) over men (2 patients, or 5.3%). Mean age at the time of surgery was 59 years (range: 38-83 years). Minimum and maximum postoperative follow-up times were 60 months and 108 months, respectively, with a mean 79 months (6.58 years). The right side was the most affected one, with 25 feet (58.1%), compared with the left side, com 18 feet (41.9%). Five patients presented with bilateral deformity.

In addition to hallux valgus, 37.2% of the operated feet (18 feet) had other associated conditions, which were corrected during the same surgical percutaneous procedure. These conditions were the following: tailor's bunion (2), 2nd supra-adductus toe (7), 2nd and 3rd ray metatarsalgia (3), 2nd, 3rd, and 4th ray metatarsalgia (1), Claw of the 2nd toe (1), claw of the 2nd and 3rd toes (2), claw of the 2nd and 4th toes (1), and claw of all the lesser toes (1).

Mean pre- and postoperative HVAs were 26.5° (SD=7.3°) and 12.0° (SD=6.7°), respectively, showing a reduction of 14.5° (SD=7.8°; 95%CI: -16.9° to -12.1°; $p<0.0001$*). With regard to IMA, pre- and postoperative means were 14.1° (SD=3.1°) and 10.3° (SD=2.0°), showing a mean decrease of 3.8° (SD=3.4°; 95%CI: -4.8° to -2.7°; $p<0.0001$*). Mean pre- and postoperative DMAA ranged from 19.6° (SD=8.9°) to 10.0° (SD=7.0°), with a decrease of 9.7° (SD=8.5°; 95%CI: -12.3° to -7.0°; $p<0.0001$*). Mean values for the three angles were statistically lower in the postoperative period (Table 1).

Mean AOFAS score was 38.7 (SD=11.4) points in the preoperative period and 93.7 (SD=5.1) points in the postoperative period, showing a statistically significant increase ($p<0.0001$*) of 55.0 points (SD=12.3; 95%CI: 51.2 to 58.8; $p<0.0001$*) (Table 2).

Mean shortening of the first metatarsal bone was 3mm (SD=0.9mm; 95%CI: 2.7 to 3.3mm), with a minimum of 2mm and a maximum of 5mm.

Complications

Surgical complications are shown in table 3. Moderate restriction of metatarsophalangeal flexion and extension (between 30 and 74°, according to the AOFAS questionnaire) was the most common complication, being present in six feet (13.9%). There was a case of asymptomatic insufficient exostectomy (incomplete smoothing of exostosis[4]) diagnosed radiographically in the postoperative period. A case of pain on the surgical scar was reported (secondary to a burn caused by the burr), as well as a case of hypoesthesia of the medial hallux surface, which was resolved after 4 months, and of delayed consolidation, with the presence of bony callus after 3 months. All of these cases resolved spontaneously with no sequelae.

Figure 6 shows a case of satisfactory correction and a case of complication as examples.

Table 1. Variation in pre- and postoperative measures in the sample of feet

n=43	Assessment			p
	Preoperative	Postoperative	Variation (Post-Pre)	
Hallux Valgus Angle (°)				<0.0001*
Mean (SD)	26.5 (7.3)	12.0 (6.7)	-14.5 (7.8)	
Median	26.0	10.0	-13.0	
Minimum – maximum	12.0 to 42.0	0.0 to 34.0	-30.0 to -2.0	
Intermetatarsal Ângle (°)				<0.0001*
Mean (SD)	14.1 (3.1)	10.3 (2)	-3.8 (3.4)	
Median	14.0	10.0	-4.0	
Minimum – maximum	9.0 to 24.0	7.0 to 16.0	-11.0 to 5.0	
Distal Metatarsal Articular Angle (°)				<0.0001*
Mean (SD)	19.6 (8.9)	10.0 (7.0)	-9.7 (8.5)	
Median	16.0	8.0	-9.0	
Minimum – maximum	5.0 to 45.0	0.0 to 28.0	-30.0 to 6.0	

n: number of feet; SD: Standard Deviation.
p: descriptive level of the Student's t test for paired samples.
Intraclass correlation - Hallux Valgus Angle (0.15; 95%CI: 0.02 to 0.63), Intermetatarsal Angle (0.15; 95%CI: 0.02 to 0.62), Distal Metatarsal Articular Angle (0.44; 95%CI: 0.23 to 0.67).

Table 2. AOFAS scores

n=43	Assessment			p
	Preoperative	Postoperative	Variation (Post - Pre)	
AOFAS score				p<0.0001*
Mean (SD)	38.7 (11.4)	93.7 (5.1)	55.0 (12.3)	
Median	35.0	95.0	60.0	
Minimum – maximum	22.0 to 70.0	75.0 to 100.0	25.0 to 73.0	

n: number of feet; SD: Standard Deviation.
p: descriptive level of the Student's t test for paired samples.
Intraclass correlation: 0.33 (95%CI: 0.00 to 0.99).

Table 3. Complications

Complications	n (%)
Medial displacement of 1st MT osteotomy	1 (2.3%)
MTP edema	1 (2.3%)
Hallux hypesthesia	1 (2.3%)
Burn/painful scar	1 (2.3%)
Insufficient exostectomy	1 (2.3%)
Relapse	1 (2.3%)
Delayed consolidation	1 (2.3%)
Reduced MTP range of motion	6 (13.9%)

MT: Metatarsal; MTP: Metatarsophalangeal; n: Number.

Figure 6. A. Preoperative clinical aspect; B. Preoperative radiographic image; C. Postoperative clinical aspect; D. Postoperative radiographic image; E. Radiographic image from another patient who evolved with medial displacement of the metatarsal head.

Discussion

Mean AOFAS score was 38.7 points before surgery and reached 93.7 after surgery, showing a mean increase of 55 points. In a study previously published by the same authors of the present study and involving the same surgical technique, but with a shorter follow-up, mean variation was 40.9 points[3]. This improvement in scores may be justified by the fact that we have already overcome the learning curve, thus improving our results. In the searched literature, postoperative values obtained by the questionnaire were close to 90 points[7,16-20], reaching up to 95 points, according to Restuccia et al.[21] and Reyes et al.[22]

HVA correction followed the procedures described by most studies that used the same technique, resulting in a mean decrease of 14.5°[7,18-20]. IMA had a mean decrease of 3.8°, a value similar to that found by other authors[7,19,21] and comparable to that reported in studies using the Bosch technique[16, 17].

The Reverdin-Isham technique allowed us to achieve a significant correction of DMAA, with a mean of 9.7°. This result was superior to that of other studies using the same technique[17,20,21] Compared to studies that used the Bosch technique[16,17,23], a greater DMAA correction with a smaller surgical approach. Since the Reverdin-Isham technique is an intracapsular technique, it is not recommended in isolation on feet with an intermetarsal angle higher than 18°, because the capacity of correction of this technique is relativity lower than that of extracapsular techniques[4]. For this reason, patients with severe hallux valgus were excluded from the study.

Excessive shortening of the first metatarsal bone leading to imbalance of the metatasal formula is one is one of main factors causing transfer metatarsalgia in the long-term post--operative period. According to Isham, the expected value for shortening with this technique would be 5 mm[24]. Prado et al. found 7mm of shortening, and metatarsalgia was present in 25% of their cases[9]. Our mean shortening was 3 mm, and there were no complaints of metatarsalgia after the procedure. The fact that we used burrs with a thickness of 2 or 2.2mm may have led to a lower shortening of first ray, thus maintaining a harmonious metatarsal formula and a painless foot.

The decrease in MTPJ range of motion (included in the AOFAS questionnaire) is one of the main complications of hallux valgus surgery[7,22,25]. In the present study, it was the most common complication, occurring in six feet (Table 3) that showed moderate limitation in flexion-extension range (between 30 and 74°). This fact may be justified by the fact that, in intra-articular osteotomies, correction is maintained by postoperative immobilization, favoring mobility limitation. According to Carvalho et al.[19], when performing osteotomy and extra-articular fixation of the metatarsal bone, motion can start earlier, leading to a greater mobility gain. In a study with 189 patients treated with the percutaneous Reverdin-Isham technique, Bauer et al.[26] observed that MTPJ range of motion had a mean limitation of 15° in the postoperative period, corresponding to a 17% decrease in total range of motion. A decrease of 10-20% may be expected in open osteotomies[27] and of nearly 15 degrees in percutaneous Reverdin-Isham osteotomy[7,9,20].

Other complication present in our study was medial displacement of first metatarsal osteotomy. Although not being frequent, this deviation is described in other studies[19,28] and may have been caused by instability inherent to the osteotomy, to creating an excessive medial-based wedge, and poor postoperative immobilization.

Hallux hypoesthesia occurred in one foot, evolving with complete recovery of symptoms in the third postoperative month. According to Prado et al.[9], this complication reached 30% of feet in the immediate postoperative period, but remained symptomatic in only 7% of the cases.

Skin burn at the site where the burr was introduced occurred in one foot, and evolved with good healing with no adherences. In another study of ours, this was the main complication[3]. We attributed this fact to the learning curve of the technique and may have occurred due to inadequate handling of the end mill and by the prolonged contact of this tool with the skin.

In the literature, the rate of infection after percutaneous foot surgery ranged from 0% to 3.5%[27,29]. There was no report of this event in the present study, and we believe that it may be justified by the little aggression to tissues and minimum bone exposure, according to Prado et al.[9].

Only one case of delayed consolidation was visualized, with complete ossification in the postoperative sixth month. In the remaining cases, osteotomy consolidation was radiographically proven nearly the eight postoperative week.

In order to reduce skin complications (such as infection and burns) and prevent delayed consolidation caused by osteonecrosis at the osteotomy site, we should avoid overheating of the end mill during its use. This may be minimized with the non-use of tourniquet and intermittent irrigation with saline[29].

There was only one case of recurrence requiring a new intervention. Recurrence of deformity is little frequent with this technique, as observed by other authors[7,9,19]. Our study did not observed other complications described in previous studies with the percutaneous technique, such as reflex sympathetic dystrophy, pseudarthrosis, necrosis of skin or of first metatarsal head, and deep vein thrombosis[7,9,18,30].

The main strength of this study is its follow-up. Minimum follow-up was established as 5 years, which allowed us to observe the long-term evolution of each patient, including whether there were complications or recurrences. Other positive point was the fact that our pre- and postoperative assessment covered both objective radiographic measurements (variations in angle and metatarsal length) and patients' functional assessment (clinical assessment and AOFAS questionnaire).

The AOFAS questionnaire was used in a version translated from English, since this questionnaire has not been officially validated for the Portuguese language yet. It is know that this score has little validation in the literature due to its limitations in clinical assessment[30-32]; however, it is still one of the most used assessment methods. For this reason, the use of this questionnaire allowed us to compare our clinical and radiological results with a wider literature.

Some limitations of the study should be mentioned. The entire pre- and postoperative assessments were performed by the same surgeons' team that conducted the procedures, which may represent a performance bias. Data were collected by more than one examiner. Furthermore, many patients did not return for follow-up, which resulted in a relatively small sample (attrition bias) and did not enable sample calculation. This may be justified by patients' difficulties to reach our service, since it is a public hospital with a great coverage. Patients with arthrosis were not included in the present study because, as previously mentioned, joint stiffness is a possible complication of the technique applied in this study. By excluding these patients, we are preventing further damage to an already compromised joint. Since this is a retrospective study to evaluate the outcomes of a single surgical technique, there was no control group to compare results.

Conclusion

The percutaneous Reverdin-Isham technique showed to be effective in correcting mild to moderate hallux valgus, promoting a significant clinical-functional improvement and adequate radiological correction during a mean postoperative follow-up of 6.5 years. This is a potentially less invasive procedure resulting in lower rates of complications compared with open surgery. The popularization of this technique and appropriate surgeon's training will lead to the development of additional studies with long-term follow-ups for first ray deformities.

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; wrote the article; interpreted the results of the study; participated in the review process; approved the final version; LCATF *(https://orcid.org/0000-0002-0778-2506) interpreted the results of the study; participated in the review process; approved the final version; GLFC *(https://orcid.org/0000-0001-5470-8379) interpreted the results of the study; participated in the review process; approved the final version; RPV *(https://orcid.org/0000-0002-1775-6870) interpreted the results of the study; participated in the review process; approved the final version; GB *(https://orcid.org/0000-0001-5273-4303) interpreted the results of the study; participated in the review process; approved the final version; JAG *(https://orcid.org/0000-0003-4652-4400) interpreted the results of the study; participated in the review process; approved the final version iD.

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Systematic Review

Percutaneous surgery in the treatment of Haglund syndrome: a systematic review

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Abstract

Objective: The present study aimed to verify the state of the art of minimally invasive percutaneous surgical treatment for Haglund syndrome.

