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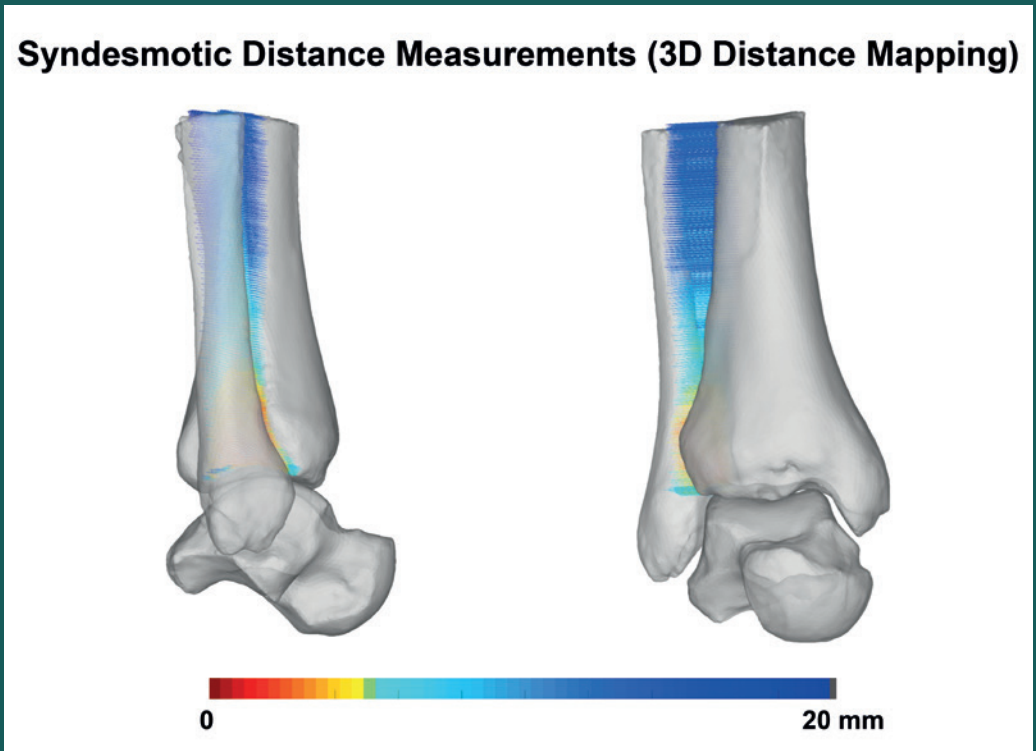

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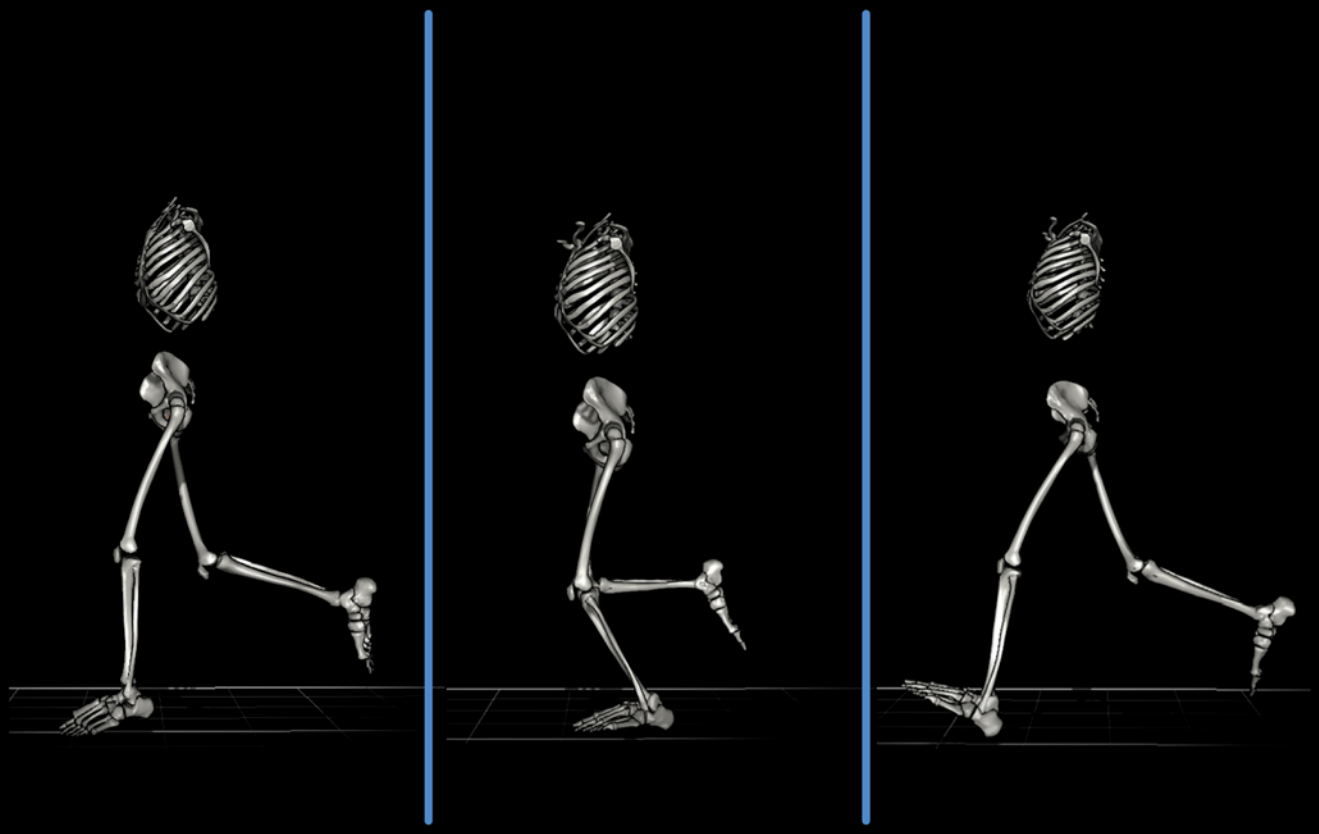

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JOURNAL OF THE Foot & Ankle IFA

# On the way to maturity...

**CAIO AUGUSTO DE SOUZA NERY**

*FEDERAL UNIVERSITY OF SAO PAULO, DEPARTMENT OF ORTHOPEDICS AND TRAUMATOLOGY, SAO PAULO, SP, BRAZIL*

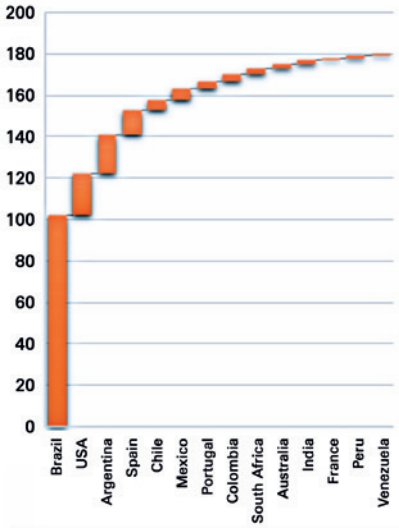
**ALEXANDRE LEME GODOY-SANTOS**

*AFFILIATED PROFESSOR AT DEPARTMENT OF ORTHOPEDIC SURGERY, UNIVERSITY OF SAO PAULO, SAO PAULO, SP, BRAZIL.*

As we close another year of existence with the publication of this third issue of volume 16, we take the opportunity to share with everyone the joy of having complied with the requirements of the indexing platforms, reaching the milestones outlined for the first three years of the JFA.

Thanks to the joint effort of authors, reviewers, editors, and management team, who prepare, organize, and produce the journal, we achieved the appropriate temporal, quantitative, and qualitative flows whose results are expressed by the publication of 180 articles in three years.

We must celebrate the participation of countries worldwide, which surprised us with their interest in our vehicle of scientific dissemination. The chart and table below demonstrate that important countries such as the USA, Spain, Portugal, South Africa, and Australia have already become familiar with our system and honored us with their submissions.




| COUNTRY | N | % |
|---|---|---|
| Brazil | 102 | 56.7% |
| USA | 20 | 11.1% |
| Argentina | 19 | 10.6% |
| Spain | 12 | 6.7% |
| Chile | 5 | 2.8% |
| Mexico | 5 | 2.8% |
| Portugal | 4 | 2.2% |
| Colombia | 3 | 1.7% |
| South Africa | 3 | 1.7% |
| Australia | 2 | 1.1% |
| India | 2 | 1.1% |
| France | 1 | 0.6% |
| Peru | 1 | 0.6% |
| Venezuela | 1 | 0.6% |
| **TOTAL** | **180** | **100.0%** |

But we still have a lot to do!!!

In addition to encouraging Latin American countries to collaborate more effectively by sending their studies, we would like to have young professionals on our side. It would be extremely useful for everyone if the training services for Foot and Ankle specialists throughout Latin America considered performing scientific studies and publishing them in the JFA as one of the technical training requirements. The research growth and published studies in our continent would soon be rewarded by the improvement in care and outcomes for our patients, the greatest objective of all.

The renewal and expansion of the Board of Reviewers started this year will continue, and soon, we hope to reduce even more the evaluation and decision time of each submission, in addition to improving, every day, the standard of revisions.

In this moment of reflection in which we see the end of another difficult year where we feel all the serious consequences of the pandemic that has hit humanity, we can celebrate a small victory achieved by every one of us who participated in constructing our journal to whom we are most grateful.

Happy Holidays to all!

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Original Article

# Ankle syndesmotic instability assessment using a three-dimensional distance mapping algorithm: a cadaveric pilot WBCT study

Kevin Dibbern[1], Grayson Talaski[1], Eli Schmidt[1], Ryan Jasper[1], Vineel Mallavarapu[1], Matthew Jones[1], Hannah Steabral[1], Andrew Behrens[1], Kepler Alencar Mendes de Carvalho[1], Ki Chun Kim[1,3], Nacime Salomão Barbachan Mansur[1,2], César de César Netto[1]

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## Abstract

**Objective:** This cadaveric pilot study was to develop a weight bearing computed tomography (WBCT) three-dimensional (3D) distance mapping algorithm that would allow for detection of syndesmotic instability.

**Methods:** Pilot study, two cadaveric specimens. Syndesmotic instability was induced by release of all syndesmotic ligaments through a conventional lateral ankle approach. WBCT imaging under simulated weight bearing was acquired before and after syndesmotic destabilization. Syndesmotic incisura and ankle gutter distances were assessed using a 3D distance mapping WBCT algorithm.

**Results:** We found increases in the overall mean syndesmotic distances in the injured syndesmosis when compared to pre-injury state, and color-coded distance maps allowed easy interpretation of the syndesmotic widening following ligament sectioning and destabilization of the syndesmotic joint.

**Conclusion:** The WBCT 3D distance mapping algorithm has the potential to allow detection of mild syndesmotic instability with a relatively ease of interpretation by using color-coded distance maps.

**Level of Evidence V; Cadaveric Study.**

**Keywords:** Joint instability; Orthopedic procedures; Syndesmosis; Tomography, x-ray computed; Weight-bearing.

## Introduction

The importance of the distal tibiofibular syndesmotic ligaments in maintaining the overall stability of the ankle joint has been frequently emphasized in the literature. Ramsey and Hamilton[1], in their classic study, demonstrated that a minimal lateral displacement of one millimeter of the talus within the ankle mortise would lead to a decrease of 42% of the ankle contact area. This decrease in total contact area could cause an increase in the articular pressures and subsequent joint degradation. Because of that, diagnosing syndesmotic instability is paramount.

Study performed at the UIOWA Orthopedic Functional Imaging Research Laboratory (OFIRL). University of Iowa, Carver College of Medicine, Department of Orthopedics and Rehabilitation, Iowa City, IA, USA.

**Correspondence:** Grayson Talaski. Carver College of Medicine, Department of Orthopedics and Rehabilitation University of Iowa, 200, 52242-0000, Hawkins Dr. John PappaJohn Pavillion (JPP), Iowa City, IA, USA. **E-mail:** gtalaski@uiowa.edu. **Conflicts of interest: César de César Netto:** CurveBeam: Paid consultant; Stock or stock Options; Foot and Ankle International: Editorial or governing board; Editor in Chief Foot and Ankle Clinics; Nextremity: Paid consultant; Ossio: Paid consultant; Paragon 28: IP royalties, Paid consultant; Weightbearing CT; International Study Group: Board or committee member; Zimmer: Paid consultant. **Nacime Salomao Barbachan Mansur:** Brazilian Foot and Ankle Society: Board or committee member; American Orthopaedic Foot and Ankle Society: Board or committee member. **Source of funding:** none. **Date received:** December 9, 2022. **Date accepted:** December 11, 2022. **Online:** December 20, 2022.

**How to cite this article: Dibbern K, Talaski G, Schmidt E, Jasper R, Mallavarapu V, Jones M, et al. Ankle syndesmotic instability assessment using a three-dimensional distance mapping algorithm: a cadaveric pilot WBCT study. J Foot Ankle. 2022;16(3):190-4.**

Weight bearing computed tomography (WBCT) has emerged as a promising diagnostic tool that can assess the ankle joint under physiological weight-bearing load, potentially allowing detection of these small deviations of an unstable syndesmosis[2-5]. This weight load in isolation has been shown to not induce enough stress to reliably demonstrate syndesmotic instability[6,7], with a better diagnostic accuracy being observed when an external rotational torque is applied in combination[8,9]. This imaging modality also allows three-dimensional (3D) segmentation of the ankle bones and highly accurate assessments of the syndesmotic area and of volumetric measurements[10-13], as well as 3D distance mapping of the entire relationship between the talus, fibula, and tibia[14-16].

With that in mind, the overall objective of this cadaveric pilot study was to develop a WBCT 3D distance mapping algorithm that would allow for detection of mild syndesmotic instability in the absence of external rotation torque. The aim of this cadaveric pilot study is to describe the 3D WBCT Distance Mapping methodology utilized to detect syndesmotic instability.

## Methods

In this cadaveric experimental pilot study, a total of two through-knee specimens were utilized. No prior surgical procedures or fractures were found, by means of fluoroscopic assessment. University Ethics Committee approved this research under the number 202006176 in accordance with the Declaration of Helsinki.

### Specimen preparation and external frame

The proximal aspect of the through-knee specimens was prepared by detaching the surrounding soft tissue, with care to avoid destabilizing the proximal tibiofibular joint. The proximal tibia was then potted in a square block using polymethylmethacrylate bone cement. The cemented block was utilized to fix the specimen vertically and in a plantigrade fashion into an external radiolucent frame that was previously utilized in the literature to allow for simulated weight bearing[17]. Weight bearing was simulated by introducing 36.3 kilograms (356N) of vertical load into the specimen frame construct (Figure 1).

### Simulated weight-bearing CT imaging

The radiolucent frame with the specimen under simulated weight-bearing was place in a WBCT scan machine (HiRise, Curvebeam®), and images of the foot and ankle were acquired under a metal artifact reduction algorithm. Each specimen underwent a total of three WBCT images with simulated weight bearing in the external frame. The initial imaging was acquired as a baseline normal scan with intact syndesmotic ligaments performed after the specimen was thawed. The second set of WBCT images was acquired after the syndesmotic ligaments were surgically sectioned.

### Surgical procedures

Surgical procedures were all performed by a single fellowship-trained orthopedic foot and ankle surgeon with more than ten years of experience. All syndesmotic ligaments were released. The surgical sectioning of the syndesmotic ligaments was performed through a direct lateral approach to the distal fibula. The anteroinferior tibiofibular ligament (AITFL) and the interosseus ligaments were sectioned under direct visualization of the anterior aspect of the syndesmosis. The posteroinferior tibiofibular ligament (PITFL) was sectioned under direct visualization posteriorly, by retracting the peroneal tendons and giving access to the posterior aspect of the syndesmosis. The superior peroneal retinaculum and deltoid ligament complex were kept intact.

### 3D distance mapping

Creation of distance maps began with a semi-automated segmentation of the tibia, talus, and fibula using a commercially available software package (Bonelogic, Disior™). Models were verified and finalized by an expert with more than 9 years of image segmentation experience to remove any imperfections. Thousands of distance measurements were then automatically made based on a previously published protocol[18] (Figure 2) and were performed along the entire tibiofibular interface and additionally included the gutters of the ankle joint.

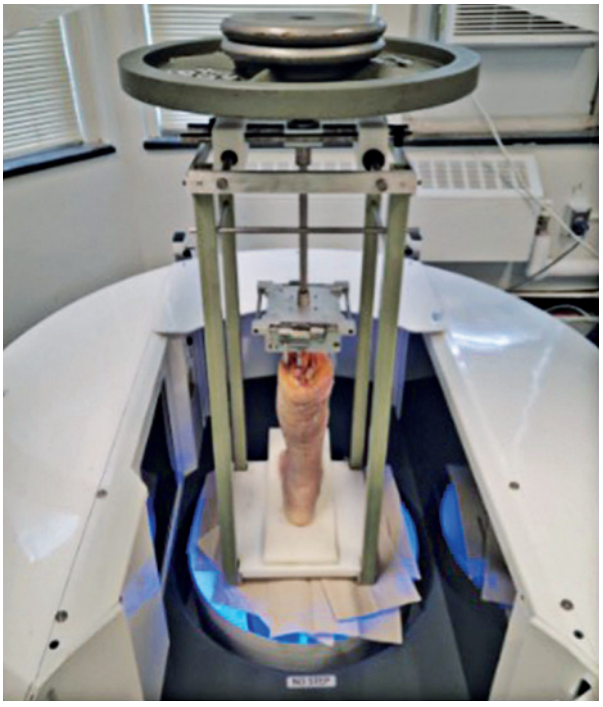

**Figure 1.** WBCT scanner and radiolucent external frame, which holds the leg in the simulated weight-bearing position.

Measurements performed in articular areas were defined as the distance along the normal direction of vectors projected from the tibial subchondral surface to the opposing surfaces of the talus or distal fibula, as previously described[19,20]. Distances in the syndesmosis were defined along the averaged normal direction between the fibula and tibia.

Color-Coded maps were then created to facilitate the interpretation of distance maps results. For each one of the WBCT scans (before and after syndesmotic ligament sectioning), the distances between the tibia and fibula were color-coded with small distances (0-5 mm) ranging from dark to light blue, and larger distances (6-10 mm) ranging from green to dark yellow and then light yellow. The comparative assessment between pre-injury to post-syndesmotic ligament sectioning utilized then a different set of color-coded maps (post-injury minus pre-injury state). When the post-injury unstable state demonstrated relative widening of the syndesmotic space when compared to the pre-injury state, red color was utilized to depict widening. White colored maps demonstrated similar syndesmotic distances before and after syndesmotic destabilization, and blue color depicted decreased and closer relative distances between the tibia and the fibula when comparing post and pre syndesmotic injury.

### Volumetric and area analyses

Automated volumetric and area measurements of the distal tibiofibular syndesmosis at 1cm, 3cm, and 5cm from the tibiotalar joint (apex of the distal tibia articular dome) were performed (Figure 3).

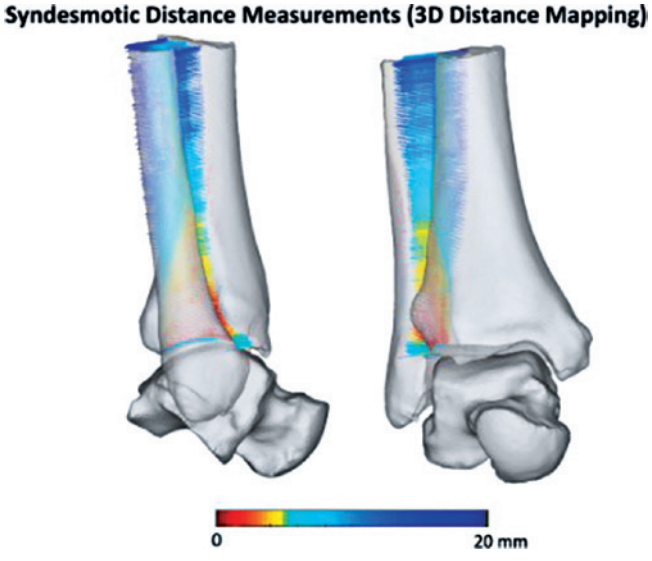


**Figure 2.** Three-Dimensional distance measurements (distance mapping) of the tibiofibular relationships.

## Results

We found overall increases in the mean syndesmotic distances between the distal tibia an fibula in the injured unstable state when compared to the native pre-injury state. Qualitatively, these changes were visually apparent in comparison distance maps (Figure 4), with diffuse red colors

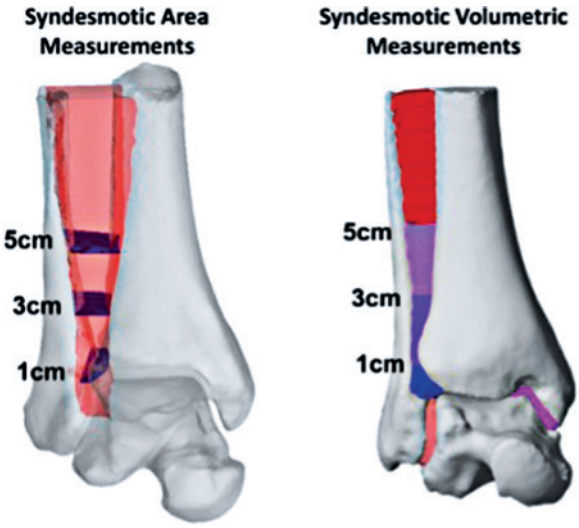


**Figure 3.** Three-Dimensional graphical representation of area (left) and volumetric (right) measurements of syndesmotic relationship at 1, 3, 5cm proximally to the ankle joint line.

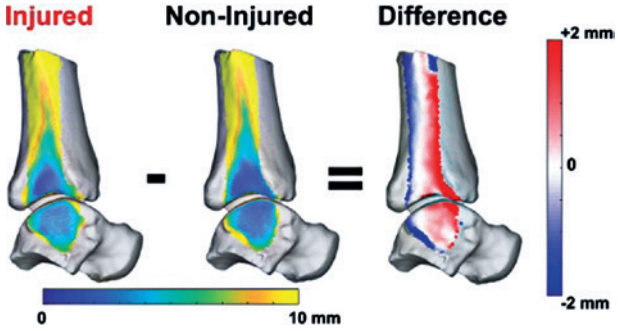


**Figure 4.** Distance mapping of the injured state (left), uninjured state (middle), and the difference between the injured and uninjured (right). Relative widening in the injured condition (red), narrowing (blue) and no relative change (white). Small distances (0-5mm) ranging from dark to light blue, and larger distances (6-10mm) ranging from green to dark yellow and then light yellow (first two images). In the comparative assessment between post--injury minus pre-injury state (third image), red color was utilized to depict widening, white color demonstrated similar syndesmotic distances, and blue color depicted decreased and closer relative distances between the tibia and the fibula when comparing post and pre syndesmotic injury.

in the comparative color-coded distance maps, particularly in the anterior aspect of the tibiofibular syndesmosis and lateral ankle gutter.

## Discussion

This cadaveric pilot study aimed to assess the capability of a WBCT 3D distance mapping algorithm in identifying syndesmotic injury and instability. The 3D WBCT distance mapping algorithm demonstrated promising diagnostic capability even in the absence of external rotation torque applied in the cadaveric specimen, shining light in the possibility of development of a non-invasive diagnostic tool to detect mild syndesmotic instability. To the author's knowledge, this was the first pilot study to utilize 3D distance mapping in the assessment of syndesmotic Instability.

The use of 3D WBCT distance mapping is an emerging technique with the intrinsic potential of assessing bone interaction in a wide range of orthopedic conditions[14,15,21]. Dibbern et al.[20] used the technology to exhibit differences in peritalar subluxation in patients with progressive collapsing foot deformity and controls (decreased middle facet coverage: 46.6%, p<0.001, increase sinus tarsi coverage: 98.0%, p<0.007). When evaluating cavovarus deformities, Lintz et al.[15] used WBCT distance mapping to objectively represent several positional changes in the diseased population, such as the ankle, subtalar, midtarsal, and tarsometatarsal joints. Fibular malpositioning in subtle syndesmotic instability can be in the range of the tenth of the millimeters, making it impossible for conventional, manual, and isolated measurements to make accurate diagnosis[3,8,22]. Given this, and considering all the challenges of a reliable clinical diagnosis, this new technology can hopefully provide ground-breaking and accurate assessment of these extremely challenging and unforgiving injury[23,24]. Additional full study with larger number of cadaveric specimens as well as clinical applicability of this 3D WBCT distance mapping algorithm will follow.

## Conclusion

In this cadaveric pilot study, we described a novel 3D WBCT distance mapping protocol to detect the relative positioning of the distal fibula and tibia, aiming to develop an accurate diagnostic tool to detect subtle syndesmotic instability, in the absence of external ration torque application. The color-coded 3D distance maps acquired allowed for a relatively simple interpretation of syndesmotic distances, particularly in the comparative pre- and post-injury analysis, that could allow for detection of subtle syndesmotic instability by means of visual interpretation of the distance maps. This technology could be applied to a comparison between injured versus contralateral control side in a clinical scenario of potential subtle syndesmotic instability. Additional large scale cadaveric and clinical studies are needed to establish the role of WBCT 3D distance mapping in the diagnosis and management of ankle syndesmotic instability.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: KD *(https://orcid.org/0000-0002-8061-4453), and GT *(https://orcid.org/0000-0002-0018-6410) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; ES *(https://orchid.org/0000-0002-6922-5238) Data collection and interpreted the results of the study, and approved the final version; VM *(https://orcid.org/0000-0002-8612-5941), and RJ *(https://orcid.org/0000-0003-3448-1300), and MJ *(https://orcid.org/0000-0003-0773-7286), and HS *(https://orcid.org/0000-0003-2664-0762), and AB *(https://orcid.org/ 0000-0002-4588-9291), and KCK *(https://orcid.org/0000-0002-3731-8448) Data collection and interpreted the results of the study; KAMC *(https://orcid.org/0000-0003-1082-6490) Interpreted the results of the study, participated in the review process and approved the final version; NSBM *(https://orcid.org/0000-0003-1067-727X) Interpreted the results of the study and approved the final version; CCN *(https://orcid.org/0000-0001-6037-0685) Interpreted the results of the study and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID)

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## Original Article

# Hindfoot arthroscopy management of flexor hallucis longus tenosynovitis: 24-month outcomes

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2. Hospital General Dr. Manuel Gea Gonzalez, Ciudad de Mexico, Mexico.

## Abstract

**Objective:** We present a series of patients with flexor hallucis longus tenosynovitis submitted to hindfoot endoscopy, describing clinical outcomes and reporting surgical findings and complications seen throughout the treatment.

**Methods:** Thirty-one patients diagnosed with flexor hallucis longus tenosynovitis submitted to posterior ankle endoscopy were followed. The mean follow-up was 24 months. Patients were classified according to American Orthopaedic Foot and Ankle Society (AOFAS) and Visual Analogue Scale (VAS) scores. Patient satisfaction was measured.

**Results:** The mean age of patients was 35.13 (± 10.68) years. The VAS score improved from 7.16 preoperatively to 2.16 in postoperative follow-up. The AOFAS score improved from 76.39 (± 5.06) preoperatively to 97.10 (± 3.78) in postoperative follow-up. Patients were able to return to sports activities at the same level as before surgery by a mean of 4.6 (± 1.27) months. One of our patients developed a complication of wound erythema in a portal, which resolved without additional treatment.

**Conclusion:** The diagnosis of flexor hallucis longus tenosynovitis is commonly associated with a large Stieda process or os trigonum impingement, limiting participation in sports activities. In our series, the endoscopic procedure showed good results in treating this condition, promoting a swift return to sports activities. Patients further presented a good postoperative recovery with few complications.

**Level of Evidence IV; Therapeutics Studies; Cases Series.**

**Keywords:** Arthroscopy/methods; Tenosynovitis; Treatment outcome.

## Introduction

Conflict between bony and capsular ligament structures in the posterior aspect of the ankle can often lead to chronic pain, worsened by overuse in repetitive plantar flexion movements[1,2]. A Stieda process or an os trigonum may cause this impingement, which can also be due to edema of the flexor hallucis longus (FHL). In most cases, posterior impingement affects patients who perform repetitive and forceful plantar flexion, such as dancers, football players, gymnasts, and runners[3,4].

Os trigonum is present in 3% to 15% of patients with posterior ankle pain. Though plain radiographs are useful in the diagnosis of posterior ankle impingement, plain magnetic resonance imaging (MRI) is the most useful non-invasive diagnostic tool[5], as it detects fluid in the FHL tendon sheath, partial ruptures or adjacent inflammatory processes[6].

Conservative treatment is the first line of attack, with a success rate between 13% and 64%[7,8]. Open surgical techniques can be beneficial for treating the impingement in cases where conservative treatment is unsuccessful, or there is a pathology recurrence[9,10]. Endoscopic treatment is sought by athletes seeking shorter recovery times and maximal improvement as an alternative to open surgery procedures. It has also shown a lower incidence of complications making it appealing to surgeons[11-14].

The purpose of this study is to report the outcomes of posterior endoscopy of the ankle in a series of 31 patients with FHL tenosynovitis. We report functional results similar to those previously reported in the literature with open techniques[1] offering a quick return to sports activities and a low complication rate.

Study performed at the Hospital Medica Sur, Ciudad de Mexico, Mexico.

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## Methods

This is a retrospective, observational, case-series study. Medical records of 31 patients submitted to posterior endoscopy of the ankle between 2014 and 2017 due to a diagnosis of FHL tenosynovitis were reviewed.

All patients had a preoperative evaluation. During this evaluation, pain in the medial retromalleolar region was reported by 96.8% of our patients. Pain increased when ankle plantar flexion was sustained and flexion of the hallux was performed. The following auxiliary tools corroborated the pathology: a plain radiograph with or without a Stieda process or an os trigonum, an MRI showing signs of FHL tenosynovitis, presence of Stieda process or os trigonum, or synovial hypertrophy. All patients received medical treatment for at least three months before surgery, which consisted of physical therapy, reduction of sports activities, and a course of non-steroidal anti-inflammatories. All medical records in our series had at least a preoperative and a postoperative evaluation at 24 months from surgery. We did not include medical records of patients who did not complete the follow-up period or had a history of previous ankle surgery. The evaluation was based on functional scales and patient satisfaction. All medical records included an American Orthopaedic Foot and Ankle Society (AOFAS)[15] score, a satisfaction score using the Likert scale[16], and a pain score using the Visual Analogue Scale (VAS) for each patient. The AOFAS score consisted of excellent result (100-91 points), good result (90-81 points), regular result (80-61 points), and bad result (<60 points).

### Surgical Technique

The procedure was performed with antibiotic prophylaxis under regional anesthesia and ischemia. Patients were placed in ventral decubitus position, assuring ankle mobility (Figure 1A).

Endoscopy portals and procedures popularized by van Dijk[17] were followed (Figure 1B). All surgeries were performed using a 4.0 mm arthroscope and conventional arthroscopic instruments. The scope was introduced through the lateral portal and the shaver, through the medial portal.

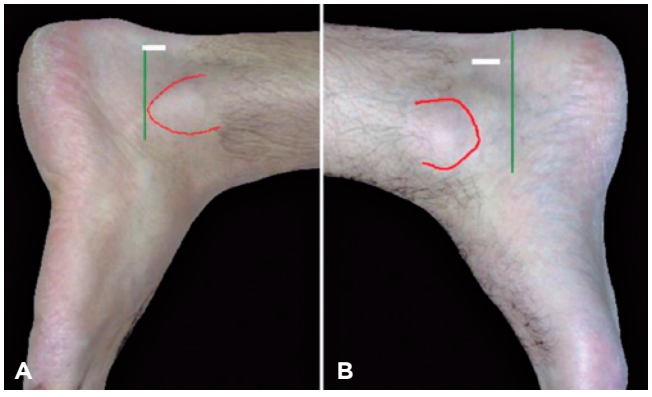


**Figure 1.** Portals. A) Lateral view. B) Medial view.

The first step of the surgery was to identify the FHL and ensure that it moved freely by flexing and extending the hallux. If a posterior process or an os trigonum was thought to cause the impingement, it was removed. Where the impingement was caused by an inferior muscular insertion of the FHL, the exceeding muscle was removed with radiofrequency (Figure 2A-C). Once these procedures were completed, it was checked again for any conflict by moving the ankle and the hallux.

### Postoperative Care

Immobilization was ensured during the early postoperative phase with controlled ankle movement (CAM) walker boots, with immediate weight bearing for ten days. After immobilization, a rehabilitation program was assigned to patients for six weeks to restore mobility, reinforce muscle strength, and improve the ankle range of motion. Patients were advised to return to sports training around the seventh week after surgery.

### Statistical Analysis

Statistical analysis was performed using the SPSS software version 19 (IBM corp released 2010 IBM SPSS Statistics for windows version 19.0 Armonk, NY : IBM Corp.). Descriptive analysis was performed using measures of dispersion and central tendency for continuous variables and frequencies for categorical variables. Difference between means of continuous variables was measured with paired student t-test. The statistical significance level was set at <0.05.

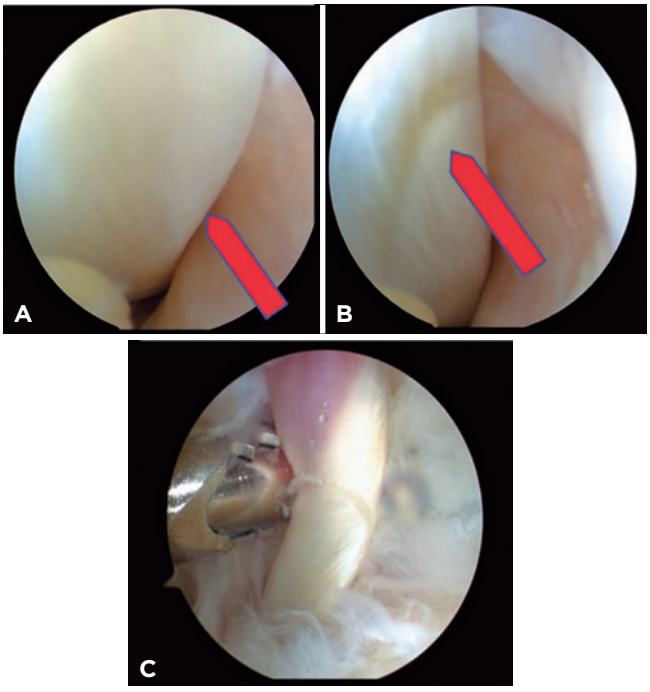


**Figure 2.** Surgical findings. A) Bony conflict. B) Stenosing FHL. C) Low muscle insertion.

## Results

The study included 31 patients with a mean age of 35.13 years. The mean follow-up was 24 months after surgery.

The competitive, leisure, active, and sedentary (CLAS) level was used to determine the sports activity level of our patients (Table 1). Out of 23 patients who practiced sports, 19 returned to some level of sports activities by the seventh week after surgery. After surgery, all patients returned to regular sports activities with a mean of 4.5 months (± 1.27).

Preoperatively, 96.8% of the patients presented pain posterior to the medial malleolus, and 24 (77.4%) presented a positive FHL sign. The AOFAS and VAS pain scales were used to evaluate function and pain preoperatively and postoperatively; preoperative and final follow-up results are shown in Table 2. The Mann-Whitney test was performed on these values and a statistical difference (p<0.001) was found between the preoperative evaluation and the final evaluation in the VAS pain score and the AOFAS scores.

Surgical findings were reported as follows: 20 cases with FHL tenosynovitis, 20 cases with an os trigonum, six cases with fibrotic bands in the posterior medial region mainly five cases with low insertion of the muscle, and three cases with a hypertrophic talar process (Stieda process).

Osteochondral lesions were found in all patients. Lesions were classified according to the Outerbridge classification (Table 3): Grade I in 24 cases (77.4%), Grade II in six cases (19.4%), and Grade III in one case (3.2%).

**Table 1.** Baseline characteristics of patients undergoing posterior ankle endoscopy

| | n | % |
|---|---|---|
| Age | | |
| <35.1 | 15 | 48.39 |
| >35.1 | 16 | 51.61 |
| Sex | | |
| Male | 21 | 67.74 |
| Female | 10 | 32.26 |
| CLAS | | |
| C: Competition | 10 | 32.26 |
| L: Leisure | 11 | 35.49 |
| A: Active | 2 | 6.45 |
| S: Sedentary | 8 | 25.8 |
| Comorbidities | | |
| No | 22 | 70.97 |
| Systemic | 2 | 6.45 |
| Musculoskeletal | 7 | 22.58 |

**Table 2.** Difference in the AOFAS and VAS pain score pre-and post-posterior ankle endoscopy

| | Preoperative | Final follow-up | t-value | p-value |
|---|---|---|---|---|
| **AOFAS** | 76.38 ± 5.29 | 97.09 ± 3.96 | 5.65 | <0.00001 |
| **VAS** | 7.16 ± 3.53 | 2.16 ± 2.46 | 4.97 | <0.00001 |

By the final follow-up, 81.9% of the patients ranked their satisfaction with the procedure as very good or excellent.