Methods: This systematic review of the literature was based on a bibliographic survey in the PubMed, Medline and Embase databases. The descriptors "Haglund syndrome", "Haglund", "Achilles", "Minimally invasive", "Percutaneous surgery" and "Osteotomy" were used, in addition to the filters "Randomized Controlled Trial", "Randomized Clinical Trial", "Meta-Analysis", "Systematic Reviews", "Reviews", and "Clinical Trial".

Results: A total of 37 articles were included. The total number of patients with Haglund syndrome treated in the included studies was 831 and 920. The mean patient age was 46.6 years (range, 28.7 to 61) and 58% were men. A higher success rate and a lower rate of complications were reported in men, and physically active patients had better treatment results. The mean success rate for minimally invasive percutaneous procedures was 83.4% (range 66 to 100%). Overall patient satisfaction was 77.5% (range 60 to 95%) and the complication rate was 6.3% (range 0 to 23%).

Conclusion: Despite a lack of studies with the recommended evidence level, minimally invasive and percutaneous surgical treatments seem to be a good option for patients with Haglund syndrome when conservative treatment fails.

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

Keywords: Achilles tendon; Minimally invasive surgical procedures; Treatment outcome; Systematic review.

Introduction

Haglund syndrome is a triad of posterosuperior prominence of the calcaneus (Haglund deformity), retrocalcaneal bursitis and insertional Achilles tendinopathy. It is usually bilateral, affects middle-aged people and has a higher incidence in women. The most common symptoms are heel pain, swelling, redness and post-static dyskinesia(1-5).

Most often, the condition is diagnosed by associating a clinical evaluation with imaging tests. Radiography is the most commonly used test for diagnostic confirmation, although MRI is indicated in doubtful cases. Recently, several studies have suggested that ultrasonography has 100% specificity but only 50% sensitivity for diagnosing retrocalcaneal bursitis, and it is even less sensitive in determining whether the superficial Achilles tendon bursa is involved. Differential diagnoses include traumatic causes, such as a stress fracture of the calcaneus or a malunited "tongue-like" fracture of the calcaneus. There are also infectious causes, such as tuberculosis of the calcaneus, neoplastic causes, such as osteochondroma of the calcaneus, and inflammatory causes, such as negative spondyloarthropathies(2-9).

The treatment of choice is usually conservative, with the following indications: rest, shoe modification, a change of habit regarding impact sports and the use of non-steroidal anti-inflammatory drugs. Although many cases are resolved without surgical intervention, in patients who have persistent signs and symptoms after six months of conservative treatment, surgery is indicated(2-13).

Study performed at the Real Hospital Português de Beneficência em Pernambuco, Recife, PE, Brazil.

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Surgical treatment has improved in recent decades, mainly due to a better understanding of the pathophysiology of Haglund syndrome. There has also been recent discussion about the best techniques and approaches, including endoscopy, minimally invasive surgery or techniques for repairing the tendon to the bone with suture anchors. Many changes have occurred since the Zadek osteotomy was introduced, in which catgut was used for osteosynthesis. Percutaneous screws with reliable and stable fixation are now available, as are modern techniques that allow functional recovery with less tissue injury due to smaller portals[6-19], even minimally invasive surgery and endoscopic treatment.

In this context, the objective of the present review was to systematize the minimally invasive percutaneous surgical treatments for Haglund syndrome.

Methods

This evidence-based systematic review followed Joanna Briggs Institute practices, including a comprehensive synthesis without bias using a sample of relevant studies to synthesize the existing knowledge in order to assist healthcare decision-making[20]. To determine the components of the review, a research question was formulated based on PICO (Population, Intervention, Comparison and Results) criteria[21].

This review was guided by the PRISMA recommendations: database search for material, determining inclusion and exclusion criteria, extracting information from the selected manuscripts, and evaluation and interpretation of the content[22].

Database, search strategy and study selection

The PubMed, Medline and Embase databases were searched. The Boolean search used the connector "and" to find manuscripts with more than one of the terms. The following health descriptors were generated from the U.S. National Institutes of Health MeSH on Demand: "Haglund syndrome"; "Haglund"; "Achilles"; "Minimally invasive"; "Percutaneous surgery"; and, "Osteotomy". The following filters were used to arrive at the expected final result: "Randomized Controlled Trial; "Randomized Clinical Trial"; "Meta-Analysis"; "Systematic Reviews"; "Reviews", "Clinical Trial".

Eligibility and selection criteria

The following inclusion criteria were used in the study selection process:

- Studies related to the theme;
- Studies with an evidence level of I or II; if this level of evidence could not be found, lower levels were included;
- Studies published in indexed journals;
- Articles published in English, Spanish or Portuguese;
- Research carried out on humans;
- Articles with a full version available.

The exclusion criteria were:

- Simple case report studies;
- Theoretical essays.

Investigated variables and extracted data

A database was created with the following information: article identification, study type, objectives, methodological procedures, data sources and main results.

Results

Exclusion and inclusion process

The database search found 112 studies, whose design and relevance were again assessed according to the study type and inclusion criteria filters. After reading the titles, abstracts and keywords, 56 articles underwent a more rigorous selection process[22] (Figure 1).

After the exclusion and inclusion process shown in figure 1, eight studies were excluded and a total of 37 articles were selected for the present review[1-19,23-40].

Identification and characteristics of the studies

Table 1 presents an overview of the study design, objectives and clinical outcomes of the 37 selected articles, including the main characteristics and findings. Many of the studies were systematic reviews and/or meta-analyses based on clinical evidence (48.65%). The other studies were retrospective (21.62%), clinical (18.92%) and prospective (10.81%), as shown in figure 2. A total of 86.49% of the tested treatments had positive results (Figure 3).

Population characteristics

The total number of treated Haglund syndrome patients in the 37 included studies was 831 and 920 foots. The mean patient age was 46.6 years (range, 28.7 to 61) and 58% were men. A higher success rate and a lower rate of complications were reported in men, and physically active patients had better treatment results.

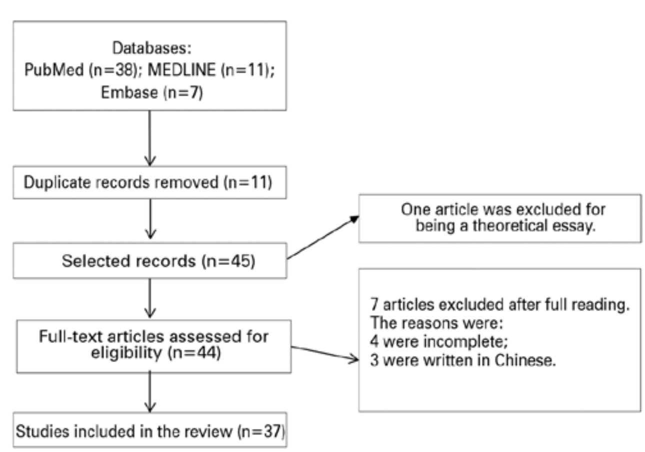

Figure 1. Flowchart of article identification, selection and inclusion.

Table 1. Characterization of the selected articles

Study	Study design	Objective	Clinical outcomes
Tian et al. (2020)	Clinical study	To compare the open Giftbox technique with a peritendon fixation technique called the "Locking Block Modified Krackow" (LBMK) technique using a simulated early rehabilitation protocol.	After the first loading stage, the mean tendon gapping was 0.76±0.44mm in the LBMK group and 0.86 ±0.47mm in the Giftbox group (P=0.620). After the second loading test, the average gapping measures of the LBMK and Giftbox groups were 3.8 ±1.9mm and 4.2±2.2mm, respectively (P=0.466). Finally, the catastrophic load to failure was 732.8±138 N in the LBMK group and 645.5 ±121 N in the Giftbox group. The difference was statistically significant (P=0.023).
Ge et al. (2020)	Retrospective	To compare the clinical results of dorsal wedge calcaneus osteotomy (DCWCO) and posterosuperior prominence resection to treat Haglund syndrome.	Both groups exhibited a significant increase in their AOFAS and VISA-A scores after surgery. The DCWCO group had lower AOFAS scores than the PPR group at 6 months (77.6±5.1 vs. 82.8±7.8; P=0.037) but had higher scores at the latest follow-up (98.2±2.3 vs. 93.4±6.1; P=0.030). The DCWCO group had lower VISA-A scores at 3 months (56.9±13.9 vs. 65.2±11.0; P=0.044) but higher scores at the latest follow-up (98.2±2.6 vs. 94.3±5.0; P=0.010) than the PPR group. Both groups exhibited significant changes in the Fowler-Philip angle and Bohler's angle after surgery. The postoperative Fowler-Philip angle of the DCWCO group was greater than that of the PPR group (35.9°±4.9° vs. 31.4°±6.2°; P=0.026). However, there was no statistically significant difference in any other angle of the two groups postoperatively.
Lughi (2020)	Clinical study	To correlate the most reliable and reproducible treatment possible with the variables of Haglund syndrome.	The group of patients that participated to the study was heterogeneous in age and functional requirements therefore presenting different anatomopathological characteristics. For these reasons considerations with correct statistical meaning are not possible. Despite different post-operative programs, patients demonstrated optimal clinical and functional recovery. There were no local neurological or skin complications.
Yang et al. (2020)	Retrospective	To evaluate the effect of intraoperative ultrasound assistance for minimally invasive repair of acute Achilles tendon rupture.	All patients were followed up for at least 12 months. No sural nerve injury or other complications was found intraoperatively and postoperatively. All the patients returned to work and light sporting activities at a mean of 12.78±1.40 weeks and 17.28±2.34 weeks, respectively. The Mean American Orthopaedic Foot & Ankle Society (AOFAS) scores improved from 59.17±5.31 preoperatively to 98.92±1.63 at the time of 12 months follow-up. There was statistically significant difference (P<0.001). No patient complained of negative effects on their life.
Chegini Kord et al. (2019)	Retrospective	To present a modified technique for minimally invasive repair of Achilles tendon rupture using gift-box sutures, including preliminary clinical and functional results for several patients.	After two years, the mean scores of American Orthopedic Foot and Ankle Society and the Achilles tendon rupture score were obtained at 83±4 and 81.9±6.3, respectively. Approximately 87.5% of patients regained their previous level of activity. The mean visual analog scale score was 7.7±0.9 regarding the satisfaction with the outcomes. Moreover, isokinetic testing of plantar flexion and dorsiflexion strength were 82.7±5.8 and 87.7±4.1%, respectively, compared to those of the normal side. The calf atrophy was not statistically significant. The range of operated ankle motion decreased significantly, compared to that of the other side; however, the differences were not significant functionally. There was no patient with wound complications, nerve injury, or complaints about footwear problems.
Liu et al. (2019)	Clinical study	To determine whether modified minimally invasive repair (MMIR), which provides direct visualization of the proximal tendon stump without specialized equipment could provide comparable functional and surgical results to the Achillon system.	There was no significant difference between groups in demographic characters. There was no statistical difference between both groups regarding to time return to work and ATRS at 3rd, 6th, 12th, and 24th month, respectively. Five reruptures and two Achilles tendons tethering to skins were found in the Achillon group, and two reruptures and one sural nerve injury in the MMIR group. No wound infection and dehiscence occurred. Overall complication rate in the Achillon group is higher (16.3% vs. 4.4%, p¼0.044). The operation time of Achillon is less than MMIR (34.84 vs. 39.71, p<0.001)
Barg & Ludwig (2019)	Literature review	To review surgical strategies for insertional Achilles tendinopathy.	Insertional Achilles tendinopathy often results in pain relief and functional improvement. However, complete rehabilitation, including a return to sports, is often postponed until 1 year postoperatively.
Lui et al. (2019)	Literature review	To address minimally invasive treatment and endoscopy for Haglund syndrome.	Most surgical treatment options for Haglund syndrome can be performed endoscopically or with minimally invasive approaches.
Xu et al. (2018)	Prospective	To develop a method that can solve the problem of partial rupture of the Achilles tendon insertion	The arthroscopic approach is a reliable technique and indicated in the treatment of Haglund syndrome.
Vega et al. (2018)	Literature review	To describe endoscopic calcaneoplasty with increased anchor suture of the Achilles insertion area and its results in patients at high risk of Achilles tendon rupture after calcaneoplasty.	Endoscopic calcaneoplasty is reproducible and safe, with the advantages of the endoscopic technique.

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Table 1. Characterization of the selected articles

Study	Study design	Objective	Clinical outcomes
Alfredson et al. (2018)	Retrospective	To present the effects of clinical and surgical treatment of chronic Achilles tendon disorders.	Patients with high pain scores were the most common. Plantar tendon involvement is a frequent observation. Pathology in the subcutaneous and retrocalcaneal pouch, Haglund deformity and distal Achilles tendinopathy/tendinosis were more frequent reasons for insertion Achilles tendinopathy.
Shakked et al. (2017)	Prospective	To analyze a case of posterior injury to the tibial nerve after arthroscopic calcaneoplasty.	The objective of the case report was to raise awareness of this possible complication to ensure early recognition and referral to a peripheral nerve specialist. The results illustrate the importance of surgical technique and arthroscopic calcaneoplasty to prevent lesions in the neurovascular bundle.
Xia et al. (2017)	Retrospective	To evaluate the surgical outcomes of correcting Haglund's triad using a central tendon-splitting approach.	Haglund prominence and Achilles tendon replacement provide effective treatment, providing pain relief, functional improvement, and overall improvement in patient health. Sex and BMI do not affect surgical results.
Holtmann et al. (2017)	Literature review	To show that gastrocnemic recession leads to increased ankle movement.	The benefits of better Foot Function Index scores, patient satisfaction, pain relief and increased function far outweigh the possible complications.
Shakked et al. (2017)	Literature review	To demonstrate the effects of Achilles tendinopathy debridement.	Insertional tendinopathy repair is a successful procedure, allowing a quick return to activities.
Vaishya et al. (2016)	Literature review	To demonstrate that Haglund syndrome is a common cause of back foot pain in adults, but it is still a poorly understood clinical condition.	Haglund syndrome is a common cause of hindfoot pain in adults, but it is still a poorly understood clinical condition. Conservative management is generally effective in most cases, and surgery is needed only in resistant cases.
Huh et al. (2016)	Retrospective	To highlight the characteristics of Achilles sleeve avulsions and present the outcomes of operative repair using suture anchor fixation.	Avulsions of the Achilles tendon sleeve occurred predominantly in middle-aged men with pre-existing insertional disease while involved in athletic activity. The fixation of the suture anchor with concomitant insertion was a reliable and safe technique for the operative management of the Achilles tendon sleeve avulsion. Most patients returned to pre-injury levels of work and recreational activity.
Caudell (2016)	Literature review	To demonstrate the effects of local bone graft for Evans calcaneal osteotomy to correct flat feet and valgus deformity.	The iliac crest autograft or allograft can be used for treating stage II flat foot deformity. The authors describe a new method of obtaining bone graft locally from the calcaneus and, therefore, avoiding the complications and morbidity associated with iliac crest grafts.
Syed et al. (2016)	Literature review	To present a staging system for minimally invasive treatment of Haglund syndrome with percutaneous and endoscopic surgery.	Modern techniques allow anterior functional recovery with less tissue damage, whether minimally invasive surgery or endoscopic treatment of heel conditions. The principle of osteotomy is the same, but its execution is different.
Vernois et al. (2015)	Literature review	To demonstrate the effects of minimally invasive calcaneal osteotomy surgery and minimize soft tissue injuries.	They concluded that percutaneous surgery minimizes soft tissue damage and preserves the soft tissue envelope, which allows a wider range of surgical procedures.
Carreira & Ballard (2015)	Literature review	To review various endoscopic techniques for treating equinus contracture, Achilles rupture, Haglund's deformity and noninsertional Achilles tendinopathy.	Minimally invasive treatment of equine contracture, Achilles rupture, Haglund deformity and non-institutional Achilles tendinopathy produce good clinical results, and the technique has the advantages of any minimally invasive procedure. A thorough understanding of anatomy and endoscopic techniques minimizes complications.
Ahn et al. (2015)	Clinical study	To show the operative treatment of Haglund syndrome with a central |splitting approach to the Achilles tendon.	The central tendon-splitting approach appears to be safe and satisfactory for intractable Haglund syndrome. Future comparative studies may be needed to investigate the significance of the association between Haglund syndrome and cavity deformity.
Jerosch et al. (2015)	Prospective	To determine the most typical surgical technique and intraoperative findings, as well as medium and long-term results of endoscopiccal caneoplasty.	Endoscopiccal caneoplasty is an effective and minimally invasive procedure treating calcaneus exostosis. After a brief learning curve, endoscopic exposure is superior to the open technique, has less morbidity, a shorter operating time and almost no complications. In addition, the pathology can be better differentiated.
Ettinger et al. (2015)	Retrospective	To evaluate the outcome of a transtendinous approach to insertional Achilles tendinopathy.	The transtendinous approach allowed access to all pathologies associated with insertional Achilles tendinopathy. The technique had relatively few complications and good clinical results.
Bulstra et al. (2015)	Clinical study	To determine whether heel overhang can measured and whether Haglund's deformity can be assessed through radiography.	A significant difference was found in women ($p<0.00$) but not men ($p<0.48$). Women with Haglund deformity have a higher calcaneal pitch angle than those without it. Calcaneal pitch angle differed between the Haglund and non-Haglund groups, although mainly in women.

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Table 1. Characterization of the selected articles

Study	Study design	Objective	Clinical outcomes
Weinfeld (2014)	Literature review	To present an overview of Achilles tendon disorders.	Complete repair of 4 cm tendons is generally possible. In major defects, tendon integrity can be restored with a V-forward procedure or the central sliding opening.
Sundararajan et al. (2014)	Clinical study	To investigate radiographic, clinical and MRI analysis of insertion Achilles tendinopathy.	The results of the present study confirmed the absence of morphological variation in the calcaneus and the presence of angular changes in the calcaneus in symptomatic patients. Both clinical examination and MRI revealed a 25% frequency of Haglund syndrome in the insertion Achilles tendinopathy group. As these two diagnoses are clinically and radiographically divergent, their surgical interventions justify different objectives using separate methods. By understanding the abnormality, the surgeon can reduce the correction in a precise and specific for insertion Achilles tendinopathy patients.
Madarevic et al. (2013)	Clinical study	To reduce morbidity and recovery time by introducing an ultrasound-assisted technique for calcaneoplasty.	Ultrasound-assisted calcaneoplasty allows for precise resection of the posteroanterior part of the calcaneus and the removal of the retrocalcaneal impact. This method may become clinically relevant, as it allows the effective treatment of Haglund deformity, and the results of this study showed rapid functional recovery.
Rigby et al. (2013)	Literature review	To review early weight bearing using the Achilles suture bridge technique for insertional Achilles tendinosis.	The findings supported the use of the Achilles tendon suture-bridge technique for replacing the Achilles tendon in the surgical treatment of insertion Achilles tendinosis.
Rakovac et al. (2012)	Prospective	To introduce the "cello technique": a new technique for ultrasound-assisted calcaneoplasty.	It is possible to resect the posterosuperior part of the calcaneus under direct ultrasound control with the patient in the prone position, with a dorsally positioned ultrasound probe, in line with the Achilles tendon fibers (sagittal line), and with the abrader in the posteromedial working portal. We describe in detail the technique for this new procedure in foot and ankle surgery. This innovative technique offers the possibility of expanding the indications for ultrasound-guided surgery in other fields of orthopaedic surgery.
Kang et al. (2012)	Literature review	To analyze the characteristics of Haglund deformity in patients with and without insertion Achilles tendonitis to see if there was a correlation.	A Haglund's deformity was not indicative of insertional Achilles tendinitis and was present in asymptomatic patients. Also, a majority of the insertional Achilles tendinitis patients had calcification at the tendon insertion. We believe it is possible removing the Haglund's deformity may not be necessary in the operative treatment of insertional Achilles tendinitis.
DeVries et al. (2009)	Retrospective	To present surgical correction of Haglund's triad using complete detachment and replacement of the Achilles tendon.	Surgical correction of Haglund's triad using complete detachment and replacement of the Achilles tendon, exostectomy and retrocalcaneal bursectomy provided patient satisfaction with limited complications.
Frey (2009)	Literature review	To discuss technical and diagnostic points about advanced uses of arthroscopy in athletes.	The present study shows advances in surgical techniques that have expanded the use of arthroscopy as a viable alternative to open procedures in the evaluation and treatment of common foot, ankle and tendon injuries. These techniques can result in a shorter and more comfortable recovery, decreased postoperative pain and fewer complications.
Lee et al. (2008)	Literature review	To review posterior impingement syndromes of the ankle.	Although surgery is occasionally necessary, the radiologist can contribute to treatment, using ultrasound or fluoroscopy to assist in the accurate placement of steroid/local anesthetic injections. Therefore, the radiologist plays a crucial role not only in diagnosis, but also in the management of posterior ankle impingement syndrome.
Jardé et al. (1997)	Literature review	To report on Haglund disease treatment through a simple resection of the calcaneus tuberosity.	Simple resection of the tuberosity of the os calcis showed good results in 73% of the cases, with a mean follow-up of 6 years and 9 months.
Reinherz et al. (1990)	Literature review	To present an overview of pathologic Haglund deformity.	Pathological conditions behind the calcaneus are common and may initiate during early childhood. Radiographic and clinical evaluation is considered.
Miller & Vogel (1989)	Literature review	To present a retrospective analysis of Keck and Kelly osteotomy in conjunction with resection of the bone prominence.	Results have been gratifying, with no complications experienced with healing of the osteotomy and no recurrence of the deformity.

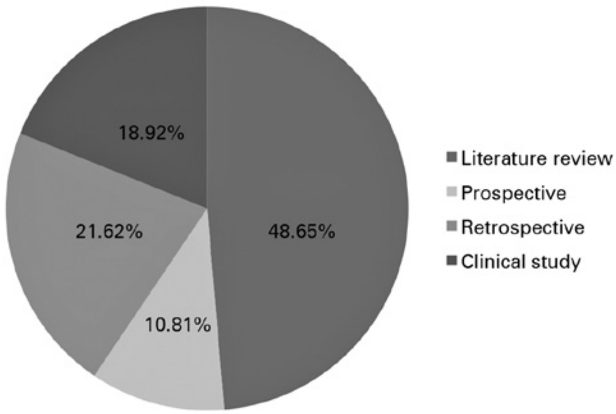

Figure 2. Number of articles according to the study design.

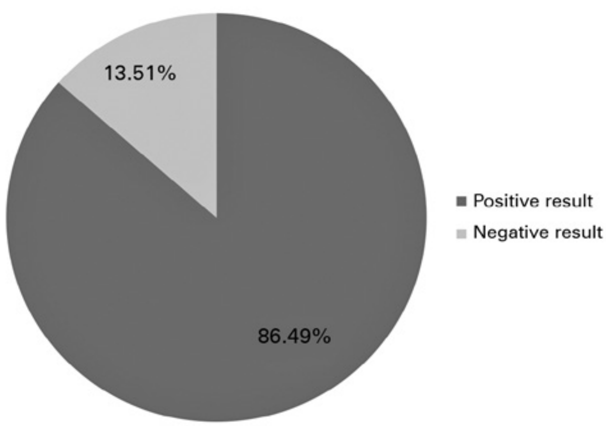

Figure 3. Articles reporting positive and negative results for the involved treatments.

Preoperative treatment

Preoperatively, all patients underwent conservative treatment for at least three months. Conservative treatments included immobilization, eccentric exercise, stretching, cryotherapy, ultrasound therapy, laser therapy, orthoses, extracorporeal shock wave therapy, sclerosing injections and anti-inflammatory drugs.

Percutaneous surgical technique

The mean success rate for minimally invasive percutaneous procedures was 83.4% (range 66 to 100%). Overall patient satisfaction was 77.5% (range 60 to 95%) and the complication rate was 6.3% (range 0 to 23%). The most frequently mentioned reasons for surgical procedures were the need for surgical revision (5.8%) and rupture of the tendon during rehabilitation (0.5%). The main evaluations were: pain according to the EVA scale and subjective patient satisfaction.

Discussion

This study systematically evaluated the literature regarding the effectiveness of percutaneous treatment in Haglund syndrome patients. The analyses were based on success rates, patient satisfaction and complication rates.

The most relevant finding of this review is that it supports minimally invasive operative treatment as an option for this syndrome. Most surgical treatment options for Haglund syndrome can be performed endoscopically or with minimally invasive approaches. This finding is in line with the results of other recent reviews [3-8,12-15,30-32].

Depending on the technique used, success rates varied between 73 and 100%, although the reviewed literature does not definitively describe the pathological stage of the treated tendons. More advanced stages of Achilles tendon degeneration could lead to more complex surgical treatments. Consequently, different stages of Achilles tendon injuries may differ in response to a specific surgical technique[41].

Most of the minimally invasive techniques concentrate on peritendinous tissues in order to eliminate neovascularization and its accompanying nerves as the cause of pain and disease progression. Thus, minimally invasive approaches, in principle, address pain, while open techniques aim to treat degenerated tendon tissue. It should be declared that there was a selection bias regarding the results for the different operating techniques (subgroups analysis)[4-18,29-33].