No complications were observed in 30 patients (96.8%); one case (3.2%) presented erythema surrounding the wounds, which healed before the second week without further medical intervention.

## Discussion

The presence of an os trigonum is a potential factor for developing pain in the posterior and posterior-lateral ankle region. This is more relevant in patients who practice sports where a repetitive plantar flexion is performed.

Good results have been reported in open surgical techniques to treat posterior ankle pain, like in Abramowitz et al.[18], who report an improvement from 51.7 to 87.6 points in the AOFAS scale, but report a complication rate of 24%.

This series shows an improvement in the AOFAS functional scale from 76.38 points preoperatively to 97.09 points at the last follow-up. The results are consistent with other reports of endoscopic techniques in the literature. In addition, a good improvement in the AOFAS scale, a high personal satisfaction rate after surgery, and a low percentage of reported complications[5,11,15,19].

Lopez Valerio[20] analyzed VAS pain scores in 20 professional football players and reported an improvement from 7.5 points preoperatively to 0.8 points postoperatively. In his report, the mean time to return to sports activity was 46.7 days. The VAS pain scale improved in our series from 7.16 points preoperatively to 2.16 points in the last follow-up. In this study, the mean time to return to sports activity was seven weeks, which is compatible with that reported by Ahn et al.[10] and López Valerio[20].

In a series of 189 cases with posterior endoscopic treatment, Nickisch et al.[12] reported a complication rate of 8.5%, mainly due to sural nerve dysesthesia, complex regional pain syndrome, Achilles tendon tightness, and infection of a cyst in the portal.

**Table 3.** Surgical findings in patients submitted to posterior ankle endoscopy

| | n | % |
|---|---|---|
| Soft tissue | | |
| Tenosynovitis | 20 | 64.51 |
| Fibrosis | 6 | 19.35 |
| Low muscular insertion | 5 | 16.13 |
| Bone | | |
| Os trigonum | 20 | 64.51 |
| Free body | 2 | 6.45 |
| Chondral lesion | | |
| Grade I | 24 | 77.4 |
| Grade II | 6 | 19.4 |
| Grade II | 1 | 3.2 |
| Grade IV | 0 | 0 |

In other series of endoscopic procedures, a complication rate of 5% to 8.6% has been reported[11,13,14,19,21], while a 10% to 24% complication rate has been reported in open surgery series. In these series, the most commonly reported complications are: retractile scare, sural nerve dysesthesia, infection, complex regional pain syndrome, fibrosis, and Achilles tendon tightness[6,9,22]. In this series, only one patient had a complication (erythema at the site of a portal) that did not require additional treatment. No sural nerve lesions or other wound complications were found.

The limitations of this case series are the small sample and the lack of control cases. The strength of this case series is the 24-month follow-up. The retrospective, observational methodology allowed us to evaluate the extent of recovery over time and assess its continuity.

## Conclusion

Posterior endoscopy of the ankle through the posterior classical portals is a safe and reproducible procedure. It provides adequate visualization of structures to enable the surgeon to treat lesions completely. This endoscopic procedure offers reduced complications compared to open surgery.

In this case series, the time to return to previous sports activity was 4.5 months after surgery. We believe that endoscopic treatment of posterior ankle impingement offers adequate solutions to patients, especially the active ones seeking reduced recovery times.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: ACA *(https://orcid.org/0000-0002-6129-954X) Conceived and planned the activities that led to the study, participated in the review process, bibliographic review, formatting of the article; ACKM *(https://orcid.org/0000-0003-2457-9654) Participated in the review process, data collection, statistical analysis, bibliographic review, formatting of the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Forefoot width correction in patients with hallux valgus after rotational scarf osteotomy

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## Abstract

**Objective:** Our objective was to compare foot width (bony and soft tissues) in radiological images pre- vs. post-corrective scarf osteotomy in patients with hallux valgus.

**Methods:** We retrospectively performed measurements of forefoot width (both bony diameter and total diameter including soft tissues) on anterior-posterior standard radiographs of 30 patients, totaling 42 feet, pre- and postoperatively, at three months. These measurements were performed by two evaluators and their reliability was calculated.

**Results:** Radiologically, preoperative mean of the 1-5 metatarsal bony width was 89.30mm (SD ± 5.8), reduced to 80.42mm postoperatively (SD ± 3.5; p<0.001). Regarding the soft tissue width, preoperative mean was 102.45mm (SD ± 6.4) and postoperative, 98.3mm (SD ± 5.1; p<0.001). The interclass correlation coefficient between both observers was excellent in most measurements (range, 0.884-0.973).

**Conclusion:** We report an objective reduction in forefoot width, in both bony and soft tissue diameter, finding means of 8.88 mm (10%) and 4.12mm (4.1%), respectively, after scarf-Akin osteotomy.

**Level of Evidence IV; Case Series.**

**Keywords:** Forefoot, human; Hallux valgus; Osteotomy.

## Introduction

Hallux valgus is a progressive deformity represented by a valgus deviation of the hallux, a medial deviation of the first metatarsal, and pronation of the longitudinal axis of the metatarsal, being clinically characterized by an increase in forefoot width[1,2]. This pathology affects 2 to 4% of the general population, with a higher prevalence in females and adults[3].

For the patient, the most important concerns regarding hallux valgus postoperative outcomes are: to reduce pain over the bunion, improve walking, and restore the unrestricted ability to wear a range of shoe fashions. The physiological goal of hallux valgus corrective surgery is to perform a morphological correction of the foot by realigning the first ray, thus achieving pain relief for the patient by reducing friction between bony prominences and regular footwear. This should not only aim to improve radiographic measurements, but also prioritize comfort, since it plays an important role in the success of the surgery and patient satisfaction[4]. Medical objectives are often not necessarily aligned with patient expectations, resulting in a high percentage (25-33%) of patients who remain dissatisfied, even when radiological results are those desired by the surgeon. This is directly related to the impossibility of wearing a smaller shoe size or pointed shoes[1,2,5,6]: only 41-62% of patients can wear shoes with high and narrow heels after hallux valgus surgery[7].

A quick, simple method to better correlate medical objectives with patient satisfaction would be to measure the forefoot width[8]. The relevance of this study lies in elucidating if a metatarsal osteotomy, such as a scarf osteotomy, would decrease forefoot width, as a decrease in this measure represents a predictor of comfort in meeting patient expectations[5,9].

Study performed at the Clínica Universidad de los Andes, Santiago, Chile.

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Scarf osteotomy is one of the most popular techniques to correct hallux valgus, its main advantage being the great lateral translation of the diaphysis, which enables the correction of large deformities, preservation of joint congruence, and metatarsophalangeal (MTP) mobility, further allowing the metatarsal to descend and its length to be controlled, associated with a rigid and stable compression at the osteotomy site[10,11]. Its results are very predictable and it also makes it possible to perform corrections in both the axial and coronal planes[10,12-14].

Our objective was to compare foot width (bony and soft tissues) in radiological images pre- vs. post-corrective scarf osteotomy in patients with hallux valgus.

Our hypothesis predicts an objective reduction in forefoot width after scarf osteotomy, different from that seen in the previous literature, where no significant reduction in foot width is reported[15].

## Methods

We performed a comparative retrospective study where forefoot width (bony and soft tissue) was radiographically measured by two evaluators (A.B. and F.M.) using the Enterprise Imaging XERO Viewer 8.1.2 (Agfa HealthCare N.V., Mortsel, Belgium) in patients who underwent scarf osteotomy for hallux valgus from May 2018 to June 2019 in procedures performed by two independent fellowship-trained foot and ankle surgeons with over 20 years' experience. All patients gave their informed consent, and our institutional review board approved the study. Bony foot width (BW) was measured on anterior-posterior (AP) weight-bearing radiographs of the foot, by recording the maximal distance from the medial border of the first metatarsal head to the lateral border of the fifth metatarsal head, as previously described by Jung et al.[4]. Forefoot soft tissue width (STW) was measured from the most medial soft tissue shadow to the most lateral soft tissue shadow, bisecting the level of the first metatarsal head. Both BW and STW measurements were made pre- and postoperatively, at three months (Figure 1).

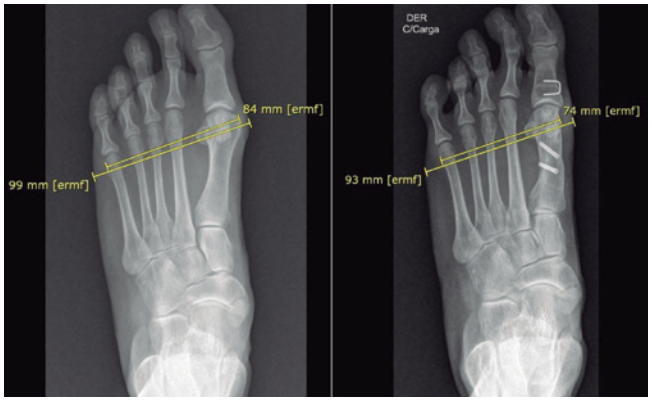


**Figure 1.** Pre-(left) and postoperative (at three months, right) measurements of bony foot width (BW) and forefoot soft tissue width (STW) on anterior-posterior weight-bearing radiographs of the foot.

Although these measurements were not calibrated, they were recorded by radiology technicians exclusively assigned to foot and ankle pathologies in a consistent manner.

Inclusion criteria were patients older than 18 years treated with scarf osteotomy for hallux valgus having weight-bearing AP radiographs pre- and postoperatively, at three months. Exclusion criteria were patients with additional surgery on the fifth metatarsal or lesser metatarsal, use of a different technique for the correction of hallux valgus, musculoskeletal inflammatory diseases, neurovascular deficits, history of previous foot and ankle surgery on the same foot, active local infection, radiological signs of MTP osteoarthritis, and hallux valgus associated with another acquired deformity, such as progressive collapsing foot deformity, pes cavus etc. As additional procedures, such as hammertoes correction, could eventually affect outcomes, especially soft tissue forefoot width, we looked for any association.

During the target time frame for our study, 81 hallux valgus surgeries were performed. Of these, 39 feet were excluded due to the use of non-scarf osteotomy or for requiring further corrective surgeries for the fifth metatarsal.

### Surgical technique

Preoperative planning should include the length of the osteotomy, the direction of the transverse cuts, and the amount of translation depending on the severity of the deformity to be corrected.

Under tight tourniquet and regional ankle anesthesia, we performed a longitudinal incision over the shaft of the first metatarsal extending to the mid-proximal phalanx, followed by blunt dissection, capsulotomy, and subperiosteal dissection. At this stage, a bunionectomy provided a flat surface on which to perform the scarf osteotomy. The distal transverse cut was aimed at the junction of the dorsal one-third with the plantar two-thirds of the head, 7mm proximal to the MTP joint and perpendicular to the second metatarsal if preservation of metatarsal length was desired.

The longitudinal cut was then extended. The orientation of this cut should be in a slightly plantar direction to marginally lower the metatarsal. The proximal transverse cut was made between the dorsal two-thirds and the plantar one-third of the diaphysis, parallel to the distal cut (Figure 2).

Using an elevator, the osteotomy was traversed to release the periosteum and perform lateral soft tissue release.

The desired lateral translation was made and fixed with two screws. Finally, a resection of the medial overhang of the osteotomy was performed.

Akin osteotomy was performed in accordance with the clinical discretion of the surgeons responsible when residual interphalangeal hallux valgus was present after appropriate hallux valgus angle (HVA) and intermetatarsal angle (IMA) correction.

Rotational deformity (if existent) was always corrected by supination of the first metatarsal to the point at which the sesamoids were hidden behind the first metatarsal head and its square shape.

Postoperatively, feet were placed in a rigid shoe for three weeks, allowing for partial weight bearing with two crutches. Sutures were removed at two weeks and patient transitioned to comfortable shoes as tolerated.

### Statistical analysis

Data was first descriptively analyzed using measures of central tendency (means, modes, and percentages for demographic variables).

A comparative descriptive analysis of results obtained in bone and soft tissue radiological images was performed.

Distribution of data (normal/abnormal) was analyzed according to the Shapiro-Wilk test, and if normal, parametric analysis (*t*-test) was performed. If not normal, non-parametric analysis (Wilcoxon test) was utilized to establish differences between the means of each measurement.

Interclass correlation coefficients (ICC) were calculated in order to look for inter-observer agreement. In case of good or excellent ICC, the average was used, and in case of moderate or poor ICC, the measurements recorded by evaluator No. 2 were used (Table 1).

A Pearson test was performed to determine which variables demonstrated an inter-variable correlation.

Linear regression analysis was performed to calculate the predictive value of postoperative variables over the preoperative ones.

With the resulting size effect values, a post hoc analysis was carried out to establish the statistical power of results. IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY IBM Corp. was used.

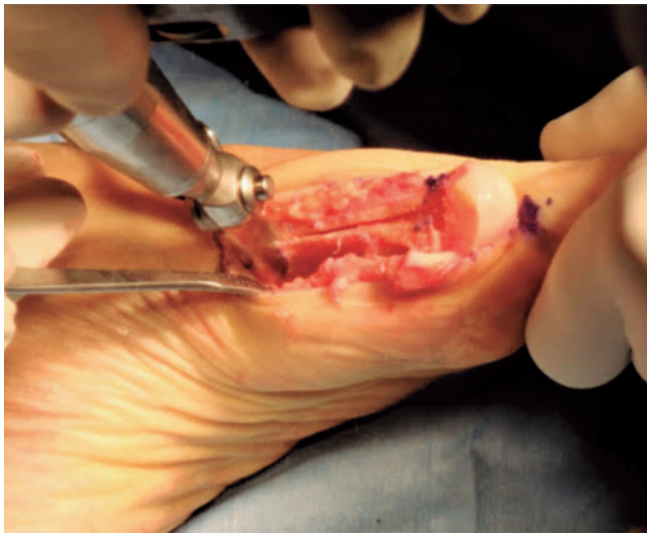

**Figure 2.** Extension of the longitudinal and proximal transverse cuts made between the dorsal two-thirds with the plantar one-third of the diaphysis parallel to the distal cut.

## Results

Thirty patients met the inclusion criteria and underwent corrective surgery for hallux valgus using rotational scarf-Akin osteotomy in all cases, with a total of 42 feet (23 left feet, 19 right feet) included.

Demographic data are summarized in table 2.

The analysis demonstrated excellent ICC between evaluators in preoperative BW, STW, HVA, and postoperative STW (range, 0.884-0.973) and good ICC in postoperative BW (0.784). With these variables, analyses were performed using the average between both evaluators.

Pre- and postoperative mean values and standard deviation (SD) are summarized in table 3, with statistical significance between preoperative and postoperative measurements in all cases (p<0.001).

**Table 1.** Interclass correlation coefficient between both observers

| ICC | Preoperative Mean (95% CI) | Postoperative Mean (95% CI) |
|---|---|---|
| STW | 0.973 (0.95–0.986)* | 0.884 (0.784–0.938)* |
| BW | 0.966 (0.937–0.982)* | 0.784 (0.599–0.884)* |
| IMA | 0.726 (0.491–0.583) | 0.479 (0.03–0.72) |
| HVA | 0.907 (0.827–0.95)* | 0.692 (0.427–0.834) |

ICC: interclass correlation coefficient; CI: confidence interval; BW: bony width; STW: soft tissue width; IMA: intermetatarsal angle; HVA: hallux valgus angle. Measures marked with an asterisk were 'excellent' or 'good' and analyses were performed using the average between both evaluators.

**Table 2.** Demographic data (N=42)

| Variable | N (%) |
|---|---|
| Sex | |
| Male | 1 (2.4%) |
| Female | 41 (97.6%) |
| Age | |
| Years | 52.9 (range 22–74) |
| Side | |
| Right | 19 (45.2%) |
| Left | 23 (54.8%) |
| Hammertoes | |
| Yes | 6 (14.3%) |
| No | 36 (85.7%) |

**Table 3.** Pre-and postoperative mean values and standard deviation

| Average measurements (N=42) | Mean (SD) (p<0.001) |
|---|---|
| Bony width | |
| Preoperative | 89.30mm (5.89) |
| Postoperative | 80.42mm (3.55) |
| Soft Tissue width | |
| Preoperative | 102.45mm (6.48) |
| Postoperative | 98.33mm (5.12) |
| IMA | |
| Preoperative (Evaluator No 2) | 13.01° (2.67) |
| Postoperative (Evaluator No. 2) | 7.25° (3.07) |
| HVA | |
| Preoperative | 20.8° (6.48) |
| Postoperative (Evaluator No. 2) | 10.7° (5.56) |

SD: standard deviation; IMA: intermetatarsal angle; HVA: hallux valgus angle.

A t-test was performed on preoperative vs. postoperative BW, STW, and IMA measurements. Wilcoxon test was performed on the HVA preoperative vs. postoperative measurements. Ordinal regression analysis was performed to evaluate the predictive value of hammertoe correction when performed in the same surgical procedure as hallux valgus correction and its effect on the forefoot width, and no significant predictive value was found.

Values obtained had a significance of p<0.001; values were considered statistically significant only when p<0.05. We made a post hoc analysis where the power of the study was calculated and, with the sample of 42 feet, a power of p=0.87 was achieved, validating our sample as sufficient.

The linear regression analysis performed to demonstrate predictive value by comparing the different pre- vs. postoperative variables yielded the results summarized in table 4, only reporting those with statistically significant differences (p<0.05).

## Discussion

In theory, a successful hallux valgus correction surgery is achieved according to radiological parameters. Based on this concept and in our results, we were allowed to interpret that, after scarf osteotomy, the forefoot BW and STW widths could be reduced.

The greatest expectation of a patient after hallux valgus correction is to have a painless great toe able to fit into conventional shoes[16,17]. This has a direct correlation with and could be the best predictor of good results[16-18]. The severity of the deformity or the correction of radiographic measurements (HVA/IMA), alone, does not necessarily have a direct correlation with an improvement in functional scores[6,19]. Axt et al.[20] reported a 90% satisfaction among patients after Keller-Brandes operation for hallux valgus, despite 23% of the feet remaining with an altered HVA of more than 30 degrees[20]. It is possible to conclude that the ability to have a choice in footwear, unrestricted by deformity, had a positive effect on quality of life, and that is the reason why we wanted to demonstrate that, after scarf osteotomy, the decrease in forefoot width may represent the mean difference between a wide and medium shoe width size[2].

Forefoot width is a useful, objective measure of patient postoperative expectations. Tenenbaum et al.[15] previously reported a decrease in BW and STW by 5% and 2%, respectively, after scarf-Akin osteotomy and soft tissue release. However, unlike our results, in 36% of feet, the forefoot width did not change, while in 18% it increased (>5%); in our study, we demonstrated forefoot reduction in all patients. These authors concluded that patients with wider feet tended to achieve foot narrowing, while those with narrower feet had a forefoot width increase postoperatively[15].

After linear regression analysis, we were able to predict that, in a considerable percentage of cases (41.6% for BW and 59.6% for STW; p<0.001), values followed a direct correlation pattern. The wider the feet preoperatively, the wider it remained within the postoperative cohort, despite the forefoot width reduction after surgery. The same correlation for narrower feet was observed.

Similar to our results, Jung et al.[4] reported a foot width (1-5 metatarsal width) decrease of 16%, from 97.3mm to 81.3mm (mean 16mm; p<0.001) after proximal reverse chevron osteotomy associated with lateral soft tissue and Akin osteotomy on 117 feet with 14.2 months of follow-up (range, 12-25). They achieved an IMA reduction from 19 degrees (range, 9-28) to 4.5 degrees (range, -5-14.2) and an HVA reduction from 36.1 degrees (range, 16-44) to 5.4 degrees (range, -12.4-29.7)[4]. Our measurements after scarf osteotomy showed an 8.88 mm (10%) and 4.12 mm (4.1%) reduction in BW and STW, respectively. We also achieved a reduction of 5.85 degrees in IMA and 10.1 degrees in HVA.

Panchbhavi et al.[21] measured pre- and postoperative metatarsal span after chevron-Akin surgery in 52 patients, finding an 8.7mm mean reduction. This group reported no correlation between HVA and IMA correction according to metatarsal bony span. Conti et al.[8] reported a statistically significant BW reduction of 8.9mm (radiographic measurement) and 7.9mm (weight-bearing computed tomography-WBCT measurement) (p<0.001), as well as a STW of 6.9 mm (radiograph) and 6.7mm (WBCT) (p<0.001) at five months in 31 patients after a modified Lapidus, McBride, and Akin osteotomy[8]. These authors also reported a poor correlation between correction of HVA, IMA, and distal metatarsal articular angle (DMAA) and foot width reduction at the final follow-up. These results are similar to ours, since we did not find any correlation between IMA and HVA and forefoot width after scarf osteotomy (<0.3).

The present investigation has limitations. Despite having the capability to evaluate the use of WBCT within our possibilities, we did not consider WBCT measurements would offer

**Table 4.** Predictive value

| | BW PostOp | STW PostOp (Evaluator No. 2) | IMA PostOp (Evaluator No. 2) |
|---|---|---|---|
| BW PreOp | *41.6% (p<0.001) | *58.4% (p<0.001) | - |
| STW PreOp | *38.8% (p<0.001) | *59.6% (p<0.001) | - |
| IMA PreOp (Ev. No. 2) | 43.8% (p=0.033) | 58.9% (p=0.048) | 43.7% (p=0.013) |
| HVA PreOp | - | 31.9% (p=0.008) | - |

BW: bony width; STW: soft tissue width; IMA: intermetatarsal angle; HVA: hallux valgus angle; PreOp: preoperatively; PostOp: postoperatively. *Statistical significance between preoperative and postoperative measurements (p<0.001).

a greater precision or relevance according to our objective because our measures were unidimensional (HVA and IMA). As shown, HVA and IMA radiographic measurements are not significantly different from those obtained with WBCT[22]. On the other hand, radiographic measurements provide a greater reproducibility and external validity to our study. Another limitation to consider is that our measurement of forefoot width was always recorded using the same anatomical landmark (most medial point of first metatarsal head), which, due to potential anatomical variations among patients, might not have always been the widest point of the foot, especially after resection of the medial eminence.

Another limitation is the small sample size and the retrospective nature of this study; however, all data were obtained from a prospectively collected foot and ankle registry reviewed for consecutive patients from May 2018 to July 2019.

Finally, soft tissue width was measured according to the breadth of the foot in the radiograph. It could be more precise to make this measurement clinically, using the perimeter of the foot and a tape measure, resulting in a value closer to the actual forefoot width. Also, edema may still be present after three months of surgery, which certainly increased the STW; it may be a short postoperative time.

## Conclusion

Through scarf osteotomy, we were able to demonstrate that an objective forefoot width reduction is possible and may help patients on fitting more comfortable shoes.

**Author's contributions:** Each author contributed individually and significantly to the development of this article: FMZ *(https://orcid.org/0000-0002-6520-9775) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, data collection, statistical analysis, approved the final version; AIB *(https://orcid.org/0000-0003-4898-4259) Interpreted the results of the study, participated in the review process and approved the final version; FCR (https://orcid.org/0000-0002-3524-0624) Conceived and planned the activities that led to the study, interpreted the results of the study, performed the surgery, data collection, interpreted the results of the study, approved the final version; MPP *(https://orcid.org/0000-0002-2820-5337) Conceived and planned the activities that led to the study, statistical analysis, bibliographic review, survey of the medical records, wrote the article, participated in the review process, formatting of the article, approved the final version; GCU *(https://orcid.org/0000-0002-1993-6250) Wrote the article, performed the surgery, participated in the reviewing process, approved the final version; COM *(https://orcid.org/0000-0003-2574-9010) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the reviewing process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID)

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Original Article

# Study of the clinical aspect of diabetic foot ulcers and its surgical management

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## Abstract

**Objective:** Diabetes is a global epidemic and a leading cause of death by disease. It is the common underlying cause of foot ulcers, infection, and ischemia, which are among the most serious complications of diabetes. This work aimed to study the clinical profile, surgical management, and outcome of patients with diabetic foot infections.

**Methods:** Prospective study recruiting patients >18 years of age with diabetic foot infections. All patients underwent a detailed history and clinical examination, being distributed as per their different sociodemographic, clinical, and foot ulcer site characteristics, with further management and evaluation.

**Results:** One hundred patients were recruited, with a mean age of 51.32±11.45 years. Majority of patients (73%) had a lower socioeconomic status. All patients had type 2 diabetes, with male predominance (78%). Mean diabetes mellitus duration was 9.68±5.03 years. Ulcer (92.31%) and discharge (72.31%) were the commonest complaints. During correlation analysis, a strong statistically significant ($p<0.001$) correlation was observed between amputation and HBA1c level (0.747) and SINBAD score (0.871), while correlation with RBS level was weak (0.532). Commonest presenting site was forefoot, followed by hindfoot.

**Conclusion:** The SINBAD score is simple to use in daily practice, being more effective in describing diabetic foot. Primary and secondary healthcare systems in developing countries have limited resources, using different approaches to manage diabetic foot care. The SINBAD system can be used as a primary screening tool. Provision of correct and convenient footwear and efficient treatment of minor injuries are recommended to downturn ulcer occurrence.

**Level of Evidence II; Prospective Study; Lesser Quality (eg, patients enrolled at different points in their disease or <80% follow-up).**

**Keywords:** Diabetic foot; Infections; Ulcer.

## Introduction

Diabetes is the biggest cause of disease-related mortality on a global scale. The International Diabetes Federation estimates that 8.8% of adults globally, or 425 million individuals, have diabetes. It has been estimated that 72.9 million people in India have diabetes, and this number is expected to increase to 134.3 million by the year 2045[1].

The three most serious consequences of diabetes-foot ulcers, infection, and ischemia-are significantly attributed to the disease. The most frequent diabetes mellitus consequence requiring hospitalization is diabetic foot infection (DFI), which is a soft tissue or bone infection just under the malleoli and the most frequent cause of non-traumatic lower extremity amputation[2].

Decreased blood supply and lack of sensation because of neuropathy leads to foot infections in diabetic individuals, which makes DFIs a common and serious problem. Such infections can emerge in a wound from trauma or from skin ulcers brought on by peripheral neuropathy. Osteomyelitis can result from an infection that often involves more than one type of germ and can spread to other surrounding tissues, including bone[3].

Study performed at the Department of General Surgery, Gandhi Medical Collage and Associated Hamidia Hospital, Bhopal (M.P.), India.

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Those with diabetes mellitus have a 15% risk of developing foot ulcer. Over two thirds of the affected population undergo lower limb amputations, with ulceration being the most frequent precursor to this[4]. When diabetes is in its advanced stages and management fails, lower extremity amputation is a disease consequence. Diabetes patients have a 15–30-fold increased risk of amputation compared to non-diabetic people. Every 30 seconds a lower limb or a portion of a lower limb is amputated as a result of diabetes somewhere around the globe[5].

Due to the high incidence of diabetes, diabetic foot occurrence is also increasing because of the increased life expectancy among affected patients. The patient or primary care physician ignorance continues to be a hurdle in improving the outcome of diabetic foot lesions. In India, situation has worsened due to habits like walking barefoot, poor awareness, hygiene issues etc.[6].

In this context, the present prospective, observational study was conducted to evaluate the various presentations of diabetic foot ulcer (DFU). We also studied different aspects of DFU management by dressing/debridement/amputation.

## Methods

A cross-sectional study with an 18-month duration was carried out among 100 patients having history of diabetes, aged above 18 years, of both genders, and diagnosed with diabetic foot. The study was conducted in the surgical department of a tertiary care center from January 2020 to June 2021. Prior to the study, approval from the ethical committee and an informed written consent from patients were obtained. Random blood sugar (RBS) and glycated hemoglobin (HbA1c) levels were checked from collected blood samples. The Site, Ischemia, Neuropathy, Bacterial Infection, and Depth (SINBAD) score classification was performed after examining the DFUs. Demographics, such as age, gender, diabetes mellitus duration, and other risk factors of foot ulcers were also noted. The mean and standard deviation for continuous variables, i.e., age, RBS level, and HbA1c level, and the frequency and percentage for categorical variables, such as distribution of age, HbA1c, gender, diabetes mellitus duration, SINBAD scores, and other risk factors of foot ulcers, were calculated. The correlation among amputation, SINBAD score, HbA1c level, and RBS level was assessed taking $p \leq 0.05$ as statistically significant.

## Result

A total of 100 patients were included in the study. All patients were aged between 18 years and >65 years. Mean age of patients was 51.32±11.45 years and the male:female ratio was 3.54:1. Maximum incidence of diabetic foot lesions was seen in the age group range of 51 to 60 years. Nearly 70% of patients belonged to the lower socioeconomic class (Table 1). Maximum duration of diabetes among the study population was 11–15 years, with a mean duration of 12.03±6.96 years. Ninety eight percent of patients had an RBS level higher than 200 mg/dL, with a mean level of 276.68 mg/dL. An HbA1C level higher than 10 mmols/mol was observed only in 8% of patients, with majority of patients presenting an HbA1C level between 8 and 9 mmols/mol (98%), while mean HbA1C level among studied population was 7.648 mmols/mol. Sixty percent of the study population had a family history of diabetes, and hypertension was a chief comorbidity reported in 32% of patients. Smoking and alcohol use history were reported in 60% and 32% of patients, respectively, while previous surgery and DFU history were reported by 12% and 14% of patients, respectively (Table 2). Out of the total 100 patients included in the study, forefoot was found to be the major ulcer site (35%). When it comes to grading, Grade 2 DFUs (28%) were predominant, followed by Grade 3 (24%), Grade 6 (20%), Grade 1 (16%), Grade 4 (6%), and Grade 5 (6%) according to the SINBAD score (Table 3). Foot ulcers were pure neuropathic in 32 cases and ischemic in 30 cases. Infection was found in approximately 75% of cases. About 94% of cases presented with ulcers with an area larger than 2 $cm^2$. Concerning depth, ulcer restricted to skin and surrounding subcutaneous tissue was observed in 74% of cases; ulcer reaching muscle and tendon, in 10% of cases; and ulcer reaching muscle and tendon and exposed bone, in 16% of cases. Table 3 shows the different management options for therapeutic treatment of patients classified according to the SINBAD score. Among surgical procedures, serial debridement and amputation was done in 32% of patients, as majority of ulcers were Grade 4 according to the SINBAD score. Below-knee amputation was performed in the majority

**Table 1.** Sociodemographic profile of study subjects

| Sociodemographic variables patients (n=100) (%) | | |
|---|---|---|
| Age group (years) | | |
| 18–25 | 2 | |
| 26–30 | 6 | |
| 31–35 | 2 | |
| 36–40 | 12 | 51.32±11.45 years |
| 41–45 | 8 | |
| 46–50 | 12 | |
| 51–55 | 20 | |
| 56–60 | 14 | |
| 61–65 | 14 | |
| >65 | 10 | |
| Sex | | |
| Male | 78 | |
| Female | 22 | |
| Socioeconomic class | | |
| Lower class | 33 | |
| Upper-lower class | 40 | |
| Lower-middle class | 23 | |
| Upper-middle class | 3 | |
| Upper class | 1 | |

**Table 2.** Characteristics of diabetic foot ulcer patients

| Characteristics of diabetic foot ulcer Patients (n=100) (%) | | |
|---|---|---|
| Diabetes duration | | |
| <5 years | 22 | |
| 5–10 years | 34 | 9.68±5.03 years |
| 11–15 years | 28 | |
| 16–20 years | 16 | |
| >20 years | 0 | |
| <5 years | 22 | |
| Smoking history | 60 | |
| Alcohol use history | 68 | |
| Previous surgery history | 12 | |
| Diabetic foot ulcer history | 14 | |
| Family history of diabetes | 54 | |
| RBS level (mg/dL) | | |
| <200 | 2 | |
| ≥200 | 98 | |
| HbA1C level (mmols/mol) | | |
| 6–8 | 77 | |
| 8–10 | 15 | |
| >10 | 8 | |

RBS: Random blood sugar; HbA1C: Glycated hemoglobin.

**Table 3.** Characteristics of foot ulcer site among the study population

| Characteristics of foot ulcer site Patients (n=100) (%) | |
|---|---|
| Foot ulcer site | |
| Forefoot | 36 |
| Forefoot and great toe | 8 |
| Hindfoot | 22 |
| Hindfoot and midfoot | 10 |
| Hindfoot, midfoot, and forefoot | 18 |
| Distal one-third of the leg and foot | 2 |
| Midfoot | 4 |
| Ischemia | 30 |
| Neuropathy | 32 |
| Bacterial infection | 74 |
| Ulcer area | |
| <1 cm | 0 |
| 1–2 cm | 6 |
| >2 cm | 94 |
| Ulcer depth | |
| Limited to skin and subcutaneous tissue | 74 |
| Limited to involvement of muscle and tendon | 10 |
| Involvement of muscle and tendon and exposed bone | 16 |
| SINBAD score | |
| Grade 1 | 16 |
| Grade 2 | 28 |
| Grade 3 | 24 |
| Grade 4 | 6 |
| Grade 5 | 6 |
| Grade 6 | 20 |

SINBAD score: Site, Ischemia, Neuropathy, Bacterial Infection, and Depth score.

of cases (24%), while ankle amputation was necessary in 6% of patients. Partial foot/transmetatarsal amputation was performed in only 2% of cases. Correlation analysis was used to determine which factors can most accurately predict the risk of outcome measures (Table 4). Strong statistically significant ($p<0.001$) correlation coefficients were observed between amputation and HBA1c level (0.747) and SINBAD score (0.871), while there was a weak correlation between amputation and RBS level (0.532). The SINBAD score showed a weak correlation with RBS level (0.578) and HbA1C level (0.571).

## Discussion

Diabetic foot ulcer is a prevalent cause of hospitalization in patients with diabetes, and is the result of several sociocultural habits in India, such as barefoot walking, insufficient diabetic treatment facilities, low education level, and poor socioeconomic status. This condition is the most common consequence of diabetes mellitus, usually not healing and resulting in lower limb amputation. However, it can be effectively managed with awareness, blood sugar management, wound debridement, advanced dressing, and treatments. In certain circumstances, surgery can diminish the severity of problems, which can enhance patients' health and quality of life, notably when a multi-disciplinary team effort is used.

Concerning age distribution in our study, among the 100 cases involved, the age of the youngest patient was 24 years and the age of the eldest patient was 71 years. The highest number of cases was found in the age group 51–55 years (20.0%). These findings were concordant with the study reported by Seth et al.[7], where majority of cases were reported in the age group 55–64 years, while being partially concordant with observations reported by Madan et al.[8] (33%), Rooh-Ul-Muqim et al.[9] (32%), and Kumar and Gupta[10] (30.9%) with the age group 51–60 years. The mean age of disease presentation in our study was 51.32±11.45 years, being comparable to that found in the study conducted by Madan et al.[8]. This age aspect might be associated with type 2 diabetes mellitus, which is often prevalent in older patients, although new findings reveal that it also affects

**Table 4.** Correlation analysis between amputation and SINBAD score and other variables (n=100)

| | | HbA1C Level | Amputation | RBS Level | SINBAD score |
|---|---|---|---|---|---|
| Amputation | Correlation coef. Significance level (p) | 0.747 <0.0001 | ---- | 0.532 <0.0001 | 0.871 <0.0001 |
| SINBAD score | Correlation coef.* Significance level (p) | 0.571 <0.0001 | 0.871 <0.0001 | 0.578 <0.0001 | ---- |

*Pearson correlation coefficient.
SINBAD score: Site, Ischemia, Neuropathy, Bacterial Infection, and Depth score; HbA1C: Glycated hemoglobin; RBS: Random blood sugar.

adolescents[11,12]. Among the 100 cases evaluated, 78 patients were male, while 22 patients were female (M:F 3.54:1), which was consistent with previous studies reported by Madan et al.[8], Mote et al.[13], and Gohel et al.[14], who reported that more male patients were affected by the condition when compared to female patients. Male patients may have a higher prevalence of diabetic foot due to injuries acquired at their workplaces and during outdoor activities. In our study, upper-lower class population was predominant, with about 40% of cases, while the population belonging to the upper class constituted only about 1% of patients. Gohel et al.[14] also reported a majority of lower class patients (57%) in their study. Duration of diabetes was 5–10 years in most patients, with a mean duration of 9.68±5.03 years; in contrast to our study, Kumar and Gupta[10] reported a duration of 1–5 years in majority. This variation may be due to a late detection of diabetes in our selected population. Alcohol use and cigarette smoking were reported by 32% and 60% of patients, respectively, which was quite comparable to the findings reported by Chalya et al.[15], where smoking habits and alcohol use were reported by 35.3% and 49.3% of patients, respectively. In our study, 54 patients (54%) had a family history of diabetes mellitus, a percentage higher than that found in the study by Kumar and Gupta (38.2%)[10]. Forefoot was found to be the major ulcer site (36%) in our studied population. Ulcer at distal one-third of the leg and foot (2%) was the least common site. Yosuf et al.[16] also found forefoot as the most common site of DFU.

Fourteen percent of patients had a past history of foot ulcers, and 12% of patients had a history of previous amputations in our study. This was partially comparable to a previous study[15] in which 10.3% of patients had a previous history of foot ulcers and 4.4% of patients had previous amputations.

Considering the distribution of ischemia, clinical evidence of reduced blood flow was observed in 30% of patients, while loss of protective sensation was found in 32% of patients during assessment of neuropathy. Ischemia and neuropathy were observed by Chalya et al.[15] in 57.4% and 30.8% of patients, respectively, which was partially comparable with results found in our study. Typically polymicrobial in nature, DFIs include anaerobes and gramme-positive and gramme-negative aerobes. Bacterial infection was noted in 74% of the population with DFU. In the study by Jasmine et al.[17], 20.4% of patients had sterile cultures, whereas they were seen only in 9.8% of patients in Bansal et al.[18]. The traditional recognition that DFI is mostly caused by *S. aureus* or gram-positive species may not reflect a universal clinical feature, and geographic variance emphasizes the need for local treatment guidelines[19]. Most of the ulcers in our study were larger than 2 $cm^2$ (94%), none of them was found smaller than 1 $cm^2$, and the mean ulcer size was 32.87 $cm^2$, while the study reported by Seth et al.[7] found a mean ulcer size of 14.85 $cm^2$. Ulcer confined to skin and subcutaneous tissue was observed in 74% of cases. About 10% of cases observed involved ulcers reaching muscle and tendon, while ulcer reaching muscle and tendon and exposed bone was observed in 16% of cases. Considering the SINBAD score, Grade 2 DFUs were predominant and Grade 5 DFUs were the least common. In the study by Venkataramana et al.[20], the majority of DFU cases reported were Grade 3, followed by grades 4, 6, 2, 5, and 1. The difference may be attributed to the variation of locality of participant settings.

Regarding the RBS level, only 2% of patients had a blood sugar level of less than 200 mg/dL, while majority (98%) of patients had a blood sugar level higher than 200 mg/dL, with a mean level of 276.68 mg/dL. With regards to diabetes control, in our study, the majority of patients had an HbA1C level of 8–9 mmols/mol (98%), which was comparable to previous findings[21] of HbA1c levels >7 (mmols/mol) in more than 82% of patients. Conservative management of ulcer was predominant (68%), and other surgical procedures were also seen, such as serial debridement and amputation (32%), with below-knee amputation (24%) being the most common and ankle amputation (6%), the least common procedure. Partial foot amputation/transmetatarsal amputation was performed in only 2% of cases. In their study, Karbhari et al.[21] performed a conservative management in two patients and below-knee amputation, in 2% of patients. Our study has higher figures due to late presentation, unawareness, and to the low socioeconomic status of participants. During correlation analysis, strong statistically significant ($p<0.001$) correlation coefficients were observed between amputation and HBA1c level (0.747) and between amputation and SINBAD score (0.871), while there was a weak correlation between amputation and RBS level (0.532). The SINBAD score showed a weak correlation with RBS level (0.578) and HbA1C level (0.571). The limitation of this study is its small sample size.

## Conclusion

Diabetic foot is a widespread condition, especially in developing countries. Effectiveness in classification systems demands quick and cost-effective treatments, which require patient compliance. The classification system used has advantages and disadvantages. Recently described, the SINBAD score is a simplified version of the S(AD)SAD system and considers size, ischemia, neuropathy, bacterial infection, area, and depth. One point is attributed to the presence of each feature, and the total score is then calculated. The SINBAD score is simple to use in daily practice and more effective in describing the disease processes for auditing purposes. Primary and secondary healthcare systems have different approaches to manage diabetic foot care. Moreover, the effective use of diagnostic tools by physicians to assess the nature and severity of diabetic foot is crucial. Simple hygienic practices, regular or at least annual foot examination, and patient education are recommended. Provision of correct and convenient footwear and efficient treatment of minor injuries can downturn ulcer occurrence.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: AS *(https://orcid.org/0000-0003-4489-2197) Conceived and planned the activities that led to the study, approved the final version; SM *(https://orcid.org/0000-0001-9542-8146) Conceived and planned the activities that led to the study, participated in the review process and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Minimally invasive surgery for lesser toe deformity: a clinical audit of a proposed treatment algorithm

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## Abstract

**Objective:** There is increasing interest in the performance of minimally invasive foot surgery (MIS); however, limited evidence and treatment algorithms are available to support its use and guide surgical decision-making. The aim of this prospective clinical audit was to report the efficacy of a treatment algorithm used to treat patients presenting with lesser toe deformities using MIS techniques.

**Methods:** A prospective clinical audit of 38 patients who underwent 55 MIS procedures for complex and simple lesser toe deformities was conducted between April 2018 and June 2022. All patients were followed up for a minimum of 12 months post-operatively. The audit was conducted following the National Research Ethics Service (NRES) guidelines on clinical audit.

**Results:** Mean pre-operative Visual Analogue Pain (VAS) score was 3.95 with a median of 5.00. The mean post-operative VAS scores improved to 0.23 after six weeks and 0.43 after 12 weeks. A Mann-Whitney U test concluded that this improvement was statistically significant ($p<0.05$).

**Conclusion:** This algorithm appears effective in treating lesser toe deformities independent of deformity classification, concomitant surgery, gender or whether the surgery was performed in a hospital or private clinical setting.

**Level of Evidence V; Therapeutic Study; Expert Opinion.**

**Keywords:** Clinical audit; Foot deformities; Hammer toe syndrome; Metatarsal bones; Minimally invasive surgical procedures.

## Introduction

The global interest in minimally invasive foot surgery (MIS) continues to grow in the peer-reviewed foot and ankle surgical literature[1-8]. MIS is defined as surgery performed through small openings without direct visualisation of anatomical structures. Its practice has increased in popularity due to theoretical advantages, including reduced soft-tissue damage, smaller scars, shorter surgery times and hospital stay, lower post-operative pain and reduced risk of infection[9]. The use of MIS is increasing, but there is limited evidence to support its use in the forefoot. Currently, few treatment algorithms exist to guide surgical decision-making for lesser toe deformities[10].

Lesser toe surgery is often indicated to address painful cutaneous lesions that can lead to ulceration and have not responded to non-surgical measures. The aims of lesser toe surgery include the correction of deformity whilst preserving the biomechanics of the foot, but controversy exists over the best surgical approach[9]. Surgeons must focus on the anatomical structures and contractures involved to guide their decision-making[10]. The ambiguous definitions and treatment strategies regarding diagnosing and managing lesser toe deformities have been well documented[11].

The symptoms of lesser toe deformities are often attributed to callosities and pressure[3]. Conservative treatment involves improving comfort, and its success largely depends on the level of deformity present. Orthoses, footwear advice, protective devices and corticosteroid injections have been employed as non-operative management[12]. When conservative treatment fails, surgery may be indicated.

Study performed at the Australasian College of Podiatric Surgeons, Victoria, Australia.

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There is a paucity of empirical research assessing the efficacy of MIS for lesser toe deformities and no adequate treatment algorithm for surgical management.

An audit assessing the efficacy of a treatment algorithm for the MIS management of lesser toe deformities is an important step towards informing surgical decision-making in this emerging field. The aim of the retrospective clinical audit is to assess the efficacy of a pre-derived treatment algorithm used to surgically treat a cohort of patients presenting with lesser toe deformities using MIS techniques.

## Methods

### Audit design

The study methods described correspond with the principles of audit activity defined by the National Research Ethics Service (NRES)[12]. Patients were not allocated to a specific treatment group and elected to have their procedure(s) performed by the primary surgeon (MG). The option of open versus percutaneous techniques was not influenced by the severity of the deformity. The perioperative protocols did not deviate from standard practice. This work complies with the ethics in publication policy of the Australasian College of Podiatric Surgeons (ACPS). Consent was obtained from all patients included in this audit.

### Inclusion criteria

Inclusion criteria were patients fit for elective surgery presenting with lesser toe deformities that were not responsive to conservative care and that underwent MIS for treating lesser toe deformities by the primary surgeon between April 2018 and October 2022. Patients who underwent concomitant surgery (e.g for hallux valgus correction) were included. The summary of the method is detailed in table 1.

### Exclusion criteria

Patients were excluded if they had already undergone surgery on the digit in question.

### Perioperative management

Procedures were performed under local anaesthetic (LA) or a combination of LA and general anaesthetic (GA). All procedures were performed either in a clinical procedure room or hospital setting (including surgi-centre) on an ambulatory day-case basis.

Patients who underwent procedures within a hospital environment were administered intravenous antibiotic prophylaxis pre-operatively and a single subcutaneous dose of enoxaparin sodium 20 or 40mg intra-operatively for thromboprophylaxis as part of the routine protocol, often due to additional procedures involving the use of internal fixation (e.g. for hallux valgus correction). Those performed in an office setting did not receive either form of prophylaxis.

### Osteotomies

The location of the osteotomy and algorithm used in this audit can be found in figure 1.

### Instrumentation

All procedures were carried out using standard MIS hand instrumentation and Osada low-speed/high-torque power instrumentation. Fluoroscopy was utilised as appropriate with a Fluoroscan® InSight 2 Mini C-Arm (Hologic Inc., Marlborough, Massachusetts, USA).

**Table 1.** Summary of method

| | |
|---|---|
| 1. Pre-surgical consultation | Assessment of presenting concerns with the primary surgeon.<br>Thorough medical history and evaluation to determine the cause of deformity. |
| 2. Deformity classification | Recording of any hyperkeratosis or pressure lesions.<br>Assessment of passive range of motion at all joints to determine if the deformity was reducible or fixed.<br>Deformity was classified into simple or complex based on the involvement of the metatarsophalangeal joint.<br>Digital balance test to define muscular imbalance between the flexors and extensors.<br>Weight-bearing radiographs to confirm baseline deformity and correlate the apex of deformity with the osteotomy to be used.<br>Patient was triaged for surgery following a pre-derived treatment algorithm. |
| 3. Pre-operative data collection | Patient records pre-operative VAS score and frequency.<br>Patient was issued with a consent form detailing surgical intervention and requesting permission to use the data for audit purpose. |
| 4. Surgical intervention | Percutaneous surgical techniques were used to treat all lesser toe deformities.<br>Surgery was performed in a hospital or office setting under LA or GA alongside LA.<br>Surgical procedures were based on the treatment algorithm employed, see Figure 2. |
| 5. Post-operative care | Patients recorded post-operative VAS scores.<br>Routine post-operative care was provided, including analgesic medication, elevation and compression bandages.<br>Digital splinting was used for up to six weeks to maintain alignment, followed by a return to sizeable footwear. |

* VAS = Visual Analogue Pain Scale; LA = local anaesthetic; GA = general anaesthetic.

## Treatment algorithm

A treatment algorithm developed by the primary surgeon was used to guide surgical decision-making (Figure 2). Upon the presence of a symptomatic lesser toe deformity, a clinical assessment was conducted encompassing the use of the digital balance test to identify the presence of flexor or extensor substitution[13,14]. If surgery was indicated, the surgeon identified the point of most severe soft-tissue contracture correlating with the formation of a lesser toe deformity.

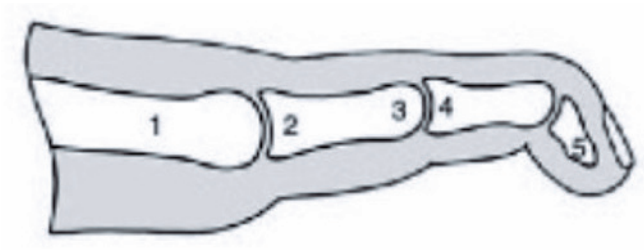


**Figure 1.** The various osteotomies employed within this algorithm. 1: Middle metatarsal neck 2: Base of the proximal phalanx 3: Dorsal aspect of the head of the proximal phalanx 4: Neck of intermediate phalanx 5: Osteectomy of distal phalanx.

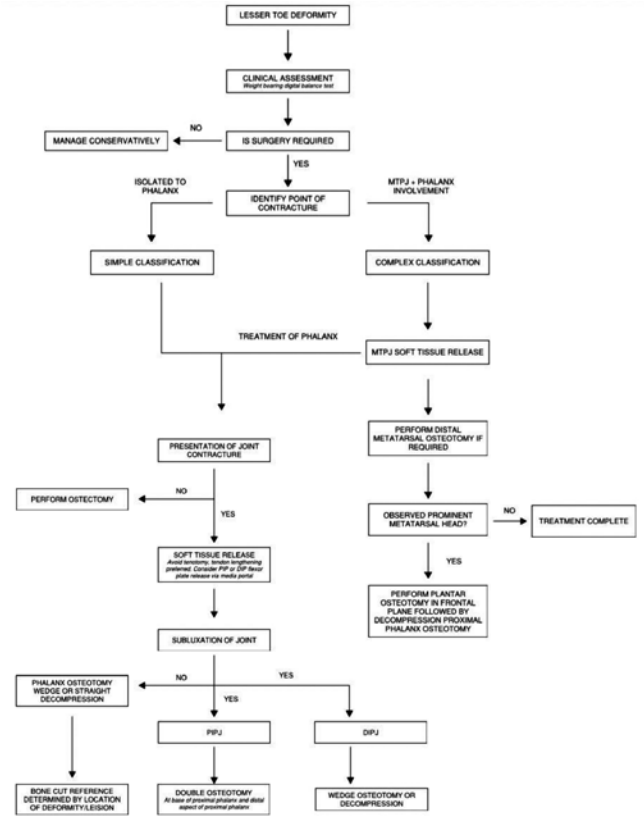


**Figure 2.** The treatment algorithm.

## Digital pathology definitions

Lesser toe pathology was defined as digital deformity resulting in a condition or malposition of the toe(s), which required surgical intervention. Digital deformity was further classified as simple or complex based upon the level of anatomic involvement. The following definitions were applied:

*Simple digital deformity* was deformity isolated to the phalanges and soft-tissue structures involving the interphalangeal joints. Surgical procedures in this group included percutaneous phalangeal osteotomies and/or osteectomy with or without percutaneous lengthening release procedures to flexor/extensor tendons and capsular releases as required.

*Complex digital deformity* was defined as a simple digital deformity with the addition of metatarsophalangeal joint (MTPJ) contracture resulting in subluxation or dislocation. In the case of a complex deformity, surgical procedures began with soft-tissue release at the level of the MTPJ and progressed to phalanx osseous work and, when necessary, osseous metatarsal work. A distal metatarsal osteotomy was also performed as required.

The procedures performed were based on the principles and techniques described in Maffulli and Easly[3].

## Procedural Approach - Simple Digital Deformity

Deformities isolated to the phalanx were classified as simple deformities. Osseous procedures were performed from distal to proximal. In the absence of joint contracture and the presence of an isolated hyperkeratotic lesion, the primary surgeon performed an osteectomy, removing the exostosis correlating with the location of the lesion. In the incidence of joint contracture, soft-tissue releases were performed.

If subluxation of the joint was not present, a simple phalanx osteotomy was performed using a wedge or straight decompression; the osteotomy correlated with the use of the specific osteotomy outlined in figure 1. A decision on which osteotomy to use was determined based on the location of the deformity and the presence of a lesion.

In the presence of joint subluxation at the proximal interphalangeal joint, the surgeon conducted a double osteotomy using osteotomy cuts 2 and 3. When subluxation was present at the distal interphalangeal joint, a wedge osteotomy or decompression was adopted.

## Procedural Approach – Complex Digital Deformity

A complex deformity was defined as incorporating MTPJ involvement. In this case, the procedure always began with a soft-tissue release at the level of the MTPJ and then progressed onto phalanx osseous work. A distal metatarsal osteotomy was performed when necessary, correlating with osteotomy 1. A plantar osteotomy was conducted in the frontal plane, followed by a decompression proximal phalanx osteotomy if a prominent metatarsal head was exhibited.

## Post-operative management

Patients were given routine post-operative analgesic medication and allowed to weight-bear in a rigid post-operative sandal. Patients were advised to elevate the affected limb(s) for the first 48 hours. Routine compression bandages were used on the operated foot or feet alongside standard digital splinting protocols. The purpose of splinting was to ensure alignment and continued for up to six weeks post-operatively.

Patients were reviewed by the primary surgeon in the clinical rooms at routine intervals at seven days, then again at 3, 6, 9, 12, 26 and 52 weeks. This regimen reflects the typical post-operative follow-up performed by the primary surgeon and his peers in Australia. Subjective post-operative Visual Analogue Pain (VAS) scale and pain frequency sheets were provided to patients to complete at six and 12 weeks post-operatively to assess pain scores.

## Data collection

Vascular assessment was conducted directly following surgery by evaluating clinical signs of colour and temperature together with superficial venous plexus filling time (SVPFT). Neurological status was assessed utilising a Semmes-Weinstein 5.07/10 g monofilament at initial review and six weeks post-operatively. Neurological status was not assessed immediately post-operatively due to long-acting local anaesthesia. Signs of infection were checked for at the initial review and follow-up appointments. Data was explicitly recorded relating to post-operative complications or infections. Objective surgical and general demographic data were collected and recorded in patient charts by the primary surgeon (MG).

## Results

Complete data were obtained on 38 patients (3 male, 35 female) that underwent MIS surgery for digital deformity during this period. The age ranged from 19-84 years (mean 63.3 years) with a standard deviation (SD) of 16.4 years, and 81% were 51 years or older. A summary of the study participants can be found in table 2.

**Table 2.** Characteristics of the sample group

| Variable | Description | Value |
|---|---|---|
| Sample size | No. Subjects | N=38 |
| | No. Procedures | N=55 |
| Age | Mean | 63.3 years |
| | Median | 66 years |
| Gender | Male | N=3 (7.9%) |
| | Female | N=35 (92.1%) |
| Surgery location | Hospital | N=21 (38.2%) |
| | Office | N=34 (61.8%) |
| Deformity classification | Simple | N=28 (50.9%) |
| | Complex | N=27 (49.1%) |
| Concomitant surgery | Isolated | N=43 (78.2%) |
| | Concomitant | N=12 (21.8%) |

Thirty-four (61.8%) procedures were performed in an office clinical procedure room, and 21 (38.2%) were performed in a hospital setting. Thirty-four (61.8%) were performed under a combination of GA and LA, whilst 21 (38.2%) were performed under LA alone. Local blocks were performed during either 0.75% ropivacaine hydrochloride or 0.5% bupivacaine hydrochloride plain solution.

A total of 55 digits were operated on out of the 38 patients in this study. Of these, 12 patients underwent concomitant procedures (e.g. hallux valgus correction).

Twenty-eight (51%) deformities were classified as simple, and 27 (49%) were classified as complex. Interestingly, patients with simple deformities had higher pre-operative VAS scores compared with complex deformities. Of the 12 procedures performed with concomitant surgeries (e.g. hallux valgus correction), nine (75%) were classified as complex.

The most utilised MIS osteotomy was number 2, referring to an osteotomy at the base of the proximal phalanx. Osteotomies 1 and 3 were used sparingly, accounting for less than 10% of the procedures. Osteotomies 5 and 2 were used predominantly on deformities classified as simple. Complex deformities were predominantly treated with osteotomy 2, accounting for 70% of osteotomies. Osteotomy 1 correlates with an osteotomy of the distal metatarsal, which was used in treating 10% of complex deformities. A summary of the osteotomy frequency used within this audit is detailed in figure 3.

Pre-operatively, the sample mean VAS score was 3.95 (SD = 3.58) with a variance of 12.84, indicative of a large range and dispersed data set. The post-surgical sample mean VAS scores at six and 12 weeks of follow-up consultations were 0.23 and 0.43, respectively (Table 3). Post-operative VAS scores followed a normal distribution and were tightly clustered with a small SD from the mean.

At six weeks, 34 (88.7%) patients reported a VAS score of 0, with 37 (98.1%) reporting a VAS score of ≤2. As a non-parametric statistical test was used to test the significance level in VAS scores pre-and post-operatively, these outliers would not have been considered. Two patients did not record a VAS score at six weeks post-surgery, and four did not record a VAS score at 12 weeks post-surgery resulting in a useful data set of 51 entries.

At 12 weeks, 31 (82.4%) patients reported pain levels at 0, with 36 (96%) reporting a VAS of ≤ 2. This suggests relative effectiveness of the pre-derived treatment algorithm. These results compared with the findings of Yassin et al.[13], who evaluated pre-and post-operative VAS scores in a prospective case-control study comparing percutaneous surgery with traditional techniques, finding the mean post-operative VAS score to be 1.9 at six weeks and 0.43 at the 12 weeks of follow-up. Figure 4 illustrates pre-and post-operative VAS score distributions.

## Discussion

In 1991, White[6] mentioned the potential for less post-operative pain and discomfort following MIS forefoot surgery compared to the traditional open approaches due to reduced soft-tissue dissection. The results of this audit add further strength to this argument.

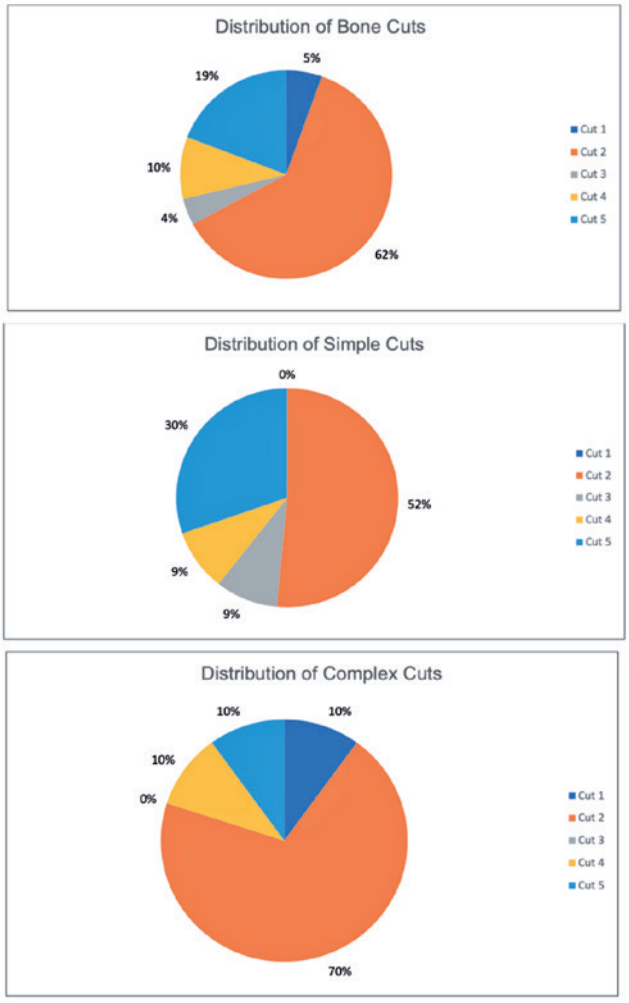


**Figure 3.** The distribution of osteotomies employed within this audit.

**Table 3.** Pre-and postoperative VAS score

| | N | Range | Mean | Standard Deviation |
|---|---|---|---|---|
| VAS Score Pre-Surgery | 55 | 9.0 | 3.95 | 3.58 |
| VAS Score 6 weeks Post-Surgery | 53 | 3.0 | 0.23 | 0.67 |
| VAS Score 12 weeks Post-Surgery | 51 | 7.0 | 0.43 | 1.19 |

The treatment algorithm employed specific osteotomies in this audit to surgically correct lesser toe deformities. The results suggest that through implementing a pre-derived MIS treatment algorithm, lesser toe deformities can be treated effectively. These results were independent of complex or simple deformity classification, location, age, gender, and concomitancy. The second ray was the most common site presenting with deformity, and MIS techniques using osteotomy 2 (osteotomy at the base of the proximal phalanx) were used to conduct 62% of procedures. Pre-and post-operative pain scores were used as the primary outcome measure, and statistically significant improvements in post-operative VAS scores were reported.

The most common osteotomy used was number 2, an osteotomy at the base of the proximal phalanx; 44% of procedures were performed on the second ray, followed by deformities of the fifth ray accounting for 31% of osteotomies. Schrier et al.[10] attribute the second ray as the most commonly affected in the case of lesser toe deformities.

An analysis of such a small size is intended to represent the wider population. To justify the results, it was considered important for the cohort to represent patients receiving surgical treatment for lesser toe deformities. The conclusions drawn from this audit could be strengthened through post-stratification; however, this was omitted due to research time constraints.

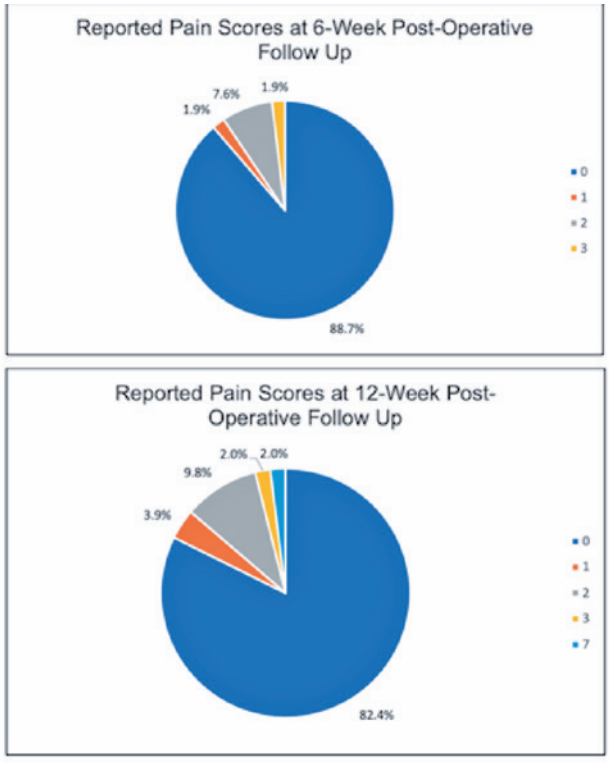


**Figure 4.** Pre-and post-operative VAS pain score distributions.

These results are consistent with Nieto-Garcia et al.[15], who compared incomplete osteotomies (IO) with and without tenotomies in another retrospective case-control study. They reported at the 12 months of follow-up that the cohort operated on with IO and tenotomy displayed higher rates of complications, including delayed union, hypertrophic callous and fracture of the phalanx at the osteotomy site.

The impact of co-morbidities may provide a counter-argument to explain the lower post-operative VAS scores illustrated within the current study. Yassin et al.[13] reported a high incidence of co-morbidities in the sample population, with one-third diagnosed with diabetes mellitus. The hypertensive patients in the percutaneous cohort did not respond as well to surgery as the non-hypertensive patients. This shows that patients with co-morbidities may not respond as well or heal as fast as patients without it. The data set from this study did not include or refer to co-morbidities present at the time of surgery. If there was a low degree of co-morbidities in the study, it could explain the slightly lower post-operative VAS scores. If the treatment algorithm used within this study were to be deployed, research into the impact of co-morbidities would need to be explored to ensure it could be applied to all patients. The lack of information regarding the presence of co-morbidities is a limitation of the study.

A limitation of this algorithm relies to an extent upon the surgeon's experience and assessment of the anatomical structures leading to contracture to inform what osteotomy to use. The subjectivity of osteotomy selection may lead to variability in different surgeon's use of the treatment algorithm. The treatment algorithm could be improved if the process regarding the selection of which osteotomy was to be clearly defined.

The authors advocate future research to determine the efficacy of the treatment algorithm on a sample group with a higher number of third or fourth-ray deformities, which were limited in this sample group.

## Conclusion

This audit illustrated that performing MIS to address simple and complex digital deformities via a treatment algorithm results in favourable reductions in post-operative pain scores. Furthermore, MIS procedures were safely performed in various clinical settings and on varying degrees of digital deformity. Further studies investigating the effectiveness of these techniques are recommended and should evaluate longer post- operative patient-reported outcome measures, as well as refining treatment algorithms to guide clinical decision-making.

**Authors' contributions:** SRE *(https://orcid.org/0000-0002-9866-0327) Interpreted the results of the study, participated in the review process and approved the final version; MGM *(https://orcid.org/0000-0001-9533-7797) Conceived and planned the activities that led to the study, approved the final version; MFG *(https://orcid.org/0000-0002-8179-7992) Performed the surgeries, data collection and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Foot and ankle offset in the setting of severe rotational foot and ankle deformities

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## Abstract

**Objective:** The goal of this paper was to evaluate the validity of foot and ankle offset (FAO) measurements in the setting of severe foot and ankle deformities.

**Methods:** This study included 57 feet (36 patients) that had a history of severe cavovarus deformity. Each participant received a weight-bearing computed tomography (WBCT) scan that was then used to measure FAO. This measurement was performed once using the traditional measurement technique and two additional times using a modified technique that allows for rotational correction of the images to align the talus.

**Results:** Traditional FAO (TFAO) and modified FAO (MFAO) were found to have a significant correlation with one another (r (54)=0.92, p<0.001). There was a high positive correlation between the variables of the two techniques (r=0.92) with the intraobserver reliabilities (ICC=0.95) for FAO measurements. The agreement between TFAO and Modified foot and ankle offset (MFAO) measurements was also considered excellent (ICC=0.99).

**Conclusion:** The MFAO method provides statistically similar FAO measurements compared to the TFAO method in this population. Thus, the TFAO method could potentially expand its patient population to provide surgeons with a reliable tool for assessing more severe deformities.

**Level of Evidence IV; Retrospective Study.**

**Keywords:** Ankle joint; Foot deformities; Tomography, x-ray computed; Weight-bearing.

## Introduction

Foot and ankle offset (FAO) is a three-dimensional (3D) measurement for overall foot and ankle alignment assessment. It is characterized by the relation between the weight-bearing tripod of the foot and the center of the ankle joint[1-3]. The most plantar voxel of the heads of the fifth and first metatarsal and the calcaneal tuberosity make up the tripod of the foot, while the most proximal and central points of the talus represents the center of the ankle. Foot and ankle offset characterizes the normalized percentage of the shortest distance between the center of the ankle joint and a bisecting line of the foot tripod[1].

Study performed at the UIOWA Orthopedic Functional Imaging Research Laboratory (OFIRL). University of Iowa, Carver College of Medicine, Department of Orthopedics and Rehabilitation, Iowa City, IA, USA.

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The FAO is clinically relevant due to its ability to produce an objective value portraying the foot alignment[3-5]. In addition, it represents a measurement of the offset between the body weight vector and the ground reaction force vector, thus making it a biomechanically relevant measurement. Foot and ankle offset has been found to be reliable in assessing preoperative deformity and postoperative correction in adult-acquired flatfoot deformity[6,7]. It has also been shown to be an effective way to discriminate clinically normal feet from varus and valgus hindfoot alignment with excellent interobserver and intraobserver reliability, 0.99 and 0.96, respectively[2,8].

Patients were divided into three groups based on their foot and ankle alignment. Normal alignment was defined as an FAO of 2.3%±2.9%[2]. Negative values show varus alignment for FAO, -11.6%±6.9% (95% CI, -13.9%–9.4%)[2], demonstrating that the ankle joint is positioned laterally relative to the bisecting line of the foot tripod[9]. Valgus alignment was defined as having an FAO of 11.4%±5.7% (95% CI, 9.6%–13.3%), demonstrating that the center of the ankle joint is located medial to the bisecting line of the center of the ankle joint[2]. While measurements in the varus and valgus alignment setting are reliable, FAO measurements' reliability has not been shown in the setting of severe foot and ankle deformities.

In cases with severe dysplasia and rotation of the talus, consistent and reliable measurements of the established anatomical landmarks might be challenging. The first and fifth metatarsals, the calcaneus, and mostly the talus may be difficult to identify if the axes of the semi-automatic software are not adjusted. Therefore, the objective of this study is to compare FAO measurements in patients with severe rotational deformities of the foot and ankle by using the traditional measurement method with a modified one consisting of an axis-based determination. We hypothesized that by adjusting to the use of the bimalleolar axis when identifying the center of the ankle voxel, FAO values would change in cases of severe foot and ankle deformities.

## Methods

This is a retrospective comparative study performed at the Orthopedic Functional Imaging Laboratory (OFIRL), Carver College of Medicine, University of Iowa. The study obtained an Institutional Review Board approval (#202012422), complying with the Health Insurance Portability and Accountability Act (HIPAA) and the Declaration of Helsinki.

### Design

Weight-bearing computed tomography (WBCT) scans of patients with a history of severe cavovarus performed between January 2015 and July 2020 were analyzed. Foot and ankle offset was measured three times per foot, once using the traditional measurement method and twice using a novel modified method. This can be visualized in the corresponding flow chart (Figure 1).

The three measurements were taken to assess the ability of the traditional measurement technique to identify the most central and proximal points of the talus and validate the intraobserver reliability and consistency of using the rotation method for measurement. These measurements were done using the semi-automatic TALAS™ instrument (Cubevue, CurveBeam®, Hatfield, PA, USA) measurement tool[4,10].

### Subjects

A total of 57 feet (36 patients) with a history of severe cavovarus were analyzed in this study. Inclusion criteria included patients over 18 years with a clinical and radiographic diagnosis of the deformity. Patients with metallic implants deterring visualization of the first and fifth rays and patients with isolated ankle WBCT acquisitions without the forefoot were not included in this study.

### Weight-bearing computed tomography imaging

Weight-bearing computed tomography studies were performed with a cone-beam computed tomography extremity scanner (HiRise®, LLC, Warrington, PA, USA). Patients were instructed to place their feet aiming frontward, shoulder width apart from one another, distributing their body weight evenly between their lower limbs, and bearing weight in a physiological straight position.

### Foot and ankle offset measurements

Foot and ankle offset measurements were performed using TALAS™. In all measurements, the 3D coordinates (X, Y, Z) of the calcaneal tuberosity, the head of the first metatarsal, and the head of the fifth metatarsal were manually selected on multiplanar reconstruction (MPR) views and used to represent the tripod of the foot[1]. For the one measurement per foot that was done using the traditional FAO (TFAO) technique, the most central and proximal points of the talus were identified using both sagittal and coronal views. In the coronal view, a distance line with a demarcated midpoint was placed on the medial and lateral end points of the talar dome. This was done to identify the most proximal point of the talar dome in the sagittal view, which was then manually selected and used to calculate the FAO (Figure 2).

The modified FAO (MFAO) measurement was done using the bimalleolar axis, and the foot and ankle tripod was marked using the same procedure described above. Before identifying the most central and proximal points of the talus, specific rotations of the axes were performed. First in the axial view, the talus was brought into focus where both the medial and lateral malleoli were visible (Figure 2). Then using the same view, the intersection point of the X and Y axes was placed in the middle of the talus. Next, rotation about the Z-axis was done to have the most medial point of the medial malleolus and the most lateral points of the lateral malleolus intersected by the X-axis. Then using the coronal view, the Y and Z axes were rotated about the X-axis so that the

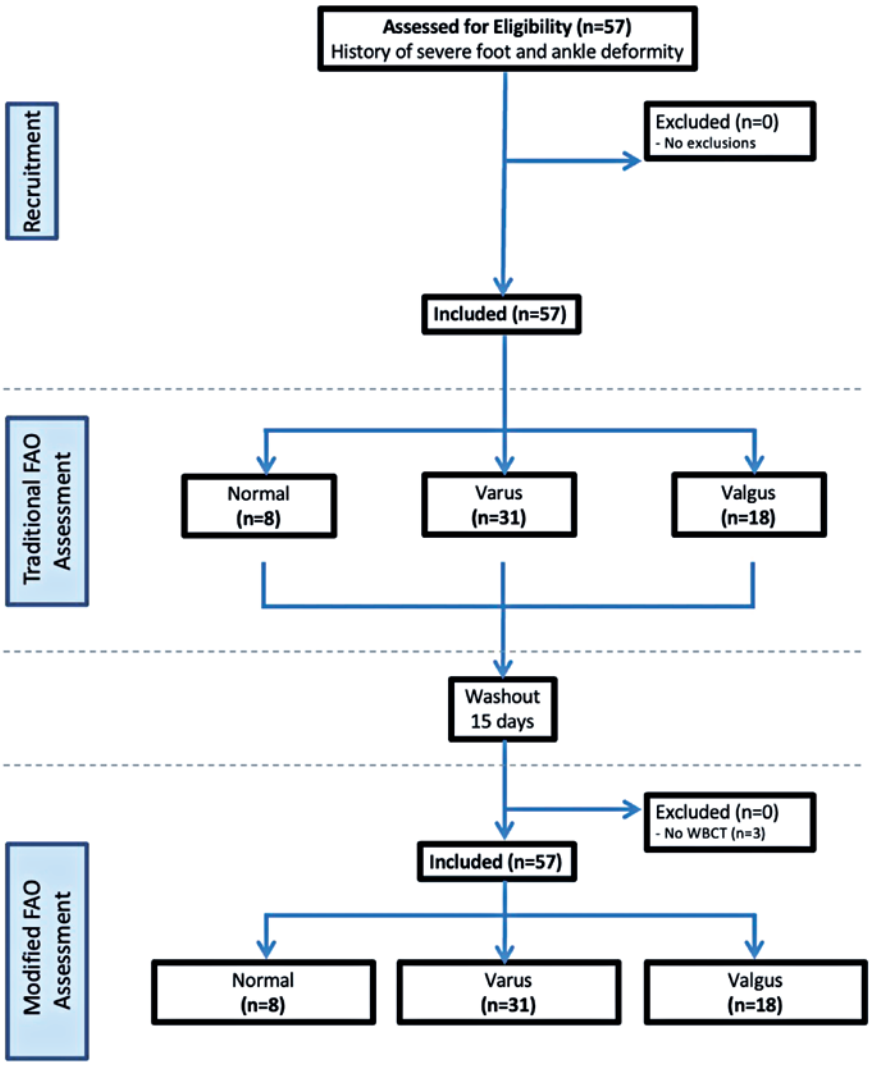


**Figure 1.** Flow chart depicting the steps taken during this study, including a 15-day washout period between the traditional and modified FAO measurements.