Considering these limitations, this systematic review does not indicate differences in success rate and patient satisfaction between open surgical techniques and a minimally invasive percutaneous approach (78.1% vs. 78.5%; P=0.211). Nevertheless, the complication rate tended to be higher after open surgery (10.5% vs. 5.3%; P=0.053).

Random comparisons between open and minimally invasive procedures regarding the same severity/degree of Achilles tendinopathy and other pathologies associated with Haglund syndrome are still lacking and should be carried out in the future (42). Likewise, meta-analyses are necessary to definitively demonstrate the value of different techniques. Despite attempting to detect all relevant articles in the search algorithm, some studies may have been excluded due to their choice of terminology.

A similar criticism applies to postoperative treatment, since the short follow-up period used in several studies is another concern. Some studies on conservative treatment had follow-up periods of more than five years, while the shortest in our sample was only six months. To classify their results, the authors often used questionnaires that had neither been validated nor were specific to the anatomical region, which could also have influenced the results and should be adequately addressed in future research.

Future studies should use valid, reliable and sensitive outcome measures, such as the VISA-A questionnaire, in longitudinal studies to evaluate the effects of their interventions. Randomized controlled trials focusing on the single effect of operative treatments are essential, since they provide evidence about the most applicable treatment for specific Haglund syndrome patients.

Conclusion

Despite a lack of studies with the recommended evidence level, minimally invasive and percutaneous surgical treatments seem to be a good option for patients with Haglund syndrome when conservative treatment fails. However, given that this is a literature review, the results should be carefully evaluated, since the choice of databases limited the selected studies. Although a rigorous search strategy was employed, relevant articles may have been overlooked.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MALG *(https://orcid.org/0000-0001-8325-4986) conceived and planned the activities that gave rise to the study, wrote the article, participated in the review process, approved the final version; GFM *(https://orcid.org/0000-0001-6285-4771): participated in the review process, approved the final version; Neto JFAN *(https://orcid.org/0000-0003-0551-1435): participated in the review process, approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Technical Tips

Free adipose tissue (FAT) graft pooling for severe dead space management: a technical trick

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Abstract

Complex lower extremity trauma with large soft tissue defects requires early wound coverage to reduce the risk of complications. In particular circumstances, however, local or free flaps may be contraindicated due to local or systemic issues. This study presents a helpful and effective salvage procedure for soft tissue reconstruction that uses autologous fat grafting combined with negative pressure wound therapy.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Surgical flaps; Adipose tissue/transplantation; Bone exposure; Hyperbaric oxygenation; Negative pressure wound therapy.

Introduction

Early soft tissue coverage plays a critical role in minimizing complications in the setting of complex lower extremity trauma. For smaller defects, local rotational muscle flaps can help to provide an adequate local blood supply, which is essential for fracture healing. For larger defects, fasciocutaneous (ie, anterolateral thigh) or muscle (ie, rectus abdominis, latissimus dorsi) free flaps can also achieve similar goals, with recent data suggesting that fasciocutaneous flaps may be associated with delayed union compared to muscle flaps[(1)].

In certain clinical situations, however, the use of local flaps may not be possible due to soft tissue trauma/damage, and even free flaps may be contraindicated due to the lack of suitable vessels for anastomosis or due to systemic issues. In these settings, options for dead space management are limited and amputation may seem inevitable. Another option, however, can be implemented. Here, we present a novel technique for the management of dead space not amenable to free flap coverage. The free adipose tissue (FAT) graft pooling technique combines the angiogenic and reparative properties of adipose-derived stem cells with negative pressure wound therapy (NPWT) to manage these complex clinical situations.

The successful use of adipose-derived stromal/stem cells has been reported in aesthetic, cardiac, and reconstructive posttraumatic procedures[(2)]. Potential advantages of autologous fat grafting include abundant fat, easy harvesting via liposuction, and cost-effectiveness compared to commercially available artificial skin[(3)].

Regenerative properties of adipose-derived stem cells

Adipose-derived stem cells have paracrine activity and secrete antiapoptotic and angiogenic factors, thereby promoting tissue repair. Mature adipocytes are the main part of the aspirated fat content. Fat tissue is very sensitive to ischemia and apoptosis and has a lower concentration of growth factors and mesenchymal cells than manipulated concentrates of adipose-derived mesenchymal cells, but it does act com-

Study performed at the Felício Rocho Hospital, Belo Horizonte, MG, Brazil.

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petently in wound healing, without any extra additive[4-7]. Adipocytes interact with the local environment through their microconnections (cellular niche), exerting endocrine effects on the surrounding tissues. These observations have drawn attention to the importance of the integrity of intercellular connections in the extracellular matrix, which is still present in the adipose tissue *in natura*[8].

Hamada et al.[3], comparing artificial dermis with adipose-derived stem cells in wounds with exposed bone in a rat model, reported that adipose-derived stem cells showed significantly higher expression of basic fibroblast growth factor (bFGF) and vascular endothelial growth factor (VEGF), thereby exhibiting potential for differentiation into fibroblasts and blood vessel endothelial cells.

NPWT is an extremely useful adjuvant to coverage of complex wounds due to its angiogenesis-stimulating properties and ability to reduce exudate, edema, and bacterial proliferation[9].

Methods

FAT graft pooling technique: a case example

A 28-year-old man was involved in a motorcycle accident and sustained closed subtrochanteric and distal right femur fractures associated with a Gustilo-Anderson type IIIB distal tibia fracture, precisely at the level of a preexisting ankle arthrodesis. The patient had hematogenous osteomyelitis during childhood requiring multiple surgical procedures, including debridement, tibial lengthening with the Ilizarov external fixator, and ankle arthrodesis. As a result, the patient had limb shortening and gross tibial and femoral deformities (Figure 1).

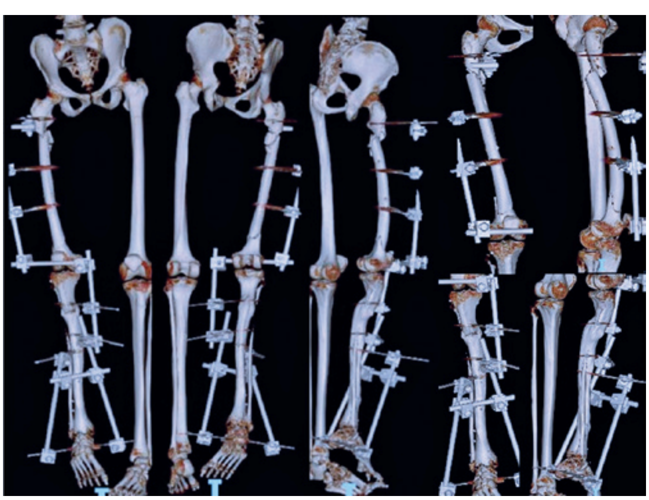

Figure 1. Computed tomography with 3D reconstruction showing subtrochanteric and distal femur fractures. Note the severity of the anterior bowing of the femur. The 3D reconstruction of the tibia also shows multiple tibial deformities and fracture at the level of the ankle arthrodesis.

No signs of active infection were observed at the time of the current trauma. Initial treatment was debridement, external fixation of the entire extremity, and intravenous antibiotics. Two additional debridements were performed at 3 and 5 days after trauma, but NPWT was not available at this time. After 9 days, the femur fracture was fixed by a combination of retrograde nailing and placement of a cephalomedullary nail, in a "kissing nail technique". The choice of 2 independent nails was based on the severity of the anterior bowing of the femur, which precluded the use of a single long nail. The choice of a short retrograde nail instead of a lateral locking plate was also based on the distal femoral deformity, which hindered adequate plate placement. After fracture fixation, another debridement was performed and NPWT was applied. Due to poor soft tissue conditions at the distal third of the leg as a consequence of previous osteomyelitis and multiple surgical procedures, local and free flaps were not indicated. After 16 days, autologous fat grafting with the pooling technique was performed using both thighs as donor sites, followed by a second NPWT application. Nine days later, the same procedure was repeated but now using the abdominal panniculus as the donor site. NPWT was repeated twice with a 7-day interval between applications, and the patient remained hospitalized because he lived in a distant city, with limited resources. Finally, 30 days after the first fat grafting session, skin grafting was performed. Because after the second debridement the wound culture was positive for multidrug-resistant Gram-negative bacteria, intravenous antibiotic was maintained until skin grafting and the transarticular external fixator was kept as a definitive treatment. Length of hospital stay was 50 days. The skin graft was fully incorporated (Figure 2). The external fixator was removed after complete ankle arthrodesis healing (77 days). After 4 months, both femur fractures were also healed (Figure 3). Eight months later, no signs of infection or systemic or local complications were detected. Written informed consent was obtained from the patient to publication of this case example and images.

Technique

Potential donor sites for fat grafting include the inner aspects of the thighs, lower anterior and lateral aspects of the abdomen, and waist. The instruments required for the FAT graft pooling technique are summarized in table 1.

Fat was harvested from de medial aspect of both thighs (first session) and from the abdominal panniculus (second session). The donor sites were infiltrated with 0.9% saline with 1:500,000 epinephrine (tumescent technique) without lidocaine, and a 4 mm x 25 cm liposuction cannula was then used for fat harvesting. The fat was processed by decantation before grafting, and a total amount of 80 cc of fat tissue was obtained per session (Figure 2C). Fat grafting was performed in 2 different ways. First, retrograde subcutaneous injection of fat was performed in multiple tunnels (lipofilling or structural fat grafting) with a 1.8-mm cannula through skin counterincisions (one proximal incision and one distal incision 3 cm away from the wound edge) to fill the wound edges. Second, fat was

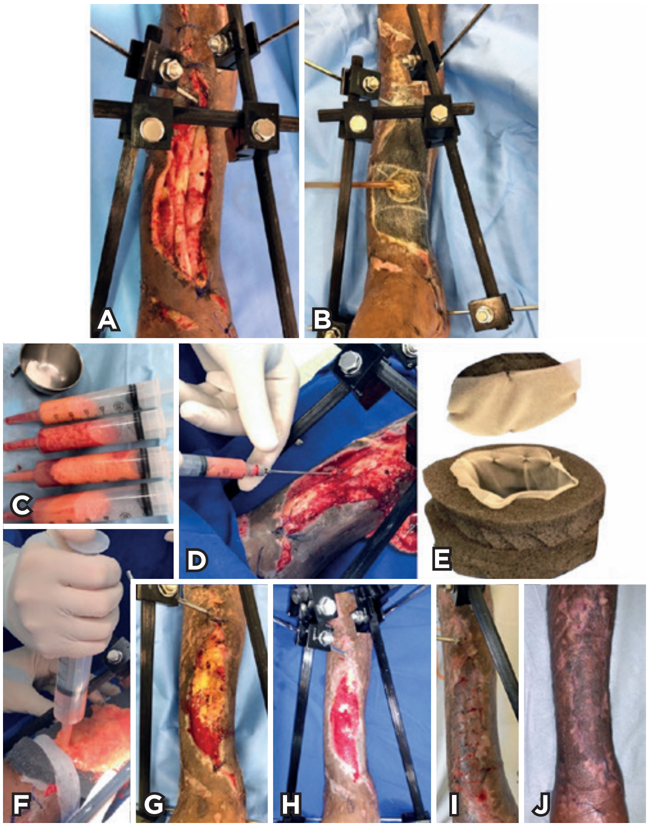

Figure 2. (A) Intraoperative photograph showing the anterior soft tissue defect at the level of the distal third of the tibia. Note the extensive exposure of the bone and anterior tibial tendon. (B) First negative pressure wound therapy (NPWT) application. (C) Approximately 80 cc of fat graft was harvested. (D) Retrograde subcutaneous injection in multiple tunnels (lipofilling or structural fat grafting) with a 1.8-mm cannula through skin counterincisions to fill the wound edges. (E) Intraoperative photograph showing the pool prepared by customizing the NPWT foam. (F) Customization of a "pool" by using the NPWT foam for containment of the grafted material. (G) Intraoperative photograph showing wound appearance 7 days after the first fat grafting procedure. (H) Note the granulation tissue covering the entire exposed bone surface and tendon after the fourth NPWT application. (I) Anterior view of the leg showing skin graft integration without necrosis 7 days after the procedure. (J) Note complete wound healing 2 months after skin grafting.

further injected subcutaneously through the wound edges, so that fat would reach the wound center from underneath and from the sides, until it filled and overflowed the wound surface (topical fat grafting) (Figure 2D).

To prevent loss of harvested fat, a "pool" was prepared and held around the wound limits by using the NPWT foam to support and keep the grafted material on the wound surface

Figure 3. (A) Panoramic radiograph of the lower limbs in the anteroposterior view showing fracture fixation. Note right limb shortening and deformity. (B and C) Radiographs of the right femur in the anteroposterior and lateral views showing fracture healing 4 months after fixation. (D) Radiographs of the right ankle in the anteroposterior and lateral views showing arthrodesis healing 4 months after external fixation.

Table 1. Instruments required for the free adipose tissue graft pooling technique

Saline solution (0.9%)
Epinephrine (dilution 1:500,000)
Liposuction cannula (4 mm) for fat grafting
Lipofilling cannula (1.8 or 2.0 mm) to fill the wound edges through skin counterincisions
60 cc syringe (vacuum syringe) or conventional liposuction probe
Vaseline gauze (Adaptic®)
Negative pressure wound therapy kit

overflowed with fat tissue (Figure 2E). The foam was "carved" or "sculpted" in a customized design to keep the fat over the wound. After all fat tissue had been injected, another piece of foam was applied over the grafted fat as a "pool" (Figure 2F). The NPWT dressing was completed with progressive application of plastic film, wrapping it around all parts until perfect sealing was achieved, thus keeping the pool made of foam full of grafted fat over the wound. After sealing and stabilization of the fat over the wound, negative pressure was set to -125mmHg in a continuous mode of administration. The skin around the wound and the fat were previously protected with a Vaseline gauze (Adaptic®) as a wound contact layer.

Discussion

Subcutaneous lipofilling for augmentation and correction of soft tissue defects remains the major indication for autologous fat grafting in clinical practice. With the processing and differentiation of adipose-derived mesenchymal cells and observation of their trophic and regenerative effects, a wide range of new indications has emerged for fat and its products, with great potential for many benefits[10-12].

Lin et al.[13] reported a case of plate and screw exposure due to skin necrosis at the medial aspect of the ankle that was successfully treated with fat grafting. Purified, emulsified fat was used with a micro-autologous fat transplantation gun. The wound healed 18 weeks after surgery. Souza et al.[14] also reported the successful combination of autologous fat grafting with NPWT in a case of chronic osteomyelitis with 10 cm of distal tibial exposure after a failed fasciocutaneous flap. Three weeks after fat grafting and NPWT, granulation tissue covered the entire exposed bone surface, thus allowing skin grafting.

Potential advantages of the FAT graft pooling technique include low morbidity at the donor site (usually the thigh), abundant fat, and no need for a long learning curve, such as that usually required for microvascular surgery. Furthermore, the graft functions as a matrix, thereby allowing for more effective cell connections and promoting anti-inflammatory and paracrine activities, which are beneficial for wound healing.

Although the technique presented here often requires prolonged hospital stay and multiple NPWT applications, which cannot be disregarded in terms of cost-effectiveness, we believe that the procedure is an extremely helpful salvage technique for complex wounds where standard techniques are contraindicated or have failed. Our preliminary results are promising, but a large case series is needed to fully validate this novel salvage procedure. Our group is currently working on this direction.

Conclusion

The FAT graft pooling technique combines the angiogenic and regenerative properties of adipose tissue with NPWT to manage complex clinical situations. We advocate this technique in certain circumstances where the use of local flaps is not possible due to soft tissue trauma/damage, or when free flaps are contraindicated due to the lack of suitable vessels for anastomosis or due to systemic issues.

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Technical Tips

Calcaneonavicular coalition resection: technical tip

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Abstract

Tarsal coalition is an abnormal connection between tarsal bones, caused by an embryogenic failure. Its most common forms are calcaneonavicular and talocalcaneal coalition, which are present in 53% and 37% of the cases, respectively. The onset of symptoms is related to tarsal bone ossification, and mean age for this event is estimated at 16 years for calcaneonavicular coalition. Surgical treatment is indicated for patients who did not improve symptoms with conservative treatment. The aim of this study is to present a surgical technique as a treatment option for resection of calcaneonavicular coalition associated with abnormal cuboid-navicular joint.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Tarsal coalition/surgery; Tarsal bones; Foot deformities, congenital; Osteotomy/methods.

Introduction

Tarsal coalition is a term used to define an abnormal connection between two tarsal bones, was officially described for the first time by Buffon in 1796, and is caused by failure of mesenchymal segmentation during embryogenesis[1].

The incidence of tarsal coalition is from 1 – 2% in the general population; its most common forms are calcaneonavicular (53%) and talocalcaneal (37%) coalitions, which may be present bilaterally in 60 – 50% of the cases, respectively. Other tarsal coalitions, such as talonavicular, calcaneocuboid, and cuboid-navicular, are less common and represent < 10% of the general population[2]. Only 25% of tarsal coalitions are symptomatic[3].

Calcaneonavicular coalition may be a osseous, cartilaginous, or fibrous bar[4] that locks the affected joint, leading to reduced range of motion of hindfoot and thus to loss of foot accommodation capacity on uneven surfaces, since overload on surrounding joints[5,4] leads to inflammation and pain, which are the most frequent symptoms in adolescents[6]. The onset of symptoms is correlated with the ossification process and usually occurs between 12-15 years for calcaneonavicular coalition[7].

The classical clinical presentation in adolescents is heel pain that worsens with physical activity, difficulty to walk on uneven surfaces along with history of ankle sprains[6], and the most evident clinical signs are hindfoot valgus deformity, forefoot abduction, collapse of the medial arch of the foot, and spasticity of fibular tendons[8]. However, some authors report cases of varus cavus deformity.

The diagnosis is based on clinical history, physical examination, and imaging tests, starting with radiographies in 3 incidences: anteroposterior (AP), lateral, and oblique- weighted scans. Computed tomography (CT) and magnetic resonance imaging (MRI) are very useful, because they provide a more detailed description of location, size, degenerative changes in joints or of any concomitant coalition, which helps develop a more effective pre-operative planning[9].

The treatment aimed to relieve pain and to reduce stress on calcaneonavicular coalition; moreover, is indicated for patients with symptomatic calcaneonavicular coalition and may start with changes in habits, wearing of rigid sole shoes, physical therapy, nonsteroidal anti-inflammatory drugs, insoles, orthesis, and immobilization with a cast.

Surgical resection of coalition is indicated when there is no improvement with conservative measures[10]. Corrective osteotomies may be used in cases when calcaneonavicular coalition is associated with pes planus valgus, or arthrodeses when it is associated with joint degeneration[11].

The objective of this study is to present a surgical treatment option for resection of calcaneonavicular coalition associated with abnormal cuboid-navicular joint using a dorsolateral access in the topography of the heel.

Study performed at the Instituto de Ortopedia e Traumatologia, Hospital das Clinicas HCFMUSP, Faculdade de Medicina, Universidade de São Paulo, SP, Brazil.

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The case used to illustrate the surgical technique consisted of a 13-year-old male adolescent with no comorbidities and history of lateral foot pain and recurrent left ankle sprains.

In this case, feet alignment was symmetrical and adequate. Range of inversion and eversion of the left foot was slightly limited, with pain in the motion threshold.

Complementary tests revealed reverse anteater nose sign in AP incidence (Figure 1A), and anteater nose sign in lateral weighted incidence (Figure 1B). Computed tomography provided information on a little usual navicular shape extending toward lateral and plantar maintaining contact with the dorsal and plantar portions of anterior process of the calcaneus. Furthermore, an abnormal facet joint was observed between the lateral portion of the navicular bone and the cuboid bone. Three-dimension reconstruction CT (Figure 2) and MRI (Figure 1C, 1D) scans were obtained to achieve a better understanding on calcaneonavicular coalition and to help operative planning.

Figure 2. Computed tomography showing the extension of the entire tarsal coalition (left and right). A. Tarsal coalition with plantar and medial contact. B. Tarsal coalition in contact with the medial portion. C. Tarsal coalition with dorsolateral contact. 3D reconstruction images. D. Lateral view. E. Plantar view. F. Medial view.

Surgical technique

This surgical technique is indicated for resection of symptomatic calcaneonavicular bar refractory to conservative treatment.

Patient positioning

Patient in the supine position under general anesthesia, on a radiolucent surgical table, with a cushion under the ipsilateral hip to promote a slight internal rotation of the limb to be operated.

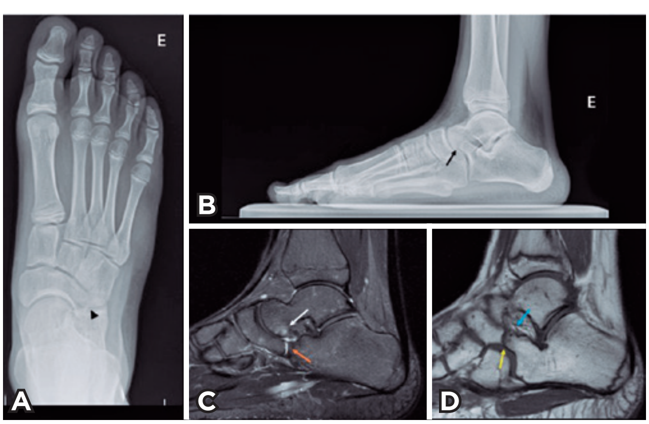

Figure 1. A. AP x-ray showing reverse anteater nose sign (arrow head). B. Weighted lateral x-ray: Elongated anterior process of the calcaneus (black arrow). Magnetic resonance imaging. C. Sagittal T2 section. Plantar elongation of the navicular in contact with the head of the talus; moreover, osseous edema and fluid between the talus and the coalition was observed (white arrow). Fibrocartilaginous coalition between the calcaneus and the navicular (orange arrow). D. Sagittal T1section. Elongation of the navicular bone creating an abnormal joint with the cuboid bone. (yellow arrow), cysts in the anterior portion of the calcaneus in contact with the navicular (blue arrow).

A non-sterile tourniquet is placed on the tight of the limb to be operated.

Surgical approach

1. An oblique 3-cm incision is made at the dorsolateral surface of the foot centered on the anterior process of the calcaneus at a line between the between towards the base of the fourth metatarsal (Figure 3A);
2. It is necessary to identify and dissect the inferior extensor retinaculum so as to maintain its integrity;
3. The proximal portion of the belly of the extensor digitorum brevis muscle is desinserted and this muscle is distally separated in order to expose the anterior process of the calcaneus, the lateral portion of the navicular bone, the dorsal portion of the cuboid bone, and the plantar portion of the head of the talus (Figure 3B, 3C), and care should be taken not to injury the lateral branch of the superficial peroneal nerve;
4. The first section is made so as to resect the dorsolateral volume of the coalition, allowing for the visual access of the deeper and more medial portion, in order to avoid inadvertently extensive resections that could compromise the healthy cartilage;

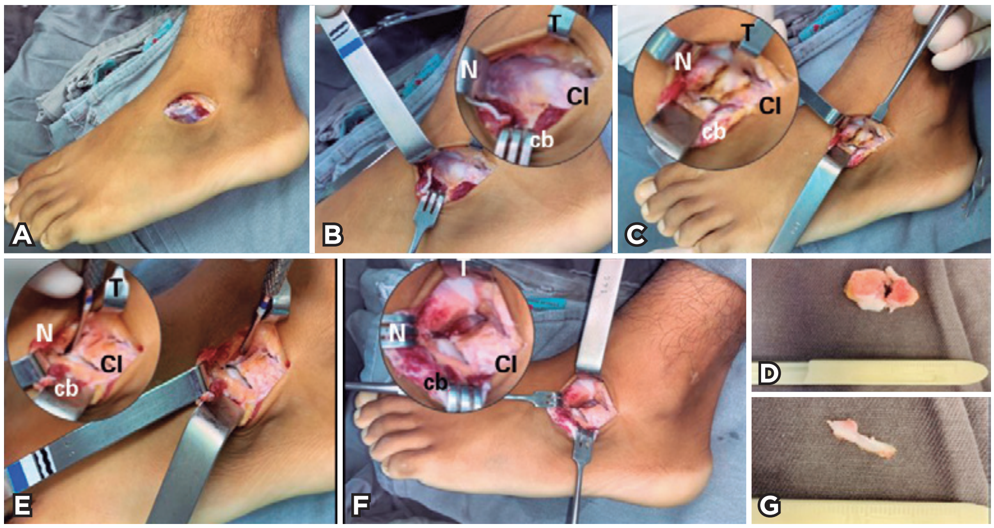

Figure 3. A. Oblique incision on the dorsolateral surface of the foot B. Exposure of calcaneonavicular bar. C. Marking of sections for calcaneonavicular bar resection. D. Resected surgical specimen of the calcaneonavicular bar. E. Identification of abnormal facet joint between the navicular and the cuboid. F. Osteotomy for resection of facet joint between the navicular and the cuboid. G. Surgical specimen of resected facet joint of the navicular bone. *T: Talus, N: Navicular, Cl: Calcaneus, Cb: Cuboid.