Z-axis would parallel the talar dome. After this, a midpoint line was placed across the talar dome in a similar process to that described for the standard technique. Next, the intersection points of the Y and Z axes, as seen in the coronal view, were placed at the midpoint marking of this line. Finally, using the sagittal view, the intersection of the X and Z axes was placed on the most central and most proximal points of the talus. This point was then selected, and its coordinates were used to calculate the FAO using the same semi-automatic technology as before (Figure 3). This measurement technique was repeated for every foot after a washout 15-day period to assess the modified method's intraobserver reliability.

## Statistical Analysis

Intraobserver reliability was assessed by Intraclass Correlation Coefficient (ICC). Traditional and modified FAO measurements were assessed for normality by the Shapiro-Wilk test. Inter-method agreement between techniques' measurements was assessed by Spearman's correlation (Þ). One-way ANOVA and Wilcoxon tests were used for comparison among groups. P-values under 0.05 were considered significant, and confidence intervals of 95% were presented. The analyses were performed by the software SPSS® V20 (IBM Corp., Armonk, New York, USA), R software (The R Foundation, Indianapolis, Indiana, USA), and Minitab® 16 (Minitab, LLC, State College, PA, USA).

## Results

The intraobserver reliabilities (ICC=0.95) for FAO measurements were excellent. The agreement between TFAO and MFAO measurements was also considered excellent (ICC=0.99) (Table 1).

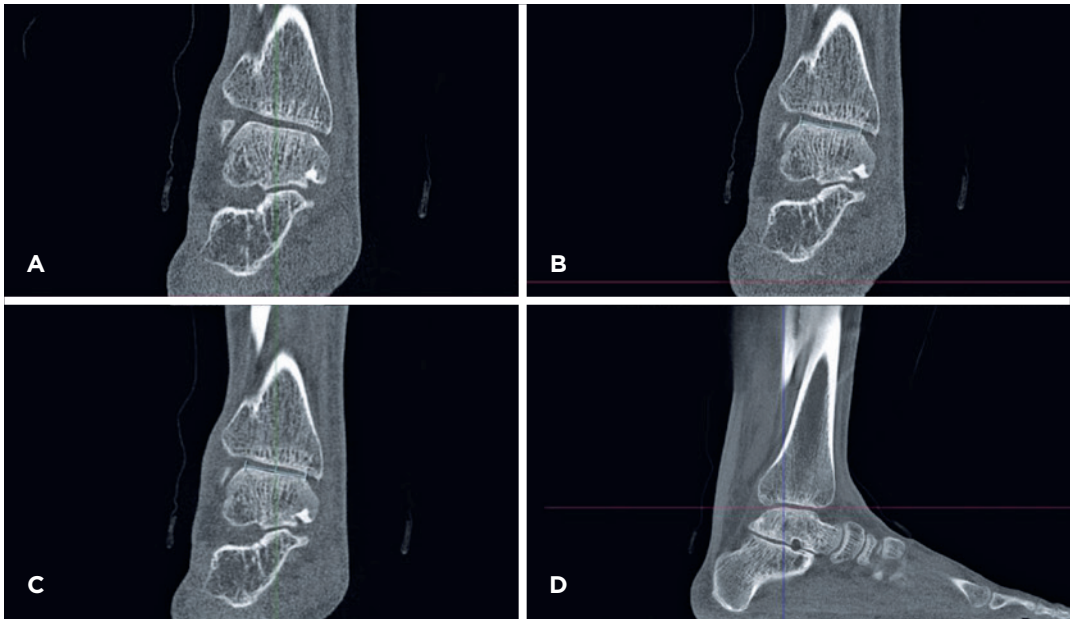


**Figure 2.** The traditional method of identifying the most central and proximal points of the talus for FAO is by sagittal and coronal planes. (A) In the coronal plane, the talus is clearly visualized, where a line with a midpoint marker is then placed across the dome of the talus in the same view (B) The Y-axis is then positioned at the midpoint of the line placed (C) Visualization of the most proximal and central points of the talus, which is identified by placing the X and Z axes intersection on that point (D) This along with the foot tripod coordinates is used to calculate the FAO.

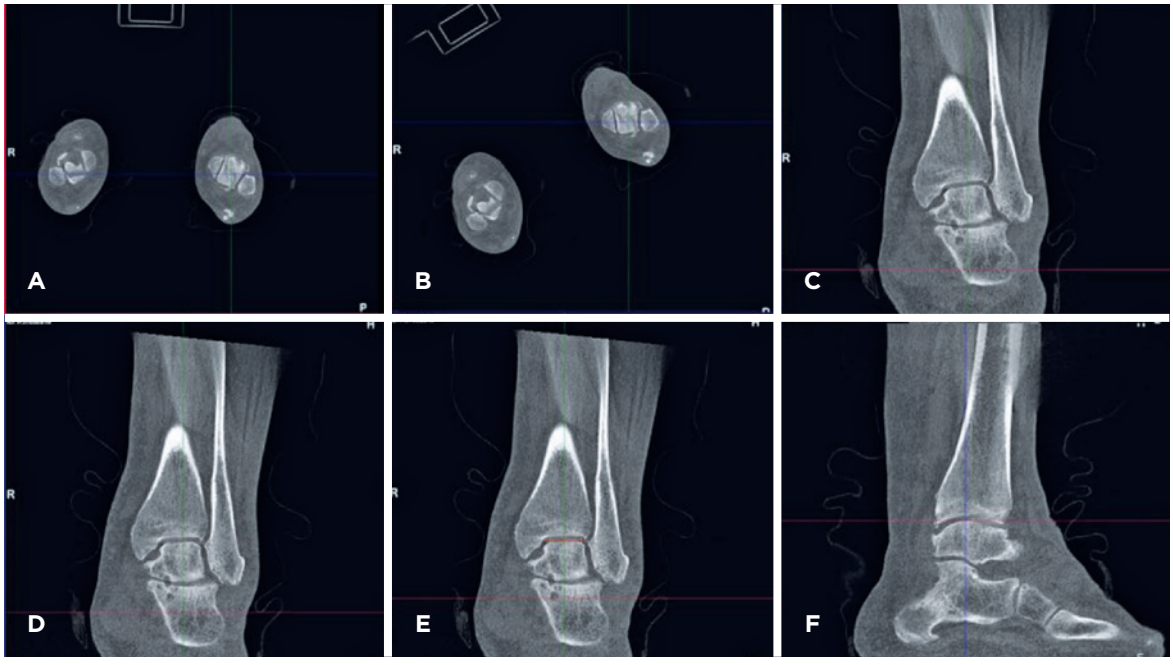


**Figure 3.** Using the bimalleolar axis and rotation to identify the most central and most proximal point of the talus. (A) Visualization of the medial and lateral malleoli in the axial view with the X and Y axes intersection point placed in the center of the talus. (B) Rotation of the X and Y axes about the Z-axis in the axial view such that the medial and lateral malleoli are intersected by the X-axis. (C) Visualization of the talus in the coronal plane, with the image then rotated about the X-axis such that the talar dome is parallel to the Z-axis with a midpoint line added across the plateau of the talus (D–E) Sagittal view after rotation with the intersection of the X and Z axes placed at the most central and proximal points of the talus.

**Table 1.** Intraobserver agreement and consistency of FAO (Traditional vs. Modified). Measurements assessed by ICC

| | Intraobserver | | |
|---|---|---|---|
| | Agreement (95% CI) | Consistency (95% CI) | p-value |
| Traditional FAO | 0.957 (0.926–0.975) | 0.956 (0.924–0.974) | < 0.001* |
| Modified FAO | 0.96 (0.931–0.976) | 0.959 (0.930–0.976) | < 0.001* |

FAO: Foot and Ankle Offset. P-values are based on F tests inherent in the function ICC/R package IRR. *Statistical significance, p<0.05.

The mean TFAO was 2.37±4.65% (95% CI=1.16–3.59). Eight patients were found to have physiological normal hindfoot alignment (mean FAO of 3.67±0.55 95% CI, 3.31–4.03). Thirty-one patients had varus malalignment (mean FAO, -0.84; 95% CI, -1.92–0.25), and 18 had valgus malalignment (mean FAO, 6.74; 95% CI, 6.74–9.15).

The mean MFAO was 2.51±4.6 (95% CI=1.3–3.71). For the patients with physiological normal hindfoot alignment, the mean MFAO was 3.8±0.55 (95% CI, 3.43–4.16). For patients with varus malalignment, the mean MFAO was -0.75±3.18 (95% CI, -1.89–0.38), and for patients that had valgus malalignment, the mean MFAO was 7.58±2.49 (95% CI, 6.39–8.76) (Figure 4).

The mean MFAO values between the different alignment groups were significantly different (p<0.0001) (Figure 5). Significant differences were also found when comparing varus to valgus (p<0.001), varus to physiological (p=0.002), and valgus to physiological alignment (p=0.002).

Traditional FAO and MFAO were compared under three hindfoot alignment conditions (normal, valgus, and varus), and a t-test showed that the difference between TFAO normal–MFAO normal was not statistically significant, t(8)=-0.53, p=0.609. Also for TFAO cavus–MFAO cavus, t(28)=-0.15, p=0.884, and for TFAO valgus–MFAO valgus, t(14)=0.68, p=0.506 (Table 2).

A Spearman correlation was performed to test whether there was an association between TFAO and MFAO. The result of the Spearman correlation showed that there was a significant association between them, *r*(54)=0.92, p=< 0.001 (Figure 6).

## Discussion

Foot and ankle offset are a validated way to measure the 3D alignment of the foot and ankle in multiple foot and ankle conditions[11]. The goal of this study was to identify if TFAO measurements are still effective when used in cases of severe deformity of the foot and ankle.

A high, positive correlation was found between the TFAO and MFAO measurements with excellent reliability. The study's findings deny our primary hypothesis that the two measurement techniques would differ. Considering the results, we

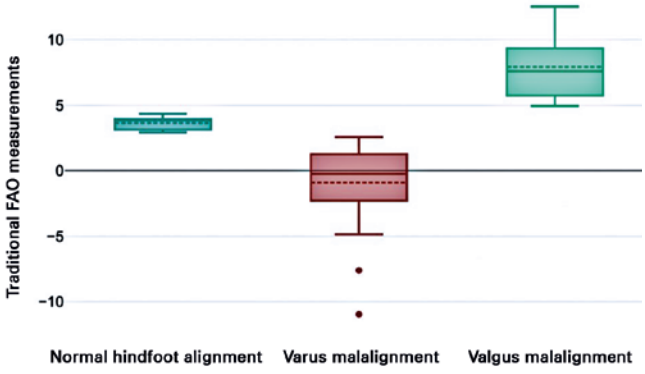


**Figure 4.** Mean values of traditional foot and ankle offset measurements (p<0.0001).

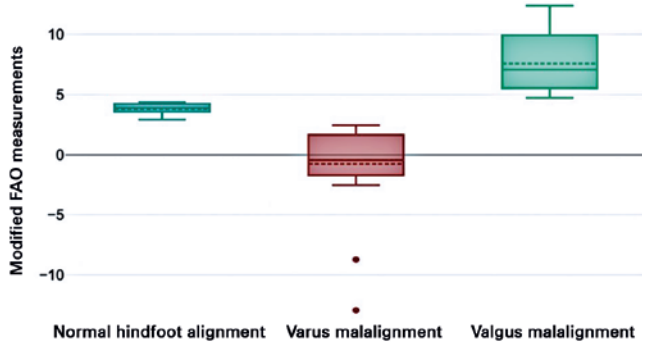


**Figure 5.** Mean values of modified foot and ankle offset measurements (p<0.0001).

**Table 2.** Foot and ankle offset in different hindfoot alignment

| | t-test | DF | p-value |
|---|---|---|---|
| FAO normal - MFAO normal | -0.53 | 8 | 0.609 |
| FAO cavus - MFAO cavus | -0.15 | 28 | 0.884 |
| FAO valgus - MFAO valgus | 0.68 | 14 | 0.506 |

FAO: Foot and ankle offset; MFAO: Modified foot and ankle offset; DF: P-values are based on t-tests inherent in the function ICC/ R package IRR. Statistical significance, p<0.05.

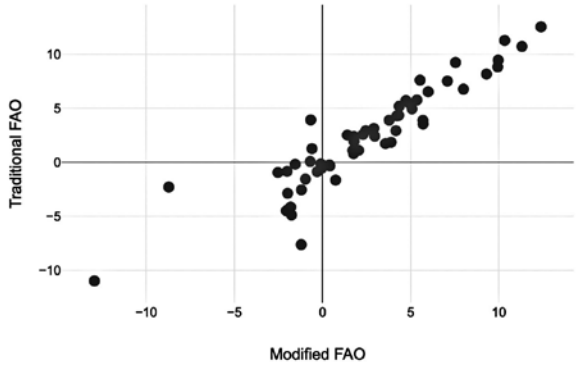


**Figure 6.** Spearman correlation, there is a high, positive correlation between the variables of traditional and modified foot and ankle offset measurements (p<0.001).

attest that the traditional method of measuring the FAO can assess severe rotational deformities.

The intraobserver reliability of both TFAO and MFAO measurement methods was excellent. This further supports the TFAO method's reliability and reproducibility, as previously indicated in the literature, and also shows how the novel MFAO method can similarly provide repeatable and consistent measures of FAO. Regarding the MFAO measurement method, this produced comparable results to the TFAO method, as there were also significant differences in mean FAO between normal hindfoot alignment and varus and valgus malalignment. These results indicate how the MFAO measurement method, like the TFAO, can produce an objective value portraying the alignment of the foot.

These results reject our previous hypothesis that adjusting the bimalleolar axis when identifying the center of the ankle voxel would change FAO values in cases of severe foot and ankle deformities. As the results indicate, the TFAO and MFAO methods produce significantly similar FAO values even in the setting of severe ankle deformities. Thus, TFAO measures show the ability to objectively portray disease progression in mild and severe forms of ankle deformities, despite the unique and severe physiological contortions of the foot and ankle in these patients. Therefore, the TFAO measurement method could potentially be used in these patients to provide a more detailed depiction of the misalignment in the foot and ankle, and physicians could more accurately treat these patients and potentially supply them with better outcomes.

The main findings of this study are subject to several limitations. The retrospective nature of the study could have presented biases regarding the study's design and methodology. Another limitation is that this study did not utilize a control group. This information would have allowed information about how this modified method impacted FAO measurements of healthy ankles. It is also important to note the lack of previous research on FAO measurement in this specific population with severe foot and ankle deformities. While the current literature illustrates the reliability of this TFAO measurement tool for assessing the preoperative deformity state in progressive collapsing foot deformity patients, there is very little research depicting this in our study's population of interest. Lastly, this study does not measure the scope in which these MFAO measurements directly correlate to patient outcomes. Thus, there is a need for further investigation in this area.

## Conclusion

We present a novel method of performing a 3D biometric WBCT measurement of FAO in a population with severe foot and ankle deformities. This modified FAO method provides statistically similar FAO measurements compared to the traditional FAO method in our specified population. Thus, the traditional FAO method could potentially expand its patient population to provide surgeons with a reliable tool for assessing more severe deformities. Further research, such as a prospective comparative study, would be beneficial to identify the correlation of these FAO measurement methods in severe foot and ankle deformity patients with their postoperative clinical and functional outcomes.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: RJ *(https://orcid.org/0000-0003-3448-1300) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; HS *(https://orcid.org/0000-0003-2664-0762), VM *(https://orcid.org/0000-0002-8612-5941), GT *(https://orcid.org/0000-0003-3448-1300), ES *(https://orcid.org/0000-0002-6922-5238), AF *(https://orcid.org/0000-0003-3448-1300), KCK (https://orcid.org/0000-0002-3731-8448), Data collection and interpreted the results of the study; KAMC *(https://orcid.org/0000-0003-1082-6490) Interpreted the results of the study, participated in the review process and approved the final version; NSBM *( https://orcid.org/0000-0003-1067-727X) Interpreted the results of the study and approved the final version; CCN *(https://orcid.org/0000-0001-6037-0685)Interpreted the results of the study and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher andContributor ID) .

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## Original Article

# Diabetic patients with inadequate flow of the posterior tibial artery and in dialysis are not good candidates for Syme amputation

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## Abstract

**Objective:** There is a renewed interest in Syme amputation (SA) as it is considered a "lower limb salvage" procedure. The aim of this study was to describe the characteristics and evolution of diabetic patients who underwent SA to search for factors that would affect the outcome by comparing a group of patients who had a successful amputation against those who required a major amputation.

**Methods:** Seventeen diabetic patients submitted to non-traumatic SA between 2008 and 2016 were analyzed retrospectively.

**Results:** Eight patients required a higher level of amputation. In this group, six patients continued with the posterior tibial artery (PTA) occluded despite the revascularization, and seven were on dialysis. When assessing the permeability of PTA and dialysis as predictors of failure, they multiplied the risk by 20 (cOR of 24 and 21, respectively). However, after adjusting for both factors, there was only clinical significance.

**Conclusion:** SA in diabetic patients may be an alternative in those with a preserved heel pad tissue vascularization and permeable posterior tibial artery at the time of surgery. Patients on dialysis are likely to fail with this level of amputation.

**Level of Evidence IV; Therapeutic Studies; Retrospective Cohort Study.**

**Keywords:** Diabetes; Ischemia; Amputation; Tibial artery, posterior.

## Introduction

Amputation is one of the most feared consequences in patients who have diabetes[1,2]. Peripheral vascular disease and diabetic neuropathy are the main risk factors for developing diabetic foot. The risk of developing foot ulceration in diabetic patients is higher than 25%[3], and in these patients, amputation occurs 10-30 more often than in the general population[1,2]. Therefore, there is a renewed interest in Syme amputation (SA) as it is considered a "lower limb salvage" procedure that would avoid a higher level of amputation[4–8]. If the ankle-level amputation fails, patients can proceed to the more proximal amputation without jeopardizing their chances for success[8].

This amputation through the ankle was described by James Syme in 1842 and popularized by Wagner in diabetic patients[9,10]. Harris stressed the importance of preserving the posterior tibial artery (PTA) indemnity during dissection, which is the one that primarily irrigates the heel pad[11,12]. For a time, diabetes and peripheral vascular disease were considered a contraindication for this surgical technique[13]. However, it has been shown that it can be performed in diabetic patients with an ankle-arm index greater than 0.5[14] and with the advent of new revascularization techniques of the lower limb, SA is possible in this group of patients[15].

The advantages of performing amputation through the ankle are the ability to temporarily bear weight on the stump

Study performed at the Hospital Italiano de Buenos Aires, Foot and Ankle Orthopaedics Department, Buenos Aires, Argentina.

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without the need for a prosthesis, better preservation of the body image, better proprioceptive feedback about the "foot position," granting gait stability[7], and lower incidence of skin complications[16,17]. In addition, it is a safer surgery than other major amputations. Finally, it presents a minimal increase in metabolic cost when walking to normal gait with infrapatellar or supracondylar level[18,19].

The aim of this study is to describe the characteristics and evolution of diabetic patients who underwent SA to search for factors that would affect the outcome of this procedure by comparing a group of patients who had a successful amputation against those who required a major amputation.

## Methods

The study was approved by the institution's ethics committee, and the medical records of the adult patients diagnosed with Diabetes Mellitus[20] submitted to non–traumatic SA between 2008 and 2016 were analyzed retrospectively. All these patients had no chance of more distal foot amputation due to tissue damage.

Patients younger than 18 years old, with a history of traumatic SA, incomplete records, and postoperative follow-up under 12 months were excluded.

Demographic data, uncontrolled Diabetes Mellitus (glycosylated hemoglobin HbA1c >7%)[20], serum albumin (<2.5g/Dl)[14], comorbidities (dialysis, history of smoking, dyslipidemia, insulin dependence, and obesity), preoperative vascular status and level change of the amputation were analyzed. It was considered successful SA, a patient who evolved favorably and did not require a major level of amputation.

Patients were divided into two groups: patients who evolved favorably and remained at the SA level (Successful SA group) and patients in whom SA failed and required a major level of amputation (Unsuccessful SA group).

The patient's vascular status was first evaluated with a preoperatively eco doppler with ankle-arm index measurement. Then they were also evaluated by the cardiovascular surgery service. After, bthrough digital angiography, they examined not only PTA the PTA condition and the vascularization of heel pad tissue. If this vascularization was not enough, patients were revascularized before amputation to achieve satisfactory revascularization of the heel pad due to the irrigation of PTA or collateral vessels like the calcaneal branch of the peroneal artery[21] (Figure 1). So, when either branch supplying the heel was intact and clinically had the same temperature as the contralateral heel pad with no infection signs and skin lesions, SA was indicated. Data were collected from electronic medical records.

## Statistics Analysis

Continuous variables are presented as absolute number and percentage. Continuous variables that assume a normal distribution are presented as means and standard deviation. Otherwise, they are expressed as median and interquartile range (IQR).

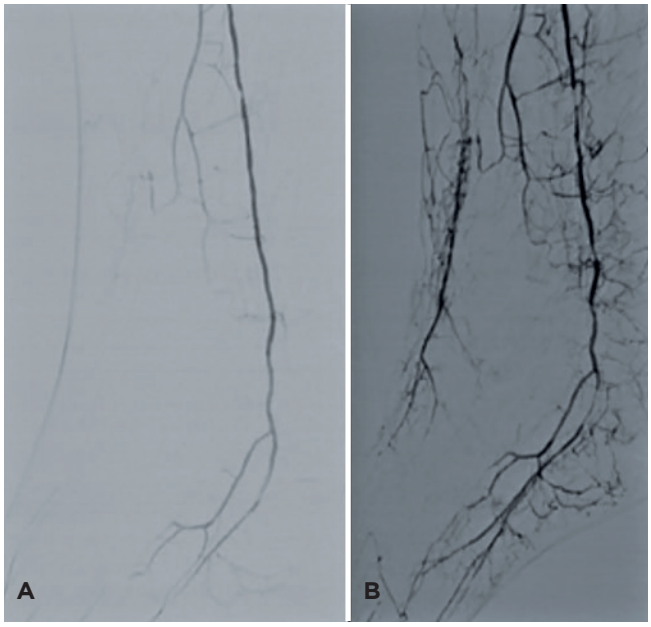


**Figure 1.** (A) Pre and (B) post revascularization angiography of the PTA.

Categorical variables were reported with their absolute number and percentage. In case of categorical variables, the chi-square test was used.

A logistic regression model evaluated the risk factors associated with unsuccessful SA. The crude and adjusted odds ratios (OR) are presented with their confidence interval and p-value. The statistically significant p-value was set at <0.05. The variables selected for the multivariate analysis were those clinically or statistically significant. STATA software version 13 was used for data analysis (StataCorp LP College Station, Texas, USA).

## Results

Eighteen SA were performed in diabetic patients between 2008 and 2016, 17 complied with inclusion criteria, and one was lost in the follow-up. The median follow-up was 14 months (IQR: 19-33), 16 patients were male, and one was a female. The median age was 57 years *(*IQR 44-64*)* (Table 1).

The main cause of amputation was ischemia. Ten patients had PTA occlusion before amputation. After digital angiography, cardiovascular surgeons considered that eight of them required a revascularization procedure before the amputation. Finally, three had successful revascularization of PTA, and five achieved satisfactory heel pad revascularization by collateral vessels. Nine out of 17 patients had a successful SA (not requiring a higher level of amputation), and eight evolved unfavorably. Seven of the last group required an infrapatellar and one supracondylar amputation (Figure 2).

Out of the nine patients who evolved favorably, eight had permeable posterior tibial at the time of SA. Permeability of

**Table 1.** Patients demographic data and associated risk factors

| | Total n = 17 | Successful n = 9 | Not successful n = 8 | p-value |
|---|---|---|---|---|
| Age, median (IQR), years | 57 (44-64) | 64 (49-70) | 52 (43-58) | 0.067 |
| Male Sex, n (%) | 16 (94) | 9 (100) | 7 (87) | 0.470 |
| Ischemia, n (%) | 10 (58.8) | 4 (44) | 6 (75) | 0.334 |
| Dialysis, n (%) | 8 (50) | 1 (12.5) | 7 (87.5) | 0.003 |
| Insulin-dependent, n (%) | 14 (82.4) | 6 (66.7) | 8 (100) | 0.072 |
| Ever-smoke, n (%) | 8 (50) | 3 (37) | 5 (62.5) | 0.317 |
| Contralateral amputation n (%) | 2 (12%) | 0 | 2 (25%) | 0.110 |
| Dyslipidemia, n (%) | 9 (56.3) | 5 (62.5) | 4 (50) | 0.614 |
| Obesity, n (%) | 4 (25) | 2 (25) | 2 (25) | 1 |
| Preoperative Glycosylated Hemoglobin, mean/average (SD), gr/dL | 7.24 (6.5-7.95) | 6.9 (6.6-7.5) | 7.6 (6.4-9.3) | 0.340 |
| Preoperative Albumin, median (IQR), gr/dL | 2,8 (2.6-3.1) | 3.1 (2.6-3.3) | 2.7 (2.49-2.85) | 0.147 |
| Permeable PTA n (%) | 10 (58.8) | 8 (88.9) | 2 (25) | **< 0.001** |

IQR: interquartile range, SD: standard deviation, PTA: posterior tibial artery, Boldface indicates statistical significance (p<0.05).

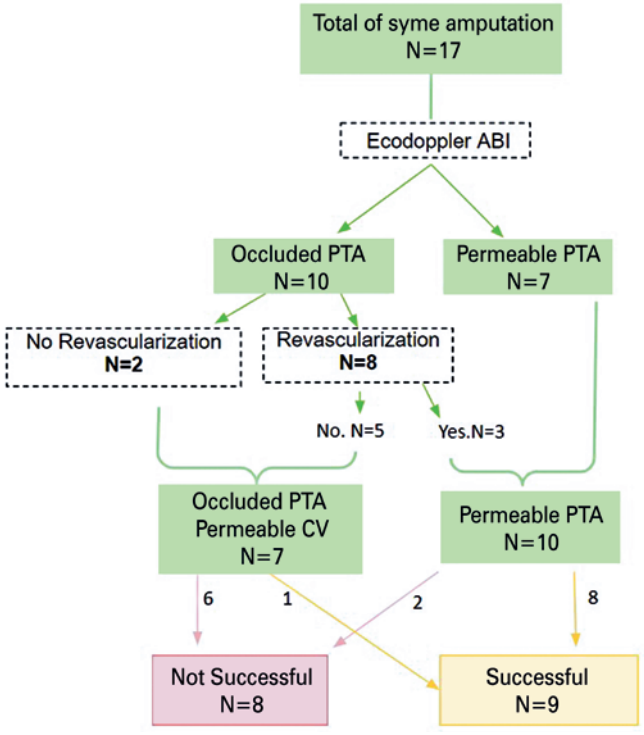


**Figure 2.** Treatment flowchart and evolution of the patients. ABI: ankle brachial index; PTA: posterior tibial artery; CV: collateral vessels.

the PTA was statistically significant (p=<0.001). Two patients who evolved unfavorably despite having a permeable PTA failed due to infectious compromise of residual tibial. Clinically there were no signs of infection in the ankle, but as a protocol procedure, the remaining bone samples were taken for culture and histopathology. Despite removing the compromised tissue and performing the amputation with healthy tissue, a multiresistant bacteria was found in the remaining tibia bone samples. After evaluating the risks and benefits with the infection committee, amputation was decided at a higher level.

Analyzing other factors that would interfere in the stump evolution, only a history of dialysis gave a statistically significant result (p=0.003). Seven out of eight patients who required a higher level of amputation were on dialysis; all required insulin. On the other hand, for oneonly one patient was on dialysis for those who evolved favorably.

When assessing the permeability of the PTA and dialysis as predictors of failure of this level of amputation, these factors multiplied the risk by 20 (cOR of 24 and 21, respectively). However, after adjusting for both factors, there was only clinical significance (Table 2). Furthermore, no relationship was found between other factors and the evolution of SA in our series.

## Discussion

The level of SA offers many advantages to diabetic patients over major amputations, including less metabolic expenditure[18,19], better proprioception, and easy gait adaptation[7,16]. A high percentage of revision at major levels was observed; patients must be adequately selected for this level of amputation. It is important to preserve the flow indemnity through the PTA for the survival of the heel flap and the wound closure of the residual limb or stump.

With the advent of revascularization procedures, major amputation rates have been reduced in diabetic patients. The success of peripheral bypass[22] and percutaneous peripheral angioplasty contributes to "lower limb salvage" procedures[23]. It has been demonstrated that SA is an acceptable option in

**Table 2.** Univariate and multivariable analysis for permeability of the PTA and dialysis as predictors of failure

| | OR | 95 % CI | p-value | aOR | 95 % CI | p-value |
|---|---|---|---|---|---|---|
| Permeable PTA | 24 | 1.74-330.8 | **0.02** | 11 | 0.58-206.8 | 0.11 |
| Dialysis | 21 | 1.5-293.3 | **0.02** | 11 | 0.58-206.8 | 0.11 |

OR: crude Odds Ratio; aOR: adjusted Odds Ratio in multivariable analysis; CI, confidence interval; PTA: posterior tibial artery. Boldface indicates statistical significance (p<0.05).

diabetic dysvascular patients who underwent a preoperative revascularization procedure[5,24]. In our series, initially, ten patients had their PTA occluded, eight were revascularized, three the PTA became permeable, and five patients achieved a satisfactory heel pad revascularization due to collateral vessels. Regarding the patients who evolved favorably, eight out of nine had permeable posterior tibial at the time of amputation. As for the two patients who evolved unfavorably despite having a permeable PTA, they failed due to infectious compromise of residual tibial.

On the other hand, the renal function was described as a predictor of transmetatarsal amputation (TMA) failure before[25], Syme procedure could be considered a minor amputation. In our series, seven patients out of eight with a non-successful SA were on dialysis. Ahn et al.[25] included 2018 patients submitted to TMA as the primary procedure to assess the relationship of renal function with TMA failure. Seventy-two patients failed and underwent major amputations. They found out that when evaluating risk for major amputation, the adjusted ORs for end-stage renal disease (ESRD) and dialysis was 2.28 (95% CI=1.27, 3.96) and 1.94 (95% CI=1.11, 3.28), respectively. ESRD negatively impacts morbidity, mortality, and survival rates after lower extremity amputation[26].

It is also important to control blood glucose levels for the evolution of the residual limb wound. Hyperglycemia disables macrophages and lymphocytes, which participate in the healing process[27]. In addition, higher levels of postoperative infection have been observed in patients with uncontrolled diabetes[28,29]. A reasonable glycosylated hemoglobin for adult patients is lower than 7%. Less stringent levels, lower than 8%, can be appropriate for patients with multiple comorbidities or long-standing diagnoses in which the objective is difficult to reach despite care education, adequate blood glucose monitoring, and effective doses of glucose-lowering medication and insulin[20]. In our series, patients who required a major level of amputation had preoperative glycosylated hemoglobin of 7.6gr/dL, and the successful patients had 6.9gr/dL; this difference is not statistically significant.

Overall, it is accepted that for the healing of successful wound normalization of serum albumin, a minimum of 3.0g/dl is required as tissue nutrition parameter[30,31]. Pinzur et al.[14] have established that a higher rate of wound healing has been achieved with adequate vascular flow and albumin higher than 2.5g/dl. They report a success of 88% with this level of amputation. In our series, the percentage of SA success was lower (53%), despite the albumin blood level being higher than 2.5g/dl. We believe that the lower percentage of success was related to vascularization of the heel flap and higher morbidity; most patients were on dialysis at the time of surgery. Even though age has been described as a predictor of failure, especially older than 65 years[13], in our series, the group that evolved favorably had a median age of 64 (IQR 25-75 49-70), and the one that required a level revision was of 52 (IQR 43-58).

One of the limitations of our study is the small and retrospective sample. Another one is the little published literature, which analyzes after the revascularization procedure not only the permeability of the PTA but the heel pad vascularization status at the time of amputation. We also found a few publications about the relationship between dialysis and not successful minor amputation.

## Conclusion

Syme amputation in diabetic patients may be an alternative in those with a preserved heel pad tissue vascularization due to a permeable posterior tibial artery at the time of surgery. However, patients on dialysis are likely to fail with this level of amputation. There is no relationship between other factors and the evolution of amputation in our series.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: VMC *(https://orcid.org/0000-0002-8115-6300) Conceived and planned the activities that led to the study, approved the final version; ACP *(http://orcid.org/0000-0001-7308-3693) Conceived and planned the activities that led to the study, approved the final version; MGSA *(https://orcid.org/0000-0002-5127-5827) Performed the surgeries, interpreted the results of the study, approved the final version; SC *(http://orcid.org/0000-0001-8144-3994) Data collection, interpreted the results of the study, participated in the review process and approved the final version; DSV* (http://orcid.org/0000-0001-5742-1226 ) Data collection, interpreted the results of the study, participated in the review process and approved the final version; LAC *(http://orcid.org/0000-0003-2333-5834) Data collection, interpreted the results of the study, participated in the review process and approved the final; PS *(http://orcid.org/0000-0001-8714-299X) Performed the surgeries, interpreted the results of the study, and approved the final version; MC *(http://orcid.org/0000-0002-1251-4936) Performed the surgeries, interpreted the results of the study, and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Effects of the SARS-CoV-2 pandemic on the incidence of surgically treated fractures in Sao Paulo city

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## Abstract

**Objective:** Evaluate the effect of the SARS-CoV-2 pandemic in the two years since it started.

**Methods:** Retrospective study to analyze the complex structured data set of high volume and variability (Big Data) publicly available on the TabNet platform (DATASUS) through artificial intelligence software. The results of foot and ankle fractures, all lower limb fractures, and all body fractures were analyzed comparatively from 2018-2019 to 2020-2021.

**Result:** The isolated fibula fracture suffered the greatest decrease from 2018-2019 to 2020, and the malleolar fracture presented the highest increase in this period. All fractures showed an increase in 2021 compared to 2020. Except for the distal tibial articular and the talar fractures, the length of hospital stay decreased for all other fractures and the malleolar fracture, remaining up to 36% fewer days hospitalized.

**Conclusion:** COVID-19 pandemic initially decreased the incidence of surgically treated fractures in most fracture patterns, but this effect was not maintained in the second year of the pandemic. The length of hospital stay of these patients decreased in the two years of the pandemic compared to 2018-2019.

**Level of Evidence II; Retrospective Study; Economic and Decision Analyses - Developing an Economic or Decision Model.**

**Keywords:** COVID-19; Fractures, bone; Hospitalization; Pandemics; SARS-CoV-2.

## Introduction

One of the current main diseases is the coronavirus-19 (COVID-19), the largest infection that has affected the world in the last 100 years[1-3]. It was first described in Wuhan/China in late 2019 but spread worldwide in early 2020 when the World Health Organization (WHO) considered it a pandemic[4,5]. The first case described in Brazil was in February 2020.

Social isolation was one of the main ways to combat the transmission of COVID-19, and it was expected to minimize contact between people[6,7]. The decrease in traumas could be possible with the isolation, especially those of high energy, due to the reduction of sports practices, the traffic of cars/motorcycles, and high falls.

Some articles described this decrease in some fracture incidence during the pandemic's peak period, but it was described for short periods of up to six months[8-13]. Therefore, the objective of this study is to describe the effect of the pandemic in its two years of duration compared to the previous two years.

## Methods

Retrospective study to analyze the complex structured data set of high volume and variability (Big Data) publicly available on the TabNet platform of the public health informatics system (DATASUS)[14] in one of the most populated cities in the world (Sao Paulo), through artificial intelligence software.

Study performed at the Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

**Correspondence:** Dov Lagus Rosemberg. Av. Albert Einstein, 627/701 - Morumbi, 05652-900, São Paulo, SP, Brazil. **E-mail:** dr.dovr@gmail.com. **Conflicts of interest:** none. **Source of funding:** none. **Date received:** October 10, 2022. **Date accepted:** December 06, 2022. **Online:** December 20, 2022.