5. Therefore, it is important to visualize the plantar portion of the head of the talus, which is the lower anatomical parameter for navicular resection;
6. An osteotome is placed at the navicular bone, respecting the lower edge of the head of the talus, and another osteotome is placed at the anterior process of the calcaneus, convergent with the first one;
7. It is important to note that this osteotome arrangement leads to an incomplete resection of coalition, since the plantar and medial bony portions of the navicular and the calcaneus will remain in contact, but this arrangement will allow for the excision of the most superficial portion of the bar, followed by the direct visualization of its deepest portion, thus allowing for a more accurate resection of the entire coalition and preventing damages to healthy joint regions, especially those located at the head of the talus;
8. The surgical specimen is removed, and complete resection of the osseous bar should be confirmed by fluoroscopy, since one of main errors in this procedure is performing an incomplete resection of the osseous bar (Figure 3D, 4A);
9. After resection of the calcaneonavicular bar, a little contact between navicular and cuboid bones is observed, residual from its abnormal joint, which is partially locking joint range of motion. Its resection is performed by vertical osteotomy of the most distal and lateral portion of the navicular bone, and, once section is finished, the surgical specimen is removed and a new control is made using direct fluoroscopy (Figure 3E, 3F, 3G, 4B);
10. The range of motion of subtalar joint is verified;

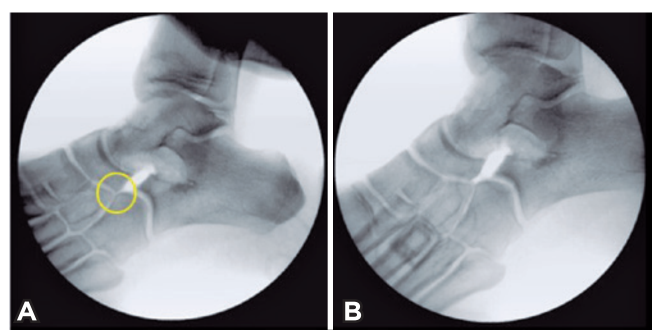

Figure 4. Intraoperative images with fluoroscopy A. Control image after calcaneonavicular bar resection, abnormal facet joint between the navicular and the cuboid (circle). B. Complete resection of calcaneonavicular coalition and abnormal navicular-cuboid joint.

11. The inferior extensor retinaculum is reinserted between the navicular bone and the anterior process of the calcaneus, interposing the muscle in place of the coalition;
12. The tourniquet is deflated and an adequate hemostasis of the surgical field is obtained;
13. Surgical planes are closed with a vicryl 3.0 absorbable thread for subcutaneous and with a nylon 4.0 non-absorbable thread for skin;
14. Sterile bandages and dressing is placed.

Discussion

The lack of identification of when other joints are involved in calcaneonavicular coalition may result in persisting symptoms and surgical failure. Although its true incidence is unknown, between 3.8% to 20% of patients with tarsal coalition have multiple affected joints[12]. For this reason, sectional imaging methods (such as CT and MRI) provide additional information for diagnostic complementation and give evidence on possible associated joints.

Therefore, these imaging tests make surgical planning more accurate, facilitating the selection of the incision technique and reducing the possibilities of maintaining abnormal tissue and resecting healthy tissue, with better surgical results.

In a clinical retrospective study with 30 patients with symptomatic tarsal coalition (14 patients with conservative treatment and 16 with surgical treatment) analyzed whether there were changes in pain levels after treatment, and concluded that, in patients with high pain levels at baseline, these were gradually intensifying during conservative treatment, and showed a drastic improvement in pain intensity after surgical treatment, whereas patients with low pain levels at baseline are likely to improve pain intensity throughout the conservative treatment[13]. With these results, it could deduced that patients with low intensity pain at the onset of symptoms could respond to conservative treatment more adequately than patients with high intensity pain; additionally, it is possible to suppose that surgery could be indicated as first-line treatment for these patients.

A historical report from Mitchell and Gibson, who undertook resection without interposition, demonstrated a recurrence rate of 66%[1]. In response to those results, Mubarak et al.[14] conducted a retrospective study that found good results using autogenous fat as an interposition graft, showing lower rates of reossification and reoperation compared with the use of extensor digitorum brevis as interposition graft. In another study published by Masquijo et al.[15] reported that using autogenous fat graft and bone wax promoted greater pain relief, higher functional scores, in addition to effectively preventing reossification of coalition compared to the use of the extensor digitorum brevis muscle as interposition graft, but additional studies are needed to assess bone wax as an interposition material. The literature still discusses which would be the best option, but most authors indicate best results when some tissue is interposed.

It is important to emphasize that complete resection of coalition is required for a good outcome. The case reported in this study is a clear example of the existence of calcaneonavicular bars with great amount of plantar and medial bone of difficult visualization. If diagnosis and surgical planning are not thoroughly performed, deeper segments of the coalition or abnormal joints would be maintained, not resolving reduced mobility, inadequate osseous impact, and patient's pain complaints.

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Technical Tips

Lapicotton technique in the treatment of progressive collapsing foot deformity

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Abstract

We present a technical surgical description of a 36-year-old female diagnosed with Progressive Collapsing Foot Deformity (PCFD) treated with a medial displacement calcaneus osteotomy, a lateral column lengthening, and a modified Lapidus fusion. In order to increase the plantar flexion power of this arthrodesis and minimize the loss in ray length with joint preparation, a bone block structured graft was used. Fixation was performed using a post implant in the medial cuneiform with crossing screws though the surfaces and the graft. Forefoot varus was properly corrected intraoperatively by using the described surgical technique. Satisfactory functional short-term results and an excellent alignment was accomplished.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Flatfoot; Foot deformities, acquired/diagnostic imaging; Arthrodesis/methods; Osteotomy/methods; Fracture fixation, intramedullary/instrumentation; Joint instability/surgery.

Introduction

Progressive Collapsing Foot Deformity (PCFD) is a three-dimensional complex condition that may affect up to 10% of adults above 65 years-old[1,2]. Pain on the medial side of the foot and ankle associated with gradual flattening are common symptoms of the disease[3]. Lateral pain is related to the possibility of subtalar and subfibular impingement as well as peroneal involvement[4,5]. Patients usually display a valgus alignment of the hindfoot, combined with midfoot abduction and forefoot varus (forefoot supination)[6]. Peritalar subluxation and medial ankle instability are potential adjunctive findings to the scenario and should be properly investigated[7-9].

Deformities may present as flexible or rigid. This can be determined by clinical and radiological findings, and places the patient in the a corresponding PCFD Classification[1,2,6]. Existence of medial column instability (MCI) is not solely determined by forefoot varus (FV) and should always be investigated due to its importance in prognosis and treatment planning[10-12]. First ray hypermobility, hallux valgus, midfoot arthritis, gapping at the tarsometatarsal (TMT) joint and dorsal metatarsal migration are findings associated with MCI[13,14]. Acknowledgement of this instability requires inclusion of a procedure to the medial column in order to correct the forefoot varus, stabilize the ray and bring the foot to a plantigrade tripod position that protects the whole foot construction and ankle joint[10,15].

The Cotton opening wedge medial cuneiform osteotomy and the Lapidus tarsometatarsal arthrodesis are the usual procedures of choice in the MCI/FV scenario[1,12,16]. Determination of the proper method is usually based on patient profile and deformity presentation[17]. Severe instability, TMT arthritis, and hallux valgus usually move the indication towards fusion[3]. Despite the reliability in terms of stability and functional results, the Lapidus does not come without inconveniences. Shortening of the medial column (2mm at minimum) and difficulty in achieving a proper plantarflexion of the first ray are the most common burdens of the technique when treating PCFD[18,19]. Solutions for these challenges are scarce within the literature, with authors usually recommending a plantar first metatarsal translation to compensate the possible losses[20,21]. There is no previous study depicting the use of a bone block wedge in TMT fusions for PCFD[22,23].

Study performed at the University of Iowa, Carver College of Medicine, Iowa City, Iowa, USA.

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This article describes the surgical treatment of a 36-year-old female patient with a symptomatic PCFD in the scenery of an adjuvant medial column instability and forefoot varus. A medial calcaneal displacement osteotomy (MDCO) combined with a lateral column lengthening (LCL) and a modified TMT arthrodesis were performed. The fusion was carried using a bone block wedge amongst both the medial cuneiform and the metatarsal base to avoid bone shortening and produce first ray plantarflexion.

Case description

This study received approval from the Institutional Review Board and complied with both the Health Insurance Portability and Accountability Act (HIPAA) and the Declaration of Helsinki. The patient signed the Consent Form for this research.

A 36-year-old female (BMI 39.45) presented to the foot and ankle orthopedic service with a right chronic medial foot and ankle pain since childhood. She was diagnosed with psoriatic arthritis two years ago and is currently treated with methotrexate and analgesics. The patient claimed that she suffered an ankle injury when she was 7 years old which was treated with braces and crutches. Since then she experiences chronic pain. Physical therapy and use of insoles in the past did not relieve pain.

During clinical evaluation, she demonstrated a severe flatfoot deformity with significant hindfoot valgus of approximately 20-25º, midfoot abduction (too many toes sign), and a supinated forefoot (Figure 1). She was also tender to palpation along the medial side of the foot and ankle as well as on the sinus tarsi area. All joints were flexible, and a fixed congruent forefoot varus (supination) was found. Medial column was found unstable by demonstrating plantar-dorsal metatarsal translation above 10mm[13,24]. Heel rise and Silfverskiöld tests were positive; posterior tibial strength was normal.

Preoperative functional scores were 41 for Tampa Kinesiophobia Scale, 20 for Pain Clinic Scale, 67 for PROMIS Pain, 91.17 for the FFI, and 9.52 for the FAAM.

Conventional radiographs showed an accessory navicular, a Meary's angle of 21.6°, a calcaneal pitch of 15.8°, and a talonavicular coverage angle of 30.9°[25] (Figure 2). No talar val-

Figure 1. Patient's photographs showing the hindfoot valgus, midfoot abduction and the collapse of the longitudinal arch.

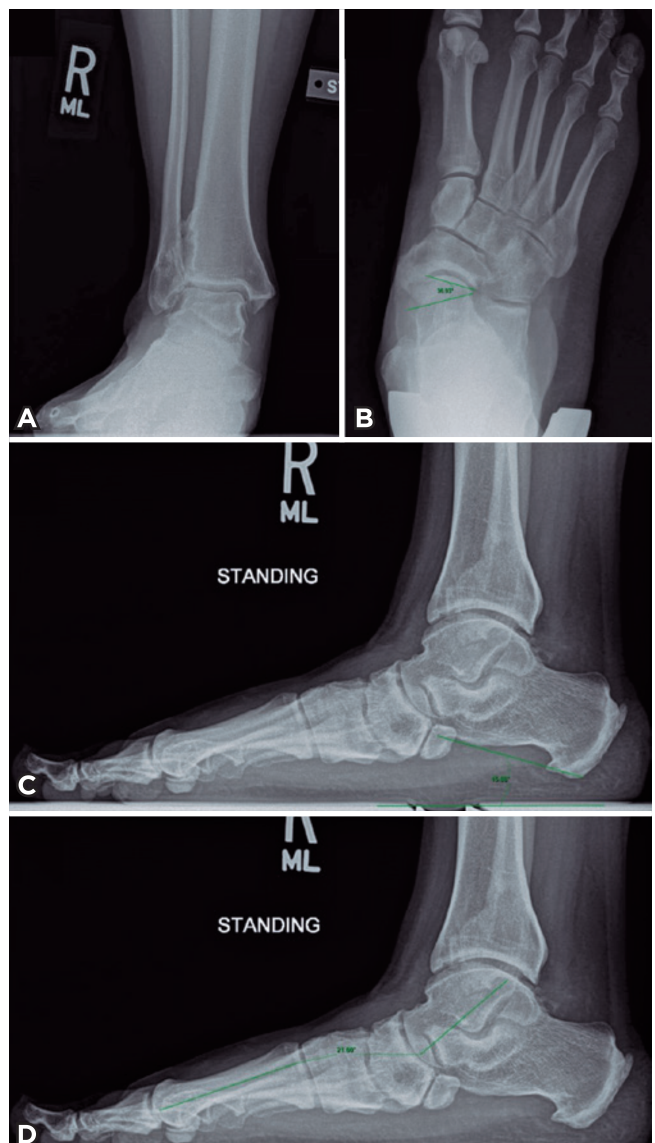

Figure 2. Preoperative radiographic series demonstrating absence of ankle tilt (A), talonavicular angle (B), calcaneal pitch angle (C) and Meary's angle (D).

gus tilt was observed. Cuneiform-metatarsal length measured 89.95mm (AP) and 89.31mm (P) on x-rays. Weightbearing CT (WBCT) findings included the presence of subtalar impingement, 24.9° in Meary's angle, 18° in calcaneal pitch, 36.2° in talonavicular coverage angle, 2.7° in the forefoot arch angle, 17.51mm in cuneiform-to-floor coronal distance, 20.13mm in navicular-to floor sagittal distance, 35.6% in middle facet subluxation, 21.6° in subtalar horizontal angle (50%), 20.73mm in hindfoot moment arm, 56.0° in hindfoot alignment angle, and absence of subfibular impingement (Figure 3)[5]. The preoperative Foot Ankle Offset (FAO) was 10.37. Cuneiform-metatarsal length was 87.07mm in the WBCT. Magnetic Resonance Images (MRI) portrayed minor posterior tibial tendon degeneration and preservation of the spring and deltoid ligaments (Figure 4). Absence of arthritic findings was observed in all imaging acquisition methods.

Considering the above findings, the patient was classified as a 1ABCD as she presented a flexible heel valgus and a flexible midfoot abduction combined with a forefoot varus and subtalar impingement. After careful explanation of the disease and treatment options, the patient decided to proceed with surgical treatment. A percutaneous MDCO combined with an LCL and a TMT arthrodesis was planned to reestablish the alignment. Resection of the accessory navicular associated with a modified Kirdner procedure and a gastrocnemius recession were also included in surgical strategy.

Surgical technique and technical tip

Operation began with aspiration of bone marrow from the right iliac crest for concentration and later injection into the joint fusion mass. A gastrocnemius recession procedure was then performed with a 3cm incision over the posterior medial aspect of the leg using the Strayer technique. A nasal speculum was inserted separating the gastrocnemius aponeurosis and the muscle belly of the soleus. At least 10 to 15 degrees of increasing dorsiflexion was noted following sectioning of the gastrocnemius aponeurosis.

We proceeded with percutaneous medial displacement calcaneal osteotomy using a Shannon burr with constant irrigation. Using fluoroscopic guidance, the burr was used to perform an oblique osteotomy of the calcaneal tuberosity percutaneously. The tuberosity was medially displaced and cannulated headless 4.0mm screws were positioned in a slightly divergent pattern. The amount of displacement noted was about 10 to 12mm in the axial fluoroscopic view.

A 6cm longitudinal separate incision was then made over the sinus tarsi and anterior aspect of the calcaneus. Subperiosteal dissection of the calcaneus was made plantarly and dorsally, exposing the lateral surface of the calcaneus at the level of the same angle. The lateral calcaneus osteotomy was then made across the calcaneus with a sagittal oscillating saw at the level of the Gissane angle, just anterior to the posterior facet of the subtalar joint. Care was taken not to injure the medial and anterior facets of the subtalar joint. The opening wedge osteotomy was distracted using a Hintermann distractor. Different size of trials for lateral column lengthening wedge were tested. Adequate correction was noted under fluoroscopy with an 8mm wedge. Construct was found to be stable (Figure 5).

After the hindfoot was corrected into neutral alignment, attention turned to the forefoot. Palpation of the heads of the first and fifth metatarsals demonstrated residual fixed supination of the forefoot. The first TMT joint was then exposed with a 5cm long dorsal approach at the level of the first TMT joint and medial cuneiform. Extensor hallucis longus and the anterior neurovascular bundle were identified and retracted laterally.

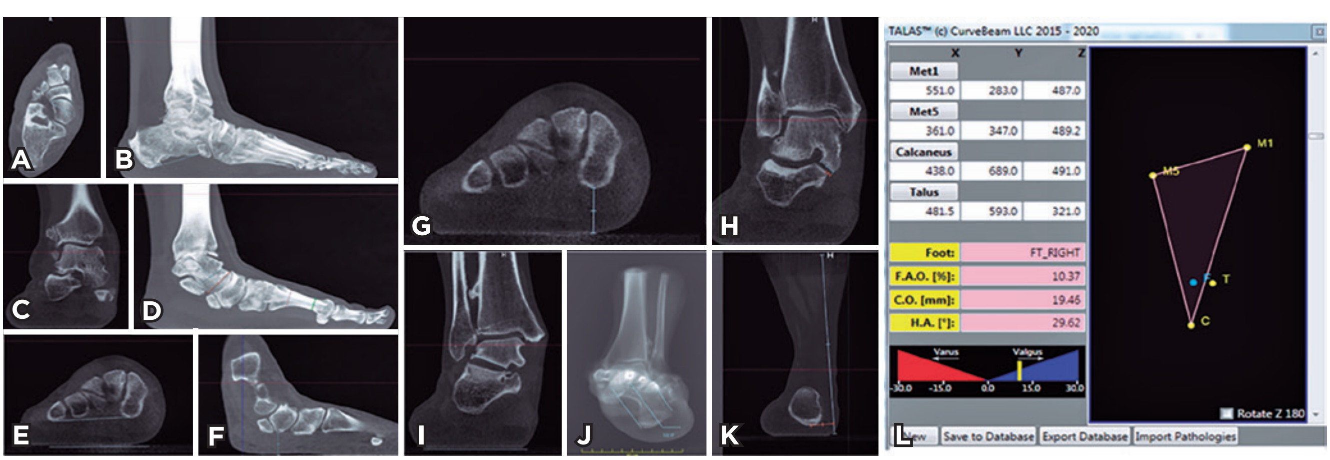

Figure 3. Preoperative WBCT images displaying the talonavicular coverage angle (A), calcaneal pitch angle (B), subtalar impingement (C), Meary's angle (D), forefoot arch angle (E), cuneiform-to-foot height (F), navicular-to-foot height (G), middle facet subluxation (H), subtalar horizontal angle (I), hindfoot alignment angle (J), hindfoot moment arm (K) and Foot and Ankle Offset (L).

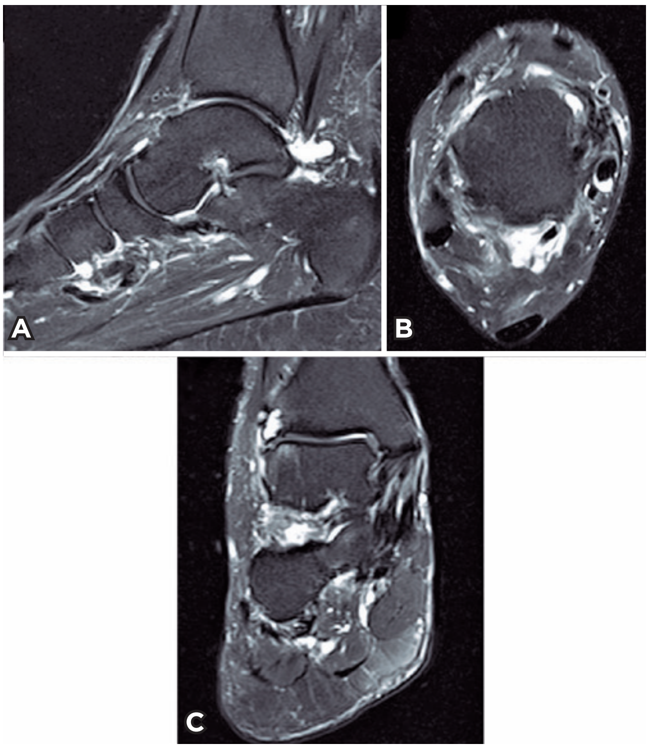

Figure 4. MRI showing spring (A), posterior tibial tendon (B) and deltoid (C) integrity.

The capsule of the first tarsometatarsal joint was incised longitudinally and elevated to expose the joint. The guidewire for the Zimmer Biomet InCore® system was inserted into the medial cuneiform from plantar to distal aiming slightly distally to accommodate a dorsal rash into the first TMT joint. We then used the appropriate drill to create the hole for the implant inside the medial cuneiform. The drilling was carried out from dorsal to plantar. The vertical implant into the medial cuneiform was then manually inserted. The external jig was then attached to the implant. An additional 2 cm dorsomedial approach was performed distally along the medial border of the first metatarsal to allow for adequate positioning of the jig. With the jig appropriately positioned, two additional K-wires were inserted distally through the jig and into the dorsomedial aspect of the first metatarsal to the adequately control rotation. The jig was then used to distract the arthrodesis site. About 8 mm of distraction was performed, exposing the base of the first metatarsal and the distal aspect of the medial cuneiform. The joint was prepared, removing the articular cartilage of both sides of the joint using an oscillating saw, a sharp chisel, and a curette. An 8mm dorsal base Lapidus Paragon 28® allograft wedge was then inserted into the fusion site. Before insertion, the wedge was soaked in the bone marrow aspirate. The first tarsometatarsal joint was reduced by performing compression using the implant jig. Adequate correction was noted under direct visualization and under fluoroscopic assessment. Insertion of the allograft provided

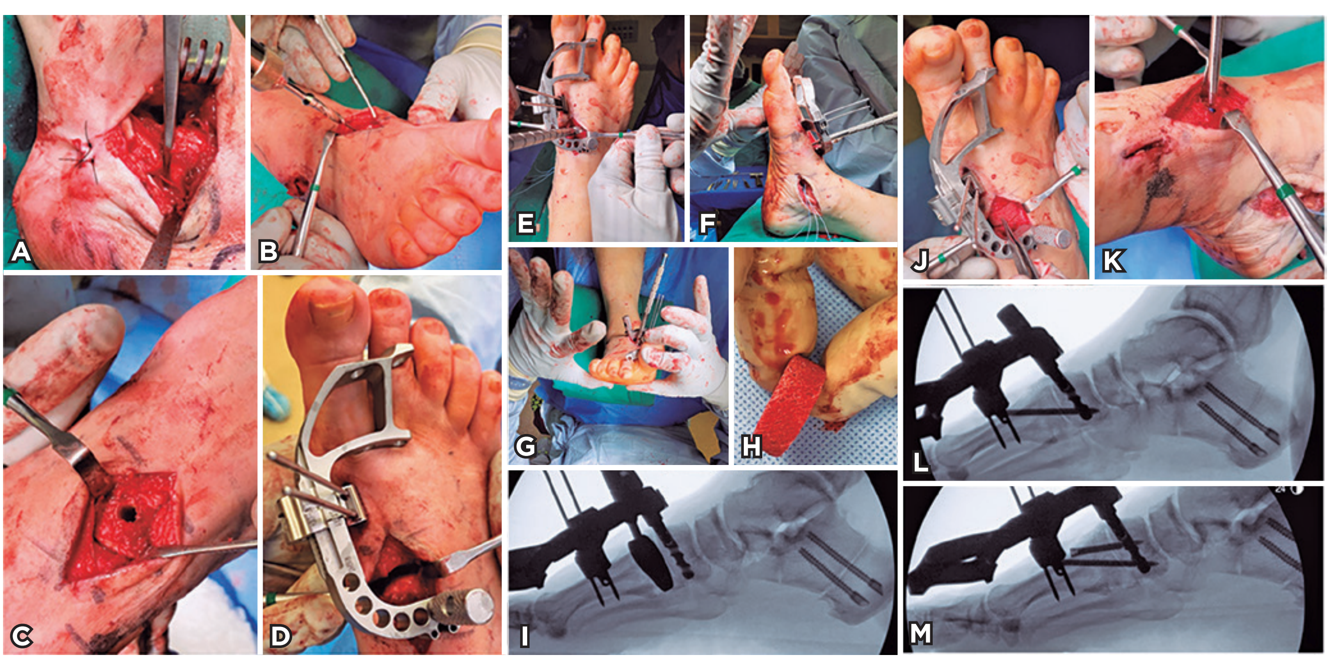

Figure 5. Intraoperative images portraying the medial column displacement osteotomy and the lateral column osteotomy (A). Following a dorsal incision, the cuneiform is exposed, and the post site is drilled (B, C). After the post is inserted, the guiding device is inserted, and joint distraction obtained (D). The surfaces are prepared, and trial sizing performed (E, F) aiming to level the metatarsal heads (G) with first ray plantarflexion (H, I). The graft is inserted (J) and the construct secured with two screws (K, L, M).

adequate stability and resulted in the correction of forefoot supination, bringing the heads of the first and lesser metatarsals to a more harmonic plantigrade position. Through two additional percutaneous approaches and adequate blunt dissection down to the level of bone, 2 screws were inserted through the jig holes to allow adequate fixation into the medial cuneiform post. Intraoperative fluoroscopy and direct visualization confirmed adequate apposition at the arthrodesis site. No plantar gapping of the first TMT joint was noted (Figure 5).