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The following codes were used:

04.08.05.049-7 Surgical treatment of bimalleolar/trimalleolar/ankle dislocation-fracture;

04.08.05.054-3 Surgical treatment of tibial pilon fracture;

04.08.05.057-8 Surgical treatment of unimalleolar ankle fracture;

04.08.05.0454 Surgical treatment of fracture/physical injury of midfoot bones;

04.08.05.046-2 Surgical treatment of fracture/physical injury of metatarsals;

04.08.05.047-0 Surgical treatment of fracture/physical injury of the toes;

04.08.05.053-5 Surgical treatment of calcaneal fracture;

04.08.05.056-0 Surgical treatment of talar fracture;

04.08.05.069-1 Surgical treatment of metatarsophalangeal/interphalangeal dislocation/fracture-dislocation;

04.08.05.070-5 Surgical treatment of subtalar and intratarsal dislocation/fracture-dislocation;

04.08.05.071-3 Surgical treatment of tarsal-metatarsal dislocation/fracture-dislocation.

In addition, information was also processed for all lower limb fractures using the ICD-10 classification (codes S72, S82, and S92) and for all body fractures using the ICD-10 classification (codes S12, S22, S32, S42, S52, S62, S72, S82, and S92), in patients over 20 years. Information on the number of hospitalizations and the length of hospital stay was collected for all these injuries. The TabNet platform or system also extracted data from the last population census of the studied city[15].

The authors defined that for an alteration to be significant, it should not exceed 5%, and less than 5% could be considered a normal variation between years.

## Results

In the incidence of fractures in 2020, the distal tibial articular fracture and foot fracture had little change with the emergence of SARS-CoV-2, with less than a 5% variation compared to the mean of 2018-2019 (Figure 1A and Table 1). The isolated fibula fracture showed a large drop in incidence from 15.83 and 16.70/$10^5$ cases-inhabitants in the pre-COVID-19 years to 10.72/$10^5$ cases-inhabitants in 2020, representing a drop of 34% compared to the mean of previous years. The calcaneal fracture, the lower limb fractures, and all fractures present a small decrease in incidence between pre-/during COVID-19 years, with a reduction of around 6% in 2020 compared to the mean of 2018-2019 (Figure 1B). The malleolar fracture presented the opposite behavior with an increase in the incidence of 10.41 and 11.29/$10^5$ cases-inhabitants in 2018-2019 to 16.95/$10^5$ cases-inhabitants. Finally, the talar fracture showed a slight increase of 7.69% in the incidence of 2020 compared to 2018-2019.

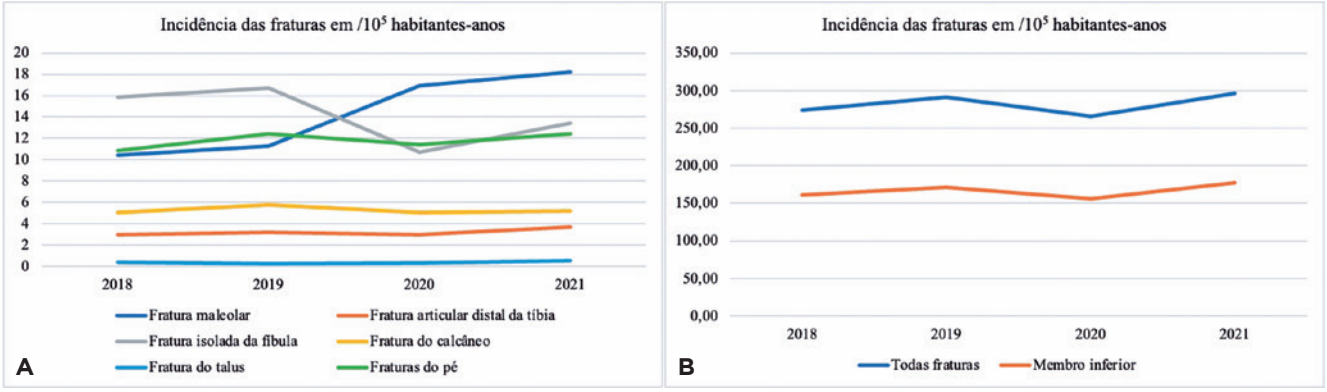


**Figure 1.** A) Graph showing the incidence of ankle and foot fractures between 2018-2021. B) Graph showing the incidence of all body and lower limb fractures.

**Table 1.** Comparison of incidences

| | 2020 vs. 2018-2019 | 2021 vs. 2020 | 2021 vs. 2018-2019 |
|---|---|---|---|
| All fractures | 6.05% | 11.43% | -4.69% |
| Lower limb | 6.42% | 13.65% | -6.36% |
| Malleolar fracture | -56.25% | 7.50% | -67.96% |
| Distal tibial articular fracture | 2.45% | 22.42% | 19.42% |
| Isolated fibula fracture | 34.10% | 25.54% | 17.27% |
| Calcaneal fracture | 6.96% | 2.21% | 4.90% |
| Talus fracture | -7.69% | 53.57% | -65.38% |
| Foot fracture | 2.08% | 9.02% | -6.76% |

There was an increased incidence of all analyzed fractures when comparing 2021 to 2020, with the calcaneal fracture the least increased (2.21%) and the talus fractures with the greatest increase (53.57%). When comparing 2021 with the mean of 2018-2019, the isolated fibula fracture still has a lower incidence than in the pre-COVID-19 years; calcaneal and general fractures returned to similar levels to these years. The other fractures have an incidence already higher than 2018-2019, with the malleolar fracture having increased by 68% compared to these years.

Regarding the length of hospital stay for these fractures, in 2020, only the talar fracture presented a longer length of hospital stay than the previous mean (51.94% more, equal to 3.24 days more) (Table 2 and Figure 2). The distal tibial articular and isolated fibula fractures did not have significant changes. However, the length of hospital stay decreased for all other fractures and the malleolar fracture, reducing by almost a third their length of stay.

Most fractures maintained a similar length of hospital stay in 2021, only the talar fracture had a significant reduction of 47.62% and the calcaneal and foot fractures showed an increase of 10.50% and 9.07%, respectively. Compared to the pre-pandemic years, only the distal tibial articular fractures and isolated fibula and foot fractures did not present a reduction in the mean length of hospital stay.

**Table 2.** Comparison of length of hospital stay

| | 2020 vs. 2018-2019 | 2021 vs. 2020 | 2021 vs. 2018-2019 |
|---|---|---|---|
| All fractures | 9.83% | -2.36% | 7.70% |
| Lower limb | 8.65% | -1.07% | 7.67% |
| Malleolar fracture | 33.10% | 4.30% | 35.98% |
| Distal tibial articular fracture | -0.40% | 0.26% | -0.14% |
| Isolated fibula fracture | 1.44% | 3.25% | 4.64% |
| Calcaneal fracture | 17.54% | -10.50% | 8.88% |
| Talus fracture | -51.94% | 47.62% | 20.42% |
| Foot fracture | 10.86% | -9.07% | 2.78% |

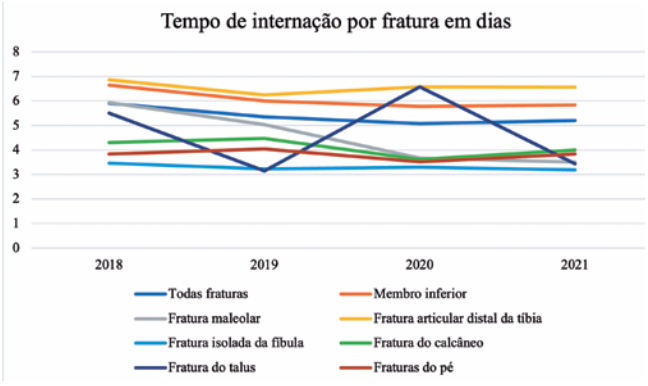


**Figure 2.** Graph showing the variation in the length of hospital stay for fractures in the last two years.

## Discussion

In the first year of COVID-19, the incidence of surgical fractures in Sao Paulo city decreased, as did the lower limb surgical fractures. The reduction may be due to the isolation applied in the city that reduced the chance of high-energy traumas such as automobile accidents, falls from great heights, or sports traumas[16,17]. This decrease in incidence was seen in most studies that described the initial phase of COVID-19[8-13,16,17]. However, malleolar and talar fractures, considered high-energy trauma, increased during this period and may be associated with changes in patient habits during the isolation period.

The second year of COVID-19 showed an increase in the incidence of all fractures compared to the initial year; this may be related to the decrease in social isolation in 2021. Mo et al.[16] also described this increasing number of cases in 2021.

In addition, Khabiri et al.[13] found that some fractures had a faster treatment due to the cancellation of elective surgeries that did not dispute the operating room and medical availability, which is more relevant in developing countries with less access to health care. This pattern of faster treatments was also found in the analyzed years, but it remained even in 2021 when most hospitals had already returned with elective surgeries, which may indicate that there was a restructuring of services to allow greater efficiency in bed management.

The study's limitations are the database where the information was extracted; there is no description of the type of accident suffered by the patient. In addition, it was not possible to verify the number of patients who underwent conservative treatment and how many patients received the diagnosis in the emergency room and were sent home and returned only on the day of surgery. Also, there is no data on the private care system and health insurance. However, this study is one of the only articles that analyze COVID-19 data in 2020-2021 and describes how much it affected the length of hospital stay and not only the occurrence.

## Conclusion

The emergence of SARS-CoV-2 decreased the incidence of in-hospital treatment of most fractures patterns, but in 2021 this effect was not maintained, with the incidence of most fractures greater than 2020. On the other hand, one of the results of COVID-19 was a reduction in the length of hospital stay, something that remained in the two years of the pandemic, which may represent a new trend.

**Author's contributions:** Each author contributed individually and significantly to the development of this article: DLR*(https://orcid.org/0000-0003-0183-8641) Conceived and planned the activities that led to the study, data collection, statistical analysis, wrote the article; NW *(https://orcid.org/0000-0003-1991-3507), and MFAS *(https://orcid.org/0000-0002-0714-5291) Interpreted the results of the study, participated in the review process, performed the surgeries; VG *(https://orcid.org/0000-0002-4429-312X), and ALG *(https://orcid.org/0000-0002-6672-1869) Interpreted the results of the study, participated in the review process, performed the surgeries. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Original Article

# Translation, cultural adaptation, and validation of the Manchester-Oxford Foot Questionnaire into Brazilian Portuguese

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## Abstract

**Objective:** Translate, culturally adapt and validate the Manchester-Oxford Foot Questionnaire (MOXFQ) into Brazilian Portuguese.

**Methods:** The translation followed the guidelines standardized in the literature, including initial translation, back-translation, committee review, pre-test phase, and application of the final questionnaire in 50 patients. Intraobserver reproducibility was evaluated by reapplying the final version of the questionnaire 14 days after the first application. The validation of the final MOXFQ translation was assessed by conjoint application with the SF-36 Quality of Life questionnaire; similar domain scores of the two questionnaires were compared and analyzed.

**Results:** Excellent reproducibility was observed for three domains with statistical significance, the intra-class correlation coefficient (ICC) values were: pain 0.98, walking/standing 0.99, and social interaction 0.98. Internal consistency/reliability obtained excellent values: pain 0.992, walking/standing 0.997, and social interaction 0.992, all with statistical significance ($p<0.001$). In the MOXFQ validation compared to the SF-36, the highest correlations of the study were found between the SF36 physical functioning domain and the MOXFQ walking/standing (-0.72) and social interaction domains (-0.73). Comparing the MOXFQ walking/standing domain, a good correlation was obtained with the SF-36 physical functioning (-0.41), bodily pain (-0.42), vitality (-0.45), and mental health (-0.40) domains. Also a good correlation was obtained on MOXFQ pain domain with the SF-36 physical functioning (-0.45) and social functioning (-0.43).

**Conclusion:** The MOXFQ Brazilian version proved reliable, valid, and reproducible in measuring the symptoms and functional limitations of patients affected by foot and ankle diseases.

**Level of Evidence IV; Therapeutic Studies; Case Series.**

**Keywords:** Pain; Reproducibility of results; Surveys and questionnaires; Translations.

## Introduction

Foot and ankle diseases have a great impact on the quality of life of patients[1]. Therefore, surgeries to treat these diseases are quite common in orthopedic practice. However, the evaluation of the results of proposed treatments may be questionable because researchers use different methods and instruments to verify their outcomes[2].

Most questionnaires used to assess the quality of life and treatment results are created in English. They are produced and applied according to the demographic and cultural characteristics of the region[3-5]. Based on the original questionnaire, translation and validation studies are performed in other languages about the characteristics and information established by the initial version[6-9].

The Manchester–Oxford Foot Questionnaire (MOXFQ) was developed by the Department of Public Health at Oxford University in the United Kingdom in 2006. They produced an instrument to evaluate results in foot and ankle surgeries based on patients' complaints. There are 16 questions with five response options to assess the frequency and intensity of the

Study performed at the Centro Universitário, Faculdade de Medicina do ABC, Santo André, SP, Brazil.

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limitation questioned. It evaluates three domains: walking/standing, pain, and social interaction[10].

The use of instruments that assess the pain and quality of life of patients is important to correlate the specific clinical complaints about a condition related to the physical, mental, and social well-being of the patient. The need for a standardized, fast, and easy-to-understand assessment method in the Brazilian Portuguese language supported our intention in this study.

The objective of this study is to translate, culturally adapt and validate the Manchester-Oxford Foot Questionnaire into Brazilian Portuguese.

## Methods

The MOXFQ was the basis for the study, which consists of 16 questions addressing three domains: walking/standing, pain, and social interaction. The patients answers the items according to their perception of limitation, varying from 0 no limitation to 4 maximum limitation[10]. The questionnaire was submitted to a strict translation and cultural adaptation protocol, and then its final translated version was applied to the patients and validated.

The study was approved by the institution's research ethics committee and all participants signed the informed consent form.

The translation and cultural adaptation of the questionnaire followed a set of guidelines and a series of norms standardized by Guillemin et al.[6]. The process also followed the recommendations proposed in the guidelines established by Reichenheim and Moraes[11], constituting a systematic approach:

***a) Initial translation:*** The MOXFQ was initially translated by two qualified and sworn independent translators, who performed the translation into their mother tongue (Brazilian Portuguese). The translators were aware of the objectives of the questionnaire and the study. Furthermore, they were instructed on the concepts involved in the translation process and cultural adaptation proposed by the protocols followed to offer a more reliable restitution of the intended measure.

***b) Back-translation (reverse translation):*** Each of the first translations was back-translated independently, generating two back-translation versions. The purpose of this stage is to reveal misunderstandings and failures of the first translations and adaptation to the target cultural context of these versions.

The back-translation was performed by two other specialists into their mother tongue (British English), fluent in the expressions and everyday use of the original language from the initial questionnaire and the intended result of the back-translation proposed.

The translators at this stage were not aware of the intentions and concepts of the material and study. The freedom of translation of this phase is free from biases and expectations of the selected professionals. It allows the generated versions to reveal unexpected meanings and interpretations that will be the object of comparison and study, identifying inconsistencies in the definition of the final version.

***c) Specialized committee review:*** A multidisciplinary committee was established to compare and review the two translations and back-translations and define a final document. The group consisted of three bilingual orthopedists and foot and ankle specialists, a sworn independent translator who had not yet participated in the study, an individual of the target population, and a bilingual physiotherapist.

The committee analyzed the documents considering semantic, idiomatic, and conceptual equivalence, sought to eliminate ambiguities, and focused on adapting to the cultural situation of the target population. The final objective of the committee was to ensure that the translation was fully understandable, even if new words were generated or inappropriate terms were rejected.

***d) Pre-test phase:*** The final translation version defined and reviewed by the committee (Figure 1) was submitted to a group of ten patients randomly chosen in the foot and ankle outpatient clinic of the orthopedics and traumatology department. All patients met the inclusion and exclusion criteria proposed by the study.

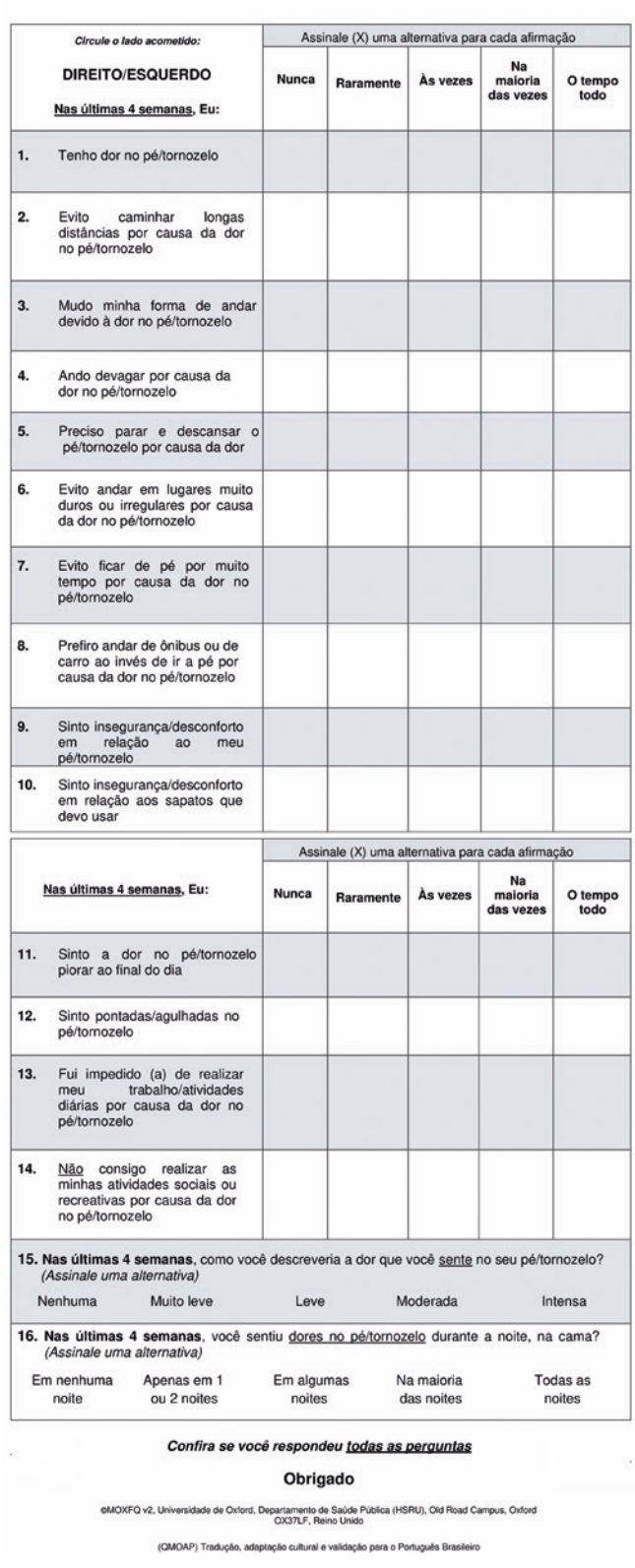
During the application, after each item was answered, the patients were asked about their understanding and could mark the question as "difficult to understand". Aiming that the final questionnaire is understood with the equivalent meaning to the original version, the questions marked as "difficult to understand" by ≥10% were reviewed and re-discussed by the multidisciplinary committee.

***e) Evaluation of intraobserver reproducibility and validity of the MOXFQ translated version:*** After approval by the ethics committee, the final revised and translated questionnaire was applied by the same specialist in a population of 50 patients treated at the foot and ankle outpatient clinic of the orthopedics department in 2019. The chosen patients signed the informed consent form.

The inclusion criteria were: patients over 18 years submitted to foot and ankle surgeries to correct deformity, osteoarthritis, neurological diseases, and ankle instability. Exclusion criteria were: patients submitted to bilateral foot and ankle surgeries or patients with an active infection in the lower limb.

Intraobserver reproducibility was evaluated by reapplying the final version of the questionnaire to 50 patients 14 days after the first application.

To obtain a correlation measure and evaluate the validity of the final translated version, the SF-36 Quality of Life questionnaire was used, which addresses eight categories based on physical and emotional functioning. This questionnaire consists of 36 questions assessing functional capacity, physical aspects, bodily pain, general health, vitality, social and emotional aspects, and mental health, and it has already been translated and validated into Portuguese by other researchers[12].



| *Circule o lado acometido:* DIREITO/ESQUERDO Nas últimas 4 semanas, Eu: | Assinale (X) uma alternativa para cada afirmação | | | | |
|---|---|---|---|---|---|
| | Nunca | Raramente | Às vezes | Na maioria das vezes | O tempo todo |
| 1. Tenho dor no pé/tornozelo | | | | | |
| 2. Evito caminhar longas distâncias por causa da dor no pé/tornozelo | | | | | |
| 3. Mudo minha forma de andar devido à dor no pé/tornozelo | | | | | |
| 4. Ando devagar por causa da dor no pé/tornozelo | | | | | |
| 5. Preciso parar e descansar o pé/tornozelo por causa da dor | | | | | |
| 6. Evito andar em lugares muito duros ou irregulares por causa da dor no pé/tornozelo | | | | | |
| 7. Evito ficar de pé por muito tempo por causa da dor no pé/tornozelo | | | | | |
| 8. Prefiro andar de ônibus ou de carro ao invés de ir a pé por causa da dor no pé/tornozelo | | | | | |
| 9. Sinto insegurança/desconforto em relação ao meu pé/tornozelo | | | | | |
| 10. Sinto insegurança/desconforto em relação aos sapatos que devo usar | | | | | |

| Nas últimas 4 semanas, Eu: | Assinale (X) uma alternativa para cada afirmação | | | | |
|---|---|---|---|---|---|
| | Nunca | Raramente | Às vezes | Na maioria das vezes | O tempo todo |
| 11. Sinto a dor no pé/tornozelo piorar ao final do dia | | | | | |
| 12. Sinto pontadas/agulhadas no pé/tornozelo | | | | | |
| 13. Fui impedido (a) de realizar meu trabalho/atividades diárias por causa da dor no pé/tornozelo | | | | | |
| 14. Não consigo realizar as minhas atividades sociais ou recreativas por causa da dor no pé/tornozelo | | | | | |

**15. Nas últimas 4 semanas**, como você descreveria a dor que você sente no seu pé/tornozelo? *(Assinale uma alternativa)*

Nenhuma | Muito leve | Leve | Moderada | Intensa

**16. Nas últimas 4 semanas**, você sentiu dores no pé/tornozelo durante a noite, na cama? *(Assinale uma alternativa)*

Em nenhuma noite | Apenas em 1 ou 2 noites | Em algumas noites | Na maioria das noites | Todas as noites

***Confira se você respondeu todas as perguntas***

**Obrigado**

©MOXFQ v2, Universidade de Oxford, Departamento de Saúde Pública (HSRU), Old Road Campus, Oxford OX37LF, Reino Unido

(QMOAP) Tradução, adaptação cultural e validação para o Português Brasileiro

**Figure 1.** Questionário Mancheste-Oxford para avaliação do pé (QMOAP). Brazilian final version.

The SF-36 questionnaire was applied concomitantly with MOXFQ for the same patients, and the scores of similar domains from the two questionnaires were compared and analyzed.

***f) Methodology of statistical analysis:*** Initially, a descriptive analysis of all study variables was performed. Then, the qualitative variables were presented in their absolute and relative values, and the quantitative variables in their central tendency and dispersion values[13]. The Kolmogorov-Smirnov and Levene tests were used to evaluate the adherence to the normal curve and the homogeneity of the variances[13].

The Kappa coefficient was used to evaluate the agreement and intraobserver reproducibility (test and retest) of the MOXFQ for each domain, with its respective 95% confidence interval[13,14]. Cronbach's alpha coefficient[13,14] was used to assess internal consistency.

Spearman's correlation coefficient (most non-parametric variables) was used to evaluate the correlation between the SF-36 and the MOXFQ domains[13,15]. The significance level was 5%. The statistical package used was SPSS 24.0 for Windows (IBM Corp., Armonk, New York, USA).

## Results

### Population Characteristics

Fifty patients with various foot and ankle diseases were included in the study. It is observed that most are women, married, and with complete high school. The mean age of the study was 54.52 years (14.49 Standard Deviation (SD)). The female representation was 78% compared to the total population. The demographic characteristics of the patients are shown in table 1.

Demographic information complementary to the epidemiological profile can be seen in Tables 2 and 3. Most participants were housewife/men or general assistants, white, and catholic (Table 2). Also, most patients were non-smokers, had already undergone physical therapy, did not practice physical activity, and had some comorbidity or personal history (Table 3).

### Visual Analog Scale (VAS), Body Mass Index (BMI), and laterality

The group VAS mean was 7.82 (2.17 SD), ranging from 2 to 10 points, and the group BMI mean was 29.67 (4.87 SD), ranging from 20.31 to 40.58. The laterality of the patients that presented pathology and pain; 21 (42%) were left, 18 (36%) right, and 11 (22%) bilateral.

### Intraobserver reproducibility (test and retest)

The reproducibility of the translated MOXFQ questionnaire was evaluated in the two applications using the Kappa coefficient based on the analysis of the intra-class correlation coefficient (ICC) with its respective 95% confidence interval. The ICC values for the domains were: pain 0.98, walking/standing 0.99, and social interaction 0.98. The reproducibility for the three domains was excellent and statistically significant (Table 4).

### Internal consistency/reliability

Internal consistency was tested by Cronbach's alpha coefficient analysis. All three domains presented values above 0.9 and excellent internal consistency and reliability (Table 5).

### MOXFQ validation

Table 6 shows the Spearman correlation analysis between the SF-36 and MOXFQ domains. There is an inversely proportional correlation between the MOXFQ domains (pain, walking/standing, social interaction) and SF-36 (functional capacity, physical aspects, bodily pain, general health, vitality, social and emotional aspects, and mental health).

## Discussion

Questionnaires that assess the quality of life and the impact of a disease on the patient's well-being play an important role as a complementary instrument in measuring the success of treatment. In this context, there is a growing need to translate, culturally adapt and validate specific scales known to be efficient and well-accepted in the scientific community to standardize the evaluation method.

The MOXFQ is an objective and well-developed questionnaire by Dawson et al.[10]. The present study aimed to create a MOXFQ in Brazilian Portuguese for the first time. The process was performed according to the guidelines and standards recommended for the validation process[6,11].

**Table 1.** Descriptive demographic analysis

| Variables | Total (N = 50) |
|---|---|
| Age (years) | |
| Mean (SD) | 54.52 (14.49) |
| Minimum – Maximum | 19 – 78 |
| Sex (N)% | |
| Female | 39 (78.0) |
| Male | 11 (22.0) |
| Marital status (N)% | |
| Single | 9 (18.0) |
| Married | 32 (64.0) |
| Divorced | 7 (14.0) |
| Widow | 2 (4.0) |
| Educational level (N)% | |
| Secondary level incomplete | 15 (30.0) |
| Secondary level complete | 5 (10.0) |
| High school incomplete | 4 (8.0) |
| High school complete | 17 (34.0) |
| University incomplete | 5 (10.0) |
| University complete | 3 (6.0) |
| Not informed | 1 (2.0) |

SD: Standard deviation.

The original questionnaire was translated and generated two independent versions that subsequently underwent a back-translation into the original language, resulting in two other versions. Finally, with the five documents in hand, the multidisciplinary committee met to discuss cross-cultural adaptation correcting erroneous interpretations in the process in the face of the Brazilian social and cultural context, and deciding the final version of the translation with good conceptual equivalence.

**Table 2.** Descriptive analysis of occupation, race, and religion

| Variables | Nº | % |
|---|---|---|
| Occupation | | |
| Retired | 7 | 14.0 |
| Housewife/man | 9 | 18.0 |
| Health care worker | 5 | 10.0 |
| Housekeeper | 2 | 4.0 |
| General assistant | 9 | 18.0 |
| Construction worker | 3 | 6.0 |
| Salesperson | 3 | 6.0 |
| Other | 12 | 24.0 |
| Race | | |
| White | 21.0 | 42.0 |
| Brown | 18.0 | 36.0 |
| Black | 8.0 | 16.0 |
| Not informed | 3.0 | 6.0 |
| Religion | | |
| Catholic | 32.0 | 64.0 |
| Spiritism | 3.0 | 6.0 |
| Evangelist | 10.0 | 20.0 |
| None | 5.0 | 10.0 |

**Table 3.** Descriptive analysis of habits, physical activities, physiotherapy, and comorbidities

| | Nº | % |
|---|---|---|
| Habits | | |
| Smoker | 5 | 10.0 |
| Ex-smoker | 3 | 6.0 |
| No smoker | 42 | 84.0 |
| Physical activity | | |
| Yes | 11 | 22.0 |
| No | 39 | 78.0 |
| Physiotherapy | | |
| Yes | 32 | 64.0 |
| No | 18 | 36.0 |
| Comorbidities | | |
| Yes | 38 | 76.0 |
| No | 12 | 24.0 |
| Personal history | | |
| Yes | 38 | 76.0 |
| No | 12 | 24.0 |

**Table 4.** Intra-class correlation coefficient of the MOXFQ domains

| Domains | MOXFQ | | ICC (95%CI) | p-value |
|---|---|---|---|---|
| | First evaluation | Second evaluation | | |
| | Mean (SD) | | | |
| Pain | 14.14 (3.97) | 13.76 (4.15) | 0.98 (0.97 – 0.99) | p<0.001 |
| Walking/standing | 20.38 (7.73 | 20.50 (8.06) | 0.99 (0.98 – 1.00) | p<0.001 |
| Social interaction | 10.48 (4.48) | 10.30 (4.73) | 0.98 (0.97 – 0.99) | p<0.001 |

SD: Standard deviation; ICC: Intra-class correlation coefficient; 95%IC: 95% Confidence interval

**Table 5.** Cronbach's alpha coefficient analysis of MOXFQ domains

| Domains | Cronbach's alpha | Level of significance |
|---|---|---|
| Pain | 0.992 | p<0.001 |
| Walking/standing | 0.997 | p<0.001 |
| Social interaction | 0.992 | p<0.001 |

**Table 6.** Portuguese MOXFQ validation according to Spearman correlation analysis between the SF-36 and MOXFQ domains

| SF-36 domains | MOXFQ domains | | |
|---|---|---|---|
| | Pain | Walking/standing | Social interaction |
| Functional capacity | -0.45** | -0.72** | -0.,73** |
| Physical aspects | -0.26 | -0.41** | -0.51** |
| Bodily pain | -0.32* | -0.42** | -0.46** |
| General health | -0.27 | -0.20 | -0.22 |
| Vitality | -0.36* | -0.45* | -0.35* |
| Social aspects | -0.43** | -0.33* | -0.42** |
| Emotional aspects | -0.29* | -0.29* | -0.37** |
| Mental health | -0.32* | -0.40** | -0.34** |

*: p<0.05; **: p<0.01

The results showed that the MOXFQ Brazilian version is a reliable, valid, and reproducible instrument to measure the symptoms and functional limitations of patients affected by foot and ankle diseases.

The results of intraobserver reproducibility (test and re-test) were excellent. The ICC value for the respective domains was: pain 0.98, walking/standing 0.99, and social interaction 0.98, all with statistical significance (p<0.001). Internal consistency/reliability assessed from Cronbach's alpha coefficient obtained excellent values: pain 0.992, walking/standing 0.997, and social interaction 0.992, all with statistical significance (p<0.001).

The result obtained at this analysis stage differed slightly from the main studies that performed the MOXFQ translation and cultural adaptation [2,8,9]. We attributed this difference to the short time interval in which the questionnaire was reapplied (14 days), the fact that the patients in our population had not undergone any procedure or surgical intervention during the performance of all stages of the study. In addition, the researcher responsible for the application was experienced and had previous knowledge of the target population that could have generated a regularity in the responses of the MOXFQ questionnaire in the two moments applied.

For the validation stage, the correlation with the SF-36 domains was analyzed. The results of our study were comparable to those of Dawson et al. in most aspects[10]. The highest correlations of the study were between the SF-36 physical functioning domain and the MOXFQ walking/standing (-0.72) and social interaction (-0.73) domains. It is worth noting that the results obtained were very close to Dawson et al.[10], which also found its greatest correlation when comparing the MOXFQ walking/standing with SF-36 physical functioning (-0.677).

Comparing the MOXFQ walking/standing domain, a good correlation with the SF-36 physical aspects (-0.41), bodily pain (-0.42), vitality (-0.45), and mental health (-0.40) domains were found. Again, similar results to the study by Dawson et al.[10] were found, who also had a good correlation between the MOXFQ walking/standing with the SF-36 physical aspects (-0.579) and bodily pain (-0.543) domains.

A good correlation was also obtained between the MOXFQ pain domain and SF-36 functional capacity (-0.45) and social aspects (-0.43) domains. Dawson et al.[10] obtained a similar correlation between the MOXFQ pain domain with SF-36 functional capacity (-0.457).

Even with so many similarities between the studies, some differences were observed when comparing the MOXFQ and SF-36 pain domain; in our study was (-0.32), while in Dawson et al. was (-0.528). Furthermore, analyzing the MOXFQ social interaction domain of our study, a good correlation was observed in comparison with the SF-36 physical aspects (-0.51), bodily pain (-0.46), and social aspects (-0.42) domains, and in this comparison, stronger correlations were found than the study by Dawson et al.[10], which respectively obtained in the SF-36 physical aspects (-0.308), bodily pain (-0.273), and social aspects (-0.134).

It is possible to attribute some of the differences between the studies to the study population number and the sociodemographic characteristics that vary between the different populations and regions, such as the female population, which, in our study, was 78%, and Dawson et al. was 95%. Another important factor is to compare a specific questionnaire for

foot and ankle pathologies (MOXFQ) with a generic quality of life questionnaire that can assess different pathologies (SF-36).

One of the limitations of our study, compared to Dawson et al., was that we did not perform a correlation with a third questionnaire, such as the American Orthopaedic Foot and Ankle Society (AOFAS). Also, our study population had different foot and ankle pathologies, and the patients were not submitted to procedures during the application of the questionnaires, while Dawson et al.[10] selected only patients with halux valgus and compared them with other questionnaires applied before and after the surgical intervention.

## Conclusion

The MOXFQ Brazilian version proved reliable, valid, and reproducible in measuring the symptoms and functional limitations of patients affected by foot and ankle diseases.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: GBP *(https://orcid.org/0000-0003-4632-9672) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, data collection, bibliographic review, formatting of the article, approved the final version; BRM *(https://orcid.org/0000-0002-5306-2972) Conceived and planned the activities that led to the study, approved the final version; LZPO *(https://orcid.org/0000-0002-5306-2972) Participated in the review process, bibliographic review; HAF *(https://orcid.org/0000-0001-9920-5636) Conceived and planned the activities that led to the study, interpreted the results of the study; MBAGAG *(https://orcid.org/0000-0003-0007-5574) Interpreted the results of the study, participated in the review process; ACPN *(https://orcid.org/0000-0003-0007-5574) Formatting of the article, approved the final version; ADPF *(https://orcid.org/0000-0001-5808-1788) Data collection; bibliographic review DRCN *(https://orcid.org/0000-0003-0227-2440) Approved the final version, formatting of the article; TMF *(https://orcid.org/0000-0002-8328-1893) Data collection, statistical analysis; RSB *(https://orcid.org/0000-0002-2870-2261) Conceived and planned the activities that led to the study; approved the final version; data collection; bibliographic review; formatting of the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Three-dimensional assessment of hallux valgus correction using the Lapicotton technique

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## Abstract

**Objective:** The objective of the study was to assess the efficacy of the LapiCotton procedure on patients with hallux valgus (HV) combined with medial longitudinal arch collapse.

**Methods:** Preoperative and postoperative weight-bearing computed tomography (WBCT) scans were obtained from patients with HV submitted to the LapiCotton procedure. Semi-automatic measurements were applied to 22 WBCT images across 11 patients enrolled in the study using a software package (Bonelogic, Disior™, Helsinki, Finland). Significance level was set at 0.05.

**Results:** The hallux valgus angle (HVA) was significantly larger (p=0.026) in the preoperative group (Mdn = 27.52) than in the postoperative group (Mdn = 20). In addition, the Meary sagittal measurement was found to be significantly increased (p=0.033) in the preoperative group (Mdn = -14.28) when compared to the postoperative group (Mdn = -11.15). It was also observed that the intermetatarsal angle was significantly larger (p=0.003) in the preoperative group (Mdn = 15.68) compared to the postoperative group (Mdn = 11.26).

**Conclusion:** The LapiCotton procedure effectively corrected radiographic parameters in patients with HV combined with the medial longitudinal arch collapse.