A longitudinal medial incision was then made to expose the posterior tibial tendon and the navicular tuberosity. Some synovitis was noted in the distal aspect of the tendon. The posterior tibial tendon was debrided off of the navicular, exposing the plantar medially located large accessory navicular bone in the substance of the posterior tibial tendon. The accessory navicular bone was then carved out of the tendon using a 15 blade, while protecting the spring ligament. The spring was completely intact with some stretching. After adequate preparation of the tuberosity, two anchors were inserted into the navicular tuberosity and used to reattach the posterior tibial tendon into the debrided navicular tuberosity as well as retain the spring ligament.

Figure 6. Postoperative radiographs obtained during the third-month follow-up visit, showing the Meary's angle (A), the talonavicular coverage angle (B) and the calcaneal pitch angle (C).

Patient was released in a non-weight bearing splint. This was replaced with a boot at the 14-day visit and non-weight bearing regime remained until the 6th week. After this period, physical therapy was introduced, and ankle range of motion slowly initiated. In the 7th week, progressive bearing was initiated, and the boot was removed by the 12th week. Gradual return to baseline activities occurred after the third postoperative month.

Results

The presented outcomes assessment occurred in the three-month follow-up visit. Radiographic parameters showed the following postoperative values: 5.9° in Meary's angle, 20.8° in calcaneal pitch and 9.1° in talonavicular coverage angle (Figure 6). Cuneiform-metatarsal length was 93.82mm (AP) and 88.71mm (P). WBCT postoperative measurements were: 7.8° in Meary's angle, 26.4° in calcaneal pitch, 4.1° in talonavicular coverage angle, 13.3° in forefoot arch angle, 24.48mm in cuneiform-to-floor coronal distance, 33.34mm in navicular-to-floor sagittal distance, 22.2% in middle facet subluxation, 11.6° in subtalar horizontal angle (50%), -1.37mm in hindfoot moment arm, -3.4° in hindfoot alignment angle and absence of subtalar and subfibular impingement (Figure 7)[5]. Cuneiform-metatarsal length was 88.99mm in the WBCT. The postoperative Foot Ankle Offset (FAO) was 1.31.

Postoperative functional scores were 44 for Tampa Kinesiophobia Scale, 9 for Pain Clinic Scale, 70 for PROMIS Pain, 64.7 for FFI and 40.47 for the FAAM. The patient presents an excellent clinical alignment with no pain at the osteotomies' sites and at the TMT arthrodesis (Figure 8).

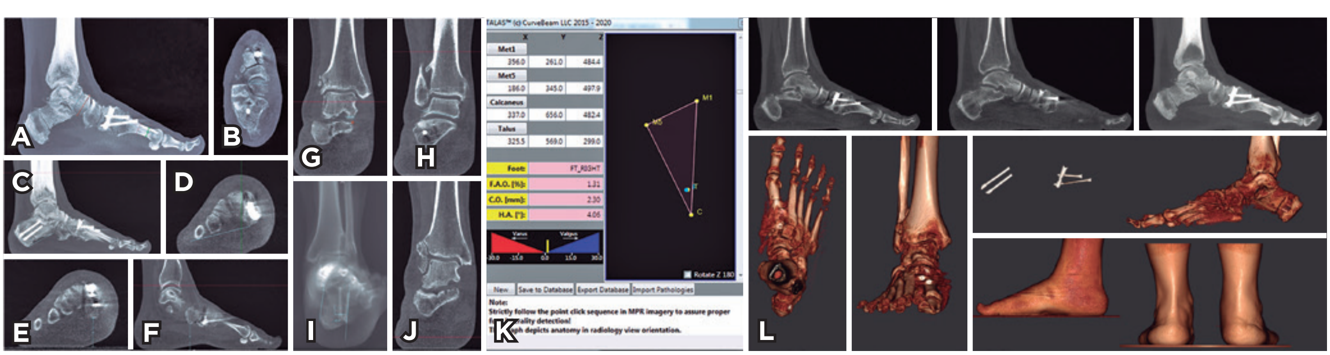

Figure 7. Postoperative WBCT acquisitions at 3-month follow-up displaying the Meary's angle (A), the talonavicular coverage angle (B), the calcaneal pitch angle (C), the forefoot arch angle (D), the navicular-to-floor distance (E), navicular-to-foot height (F), middle facet subluxation (G), subtalar horizontal angle (H), hindfoot alignment angle (I), absence of subtalar impingement (J) and the Foot and Ankle Offset (K). Fusion status and alignment are also depicted (L).

Figure 8. Clinical appearance at 3-months following PCFD reconstruction and LapiCotton.

Discussion

PCFD treatment remains a challenge in terms of defining surgical strategies and assessing the proper necessary correction[12]. We demonstrated a surgical technique that uses a wedge structured graft in the TMT fusion site with the intention to potentialize alignment gain. Tripod reestablishment and good functional results were obtained with the use of this strategy in conjunction with other procedures.

Importance of first ray plantarflexion to restore the "static triangle of support" and to further ankle joint protection was established by other authors[10,26-28]. The Cotton has the advantage of being an extraarticular osteotomy that allows different wedge graft sizes to be inserted. Benthien et al. showed that inclusion of the Cotton osteotomy in cadavers reduced load over the lateral column, bringing the foot to a more plantigrade position[28]. De Cesar Netto et al. found a significant decrease in ankle pressures through a PCFD cadaveric model when the Cotton osteotomy was performed. Additional procedures enhanced this effect[26]. On the other hand, Conti et al. performed a retrospective evaluation of patients that underwent this cuneiform osteotomy and found that moderate postoperative plantarflexion provided lower functional results in comparison to a mild plantarflexion[29]. Our patient reached good functional results and an excellent alignment (evaluated by several measures) with the presented technique that aimed a proper plantarflexion of the first ray.

Tarsometatarsal arthrodesis is a traditional procedure for correction of forefoot varus in the setting of PCFD when severe medial column instability, TMT plantar gapping, local arthritis or hallux valgus is present[1,30,31]. Reliability of this technique and good functional results are usually the arguments that supports its indication[32,33]. Few studies analyzed the contribution of the Lapidus fusion in PCFD correction but none tested the technique in isolation[34,35]. Greisberg et al. demonstrated a mean talometatarsal angle correction of 16° in patients that underwent tarsometatarsal and naviculocuneiform fusion for collapsing deformities[35]. Fuhrmann showed increase in the first metatarsal head load in all patients performing a Lapidus in the scenery of a PCFD associated with HV but did not quantify it[34]. The presented technique was able to recreate the arch, as shown by the improvement of the Meary's angle, forefoot arch angle, cuneiform-to-floor distance, and the FAO.

Performing a TMT fusion in the PCFD context may be quite complex due the intrinsic necessity to restore the medial arch[21]. Joint preparation naturally shortens the ray which may prejudice final foot alignment and the patient's gait. Previously, Greef et al. described a mean shortening of 4.1mm after TMT fusions for HV. Despite these findings, only one patient (from the 32 sampled) had symptoms of transfer metatarsalgia[20]. Dahlgren et al. showed in cadavers a mean metatarsalcuneiform length decrease of 3mm when using osteotomes in comparison to a mean of 6.9mm when the saw was used to prepare the site[36]. Plantarflexion of the first ray is also challenging. Incongruency among bone surfaces is usually noted when the metatarsal is placed in the desired plantarflexion position[37]. This may lead surgeons to resect more bone from the inferior region, intensifying ray shortening. Caudal metatarsal translation is a described strategy to bring the first ray downwards but effects in foot mechanics are still unknow[21]. In our case description, we were able to achieve first ray correction and maintain its length by using a trapezoidal wedge in the TMT joint.

The use of a bone block in a fusion site could theoretically increase the chance of non-union. The fact that two surfaces are expected to heal and the use of an allograft in this technique supports this concept. Still, no comparative data was produced regarding fusions rates in TMT joints to sustain the idea. Hamilton et al. found 18% of non-union in Lapidus arthrodesis using a autogenous bone block[38]. When using cadaveric donor bone to fill defects in metatarsophalangeals fusions, Luke et al. observed pseudoarthrosis in 13% of the sample and Malhotra et al. observed it in 12%[39,40]. Clinical and radiographical fusion was noted in this study's patient at three months, with at least 80% of trabecular formation through each surface noted.

Procedures that may combine the advantages of a wedge osteotomy and a fusion while decreasing the detriments of both techniques are desired in the PCFD setting. This technical description study demonstrated an option for medial column stabilization and forefoot supination correction that may also provide an enhanced realignment outcome. By using a structured wedge at the tarsometatarsal joint combined with a pillar fixation implant we were able to provide a good functional and radiographic result. Foot alignment was reestablished, and fusion occurred at three months in both surfaces. We would recommend this technique modification as an adjuvant powerful procedure for patients with PCFD in the setting of a forefoot varus with tarsometatarsal arthrodesis indications.

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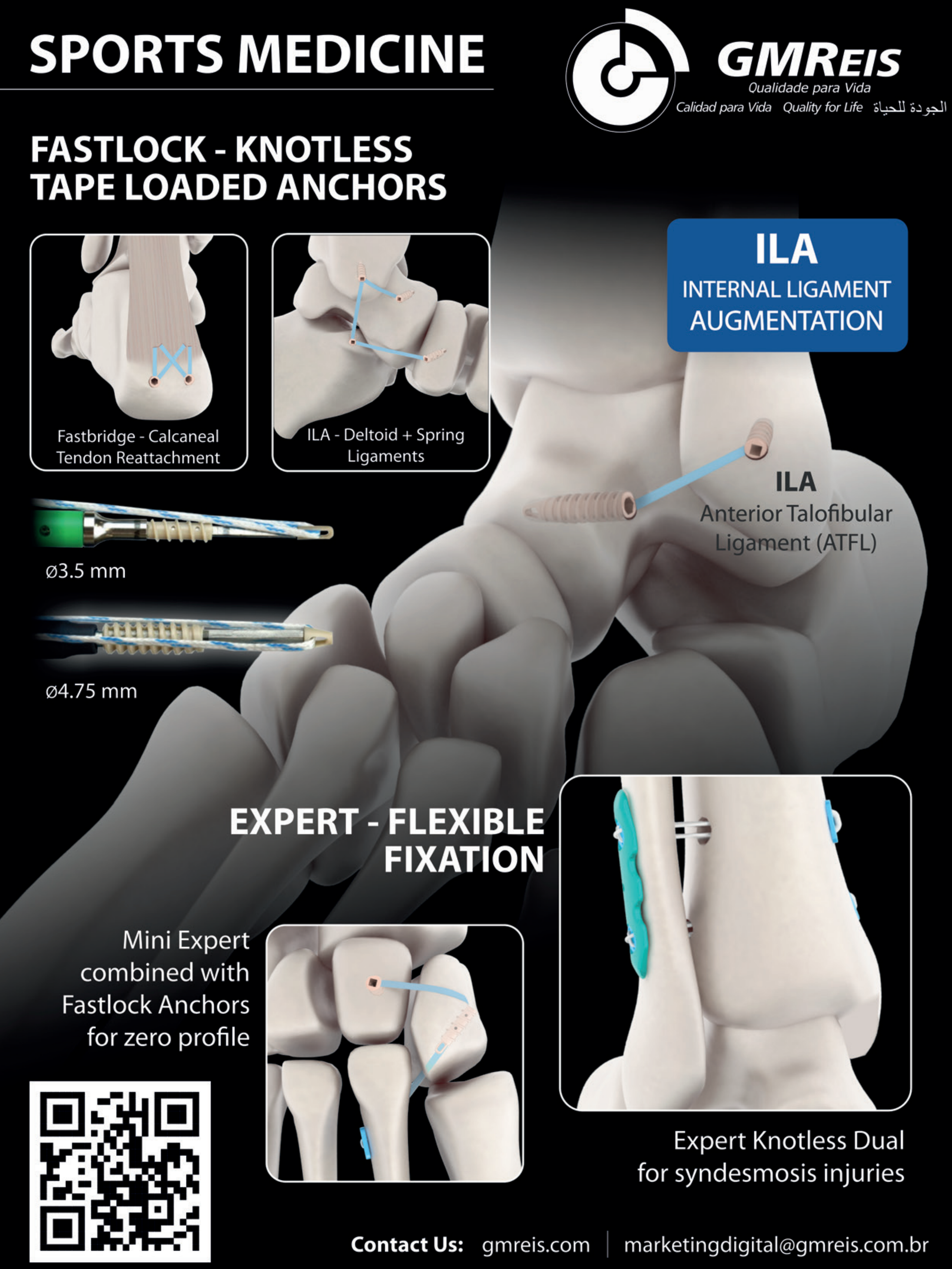
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