**Level of Evidence III; Therapeutic Studies; Comparative Retrospective Study.**

**Keywords:** Flatfoot; Hallux valgus; Orthopedic procedures; Weight-bearing; Tomography, x-ray computed.

## Introduction

Hallux valgus (HV) is one of the most common foot and ankle deformities involving the first ray. The hallux valgus angle (HVA), intermetatarsal angle (IMA), proximal phalangeal articular angle, distal metatarsal articular angle, interphalangeal angle (IPA), and sesamoid rotation (SR) are important metrics that are used in diagnosis, surgical planning, and postoperative analysis[1,2]. Hallux valgus is best evaluated using weight-bearing computed tomography (WBCT), as this three-dimensional (3D) imaging modality is not influenced by foot projection or orientation and allows for visualization of multiplanar bone anatomy in an upright position[3]. In addition, WBCT inherently provides images in 3D to offer a complete way to assess patients with HV, allowing for accurate measurements of HVA, IMA, IPA, and SR[4].

Study performed at the UIOWA Orthopedic Functional Imaging Research Laboratory (OFIRL). University of Iowa, Carver College of Medicine, Department of Orthopedics and Rehabilitation, Iowa City, IA, USA

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It is a well-established concept in the literature that the first ray and the entire medial column play a crucial role in preserving the tripod of the foot[5]. Furthermore, changes to the biochemical and structural properties of the first ray, along with the medial longitudinal arch collapse, have been associated with HV. Thus, restoring the first ray plays an important role when restoring the mechanical function of the foot tripod in the setting of HV combined with medial longitudinal arch collapse.

Treating HV using the modified Lapidus procedure, where the first tarsometatarsal (TMT) joint is fused, can pose a challenge in maintaining the length and avoiding dorsal inclination of the distal part of the first ray. This can hinder the mechanical advantage provided by the first ray in correcting medial longitudinal arch collapse for patients with HV[6]. Therefore, the Cotton osteotomy attempts to fix the plantar inclination of the distal part of the first ray to rebuild the triangle of the foot support through a dorsal opening wedge of the medial cuneiform.

The LapiCotton is a surgical technique, recently described by de Cesar Netto et al.[6], that combines the mechanical advantages of a Cotton osteotomy and a modified Lapidus procedure. It is used to treat the collapse of the medial column through the fusion of the first TMT joint using a dorsal wedge distraction allograft. This procedure maintains the length of the first ray and restores the medial longitudinal arch by the plantar inclination of the distal part of the first ray in the foot tripod. Simultaneously, the procedure allows for conventional corrections of rotational and transverse plane malalignment[6].

In light of this knowledge, the aim of our study is to assess the efficacy of the LapiCotton procedure on patients with HV combined with medial longitudinal arch collapse. Our hypothesis is that the LapiCotton procedure will produce a reliable correction of HV, and medial longitudinal arch collapse, based on semi-automatic WBCT measurements of HVA, IMA, Meary angle, and SR.

## Methods

### Design

This research study complied with the Health Insurance Portability and Accountability Act (HIPAA) and was approved by the University of Iowa's IRB (ID# 201904825). It also complied with the Declaration of Helsinki. Weight-bearing computed tomography scans were obtained from patients with HV before and after the LapiCotton procedure, with the postoperative scans being scheduled approximately three months after the surgery date.

### Patients

Patients were enrolled from February 2020 to August 2021 for the preoperative WBCT scans. The final postoperative WBCT scan was obtained in January 2022. Preoperative and postoperative scans were obtained for the foot and ankle unilaterally or bilaterally, but LapiCotton procedures were performed only unilaterally for patients in this study. Semi-automatic measurements were applied to 22 WBCT images across 11 patients enrolled in the study (unilaterally applied per WBCT scan, with two scans per patient) using the Disior® Bonelogic® Foot and Ankle Software (version 2.1; Helsinki, Finland). The patients with HV (mean age 51 years, median 51, standard deviation 10.82, range 27-63) were 64% female and 36% male with a mean Body Mass Index (BMI) of 28.78 (median 29.36, standard deviation 5.06, range 21.79-39.75). Among the patients, 9% had diabetes, 9% smoked, and 9% had rheumatoid arthritis.

### Imaging acquisitions

Weight-bearing computed tomography scans were performed with a cone-beam CT extremity scanner (pedCAT® Model, CurveBeam®, Warrington, USA). Patients entered the device and were positioned in a bipedal standing position. A radiography emitter and a flat-panel sensor on the opposite side rotated horizontally around the feet. Images were acquired at 120kVp and 5mA with a maximum exposure of 10s. The volume was reconstructed with a 0.37 mm isotopic voxel[7].

### WBCT semi-automatic 3D measurements

The semi-automatic 3D measurements were performed by a fellowship-trained orthopedic foot and ankle surgeon using the Disior® Bonelogic® Ortho Foot and Ankle Software (version 2.1; Helsinki, Finland) for the following measurements (Figure 1): Meary angle (sagittal), HVA, IMA, and SR[3,8].

### Statistical analysis

Standard descriptive statistics (mean, median, interquartile range (IQR), and standard deviation) were calculated for the following measurements: Meary angle (sagittal), HVA, IMA, and SR. Intraclass correlation coefficients were calculated for continuous data. Normality of variable distributions was evaluated using the Shapiro-Wilk test. A paired t-test was used to evaluate the difference in means between preoperative and postoperative values for each measurement. Significance level was set at 0.05.

## Results

This study found that the HVA was significantly larger (p=0.026) in the preoperative group (Mdn = 27.52) than in the postoperative group (Mdn = 20). In addition, the Meary sagittal measurement (MSM) was found to be significantly different between groups (p=0.033), with a larger value seen in the preoperative group (Mdn = -14.28) compared to the postoperative group (Mdn = -11.15). It was also observed that the IMA was significantly larger (p=0.003) in the preoperative group (Mdn = 15.68) compared to the postoperative group (Mdn = 11.26). These findings are depicted in the associated figures (Figures 2, 3, and 4).

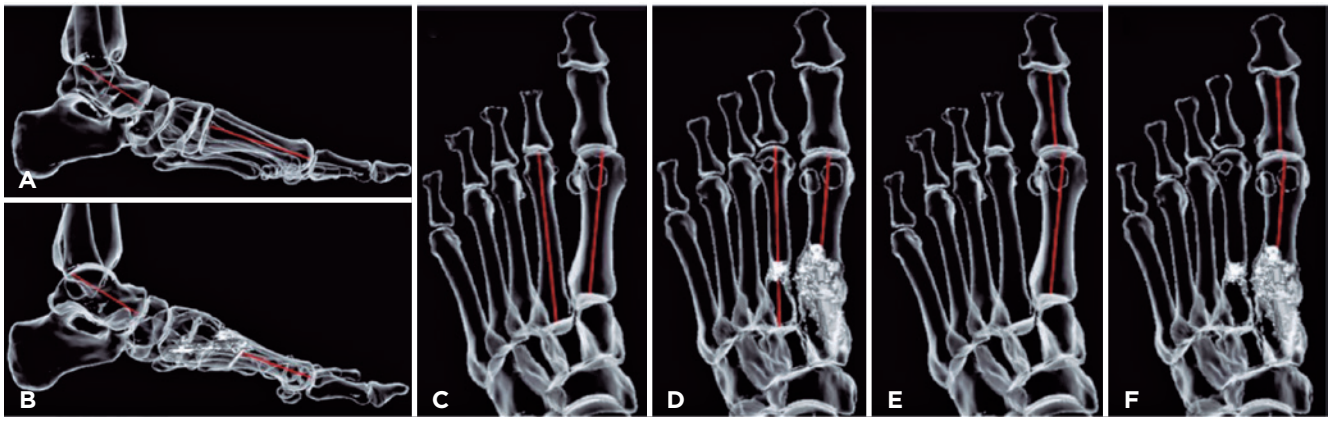


**Figure 1.** Three-dimensional semi-automatic WBCT measurements using the Disior Bonelogic Foot and Ankle Software (A) Meary angle, (C) Intermetatarsal angle, and (E) Hallux valgus angle, preoperative. (B) Meary angle, (D) Intermetatarsal angle, and (F) Hallux valgus angle, postoperative.

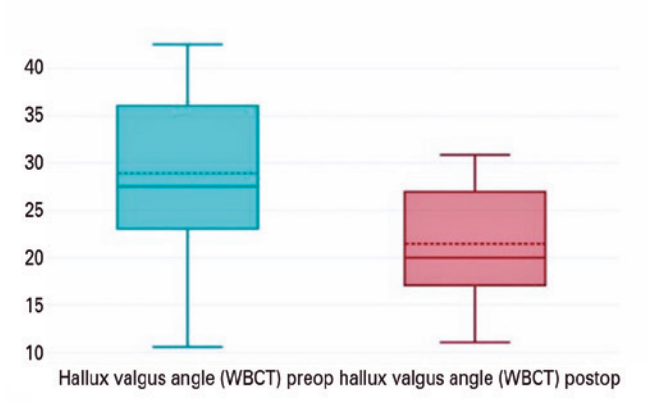


**Figure 2.** The Hallux valgus angle (WBCT) comparison between the preoperative and postoperative groups.

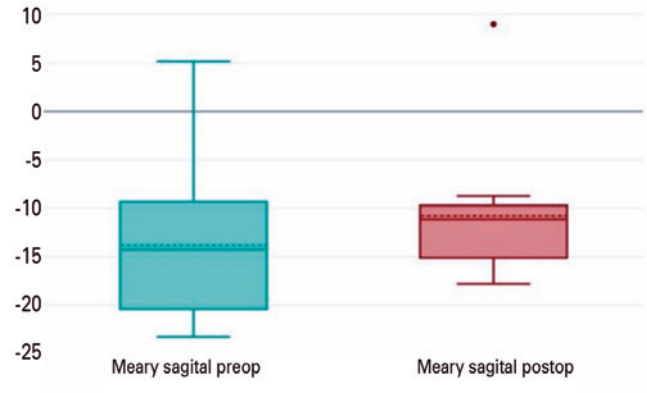


**Figure 3.** The Meary sagittal comparison between the preoperative and postoperative groups.

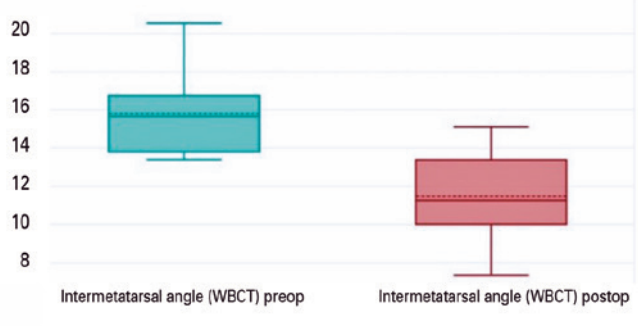


**Figure 4.** The Intermetatarsal angle (WBCT) comparison between the preoperative and postoperative groups.

The SR was found to be higher in the preoperative group (Mdn = -17.71) than in the postoperative group (Mdn = -24.98); however, these values were not significantly different from one another (p=0.203). These findings supported a failure to reject the null hypothesis (Figure 5).

## Discussion

This study focused on understanding the anatomical changes before and after surgery in patients with HV treated with the LapiCotton procedure. Weight-bearing computed tomography was utilized in this study because it is considered the best technique for quantification when measuring the horizontal and vertical alignment of HV[9-11]. Semi-automatic WBCT measurements of patients with HV, combined with medial longitudinal arch collapse, were taken before and after undergoing the LapiCotton procedure.

The LapiCotton technique was developed in an attempt to maintain the length of the first ray and, therefore, the integrity of the 3D foot tripod. In a recent prospective cohort

study by de Cesar Netto et al.[6], the LapiCotton technique was performed to treat medial longitudinal arch collapse in 22 patients with either progressive collapsing foot deformity (PCFD), midfoot arthritis, or HV deformity. This study showed promising results, as the authors observed a low complication rate (9% minor, 4.5% major) and a high healing rate three months after surgery (91%). Furthermore, only two patients were observed to have non-union, one clinically stable and the other clinically unstable, which required reoperation[6]. These early results of the LapiCotton procedure show that this technique is relatively safe and effective for treating medial longitudinal arch collapse. These results also suggest that the LapiCotton procedure should be considered for patients with deformities that include medial longitudinal arch collapse. Therefore, we analyzed patients with HV deformity and medial longitudinal arch collapse to assess the effectiveness of the LapiCotton procedure in this patient population. Our hypothesis is that the LapiCotton procedure will produce a reliable correction of HV deformity combined with medial longitudinal arch collapse based on semi-automatic WBCT measurements.

To measure the effectiveness of the LapiCotton procedure in patients with HV and medial longitudinal arch collapse, we assessed four WBCT measurements that help define corrected HV; the HVA, MSM, IMA, and SR.

## Hallux valgus angle

There was a statistically significant difference between the pre- and postoperative median HVA values (p=0.026), with a median preoperative HVA of 20° and median postoperative HVA of 27.52°. Hallux valgus angle is a well-accepted measure of the severity of HV deformity that is widely used in clinical practice. A measurement of less than 15° is considered normal. A classification of mild HV is a measurement of 16-25°, and moderate HV is 26-35°[12]. The LapiCotton procedure has shown promising results for patients with HV and has been shown to significantly reduce the severity of disease progression in this population.

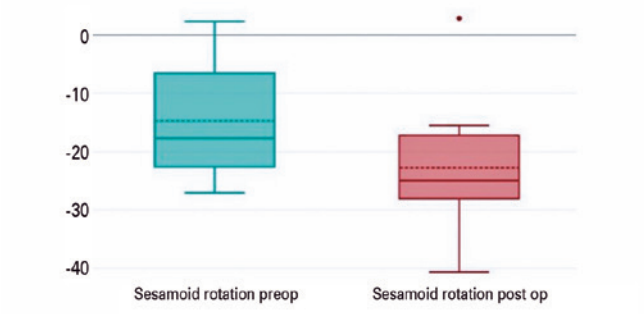


**Figure 5.** The sesamoid rotation comparison between the preoperative and postoperative groups demonstrating no statistical significance.

## Meary sagittal measurement

There was also a statistically significant difference between the pre-and postoperative MSM (p=0.033), with a preoperative of -14.28 and postoperative of -11.15. This measurement is also used to measure the severity of HV disease progression. A value of less than 15º is considered mild deformity[13]. While both pre- and postoperative measurements were classified as mild deformities, the procedure could significantly decrease this angle to lessen the degree of the longitudinal axis of the talus and the first metatarsal.

## Intermetatarsal angle

There was a statistically significant difference between the pre- and postoperative IMA (p=0.003), with a preoperative of 15.68° and postoperative of 11.26°. In literature, a normal IMA is less than 10°[12]. While the LapiCotton procedure has not fully corrected the IMA to normal physiological values, it has been shown to significantly decrease the IMA and lessen the severity of the deformity.

## Sesamoid rotation

There was no statistically significant difference between the pre- and postoperative SR (p=0.203). However, the postoperative SR was higher in the preoperative group (-17.71) versus the post-operational group (-24.98). Although the LapiCotton procedure has been shown to produce no difference in this measurement postoperatively, Kim and Young have shown that the sesamoid subluxation may or may not be present in HV deformity, and this subluxation depends on different foot physiological scenarios[14].

When looking at these WBCT measurements, it is evident that the LapiCotton procedure successfully corrected HV deformity in patients with medial longitudinal arch collapse. The two most important imaging measurements to determine the severity of HV deformity are HVA and IMA[15]. The procedure produced significantly different measurements for both angles postoperatively, providing evidence that this procedure can successfully correct medial longitudinal arch collapse in patients with HV and radiographically reduce the severity of the deformity.

## Limitations

This study has several limitations. First, this study used a small sample. It also did not include a control group or comparison with another surgical intervention. However, due to the novel treatment technique and goal to utilize semi-automatic measurements, we deemed it important to report changes in measurements after this surgical intervention. Additionally, no patient-reported outcomes (PROs) were utilized in this study. This information would be important for assessing changes in responses after the procedure and identifying any potential clinical correlations between measurements and PROs.

## Conclusion

In conclusion, our hypothesis was confirmed. The LapiCotton procedure effectively corrected radiographic parameters in patients with HV combined with the medial longitudinal arch collapse. Reliable correction of HV, along with correction of medial longitudinal arch collapse, were quantified based on semi-automated WBCT measurements of HVA, IMA, and Meary angle. Future studies with a larger number of cases will help to strengthen the findings and evaluate the effectiveness of the LapiCotton procedure.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: VM *(https://orcid.org/0000-0002-8612-5941) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; RJ *(https://orcid.org/0000-0003-3448-1300), and HS *(https://orcid.org/0000-0003-2664-0762), and GT *(https://orcid.org/0000-0002-0018-6410), and ES *(https://orcid.org/0000-0002-6922-5238) AF *(https://orcid.org/0000-0002-3905-9662), and *(https://orcid.org/0000-0002-3731-8448), and KCK *(https://orcid.org/0000-0003-1082-6490) Data collection and interpreted the results of the study; KAMC *(https://orcid.org/0000-0003-1082-6490) Interpreted the results of the study, participated in the review process and approved the final version; NSBM *(https://orcid.org/0000-0003-1067-727X), and CCN *(https://orcid.org/0000-0001-6037-0685), and KD *(https://orcid.org/0000-0002-8061-4453) Interpreted the results of the study and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Comparative result between adult men and women with ankle fractures surgically treated

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## Abstract

**Objective:** Compare the results between adult men and women treated with open reduction and internal fixation after unstable ankle fractures.

**Methods:** Prospective study including 86 patients (n=57, men; n=29, women) with unstable ankle fractures surgically treated. A socio-demographic and clinical questionnaire with 48 items was applied. The morphology of ankle fractures was analyzed according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) classification system.

**Results:** Among the 86 patients, young men predominated all variables researched. The most common injury was motorcycle crashes, followed by soccer accidents (p≤0.001) caused by high-energy trauma (p≤0.05). Other factors are fractures on the right side (p≤0.05), more fractures AO/OTA 44-B2 and C1 (p≤0.05), and malleolus lateral and bimalleolar fractures (p≤0.01).

**Conclusion:** The results indicate that adult men are more likely to suffer ankle fractures requiring surgical treatment than adult women. We suggest that the anatomical reduction of displaced malleolar fractures, especially restoring the fibula length and maintaining reduction until the fracture is healed, appears to be highly favorable for the surgical treatment of unstable ankle fractures.

**Level of Evidence II; Prognostic Studies; Prospective Study.**

**Keywords:** Ankle fractures; Adult; Open fracture reduction.

## Introduction

Fractures involving the ankle mortise are among the most common joint injuries in the lower extremity treated by orthopedic surgeons[1,2]. Moreover, these fractures are relatively common and exceed 10% of all fractures[3,4], thereby representing an important cause of morbidity among younger populations[5,6].

Since 1950, there has been an increase in the number and overall incidence of ankle fractures (AFs)[7,8], ranging from 101-184 fractures per 100,000 inhabitants per year[9], with a peak incidence among young men estimated at 157.1 fractures per 100,000 inhabitants per year[3]. Of these, approximately 53% are unstable fractures requiring surgical treatment[10].

In adult age, the most frequent cause of AFs has been road-traffic accidents[11,12] and sports activities[13,14]. However, in the last two decades, the prevalence of such fractures has increased among young, active patients, particularly younger men[2,15]. Among youth, there are more AFs in men than women, but after 50 years of age, the rate per gender reverses[6,16].

Since the mid-1970s, there has been a general trend toward surgical intervention to treat more-severe ankle injuries[17]. Several studies have shown that better results are obtained with surgical than non-surgical treatment[18,19]. Although non-surgical treatment was used for many years, open reduction and internal fixation (ORIF) has become the gold standard surgical treatment for AF[20,21].

Study performed at the Hospital Nossa Senhora da Saúde (HNSS), Diamantina, Minas Gerais, Brazil and Casa de Caridade Santa Tereza, Serro, Minas Gerais, Brazil.

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The key to success in this surgical treatment is the anatomical reduction of displaced malleolar fractures, especially restoring the fibula length and maintaining reduction until the complete union of the fracture, which is almost impossible with non-surgical treatment[13,22]. In addition, there is a concern that a non-surgical approach may fail to produce an anatomical reduction of the mortise, leading to ankle instability, nonunion, and post-traumatic osteoarthritis of the ankle[22].

Considering this information, the hypothesis of this study is to learn whether adult men are more likely to suffer AFs that are surgically treated than adult women. Therefore, this study was conducted to compare the results between adult men and women treated with ORIF after unstable AFs.

## Methods

### Patients

The study included 86 patients (n=57, men; n=29, women) with unstable AF treated with ORIF. All patients were treated as inpatients. They signed the informed consent form before surgery following the institution's ethical procedures under the number Doc14A/CE/2015.

Inclusion criteria were age between 18 and 65 and unstable AF only of one lower limb without amputation. Exclusion criteria were cranial-encephalic and spinal cord injury, pathological fracture, cognitive conditions that would interfere with providing accurate responses to a questionnaire, and previous motor disease that would alter lower-limb performance.

### Design

A prospective study was conducted in the orthopedics department, including seven orthopedic surgeons who performed the surgeries under the blinded condition. The sample included adult patients admitted to this department with AF from July 2015 to November 2016. On admission, the patient's medical records were analyzed to understand the nature of their injuries, in addition to detailed and systematic examinations to rule out associated injuries.

All patients were interviewed in person at hospital admission or, at most, within two weeks post-surgery, using a sociodemographic and clinical questionnaire with 48 items elaborated according to the research purpose. This theoretical questionnaire includes the following variables: gender, age, age range, cause of fracture, fracture subclassification, type of trauma, fractured side, characteristic of fracture, pattern of fracture, number of days waiting for surgery, delay in surgery, number of days from post-surgery to hospital discharge, surgical procedures, and complications following surgery.

### Procedures

An orthopedic surgeon reviewed all radiographs to minimize diagnostic errors. The AFs were defined according to the criteria of Müller et al.[23], and their morphology was analyzed according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) classification system based on the line location of the fracture in the fibula to the level of syndesmosis[23]. In addition, fractures of the medial malleolus and the posterior margin of the tibia, which the AO/OTA system could not classify, were recorded.

### Statistical analysis

After collection, data were analyzed using the Statistical Package for Social Sciences (SPSS) program, version 23 (IBM Corp., Armonk, New York, USA). The results of quantitative variables (age, number of days waiting for surgery, number of days from post-surgery to hospital discharge) were presented as mean, standard deviation (SD), minimum, and maximum. Qualitative variables (age range, gender, cause of fracture, fracture subclassification, type of trauma, fractured side, characteristic of fracture, pattern of fracture, delay in surgery, surgical procedures, complications following surgery) were expressed as frequencies and percentages. Normal and asymmetric distribution was observed using the Kolmogorov-Smirnov test on age, number of days waiting for surgery, and number of days from post-surgery to hospital discharge. The relationship between the gender variable and the variables age range, type of trauma, fractured side, characteristic of fracture, and complications following surgery were verified by an asymptotic chi-squared test ($\chi^2$), with its respective degree of freedom (gl) and the result of the coefficient Phi ($\phi$). The relationship between the gender variable and the variables causes of fracture, subclassification of fracture, pattern of fracture, and delay in surgery were verified by a Monte Carlo simulation for the chi-squared test ($\chi^2$), with its respective degree of freedom (gl) and the result of the contingency coefficient (C Pearson). Comparisons between the gender variable and the variables number of days waiting for surgery and post-surgical period (until hospital discharge) were performed using the Mann-Whitney U test. A p-value less than 0.05 was considered to be significant.

## Results

During the study period (July 2015 to November 2016), 86 adult patients who suffered ankle fractures surgically treated were included in this study following inclusion criteria: age between 18 and 65 and unstable AF only of one lower limb without amputation. On the other hand, patients with the following criteria were excluded from this study: cranial-encephalic and spinal cord injury, pathological fracture, cognitive conditions that would interfere with providing accurate responses to a questionnaire, and previous motor disease that would alter lower-limb performance. On admission, the patient's medical records were analyzed to understand the nature of their injuries, in addition to detailed and systematic examinations to rule out associated injuries, thus classifying whether the patients would be under the inclusion and exclusion criteria.

Among the total, men were predominant, with 57 (66.3%) and 29 (33.7%) were women. The mean age of the patients was 37.9 (SD=14.05), and their ages ranged from 18 to 65.

The mean age the men were younger than women was eight years, 35 (SD=13) vs. 43 (SD=16). Forty-nine men (86%) were under 49, and 11 women (38%) were over 50 [$\chi^2(1)=6.377$, $\phi=0.272$, p=0.012].

As shown in Table 1, the most frequent causes of AF were motorcycle crashes and soccer accidents. In both types of accidents, this represented a predominance of more than 94% of men to the total of AFs related to motorcycle crashes and soccer accidents by gender [$\chi^2(8) = 36.850$, C Pearson=0.655, p=0.000].

The breakdown into different AO/OTA 44 subgroups is presented in Figure 1. The AO/OTA 44-B2 and C1 fractures were the more frequent, with 51 cases; of these, 32 (63%) were men [$\chi^2(9)=17.157$, C Pearson = 0.408, p=0.046].

The dominant type of AF in our series was the low-energy type 50 (58.1%), but men presented with the AFs of the high-energy type 29 (80.6%) in the total of 36 patients [$\chi^2(1)=5.647$, $\phi=0.256$, p=0.017]. Of the total number of patients, the fractured side was 50% to both sides (n=43 right side; n=43 left side); men had 33 (76.7%) right side fractures [$\chi^2(1)=4.214$, $\phi=0.221$, p=0.040]. Regarding the fracture's characteristics, closed fractures were predominant, with 75 cases (n=47 men; n=28 women). Only 11 patients suffered open fractures (12.8%), of which 90.9% (n=10) were men [$\chi^2(1)=3.424$, $\phi=0.200$, p=0.064].

Table 2 shows the division of AF patterns by gender. Most patients had lateral malleolus fractures, followed by bimalleolar fractures; in both cases, the majority were men [$\chi^2(4)=15.115$, C Pearson = 0.387, p=0.004].

**Table 1.** Cause of the fracture by genre

| Cause Fracture | Men | | Women | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Road-traffic accident | 22 (Mc21, Cc1)*** | 25.6 | 4 | 4.7 | 26 (Mc25, Cc1) | 30.2 |
| Fall of horse | 3 | 3.5 | 0 | 0 | 3 | 3.5 |
| Fall from their height | 1 | 1.2 | 10 | 11.6 | 11 | 12.8 |
| Fall of height | 3 | 3.5 | 0 | 0 | 3 | 3.5 |
| Fall of stairs | 1 | 1.2 | 4 | 4.7 | 5 | 5.8 |
| Twist or sprain | 6 | 7.0 | 6 | 7.0 | 12 | 14 |
| Running over | 3 | 3.5 | 1 | 1.2 | 4 | 4.7 |
| Fall in slope | 2 | 2.3 | 3 | 3.5 | 5 | 5.8 |
| Sports injury | 16 (S15, B1)*** | 18.6 | 1 | 1.2 | 17 (S16, B1) | 19.8 |

*** p≤0.001; B = bikefall; Cc = car crash; Mc = motorcycle crash; n = number of patients; S = soccer.

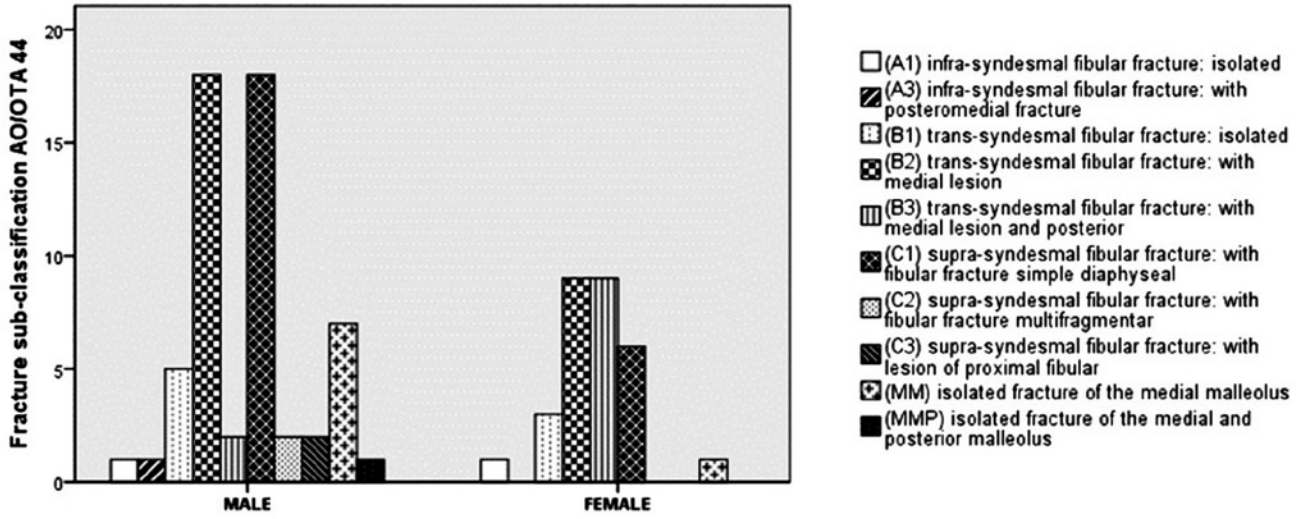


**Figure 1.** Fracture subclassification according to AO/OTA 44 by gender.
*p≤0.05; AO/OTA = AO Foundation and Orthopaedic Trauma Association; AO/OTA 44 classification AO/OTA of malleolar fractures of the tibia and fibula is 44.

**Table 2.** Pattern of fracture by gender

| | LMF | | MMF | | BMF | | TMF | | TMF1 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| Men | 25** | 29.1 | 8 | 9.3 | 19** | 22.1 | 4 | 4.7 | 1 | 1.2 |
| Women | 7 | 8.1 | 1 | 1.2 | 10 | 11.6 | 11 | 12.8 | 0 | 0 |
| Total | 32 | 37.2 | 9 | 10.5 | 29 | 33.7 | 15 | 17.4 | 1 | 1.2 |

** p≤0.01; LMF = lateral malleolus fracture; MMF = medial malleolus fracture; BMF = bimalleolar fracture; TMF = trimalleolar fracture; TMF1 = trimalleolar fracture with small posterior fracture, lesion of deltoid ligament.

The total mean of the variable, the number of days waiting for surgery, was (X=7.67, SD=5.81); there were no significant differences between men (X=7.70, SD=5.77) and women (X=7.62, SD=6.00) (U=812.000, p=0.894). Only 16 patients (18.6%) were submitted to surgery within 48 hours post-AF [$\chi^2(1)=0.126$, $\phi=-0.038$, p=0.723]. The transfer was the main reason for the delay of 32 patients (20 men (23.3%); 12 women (14.0%)) because there were no beds available in the hospital where they would have surgery. Other reasons for the delay pointed out by the patients (16 men (18.6%); 7 women (8.1%)) were related to elective surgery, the need for other professionals, and/or additional tests or exams [$\chi^2(7)=3.951$, C Pearson=0.210, p=0.785].

Regarding the period (in days) between post-surgery and hospital discharge (1.76, SD=5.25), there was no significant difference between men and women (U=805.000; p=0.750). In our study, there were no cases of bone-graft procedures; however, there were 26 (30.2%) cases of clinical problems following surgery (17 men (19.8%); 9 women (10.4%)) [$\chi^2(1)= 0.013$, $\phi=0.012$, p=0.908].

All surgeries were performed using the ORIF method, and only in one case was there a need to remove the screws. Later, an external fixator was placed following several debridements to mitigate a serious infection in the wound.

## Discussion

The aim of the study was to compare the results between adult men and women who were treated with ORIF after unstable AF. In all variables studied, young men were predominant. The most common cause of AFs was road-traffic accidents (mainly motorcycle crashes), followed by sports injuries (mainly soccer). Similarly, road-traffic accidents were found to be the main cause of AFs in most of the studies surveyed[1,11,24], and the study by Ahmad et al.[11] found that the majority were motorcycle crash related. Among sports injuries, Jensen et al.[16] and Court-Brown et al.[25] found that the main cause of AFs was soccer. People between 21 and 50 years are more prone to accidents due to their jobs and the increased use of vehicles. Men are even more vulnerable because their work is more likely to involve risks such as working at heights, driving more, and traveling more for their work[18].

The results regarding the fracture subclassification in our study were very similar to Sakaki et al.[26]. They found 37% of AO/OTA 44-C fractures and stated that the treatment for this type of fracture is more complex than for AO/OTA 44-B because it is a fibular fracture with a syndesmosis injury. The reason is the difficulty of reducing fibular fractures and the need for a perfect restoration of the tibiofibular connexion at the syndesmosis level. According to Court-Brown et al.[25], AO/OTA 44-C fractures are often high-speed injuries such as road-traffic accidents, some sports activities, and falls from any height.

The most common fracture pattern found was lateral malleolus fracture, and the least common was medial malleolus fracture. In general, most authors agree that lateral fractures of the ankle are the most common[3,18]. In this sense, the second major cause of AF pattern was bimalleolar fracture. Daly et al.[27] claimed that there had been an increase in bimalleolar fractures in young, active men over the last two decades.

The number of days after surgery to hospital discharge in most patients ranged from 1 to 2 days, but one 32-year-old men patient was hospitalized for 49 days. This patient had an unfavorable outcome because the AF did not present with anatomical reduction of the lateral malleolus. The patient had a closed bimalleolar fracture of the right side resulting from a fall from a height of more than five meters. The ORIF was performed, followed by several debridements, which resulted in a serious infection progressing to screw removal due to rejection. Our study suggests that the lateral malleolus is the key to the anatomical reduction of bimalleolar fractures. In this sense, Mahesh and Venkataramana[13] found that the accurate anatomical reduction of AF is not enough; it is also necessary to maintain this reduction until a complete fracture union is reached. This is supported by Mitchell et al.[22] study, which affirmed that the anatomical reduction of the displaced malleolar fracture, especially restoring the fibula length and maintaining the reduction, is almost impossible using the closed conservative method. There is a concern that a non-operative approach may fail to produce an anatomical reduction of the mortise, leading to ankle instability, nonunion, and post-traumatic osteoarthritis of the ankle.

Regarding the predominant side of the fracture, our results align with Dhameliya and Prashanth[12] and agree with the gender of other studies[15,28]. The right side predominance in our study, and several other studies, can be explained by the dexterity of the dominant side of the patient so that, in the case of an accident, they first support the dominant side if it is the right side. This is a limitation of our study that was not researched and is, therefore, a research suggestion for new studies.

The most common type of trauma found was low-energy, following the studies of Court-Brown et al.[25] and Dhameliya and Prashanth[29]; however, men had a higher frequency of high-energy trauma. Although the study by Larsen et al.[30] reported that men had a higher frequency of high-energy trauma due to sports activities, this finding contrasts with our study. There were only four cases of high-energy trauma due to sports activities; the remainder were due to road-traffic accidents, falls from any height, and falls from horses. This difference may have been because this study[30] investigated AO/OTA 42 fractures (fibular and tibial diaphysis fractures).

In our research, only 16 patients were submitted to surgery within 48 hours of AF. Several studies noted that the best results were seen in patients who underwent surgery 24 to 48 hours after AF[1,15]. However, Patil and Kore[19] reported that although most of the fractures in their study were treated within 24 hours, this did not change the outcome. In our study, this delay in performing surgery may be justified by the region's low income. Since the hospitals where the data were collected were financed by the Unified Health System (SUS), the lack of beds available for transferring patients who resided in another city was the main reason for this delay.

Our study has limitations due to several factors. First, our participants were selected from two hospitals with low resources financed by the SUS. Consequently, there were recurrent delays in performing surgeries due to a lack of beds and surgical materials. Another reason was recurrent strikes (more than 30 days in one of the hospitals) and the related loss of many patients who were transferred to other hospitals outside the region of our research. Thus, by the end of our research, we had obtained a relatively small sample. Therefore, future studies should investigate unstable AFs with a larger sample, and the results should be followed over a longer period. Finally, we reinforce the above suggestion regarding the patient's dominant dexterity.

## Conclusion

The results showed a predominance of AFs in young men with a mean age of 35, a mean of eight years younger than women. Despite the younger age, there is a predominance of high-energy accidents related to motorcycle crashes and soccer accidents. Other factors that can be mentioned are the fractures that are predominant on the right side, and more AO/OTA 44-B2 and C1, malleolus lateral, and bimalleolar fractures. All these indicate the severity of AFs. Accordingly, the results indicate that adult men are more likely to suffer AFs that require surgical treatment than adult women. Lastly, we suggest that the anatomical reduction of the displaced malleolar fracture, especially restoring the fibula length and maintaining the reduction until the fracture has healed, appears to be highly favorable for the surgical treatment of unstable AFs.

**Author's contributions:** Each author contributed individually and significantly to the development of this article: VRA *(https://orcid.org/0000-0003-3875-250X) Conceived and planned the activities that led to the study, interpreted the results of the study, wrote the article, participated in the reviewing process; SAS *(https://orcid.org/0000-0002-3187-3416) Interpreted the results of the study, participated in the reviewing process; WFG *(https://orcid.org/0000-0001-9555-0790) Interpreted the results of the study, wrote the article; JCL *(https://orcid.org/0000-0003-1798-2496) Interpreted the results of the study, participated in the reviewing process and approved the final version; NFS*(https://orcid.org/0000-0002-7904-7631) Participated in the reviewing process and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Original Article

# Arthrodesis in Müller-Weiss disease: is it worth keeping the navicular bone?

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## Abstract

**Objective:** Compare a case series diagnosed with Müller-Weiss disease and whether or not maintaining the diseased navicular bone influences the outcome of the arthrodesis.

**Methods:** A retrospective clinical study that evaluated patients with Müller-Weiss disease (phases 3 and 4 of Maceira's classification) submitted to surgery. The patients were divided into two groups. Group A included six patients (six feet), in whom all the navicular bone was removed, and a tricortical graft was used to replace it. Group B also included six patients (six feet) without removed navicular bone. The mean follow-up time was 101 months. For evaluation, clinical and radiographic criteria were used, including The American Orthopaedic Foot & Ankle Society (AOFAS) scale for ankle and hindfoot and the Visual Analog Scale (VAS).

**Results:** The mean consolidation time for arthrodesis was 18 weeks in group A and 16 weeks in group B. The radiographic angles in the preoperative and postoperative did not show significant changes. In group A, the preoperative mean AOFAS score was 45 points, and the postoperative was 80 points. In group B, the preoperative mean AOFAS score was 48 points, and the postoperative was 79 points. The mean VAS value was 2.5 in group A and 2.4 in group B. The pseudarthrosis index was the same in both groups, 33.3% (2 of the 6 feet).

**Conclusion:** No significant differences were found between maintaining or replacing the navicular bone by tricortical bone graft in the midfoot arthrodesis in patients with Müller-Weiss disease.

**Level of Evidence III; Therapeutic Studies - Investigating the Results of Treatment; Retrospective Comparative Study.**

**Keywords:** Arthrodesis; Bone transplantation; Flatfoot; Osteochondrosis.

## Introduction

Müller-Weiss disease was described in 1927 by Müller and Weiss in separate articles[1]. It is characterized by deformity, sclerosis, and fragmentation of the navicular, a condition that can lead to chronic pain in the foot[2]. It is more common in women and is a rare entity, with etiology not yet fully understood. The classic clinical symptoms are chronic pain in the foot, located in its dorsomedial aspect[2].

Surgery is indicated when conservative treatment fails. A surgical option is talonavicular arthrodesis (TNA) alone or associated with naviculocuneiform arthrodesis (NCA). However, there is a doubt in case of an indication of arthrodesis: should all the navicular bone be removed, filling the space left with structured bone graft, or can part of this collapsed bone be preserved? Despite the few cases, our study tries to answer this question, which has not yet been answered in the literature worldwide.

The objective of this study is to evaluate the clinical-functional and radiographic results of patients submitted to midfoot arthrodesis due to symptomatic arthrosis caused

Study performed at the Grupo do Pé e Tornozelo do Departamento de Ortopedia e Traumatologia da Santa Casa de Misericórdia de São Paulo, Faculdade de Ciências Médicas da Santa Casa de São Paulo, São Paulo, SP, Brazil

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by Müller-Weiss disease. Also, compare the results between cases where a tricortical iliac bone graft was used with those where the navicular bone and graft were used to fill the bone failure.

## Methods

This study was approved by the institution's ethics committee. Patients diagnosed with Müller-Weiss disease treated between 1994 and 2013 were included in this study. In total, 26 patients (31 feet) were registered and reassessed. Initially, conservative treatment was indicated in all cases (insole supporting the medial longitudinal arch or leg-foot orthosis). In 18 patients (21 feet), conservative treatment failed, and surgery was indicated. Two refused to participate in the study, and one had less than one year of follow-up. Then, 15 patients (16 feet) were evaluated. The mean follow-up time was 101 months (range 12 to 234 months). Two patients were male, and 13 were female. The mean age at the time of surgery was 44 years (range 23 to 56 years). The classification proposed by Maceira[1] to stratify these cases was used. Only patients in phases 3 and 4 of this classification were included and divided into two groups to compare the results. Group A: six patients in whom the entire navicular was removed, and a tricortical iliac bone graft was used to fill the space in the midfoot arthrodesis. The mean age in this group was 43 years (range 23 to 51 years). The mean body mass index (BMI) was 26.3 (range 21 to 32). The mean follow-up was 97 months (minimum 39 and maximum 180 months). Group B: six patients in whom their navicular was used as a bone graft for arthrodesis. The medial part of this bone is usually not affected by the disease and was used as a bone graft. The mean age in this group was 44 years (range 35 to 56 years). The mean BMI was 26.4 (range 23.2 to 30.1). The mean follow-up was 140 months (minimum 12 and maximum 234 months).

Each group consisted of four patients in phase 3 and two in phase 4. In group A, in all operated feet where the navicular was removed, the joint between the talonavicular (TC) and the naviculocuneiform (NC) was necessarily arthrodesed. In addition, plates and screws were used in five patients, and only wires in one. In group B, fixation screws were used in four feet, and only wires in two. Patient data, arthrodesed joints, and additional surgeries are shown in Table 1. Arthrodesed joints were considered symptomatic and with signs of radiographic degeneration.

This is a clinical, retrospective, and comparative study. The choice to remove or not the navicular bone was based on the surgeon's criteria.

The patient's medical records for reports of suture dehiscence, skin necrosis, or infection were searched to evaluate the results. In the patient's clinical examination in the outpatient return, painful points in the foot were explored, and the Visual Analog Scale (VAS) was used[3]. The preoperative pain could not be evaluated, as this data was not included in the patient's medical record. The American Orthopaedic Foot and Ankle Society (AOFAS)[4] scale for hindfoot was used for clinical-functional evaluation. The radiographs in the dorsoplantar, lateral (both performed with load), and oblique views were also used. In the preoperative radiographs, an alteration in the navicular bone was sought and used for Maceira's classification[1]. The presence of arthrosis in the TN and NC joints was studied. The angles between the talus and the first metatarsal bone were used to measure the deformity in the dorsoplantar and profile views (in the profile, this measure is known as Meary's line). The resolution of pain complaints and the presence of bone trabeculation crossing

**Table 1.** General data of patients with Müller-Weiss disease submitted to arthrodesis and evaluated in this study

| N | Group | Age (Y) | Sex | Follow-up (M) | BMI | Side | Maceira's classification | Arthrodesis | Fixation method |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 23 | F | 180 | 21 | R | 3 | TN+NC | K-WIRE |
| 2 | A | 49 | F | 108 | 25.7 | R | 4 | TN+NC | PL/SC |
| 3 | A | 50 | F | 123 | 25.7 | L | 4 | TN+NC | PL/SC |
| 4 | A | 43 | F | 74 | 28.6 | L | 4 | TN+NC+ NC1M | PL/SC |
| 5 | A | 51 | M | 39- | 32 | L | 4 | TRIPLE+NC | PL/SC |
| 6 | A | 45 | F | 44 | 26.7 | L | 3 | TN+NC+ NC1M | PL/SC |
| | **Mean** | 43 | | 97 | 26.3 | | | | |
| 7 | B | 39 | F | 234 | 27 | R | 3 | TN | SC |
| 8 | B | 35 | F | 216 | 23.3 | L | 4 | TN+NC | K-WIRE |
| 9 | B | 38 | F | 197 | 25.8 | R | 4 | TRIPLE | K-WIRE |
| 10 | B | 44 | F | 62 | 30.1 | R | 3 | TN | SC |
| 11 | B | 56 | F | 12 | 27 | R | 4 | TRIPLE | SC |
| 12 | B | 54 | F | 18 | 25.2 | R | 4 | TRIPL+NC | SC |
| | **Mean** | 44 | | 140 | 26.4 | | | | |

N: Number; F: Female; M: Male; Y: Years; M: Months; BMI: Body Mass Index; R: Right; L: Left; TN: talonavicular; NC: naviculocuneiform; NC1M: joint between the NC and the first metatarsal bone; K-wires: Kirschner wires; PL/SC: Plate and screws; SC: Screws
**Source:** Medical archives of Santa Casa de Misericórdia de São Paulo

the focus of arthrodesis on radiographs are considered signs of consolidation. After six months, if the patient persisted with pain in the arthrodesis, and there were no radiographic signs of consolidation, loosening and/or breakage, it was considered pseudarthrosis and treatment failure. The time required for arthrodesis to be consolidated on radiographic examination was also noted.

## Results

In group A, the mean consolidation time for arthrodesis was 18 weeks. The radiographic angles measured preoperatively and postoperatively showed no significant changes (Table 2). The mean preoperative AOFAS was 45 points (range 30 to 64), while in the postoperative was 80 points (range 74 to 86). At the last outpatient evaluation, the mean postoperative VAS value was 2.5 (range 1 to 4).

In group B, the mean consolidation time for arthrodesis was 16 weeks. The radiographic angles measured preoperatively and postoperatively showed no significant changes (Table 2). The mean preoperative AOFAS was 48 points (range 15 to 62), while in the postoperative was 79 points (range 68 to 90). At the last outpatient evaluation, the mean postoperative VAS value was 2.4 (range 0 to 5).

A case of deep wound infection and suture dehiscence was observed. This case occurred in a patient with a BMI of 29, submitted to TNA and NCA, using a tricortical iliac bone graft and fixed with a T-plate and 3.5 mm screws. The patient was submitted to several debridements (three procedures) and intravenous antibiotic therapy until the resolution of the infection. In the last evaluation, the patient presented an AOFAS of 78 points and VAS of 4 points and had returned to work.

Pseudarthrosis was noted in four patients (two feet in each group). Three patients successfully underwent revision of the arthrodesis, and the other patient was asymptomatic and chose not to undergo surgery again. In the last evaluation, these four patients had a mean AOFAS of 81 points and a mean VAS of 1.25. In both groups analyzed, the pseudarthrosis rate was the same, 33.3% (two of the six feet). Of the four cases, three presented complications in the TN joint (triple arthrodesis; TN + NC; and triple arthrodesis + NC) and one in the NC joint (TN + NC + NC1M (joint between the NC and the first metatarsal bone)).

## Discussion

The etiology of Müller-Weiss disease appears to be multifactorial. It is believed that an irregular load distribution in a bone that has undergone an altered ossification and with areas of possible ischemia due to its peculiar irrigation are factors associated with this disease[2,5,6]. Despite its description as navicular osteonecrosis[6,7], some histopathological studies did not provide evidence of bone necrosis[2,5,8–10]. As the navicular contributes to the NC and the medial longitudinal arch of the foot, when there is the characteristic dorsolateral collapse, the re-establishment of its length must correct the deformities produced by the disease[2,6,7,11,12]. When the treatment method chosen is arthrodesis, and the navicular is collapsed, one possibility is a tricortical bone graft, usually obtained from the patient's iliac crest[6,12,13], to maintain the NC length[5,14]. In addition to filling the navicular space, the bone graft has osteoconductive, osteoinductive, and osteogenic properties[15], which in theory, would facilitate bone consolidation[13,15]. However, while planning one of these reconstructions, the idea of using

**Table 2.** Results of patients submitted to arthrodesis and evaluated in this study

| N | Group | Graft (Y/N) | Comp. | Pseu TN | Pseu NC | DP1M (pre/post) | Meary (pre/post) | AOFAS (pre/post) | Cons. (W) | VAS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | Y | N | N | N | 4º/4º | 6º/4º | 64/83 | 12 | 3 |
| 2 | A | Y | Y | Y | N | 2º/2º | 6º/0º | 30/74 | 24 | 4 |
| 3 | A | Y | N | N | N | 8º/4º | 6º/4º | 35/86 | 18 | 1 |
| 4 | A | Y | Y | N | N | 4º/4º | 8º/2º | 56/78 | 12 | 4 |
| 5 | A | Y | N | N | N | 0º/0º | 0°/0º | 32/79 | 16 | 2 |
| 6 | A | Y | Y | N | S | 4º/2º | 0º/2º | 54/80 | 24 | 1 |
| | **Mean** | | | | | 3.6º/2.6º | 4.3º/2º | 45.16/80 | 17.6 | 2.5 |
| 7 | B | N | N | N | N | 10º/0º | 4º/4º | 38/74 | 16 | 4 |
| 8 | B | N | N | N | N | 8º/0º | 10º/6º | 54/78 | 10 | 2 |
| 9 | B | N | Y | Y | N | 20º/12º | 2º/4º | 59/90 | 16 | 0 |
| 10 | B | N | N | N | N | 0º/0º | 0º/0º | 62/92 | 14 | 3 |
| 11 | B | N | N | N | N | 8º/4º | 8º/4º | 15/68 | 16 | 5 |
| 12 | B | N | Y | Y | N | 8º/2º | 8º/2º | 60/81 | 24 | 0 |
| | **Mean** | | | | | 9º/3º | 5.3º/3.3º | 48/78.83 | 16 | 2.4 |

TN: articulation between the talus and the navicular; NC: articulation between the navicular and the cuneiform; Pseu: pseudarthrosis; pre: preoperative; pos: postoperative; DP1M: Dorsoplantar radiographic of the foot and angle calculation between the axis of the talus and the first metatarsal; Meary: angle calculated in the profile of the foot formed by the axis of the talus the first metatarsal; VAS: Visual Analog Scale of postoperative pain.
**Source:** Medical Archives of Santa Casa de Misericórdia de São Paulo.

the navicular as an interposition graft arose, employing the medial part of the bone, usually not affected by the collapse and the size necessary to fill the space between the talus and the NC. We believe the navicular bone graft should have the same properties as the iliac bone graft, which assists in bone consolidation and avoids another surgical procedure to obtain the iliac graft. The decision to use or not use the navicular itself as a bone graft was made at the time based on the surgeon's criteria responsible for the case. This retrospective study was conducted to evaluate the results of these cases and compare the results in which the patient's own tricortical iliac graft was used. When Madeira's classification was applied[1] in the cases, we noticed that it would be possible to make a comparative study with six patients in each group.

One of the concerns was how much the bone graft of the navicular itself could affect the arthrodesis consolidation since the disease is related to osteonecrosis[2,5,6]. Lu et al.[9] observed about 23% of pseudarthrosis in cases where only the TN joint was arthrodesed. Yu et al.[6] did not observe pseudarthrosis in seven cases submitted to TNA and NCA using a tricortical iliac graft to maintain the NC length and plate and dorsal screws for fixation. In our cases, however, there was pseudarthrosis in four of twelve, with two patients in each group. Despite the small number of cases, it does not seem that the use of the navicular itself as a graft affected consolidation. The size of bone failure was not measured in the surgery and may have varied a little from patient to patient; however, according to Azi et al.[15], there is no clinical evidence to prove a direct relationship between the size of bone defect and consolidation when using an autologous bone graft. These numbers encourage using the navicular as bone filling, avoiding another surgery to remove the iliac crest graft.

Surgical treatment of Müller-Weiss disease should relieve pain and correct deformities[2,5,9,16]. Several types of arthrodesis are recommended in the literature[2,5,7,9,11,17], and some authors suggest using allograft to fill the navicular failure in the midfoot[14,16]. In this case series, we sought to surgically address joints with pain on clinical examination and joint degeneration on radiographic examination. For this reason, the type of arthrodesis performed was not the same in all patients. The fixation method also varied and was defined by the surgeon's preference. Once consolidated, arthrodesis usually leads to good results[6,9,11,14,16,17]. The AOFAS scale for the hindfoot and ankle was used to evaluate the final clinical-functional result. Our patients had a mean score of 79 points, with no difference between the patients in whom the navicular graft was used (80 points) and the tricortical iliac graft group (78.5 points). Studies that used arthrodesis to treat Müller-Weiss disease, which also used the same scale, obtained a mean of between 82 and 90 points[6,7,9,11,12,14].

In Müller-Weiss disease, some factors that hinder consolidation have to be considered. The navicular blood supply (has its peculiarities, and surgical aggression can lead to damage to this circulation), and the shape of the TN joint (which hinders an adequate preparation of the surfaces to be arthrodesed), are factors that can hinder the arthrodesis consolidation in the midfoot[7,9]. In our study, the radiographic consolidation ranged between 16 and 18 weeks. Harnroongroj and Chuckpaiwong[17] describe isolated TNA to treat phase 3 of Maceira's classification and observed arthrodesis consolidation around two months. They suggest that the consolidation time in triple and perinavicular arthrodesis or when other joints are involved may be longer. Zhang and Yu[12] reported a mean consolidation time of 13 weeks in 49 patients submitted to TNA and NCA with tricortical iliac graft interposition. The arthrodesis fixation was performed with plates and screws, and the consolidation time was shorter than in our study. Yu et al.[6] also described TNA and NCA with iliac tricortical graft interposition, fixed with dorsal plate and screws, and with a mean consolidation time of 13 weeks. No differences in consolidation time were found between patients fixed with a plate and screws from the other patients, including two of the four cases of pseudarthrosis; the fixation method was plate and screws. In our opinion, noting that 1/3 of the cases treated in this study developed pseudarthrosis, the surgeon should pay extra attention to preparing the surfaces to be arthrodesed, and careful not to injure the surrounding soft tissues, avoiding damage to the local circulation.

The angle between the axis of the talus and the first metatarsal bone was used in the dorsoplantar radiograph with load (adduction) and lateral radiograph with load (flat feet) to evaluate the correction of adduction and deformity in flat feet. Despite finding an improvement in these radiographic parameters, we cannot conclude that this finding was significant. Harnroongroj and Chuckpaiwong[17] also observed an improvement in radiographic parameters without statistical significance. Cao et al.[14] proposed an osteotomy in the TN joint region to correct deformities. Based on the results, we do not find that an osteotomy is necessary to correct the deformities, especially in the TN region, which is a spherical joint. The simple removal of the articular cartilage already provides the space required for correcting deformities in most cases, as demonstrated in this study.

This study has some limitations. It is a retrospective study evaluating cases already operated. The choice to use the navicular or iliac graft was based on the surgeon's criteria and not on objective criteria. The number of patients evaluated is also small, but comparing phases 3 and 4 of Maceira's classification is an important study point. However, the number of patients evaluated was the same in both groups, additional surgeries between cases and the fixation method varied, affecting the result. The follow-up time is an important factor in this study. Comparing two similar groups according to the classification used was also important in evaluating this study.

## Conclusion

In the foot arthrodesis due to Müller-Weiss disease's sequelae, the incidence of pseudarthrosis was high, at about 30%. Still, in most cases, there was an improvement in pain without total pain relief. To fill the medial space left by the necrotic bone, using tricortical iliac graft and the navicular bone led to similar clinical-functional results.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: DAJ *(https://orcid.org/0000-0000-1854-4044) Conceived and planned the activity that led to the study, wrote the article, participated in the review process; ACB *(https://orcid.org/0000-0002-9242-4892) Data collection, bibliographic review; MTC *(https://orcid.org/0000-0001-9411-9376) Formatting of the article, bibliographic review; RCF *(https://orcid.org/0000-0002-9886-5082) Interpreted the results of the study, participated in the review process. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID).

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## Original Article

# Classification variability of ankle fractures between physicians with and without the title of specialist in orthopedics and traumatology (TEOT)

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## Abstract

**Objective:** Evaluate the classification variability of ankle fractures among physicians with and without the title of specialist in orthopedics and traumatology (TEOT) from a reference service.

**Method:** The study included 40 physicians who informed the year of training, the period they obtained TEOT, and which ankle fracture classification system(s) they use in their clinical practice. The physicians evaluated ten radiographs of five patients with ankle fractures and classified them based on the three classification systems; Lauge-Hansen, AO/OTA, and Danis-Weber.

**Result:** Most physicians with TEOT between one and five years (n=19, 47.5%), and 15 (48.4%) physicians used the Lauge-Hansen and Danis-Weber classifications. Regarding the radiographs evaluated, most (27.5%) physicians obtained correct answers using the Danis-Weber classification. It was also observed that the physicians with the lowest rates of correct answers in the classifications were those without TEOT (44.4%).

**Conclusion:** Most physicians adequately classified the five cases of ankle fracture using the Danis-Weber classification. The highest frequency of correct answers was from the physicians with TEOT.

**Level of Evidence VI; Observational Descriptive Study.**

**Keywords:** Ankle fractures; Classification; Observer variation.

## Introduction

Ankle fractures are among the injuries most attended by orthopedic surgeons and traumatologists, besides presenting high surgical costs and mortality rates[1,2]. In treating any fracture, a classification is a tool that assists in the prognosis and appropriate treatment[3,4]. Several classifications for ankle fractures have been used. They can be based on the trauma mechanism described by Lauge-Hansen, which considers the position of the foot and the direction of the deforming force[5]. The classification described by Danis-Weber considers the topography of the fracture line in the lateral malleolus. The classification of the *Arbeitsgemeinschaft für Osteosynthesefragen* (AO/OTA) group [6] redefines the three types of the Danis-Weber classification[7].

In the literature, some studies evaluate the reproducibility and comparability between the three main classifications mentioned above[8,9]. However, in Brazil, there are still few studies about the influence of time since graduation, the presence and absence of the title of specialist, and the ability to properly classify ankle fractures, relevant information for im-

Study performed at the Hospital Estadual de Urgências de Goiânia (HUGO). Secretaria de Estado da Saúde, Goiânia, GO, Brazil.

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proving teaching techniques during the residency program. The objective of the study is to evaluate the classification variability of ankle fractures among physicians with and without the title of specialist in orthopedics and traumatology (TEOT) from a reference service.

## Method

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

Ten radiographs were used from five skeletally mature patients diagnosed with ankle fractures, in anteroposterior and lateral views. The patients were treated in the emergency room of a highly complex hospital and a reference in orthopedics and traumatology in Goiânia, Brazil (Figure 1). The radiographs were performed by a radiology technician, whose x-ray tube was positioned approximately one meter from the injured site, using the standard technique with an internal rotation of 15 degrees.

Forty physicians, among residents and orthopedists, were invited and signed the informed consent form and answered a brief questionnaire with three questions: the year they obtained the title of specialist in orthopedics and traumatology (TEOT) or the year of training (for those who did not have TEOT); which ankle fracture classification system(s); Lauge-Hansen, AO/OTA, and Danis-Weber, *apud* Ramos et al.[9] are used in their clinical practice; and finally, the radiographs were presented, and the physicians were asked to determine which category each of the fractures would belong to according to the classifications below:


**Figure 1.** Radiographs (A: Case 1; B: Case 2; C: Case 3; D: Case 4 and E: Case 5) presented to the physicians for classification.

- Lauge-Hansen: supination-adduction (SA), supination-external rotation (SER), pronation-abduction (PA), pronation-external rotation (PER) *apud* Ramos et al.[9];
- Danis-Weber: infrasyndesmotic (A), transsyndesmotic (B), and suprasyndesmotic (C) *apud* Ramos et al.[9];
- AO/OTA: infrasyndesmotic – isolated (A1), with medial malleolus (A2), or with postmedial fracture (A3); transsyndesmotic – isolated (B1), with medial injury (B2), or with medial injury and posterolateral injury (B3); and suprasyndesmotic – simple (C1), multifragmentary fracture (C2), or proximal fibula fracture (C3)[6].

The physicians were accompanied separately to a room where the radiographs of each case were evaluated for a maximum of three minutes, timed by an observer, and completed a form with the responses according to the three classifications. The physicians had prior knowledge of the classifications and could consult printed material detailing the three classifications. The highest agreement or not of the classifications was evaluated in relation to the standard response elaborated by a team composed of five orthopedists and traumatologists of a reference hospital. The physicians were divided into two groups to evaluate the results: without TEOT and with TEOT. The first group included the physicians who reported not having TEOT yet, and the second group included those who already had TEOT.

The data collected were evaluated in Microsoft Excel® 2007 (Microsoft Corporation, Redmond, Washington, USA) and SPSS, Statistical Package for the Social Science, version 16.0 (IBM Corp., Armonk, New York, USA). First, the correct answers for each classification were calculated according to the case presented and the period they have TEOT. Next, the normality of the sample was assessed using the Shapiro-Wilk test. Then, Fisher's exact test was used to detect differences between the TEOT period and the number of correct answers using the three classifications. Finally, the Student t-test for paired samples was applied to verify whether there was a significant difference in the degree of interobserver agreement between the classifications. A p-value<0.05 was considered statistically significant.

## Results

Of the physicians participating in the research (n=40), 19 (47.5%) already had TEOT for between one and five years, 12 (30%) had TEOT for more than five years, and nine (n=22.5%) physicians had not yet obtained TEOT.

When asked about the classification used in their clinical practice (Figure 2), most reported using two classifications, Lauge-Hansen and Danis-Weber (n=15, 48.4%), followed by only one classification, Lauge-Hansen or Danis-Weber, equally used (n=10, 32.2%).

The highest mean of correct answers in all classifications was for physicians with TEOT (Table 1).

Regarding the classifications, the highest frequency of correct answers was for the Danis-Weber, with 11 physicians (27.5%) getting the classification right in all five cases (Table 2). Most of the correct answers for this classification were from physicians with TEOT with five years or less (n=8, 42.1%). No significant differences were observed in the TEOT period and the absence of the title in relation to the number of correct answers of the three classifications (p>0.05).

When comparing the period the physicians have TEOT between the groups, one with up to five years and the other with six years or more, a significant difference was observed only for the AO/OTA, in which orthopedists and traumatologists with up to five years with TEOT had more correct answers when evaluating the radiographs using this classification (p<0.016). No significant differences were observed between the TEOT period and the correct answers for the other classifications.

When the mean score of the 40 physicians and the different classifications were compared (Table 3), a significant difference (p<0.05) was observed between all classifications for the group without TEOT. However, physicians without TEOT and with TEOT for up to five years differed in the number of correct answers when using the Lauge-Hansen vs. AO/OTA.

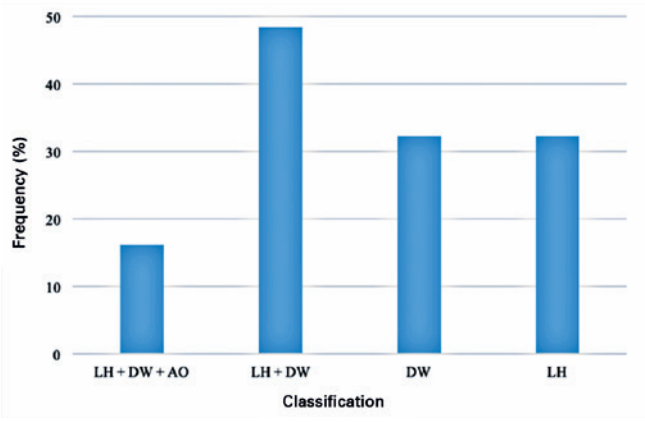


**Figure 2.** Most used classification systems by the physicians participating in the research.
LH: Lauge-Hansen classification; AO/OTA: *Arbeitsgemeinschaft für Osteosynthesefragenclassification*; DW: Danis-Weber classification; TEOT: Title of specialist in orthopedics and traumatology.

**Table 1.** Mean correct answers according to the Lauge-Hansen, AO/OTA, and Danis-Weber classifications

| Classifications* | Without TEOT (n=9, 22.5%) | With TEOT (n=31, 77.5%) | p** |
|---|---|---|---|
| Lauge-Hansen | 1.89±1.36 | 2.55±1.21 | 0.168 |
| AO/OTA | 1.11±1.54 | 1.74±1.61 | 0.303 |
| Danis-Weber | 3.67±0.87 | 4.03±0.75 | 0.221 |

* Values expressed as mean±standard deviation; ** Student t-test Statistical significance p<0.05. AO/OTA: *Arbeitsgemeinschaft für Osteosynthesefragenclassification*; TEOT: Title of specialist in orthopedics and traumatology.

**Table 2.** Frequency of correct classifications (correct answers) according to the Lauge-Hansen, AO/OTA, and Danis-Weber classifications

| Classifications | Correct answers | TEOT period | | | p** |
|---|---|---|---|---|---|
| | | Without TEOT (n=9, 22.5%) | ≤ 5 years (n=19, 47.5%) | > 5 years (n=12, 30%) | |
| Lauge-Hansen | 4 to 5 | 1 (11.1%) | 5 (26.4%) | 1 (8.3%) | |
| | 3 to 2 | 5 (55.5%) | 12 (63.2%) | 9 (25.1%) | 0.156 |
| | 1 to 0 | 3 (11.1%) | 2 (10.4%) | 2 (8.3%) | |
| AO/OTA | 4 to 5 | 1 (11.1%) | 4 (21.1%) | 1 (8.3%) | 0.020 |
| | 3 to 2 | 2 (22.2%) | 10 (52.5%) | 3 (25%) | |
| | 1 to 0 | 6 (66.7%) | 5 (26.4%) | 8 (66.7%) | |
| Danis-Weber | 4 to 5 | 6 (66.7%) | 14 (53.7%) | 17 (75%) | 0.254 |
| | 3 to 2 | 3 (33.3%) | 5 (26.3%) | 3 (25%) | |
| | 1 to 0 | 0 | 0 | 0 | |

Values expressed in n (%); ** ANOVA. Statistical significance p<0.05.
AO/OTA: *Arbeitsgemeinschaft für Osteosynthesefragenclassification*; TEOT: Title of specialist in orthopedics and traumatology.

**Table 3.** Level of agreement between the Lauge-Hansen, AO/OTA, and Danis-Weber classifications in relation to the period of TEOT

| Sample | System | Mean±SD | Pairs of classification systems | p* |
|---|---|---|---|---|
| Total (n=40) | Lauge-Hansen | 2.40±1.26 | LH vs. AO/OTA | 0.015 |
| | AO/OTA | 1.60±1.60 | LH vs. DW | <0.0001 |
| | Danis-Weber | 3.95±0.78 | AO vs. DW | <0.0001 |
| Without TEOT (n=09) | Lauge-Hansen | 1.89±1.36 | LH vs. AO/OTA | 0.272 |
| | AO/OTA | 1.11±1.54 | LH vs. DW | 0.0007 |
| | Danis-Weber | 3.67±0.87 | AO vs. DW | 0.0007 |
| ≤ 5 years of TEOT (n=19) | Lauge-Hansen | 2.79±1.27 | LH vs. AO/OTA | 0.260 |
| | AO/OTA | 2.32±1.53 | LH vs. DW | 0.0003 |
| | Danis-Weber | 4.16±0.83 | AO vs. DW | <0.001 |
| > 5 years of TEOT (n=12) | Lauge-Hansen | 2.17±1.03 | LH vs. AO/OTA | 0.0388 |
| | AO/OTA | 0.83±1.34 | LH vs. DW | <0.0001 |
| | Danis-Weber | 3.83±0.58 | AO vs. DW | <0.0001 |

* Student's t-test for paired samples; Statistical significance p<0.05.
SD: Standard deviation; LH: Lauge-Hansen classification; AO/OTA: *Arbeitsgemeinschaft für Osteosynthesefragenclassification*; DW: Danis-Weber classification; TEOT: Title of specialist in orthopedics and traumatology.

Regarding the overall correct answers (Figure 3), physicians with TEOT, regardless of the period, presented 25.9% more correct answers than those without TEOT (44.4%), being above the overall proportion of correct answers of the entire sample (53.3%).

## Discussion

The Danis-Weber and the Lauge-Hansen systems were the most used in the analyzed sample (Figure 2). However, there are more correct answers using the Danis-Weber classification, with no statistically significant difference in relation to having TEOT or not (Table 2). This result is also found when analyzing the correct classifications overall, whose highest rate of correct answers was for the Danis-Weber, differing significantly from the Lauge-Hansen and AO/OTA in relation to the TEOT period and the number of correct answers (Table 3).

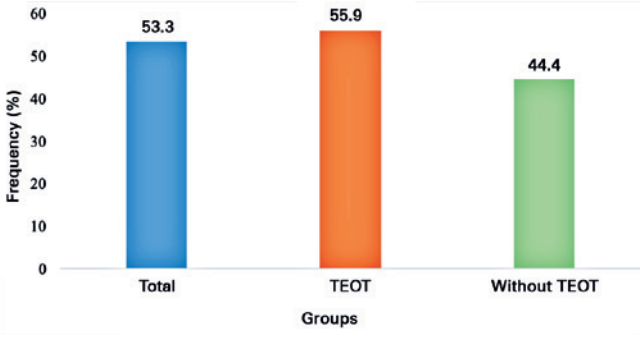


**Figure 3.** Overall correct answers of physicians with and without the title of specialist in orthopedics and traumatology (TEOT) in relation to the total classifications.

Ramos et al.[9] evaluated the inter-and intraobserver agreement regarding radiographs of 30 patients with ankle fractures evaluated by 11 physicians at different stages of professional training (five residents and six orthopedic surgeons) at two different times. They concluded that the Danis-Weber classification was the most reproducible. Fonseca et al.[10] consider that the Danis-Weber classification has more objective and more easily identifiable criteria for use in common radiographic evaluation, facilitating its application and resulting in greater agreement among physicians.

The Lauge-Hansen and AO/OTA classifications are more complex and require greater effort to acquire competence. The Lauge-Hansen and AO/OTA are similar when considering the fibular fracture. Still, in cases where there are posterior malleolus fractures or comminution of the fracture focus, they can lead less experienced professionals to a higher frequency of errors[11]. The choice of a method with a lower chance of errors may justify the fact that all participants do not use the AO/OTA classification alone[6] in their clinical practice, and there is a greater preference for the Lauge-Hansen and Danis-Weber classifications *apud* Ramos et al.[9] (Figure 2).

The lowest mean of correct answers (consequent higher proportion of errors, Table 1) was for the AO/OTA classification, and the difference was significant when comparing the groups according to the TEOT period (p=0.016). Eight of the 12 physicians (66.7%) with more than five years of TEOT could not correctly classify the five fractures using this classification (Table 2). The TEOT period was a significant fact when comparing the total number of correct answers only for the AO/OTA, in which physicians with more than five years of TEOT and those without TEOT presented a worse performance.

Tenório et al. [12] evaluated the inter-and intraobserver agreement regarding the Lauge-Hansen and Danis Weber classifications and the level of experience of orthopedists and traumatologists. There was greater agreement and reproducibility of the Danis-Weber classification, regardless of professional experience, results similar to our study.

The relevance of continuing medical education and investment in new training to bring physicians closer to knowledge is indisputable to ensure adequate patient management, better surgical results, and lower costs on the health system[13]. Furthermore, to guarantee quality and excellence in the training and performance of physicians, continuing education should be aimed at updating professionals, including tools for evaluating the performance of educational actions continuously and considering the profile of physicians trained in the Brazilian educational system[14].

This study had some limitations, such as the small number of radiographs compared to other studies that addressed the same objectives, the data being counted as correct answers based on the total number of cases, the small number of participants, and the size difference between groups. However, other aspects of extreme relevance to the quality of diagnosis and therapy exposed in the study are the appropriate professional practice, continuous improvement, criterion, and care with the quality of medical residency programs approved by the Ministry of Education and accredited by the Brazilian Society of Orthopedics and Traumatolgists, obtaining TEOT, these will lead to satisfactory experiences in the physician-patient relationship, the main scenario for the birth and development of a professional experience with excellence.

## Conclusion

Most physicians adequately classified the five cases of ankle fracture using the Danis-Weber classification. The highest frequency of correct answers was from physicians with TEOT.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: LCBR *(https://orcid.org/0000-0001-5009-6539) Conceived and planned the activities that led to the study, participated in the review process, participated in the writing of the article, data collection, approved the final version; PMFV *(https://orcid.org/0000-0002-0779-0901) Participated in the review process, formatting of the article, participated in the writing of the article, approved the final version; WWK *(https://orcid.org/0000-0002-2365-3421) Participated in the review process, bibliographic review, survey of the medical records, participated in the writing of the article, approved the final version; JSM *(https://orcid.org/0000-0003-4742-1905), and GTL *(https://orcid.org/0000-0003-3489-9192), and ACMO *(https://orcid.org/0000-0001-8516-444X), and SROJ *(https://orcid.org/0000-0002-7709-2930) Interpreted the results of the study, participated in the review process, participated in the writing of the article, approved the final version; RCA *(https://orcid.org/0000-0002-4996-7242) Participated in the review process, formatting of the article, participated in the writing of the article, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Original Article

# Radiosynovectomy of the ankle in hemophilic arthropathy: effectiveness of samarium-153 and yttrium-90

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## Abstract

**Objective:** Evaluate the effect of radiosynovectomy of the ankle with samarium-153 and yttrium-90 in hemophilic arthropathy through the possible reduction of hemarthrosis, analyzing complications, adverse effects, and the need for complementary therapies.

**Methods:** Radiosynovectomy of the ankle in 15 hemophilic patients was analyzed retrospectively and followed between January 2008 and December 2021. The analysis was performed through patients' medical records and diaries to quantify hemarthrosis that occurred six months before and six months after the procedure. Clinical follow-up and evaluation of outcomes were also analyzed.

**Results:** Eighteen radiosynovectomies of the ankle were performed in 15 patients with a mean follow-up of 124 months. A reduction in episodes of haemarthrosis has been demonstrated within six months ($p<0.001$). There were no adverse effects or complications in the short and long term. Approximately 61.1% of the patients did not require complementary therapies afterward.

**Conclusion:** The study demonstrated that radiosynovectomy of the ankle with samarium-153 and yttrium-90 in hemophilic patients is effective and safe. There was a decreased frequency of hemarthrosis, less need for complementary procedures, and no complications and adverse effects.

**Level of Evidence IV, Case Series.**

**Keywords:** Ankle; Arthropathy; Hemophilia; Synovectomy; Radioisotopes.

## Introduction

Hemophilia is an inherited bleeding disorder related to the X chromosome, characterized by deficiency or abnormality of coagulation proteins factor VIII (hemophilia A) or factor IX (hemophilia B). Hemophilia A is more common than hemophilia B, with a prevalence of 1 in 5,000 male births compared to 1 in 30,000, respectively[1]. Depending on coagulation deficiency, hemophilia can be classified as mild, moderate, or severe. Joint hemorrhage (hemarthrosis) is the finding more characteristic in hemophilia, affecting mainly the ankle, knee, and elbow[2]. The ankle has the earliest involvement and the greatest risk of progressing to terminal arthropathy in younger patients[3].

Repeated episodes of hemarthrosis lead to joint remodeling and subsequent hemophilic arthropathy. Iron deposition generates a local inflammatory response characterized by synovitis, lysosomal enzymes, and pro-inflammatory cytokines. The articular surface is progressively damaged,

Study performed at the Hospital of the State University of Campinas (UNICAMP) and the Hematology and Hemotherapy Center of the State University of Campinas (UNICAMP), Campinas, SP, Brazil.

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evolving with permanent damage and bone weakness[4]. Thus, hemophilic arthropathy is the most frequent and limiting sequelae in patients with hemophilia, determined by joint destruction, chronic pain, deformity, loss of range of motion, and disability. The patients most at risk for developing this condition are those in which the occurrence of target joint is observed, that is, three or more episodes of bleeding in six months[5].

Minimally invasive treatment with radiosynovectomy can transform a highly vascularized synovium into sclerotic tissue. The procedure delays the cartilaginous damage that intra-articular blood tends to produce in the long term. Radiosynovectomy is the first-line treatment for chronic synovitis and recurrent ankle hemarthrosis[6,7]. Studies indicate that radiosynovectomy is an efficient procedure whose success rate ranges from 76 to 80% and can be performed in any age group on an outpatient basis[8].

Most studies evaluating radiosynovectomy's effect on arthropathies are mainly based on the knee joint[9]. Even today, few studies demonstrate the use of different radiosynovectomy of the ankle in hemophilic arthropathy. In this context, the objective of this study is to evaluate the effect of radiosynovectomy of the ankle with samarium-153 and yttrium-90 in hemophilic arthropathy through the possible reduction of hemarthrosis, analyzing complications, adverse effects, and the need for complementary therapies.

## Methods

The study was approved by the institution's ethics committee and performed in a university hospital. Radiosynovectomy of the ankle in 15 hemophilic patients was analyzed retrospectively and followed between January 2008 and December 2021. The analysis was performed through patients' medical records and diaries to quantify hemarthrosis that occurred six months before and six months after the procedure. Clinical follow-up and evaluation of outcomes were also analyzed.

The inclusion criteria for radiosynovectomy were: patients diagnosed with hemophilia, recurrent ankle hemarthrosis considered as target joint, limiting clinical status, with signs of joint damage on radiography and in tertiary prophylaxis, that is, using coagulation factor continuously and regularly after diagnosis of joint involvement by physical examination and imaging. Exclusion criteria were the occurrence of acute local or systemic infection, pregnant women, and previous neoplasia.

The protocol was divided into three stages: pre-procedure, procedure, and post-procedure. In the pre-procedure phase, the patients were submitted to clinical, radiographic, and scintigraphic evaluation. In the procedure phase, under an aseptic technique and local anesthesia, the coagulation factor was administered to prevent hemarthrosis caused by the procedure, and the radiopharmaceutical (yttrium-90 hydroxyapatite (90-Y-HA) or samarium-153 hydroxyapatite(153-Sm-HA)) was injected into the ankle joint using the ultrasound-guided anteromedial approach, followed by intra-articular corticosteroids injection. Before the patient's release, radioactivity in the skin at the puncture site was monitored using a swab with gauze, monitored by portable radiation meters such as the Geiger Müller counter model MIR 7026. After the procedure, the patients received pain relievers and anti-inflammatory drugs, coagulation factors, immobilization of the tibiotarsal joint, and periodic outpatient evaluations. In addition, patients underwent scintigraphy to evaluate the radiopharmaceutical distribution and joint leakage within 72 hours. All procedures were performed by the same orthopedics, nuclear medicine, and radiology professionals. The follow-up occurred jointly between the orthopedics and hematology teams.

Eighteen radiosynovectomies of the ankle were performed in 15 patients, and three were bilateral. All patients were using tertiary prophylaxis with coagulation factor previously. Only one patient had a high response inhibitor, inhibitory alloantibodies against the infused coagulation factor. The general characteristics of the sampling are shown in table 1. The mean follow-up was 10.3 years (7.9-13.4). The mean age at the time of radiosynovectomy was 17.8 (6-42).

The number of joint bleeds six months before and six months after radiosynovectomy was considered, also pain complaints, functional limitations, and complementary procedures in the outpatient follow-up of these patients.

The patients filled out a diary with notes referring to episodes of hemarthrosis, pain, and the need for pain relievers. These diaries were reviewed monthly in the blood centers where these patients have follow-ups. Nine patients are followed-up in the blood center of our institution, and the others in other services.

**Table 1.** General characteristics

| Characteristic | General |
|---|---|
| Sex | |
| General | 15 |
| Male | 15 (100%) |
| Female | 0 (0%) |
| Hemophilia | |
| A moderate | 3 (20%) |
| A severe | 11 (73.3%) |
| B severe | 1 (6.7%) |
| Laterality | |
| Bilateral | 3 (20%) |
| Right | 8 (53.33%) |
| Left | 4 (26.67%) |
| High response inhibitor | |
| Present | 1 (6.67%) |
| Not Present | 14 (93.33%) |
| Radionuclides | |
| Samarium-153 | 13 (72.2%) |
| Yttrium-90 | 5 (27.7) |

The results were compared according to the Wilcoxon-signed-rank test for dependent samples when it cannot be assumed that the population is normally distributed. The Real Statistics extension program of Microsoft Excel® 2010 (Microsoft Corporation, Redmond, Washington, USA) was used for data analysis, considering $p<0.05$ significant. In addition, a boxplot diagram was performed to compare the data variation through position measurements.

## Results

Among the 18 procedures, 13 were performed with 153-Sm-HA and five with 90-Y-HA. The administration of 153-Sm-HA ranged from 4.2mCi to 20.2mCi, and 90-Y-HA ranged from 2.5mCi to 5.2mCi. None of the groups had an adverse effect. The administration varied according to age, weight, or volume of the patient's joint and the radioactive waste that remained retained in the syringe after administration of the tracer.

The total bleeds in the study group were 138 during the six months pre-procedure and 34 within six months post-procedure. An absolute reduction of ankle hemarthrosis by 75% has been demonstrated. The minimum and maximum number of bleeds per patient: two and 15 pre-procedure; 0 and 6 post-procedure (Table 2). Median and interquartile range in the studied group: seven (5.5) pre-procedure; two (3.0) post-procedure ($p<0.001$) (Figure 1).

During the follow-up, between 2008 and 2021, 11 of the 18 procedures performed did not require complementary therapies after radiosynovectomy. Only three patients were submitted to corticosteroid infiltration in the tibiotarsal joint, two underwent ultrasound-guided viscosupplementation, and one underwent ankle cyst curettage with grafting associated with arthroscopic synovectomy. In addition, one patient was submitted to supramalleolar variant osteotomy, evolving with moderate chronic pain (Table 3). No patient required ankle arthrodesis.

The patients who did not require complementary therapy reported a significant reduction in episodes of ankle hemarthrosis and pain improvement, which previously limited their daily activities. The number of hemarthroses was analyzed in the follow-up returns and recorded in the medical records.

Four of the 15 patients monitored through regular and daily consultations maintained moderate limitations to impact exercises associated with mild chronic pain. The other patients reported pain improvement and mild limitations to exercise.

## Discussion

This study demonstrated that radiosynovectomy of the ankle with samarium-153 and yttrium-90 in hemophilic arthro-

**Table 2.** Number of joint bleeds in each patient before and after radiosynovectomy

| Patient | Ankle | Pre-procedure | Post-procedure |
|---|---|---|---|
| 1 | Left | 7 | 2 |
| 1 | Right | 8 | 2 |
| 2 | Left | 12 | 0 |
| 3 | Left | 10 | 2 |
| 4 | Right | 2 | 0 |
| 5 | Right | 9 | 2 |
| 6 | Right | 7 | 3 |
| 7 | Right | 15 | 6 |
| 8 | Right | 5 | 1 |
| 9 | Right | 12 | 4 |
| 10 | Right | 3 | 0 |
| 11 | Left | 6 | 0 |
| 12 | Right | 6 | 1 |
| 13 | Left | 5 | 3 |
| 14 | Left | 15 | 4 |
| 14 | Right | 7 | 2 |
| 15 | Right | 5 | 2 |
| 15 | Left | 4 | 0 |
| Total bleeds | - | 138 | 34 |
| Mean | - | 7.67 | 1.88 |
| Median | - | 7 | 2 |

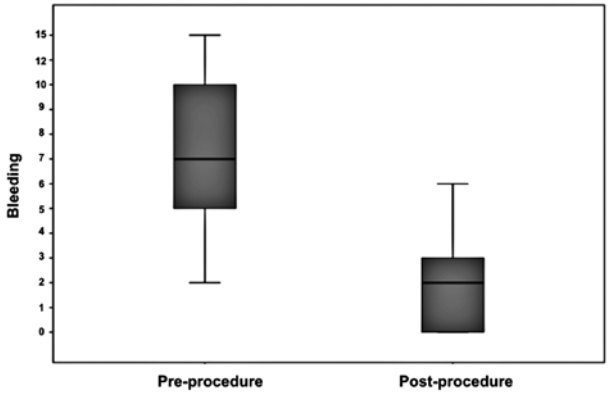


**Figure 1.** Comparison of joint bleeds before and after radiosynovectomy.

**Table 3.** Statistical relationship of complementary therapies at follow-up

| Complementary therapies at follow-up | |
|---|---|
| Did not need | 11 (61.1) |
| Corticosteroid infiltration | 3 (16.7) |
| Viscosupplementation | 2 (11.1%) |
| Curettage | 1 (5.5%) |
| Osteotomy | 1 (5.5%) |

pathy is an effective procedure to decrease the hemarthrosis rate. In addition, there was a 75% decrease in the frequency of bleeding during the study period. This result is comparable to previous studies involving other joints, with a success rate ranging from 75% to 90% after radiosynovectomy with yttrium-90, rhenium-186, and other radionuclides in patients with hemophilic arthropathy[10].

In addition, no adverse effects and complications associated with a lower need for complementary therapies during follow-up make this technique safe and validated as a therapeutic tool for hemophilic ankle arthropathy. Despite the small sample, it was observed that there was no superiority between the two radionuclides, so both groups presented favorable outcomes.

Immediately after the injection, the radiopharmaceutical particles are phagocyted by synovial macrophages, forming elements large enough not to reach the bloodstream[11]. As a result, the beta radiation emitted has low tissue penetration power, most of which is absorbed by the synovium, cartilage, and joint capsule. Therefore, radiosynovectomy is a safe procedure, sparing subchondral bone and adjacent structures[10].

Das[12] states, in a study published in 2007, that radiosynovectomy complications are rare compared to intra-articular corticosteroid injections, the most common being joint infection (1: 35,000 procedures). During the study, no infectious process was observed in any patient.

Secondary skin necrosis to radiopharmaceutical leakage and arthritis are other complications related to radiosynovectomy cited in the literature[13]. The ultrasound-guided procedure was used to ensure the presence of the radiopharmaceutical in the joint space. The absence of leakage and the radiopharmaceutical distribution in the joint was confirmed by scintigraphy within 72 hours after the procedure. Thus, it was observed that there were no significant changes in clinical and imaging findings suggestive of leakage.

The absence of skin complications in our patients contrasts with the study by Bickels et al.[13] that described unacceptable complications of radiosynovectomy of the ankle using 15 mCi of yttrium-90 citrate colloidal with fluoroscopic-guided injection, treatment of pigmented villonodular synovitis. The high incidence of complications is probably related to the increased activity of injected yttrium-90, much higher than that usually administered in larger joints such as the knee. In our study, only five of the 18 procedures were performed with yttrium-90 and activities approximately 3-6 times lower, adjusted according to age, weight, and joint volume. In addition, most procedures were performed with samarium-153, a radionuclide with lower tissue penetration power and which emits lower energy radiation when compared to yttrium-90.

The ideal radionuclide should be a pure beta-emitter to promote synovial ablation, moderate half-life, of uniform joint distribution to not lead to an exacerbated inflammatory response[14,15]. The radiopharmaceutical selection was based mainly on the availability in the local radiopharmaceutical market and on the current Brazilian sanitary regulations. However, there is still no consensus in the literature on the best option due to the insufficient comparative studies between different radiopharmaceuticals[16]. Nevertheless, previous studies suggest a better use of yttrium in joints with high synovial volume, such as knees, and samarium for medium joints with lower synovial volume, such as elbows and ankles, because it is a radiopharmaceutical that emits radiation with lower tissue penetration than yttrium[17].

With the advent of prophylactic coagulation factors, episodes of hemarthrosis were reduced, bringing a better quality of life to patients and a lower rate of interventions in the tibiotarsal joint. However, services whose prophylaxis is not widely available, patients with chronic synovitis, hemarthrosis refractory to prophylactic treatment, difficult-to-manage hemarthrosis, and patients with high titer inhibitors may still benefit from radiosynovectomy.

It is also worth noting that the reduction in episodes of hemarthrosis results in a potential decrease in the use of the coagulation factor. From a financial point of view, this directly impacts the reduction of treatment costs for patients with hemophilia and corroborates the procedure's benefits.

Finally, the relevance of this study is the contribution to the scientific literature since there is a shortage of studies on radiosynovectomy of the ankle in hemophilic arthropathy. Particularly, the use of Samarium-153 in the ankle is still little reported in this procedure, predominating radiopharmaceuticals such as yttrium-90, rhenium-186, and phosphorus-32[11]. However, this study has limitations such as retrospective design, the absence of a control group, the possibility of failure in the medical records, and the relatively small sample.

## Conclusion

The radiosynovectomy of the ankle protocol adopted in this study is a minimally invasive procedure demonstrating that administered with samarium-153 and yttrium-90 in patients with hemophilic arthropathy is effective and safe. There was a decreased frequency of hemarthrosis, less need for complementary procedures, and no complications and adverse effects.

**Authors' Contribution:** Each author personally and significantly contributed towards the development of this article: HMR* (https://orcid.org/0000-0003-0401-2968 ) Conceived and planned the activities that led to the study, wrote the paper, interpreted the results of the study, statistical analysis, formatting of the article, participated in the reviewing process, bibliographic review, approved the final version; GSMDSPC *(https://orcid.org/0000-0002-8388-5849), and MSM*(https://orcid.org/0000-0002-0502-586X) Data collection, interpreted the results of the study, participated in the reviewing process. MCMD* (https://orcid.org/0000-0001-6572-1771) Interpreted the results of the study, participated in the reviewing process. GFAP *(https://orcid.org/0000-0001-7091-9918), and JBSR *(https://orcid.org/0000-0002-1822-0576) Data collection, participated in the reviewing process, approved the final version; ETIS *(https://orcid.org/0000-0002-5791-3295), and AOS*( https://orcid.org/0000-0002-9192-6946) Performed the radiosynovectomy, participated in the reviewing process, approved the final version; MCO* (https://orcid.org/0000-0001-5938-0675) Participated in the reviewing process, approved the final version. RGP* (https://orcid.org/0000-0002-6064-2027) Conceived and planned the activities that led to the study, formatting of the article, wrote the paper, participated in the reviewing process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) .

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Original Article

# Therapeutic option for patients with severe hallux rigidus

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## Abstract

**Objectives:** Subclassify grade III of Hattrup and Johnson classification into two groups, according to the remaining percentage of plantar articular cartilage, and propose a treatment option other than arthrodesis for some of these patients.

**Methods:** Twenty-one patients with grade III hallux rigidus were operated on between February 2015 and January 2020. The radiographic Hattrup and Johnson's classification was used, and grade III patients were submitted to frontal, lateral, and oblique radiographs. Eventually, a computed tomography (CT) was performed. The viable surface of the plantar cartilage and the percentage of the total joint was determined: if there is up to 50% of remaining plantar articular cartilage, the joint was preserved, indicating Weil osteotomy of the first metatarsal, associated with wide dorsal cheilectomy (type 3A); if less than 50%, metatarsophalangeal arthrodesis was indicated (type 3B). Patients with the first metatarsal at least 5 mm shorter than the second on frontal radiograph were excluded from the study.

**Results:** A mean postoperative American Orthopaedic Foot & Ankle Society (AOFAS) score of 91 was obtained. To date, no patient has needed arthrodesis, and all patients have increased joint range of motion. Shortening the central metatarsals was not necessary as a second procedure due to transfer metatarsalgia.

**Conclusion:** Some joints classified as grade III can be treated with an osteotomy without needing arthrodesis.

**Level of Evidence IV; Therapeutic Study; Case Series.**

**Keywords:** Hallux rigidus; Metatarsal bone; Metatarsophalangeal joint; Osteotomy.

## Introduction

In a normal situation, the hallux presents a range of motion of 110° (75° dorsal and 35° plantar) in the metatarsophalangeal (MTP) joint[1].

Hallux rigidus is a pathology of the first MTP joint, which begins with pain, initially limited to dorsiflexion, and over time evolves with progressive stiffness until ankylosis in the most severe stages. Pain worsens with walking, especially in the initial support phase or when standing on tiptoe; this can lead the patient to overload the central metatarsals due to forefoot supination to compensate for the lack of hallux mobility[2]. The causes of this pathology may vary and have been described over time[3]; they are classified as primary, idiopathic, or secondary, which might be a consequence of systemic processes (gout, rheumatoid arthritis, or psoriasis), iatrogenic, post-traumatic or osteochondritis dissecans.

The joint anatomical conditions, such as the long first metatarsal[4] and/or elevation[5], the hypermobility of the first ray, and finally, the retraction of the sesamoid[6] that has been increasingly highlighted in hallux rigidus[7] are predisposing and determining factors to define the surgical conduct.

The clinical aspects include joint pain in different degrees and painful limitations in active and passive mobility. In addition, it could be episodes of edema and plantar hyperkeratosis developed over time due to hyper support under the central metatarsals.

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

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Many authors have classified this pathology differently based on subjective, objective, or radiographic concepts. Given the frequent clinical-radiological dissociation, Hattrup and Johnson's classification[8] was chosen (Table 1), subdividing it into three evolutionary degrees based on radiological changes.

The purpose of this study is:

- Describe two subtypes of grade III severe hallux rigidus based on Hattrup and Johnson's classification.
- Demonstrate that for some patients with severe hallux rigidus, and up to 50% of remaining plantar articular cartilage, Weil osteotomy of the first metatarsal can be indicated, associated with dorsal cheilectomy and extensive joint debridement.

## Methods

A prospective study with a level of evidence IV was conducted. The study was approved by the ethics committee.

Hattrup and Johnson's classification[8] was used (Table 1), subdividing the pathology into three evolutionary degrees and is based on the radiological changes that develop in the articulation with the progression of the degenerative process.

We propose to subdivide type III severe hallux rigidus by studying the percentage of remaining viable plantar cartilage measured on an oblique foot radiograph or a joint computed tomography (CT), even in cases with joint lumen loss (Figures 1 and 2). Technically, the measurement consists of locating the proximal dorsal limit and the plantar limit of the metatarsal head articular cartilage on the oblique foot radiograph. Then a central point between them following the edge of the joint metatarsal head should be identified. This point will allow the definition of hallux rigidus severity, analyzing its irregularity, subchondral sclerosis, or severe osteochondral lesion, with or without a residual joint lumen. If the cartilage lesion crosses this point towards the plantar point, then we consider the joint infeasible (3B). Otherwise, we consider that the joint can be treated with an osteotomy (3A).

Grade III was subclassified, according to these images, into two subtypes (Figure 3):

- A: up to 50% remaining viable plantar cartilage.
- B: less than 50% of remaining viable plantar cartilage.

**Table 1.** Hattrup and Johnson Classification

| Grade | Radiology |
|---|---|
| I | Mild osteophyte<br>Good joint lumen preservation |
| II | Moderated osteophyte<br>Decreased joint lumen<br>Subchondral sclerosis |
| III | Accentuated osteophyte<br>No visible joint lumen<br>Geodes |

**Figure 1.** Difference between grade II (left) and grade III (right), with joint lumen loss.

**Figure 2.** Frontal and oblique radiographs and sagittal computed tomography of the joint. The remaining plantar articular cartilage and the possibility of joint salvage are visualized.

Between 2015 and 2020, 21 patients with grade III hallux rigidus were operated on; 13 were female and eight male. The mean age was 52 years.

All patients were evaluated with frontal, lateral, and oblique radiographs, eventually, with CT, the first two with monopodial support.

## Inclusion criteria

1. Grade IIIA hallux rigidus;
2. Pain and stiffness are present but of varying intensity.

## Exclusion criteria

1. Short first metatarsal compared to the second (more than 5 mm);
2. Grade IIIB hallux rigidus;
3. Previous surgeries;
4. Simultaneous shortening of the central metatarsals.

Patients were evaluated with pre- and postoperative American Orthopaedic Foot & Ankle Society (AOFAS) scores, considering the hallux mobility compared to the preoperative score and the return to sports activity.

The mean follow-up was 22 months (range 13-35).

The anatomical location of the first metatarsal is important. In addition, the radiographic measurement of its length and elevation to the second metatarsal indicates the surgical technique presented.

The elevation of the first metatarsal is easy to identify. The simplest form was proposed by Monteagudo de la Rosa and Viladot-Pericé[9] (Figure 4). Two lines were drawn, one parallel to the dorsal cortical of the first metatarsal and the other in the dorsal cortical of the second metatarsal. Normally it should form an angle between 0° and 5°. However, when there is a clear elevation of the first metatarsal the angle formed exceeds this value.

The Meary line break should be considered on the lateral radiograph, indicating a true elevation of the first ray. If the line remains constant, the elevation of the first ray is not real and is related to a midfoot pronator component (Figure 5).

The first metatarsal length was measured on a frontal radiograph with monopodial support. Two parallel lines were drawn tangent to the most distal point of the first and second metatarsals (Figure 6). A Weil osteotomy was only performed if the first metatarsal did not show a shortening by more than 5mm to the second metatarsal head, taking this value arbitrarily.

**Figure 3.** Type IIIA (superior) and 3B (inferior) present different treatment alternatives.

**Figure 4.** Profile radiograph of the foot with monopodial support: two lines were drawn, one parallel to the dorsal cortical of the first metatarsal and the other in the dorsal cortical of the second metatarsal.

**Figure 5.** The Meary line break confirms the first ray elevation and discards the pathology with a midfoot pronator component.

## Surgical Technique

All patients were operated on in dorsal decubitus with local ankle anesthesia. The capsule is incised through a medial approach centered on the first metatarsal head, a dorsal cheilectomy was performed, and the osteophytes were removed from the metatarsal head and phalanx. The metatarsal Weil osteotomy was parallel to the floor and distal to proximal, and the reference was the upper marginal joint border. From there, the cut direction and the displacement cause the metatarsal head to descend, the controlled shortening and reorientation of the remaining plantar cartilage. Two 2.7mm screws were used to stabilize it. Sesamoid adhesions were released. The capsular plane's closure was tension-free, and the skin was closed with separate stitches. In the postoperative period, the patients used postsurgical shoes for four weeks, starting early with active joint mobilization according to the pain. Physiotherapy is indicated from the fourth week onwards.

**Figure 6.** The first metatarsal length is measured by tracing two parallel lines tangent to the most distal point of the first and second metatarsals.

## Results

The mean forefoot AOFAS score in the preoperative period was 57 (range 42-72). The MTP joint mobility improved in all cases compared to before surgery. An AOFAS score of 91 (range 67-100) was obtained postoperatively.

All patients reported pain as the main preoperative symptom. The other symptoms were decreased mobility in twelve patients (58%), inability to perform physical activity in five patients (23%), and forefoot deformity in the remaining four (19%) (Figure 7).

Almost all patients had pain improvement in the late postoperative period (Figure 8). In addition, all patients resumed their previous daily living activities and sports; the return to usual sports activity occurred before six months for 16 patients (76%), between six and nine months for three patients (15%), and after nine months for only two patients (9%).

No patients had to be reoperated, and there was no evidence of MTP arthrodesis. This corroborates with the study by Malerba et al.[10] in 2008.

## Discussion

Hallux rigidus is a very common pathology of the forefoot, described as pain in the MTP joint of the first ray, decreased or loss of mobility, and formation of periarticular osteophytes, predominantly dorsal.

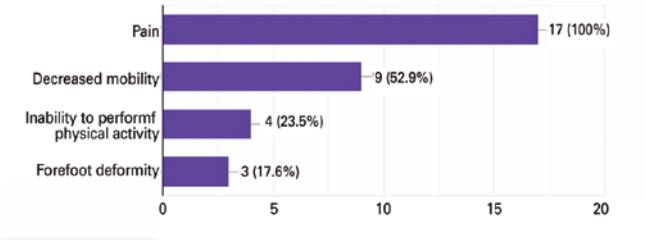


**Figure 7.** Main preoperative symptoms.

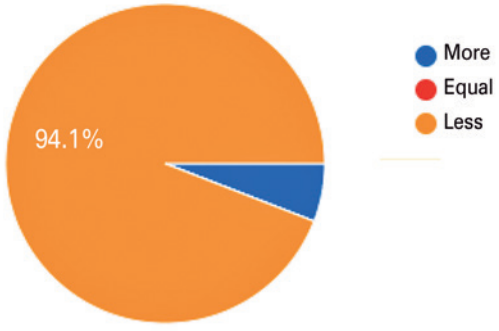


**Figure 8.** Postoperative pain.

The causes of this pathology are not clear. However, the most common presentation is primary, idiopathic, or secondary, produced by damage to the articular cartilage due to direct trauma of short/long duration or systemic disease as the most probable causes[11].

The treatment options are for the initial stages, conservative[12] consisting of non-steroidal anti-inflammatory drugs for the acute phase, followed eventually by orthosis and, if necessary, a change of activities, especially those that need extreme hallux dorsal flexion. For more advanced stages, or failure of conservative treatment, the surgical options can preserve the articular cartilage (osteotomies, cheilectomies) or sacrifice it (arthrodesis, resection arthroplasty, and replacement arthroplasty).

The objective of surgical treatment is to correct the deformity, relieve the pain, and, if possible, prevent the recurrence of the pathology. Ethiopathogenic anatomical conditions are recognized, such as the first long metatarsal and its elevation to the second metatarsal. Either the cheilectomy or the MTP arthrodesis, focus on these factors and does not prevent the disease recurrence. The osteotomy presented decompresses the joint and improves the anatomical situation of the first metatarsal, trying to avoid this recurrence[13,14].

The therapeutic options for patients with grade III hallux rigidus are dorsal cheilectomy (resection of one-third of the joint) and MTP arthrodesis; it is important to define the percentage of remaining articular cartilage to subclassify this group into type A and B (Figure 9).

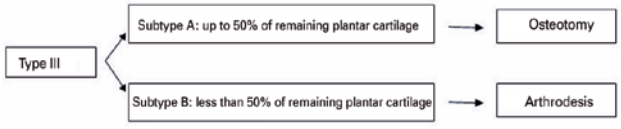


**Figure 9.** Hattrup and Johnson's classification and protocol for type III.

For subtype B, the accepted treatment is MTP arthrodesis, while for subtype A we must consider the first metatarsal's anatomical situation. The radiographic measurement of its length and elevation to the second metatarsal indicate the surgical technique presented.

The most frequent complication in hallux rigidus surgery is metatarsalgia and, in more complex cases, stress fractures of the second metatarsal due to overload because of excessive shortening. The choice of surgical technique is very important to avoid these situations. The first metatarsal length was crucial in elaborating this study and choosing the patient to perform a Weil osteotomy.

Other complications described are metatarsal-phalangeal and interphalangeal pain, avascular metatarsal head necrosis due to injury to the cephalic vessels, pseudarthrosis, infection, and the need for material removal due to intolerance[15].

The study has some limitations. First, the number of 21 operated feet is not sufficient to reach definitive conclusions about this type of pathology, but it demonstrate no complications in the short term and no need to reoperate any patient. Second, the hallux assessment was performed using radiographs and not by CT, and the measurement of cartilage percentage and the metatarsal length is less accurate with this method. Finally, the follow-up time is very short, and the conclusions reached are only short-term. Therefore, continuing this line of study, it is important to reassess these patients to provide med/long-term information.

## Conclusion

This study offers a new therapeutic option and shows the good short-term evolution of Weil osteotomy of the first metatarsal in patients with grade III hallux rigidus, subtype A, whenever the length and elevation to the second metatarsal are respected.

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

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Original Article

# Profile of clinical research related to orthopedic disorders in the last five years

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## Abstract

**Objective:** The aim of the study was to identify the profile of clinical research related to orthopedic disorders worldwide.

**Methods:** A survey of clinical research in orthopedics was performed in the ClinicalTrials.gov platform and Plataforma Brasil databases.

**Results:** According to data from the ClinicalTrials.gov platform, 1.142 clinical trials related to orthopedic disorders were registered from January 2017 to July 2022. Brazil is in the 14th position in the international ranking, and the Universidade de Sao Paulo (USP) occupies the 6th position among the collaborators who performed the most research in this area. The importance of the foot and ankle area in clinical research related to orthopedic disorders is evident when it is the 7th most studied worldwide and the 2nd most studied in Brazil. Most clinical trials related to orthopedic disorders worldwide target the adult or older adult population and involve interventional studies. On the other hand, most of the clinical trials related to orthopedic disorders in Brazil target the pediatric or geriatric population and involve observational studies.

**Conclusion:** The profile of clinical research related to orthopedic disorders worldwide showed that most clinical trials targeted the adult or older adult population and aimed to treat patients, not prevent diseases. Brazil targeted the pediatric or geriatric population focusing on characterizing populations and diseases. Clinical research related to orthopedic disorders performed worldwide and in Brazil depended on sponsorship and private institutions.

**Level of Evidence IV; Descriptive Observational Study.**

**Keywords:** Clinical trials as topic; Clinical research protocol; Musculoskeletal diseases; Orthopedics; Traumatology.

## Introduction

Orthopedic surgery has a long history. While the modern term orthopedics was defined in the early 18th century, orthopedic principles were documented earlier. In ancient Egypt, some orthopedic practices were well documented[1,2]. The Greeks and Romans later began to study medicine more methodologically and improved their understanding of orthopedic anatomy and surgical techniques[3-5]. During the Renaissance, there was a rapid advance in this area of knowledge, such as the description of injuries, surgical technique, and the establishment of orthopedic hospitals; this history provided the foundation for modern orthopedic research[6-8]. In the clinical research and randomized clinical trials era, it is essential to identify the profile of clinical research related to orthopedic disorders conducted worldwide, especially in Brazil, to discuss the challenges involved in this process.

## Methods

An observational study including clinical trials exclusively in orthopedics and traumatology. A literature review was performed, considering the following terms: “clinical research and orthopedic disorder.” The search was conducted in the PubMed, Scielo, and Google Academic databases.

Study performed at the Lab. Prof. Manlio Mario Marco Napoli, Departamento de Ortopedia e Traumatologia, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, São Paulo, SP, Brazil.

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A survey of clinical research in orthopedic disorders was performed in two different databases:

a) **ClinicalTrials.gov platform**: an active search for clinical research related to orthopedic disorders registered on the ClinicalTrials.gov platform was performed; this platform is an international public database maintained by the National Library of Medicine (NLM) at the National Institutes of Health (NIH), in which clinical trials of public or private initiative are registered (https://clinicaltrials.gov/). For this purpose, the ClinicalTrials.gov platform was accessed on July 21, 2022, at 3:00 pm (Brazilian time), and the keywords were used: "orthopedics," "orthopedic disorder," and "Start date from January 2017 to July 2022".

b) **Plataforma Brasil database:** an active search for clinical trials of public or private initiatives related to orthopedic disorders registered on the Plataforma Brasil database was performed. The Plataforma Brasil is a Brazilian, national, public, and unified database of research records involving humans for the entire country. Registration on the Plataforma Brasil database is mandatory for all clinical trials conducted in Brazil. The platform is maintained by the Brazilian government at the National Health Council, an agency linked to the Brazilian Ministry of Health (https://plataformabrasil.saude.gov.br/login.jsf). For this purpose, the Plataforma Brasil database was accessed on July 22, 2022, at 10:00 am, and the keywords were used: "orthopedics," "Start date from January 2017 to July 2022".

Data extracted from the databases were recorded in a spreadsheet using the Microsoft Excel® 2010 program (Microsoft Corporation, Redmond, Washington, USA). After checking the consistency of the data, a descriptive analysis was performed.

## Results

According to data from the ClinicalTrials.gov platform, 1.142 clinical trials related to orthopedic disorders were registered from January 2017 to July 2022. During the same period, 350 clinical trials were registered on the Plataforma Brasil database. In addition, according to the data obtained, 228 clinical trials were registered yearly worldwide, whereas, in Brazil, only 70 clinical trials were registered yearly (Figure 1).

Most clinical trials related to orthopedic disorders registered on the ClinicalTrials.gov platform during the period studied were performed in the USA, China, and Canada (Figure 2).

Although the number of clinical trials related to orthopedic disorders registered on the ClinicalTrials.gov platform or Plataforma Brasil database has not shown significant growth since 2018, Brazil is in the 14th position in the international ranking, the same position occupied by Spain and other 20 countries that most performed clinical research related to orthopedic disorders worldwide (Figure 2).

According to data from the Plataforma Brasil database, clinical trials related to orthopedic disorders in Brazil are concentrated in the southeast region and Sao Paulo state (Figure 2). Universidade de Sao Paulo (USP) occupies the 6th position among the sponsors/collaborators who conducted the most research in this area (Figure 3).

According to data from the ClinicalTrials.gov platform and Plataforma Brasil database, the foot and ankle specialty is the 7th most studied worldwide and the 2nd most studied in Brazil among clinical research related to orthopedic disorders

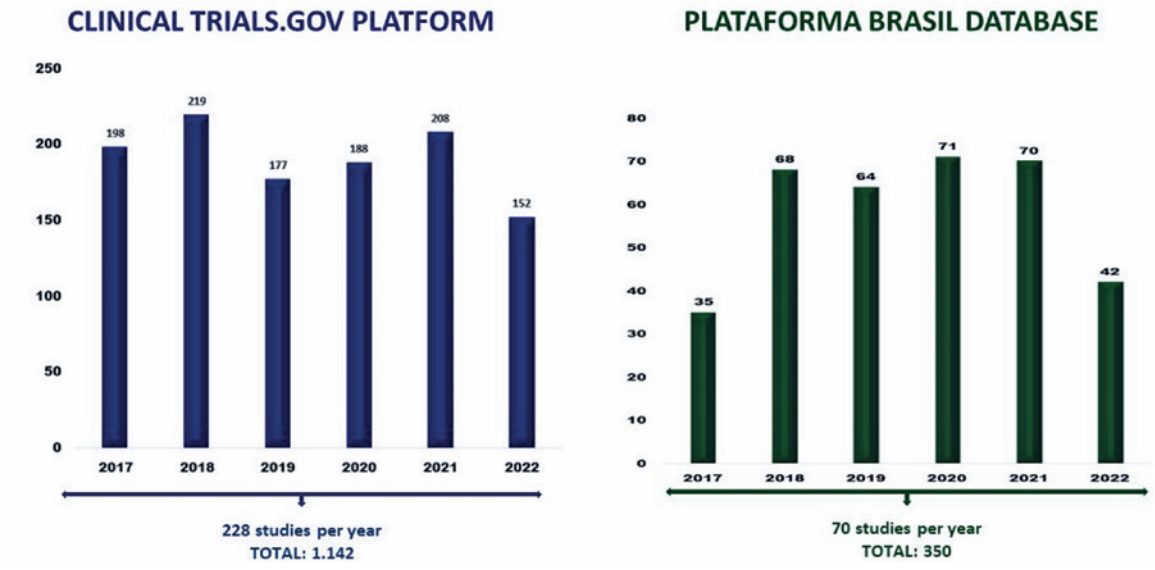


**Figure 1.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Start Year.

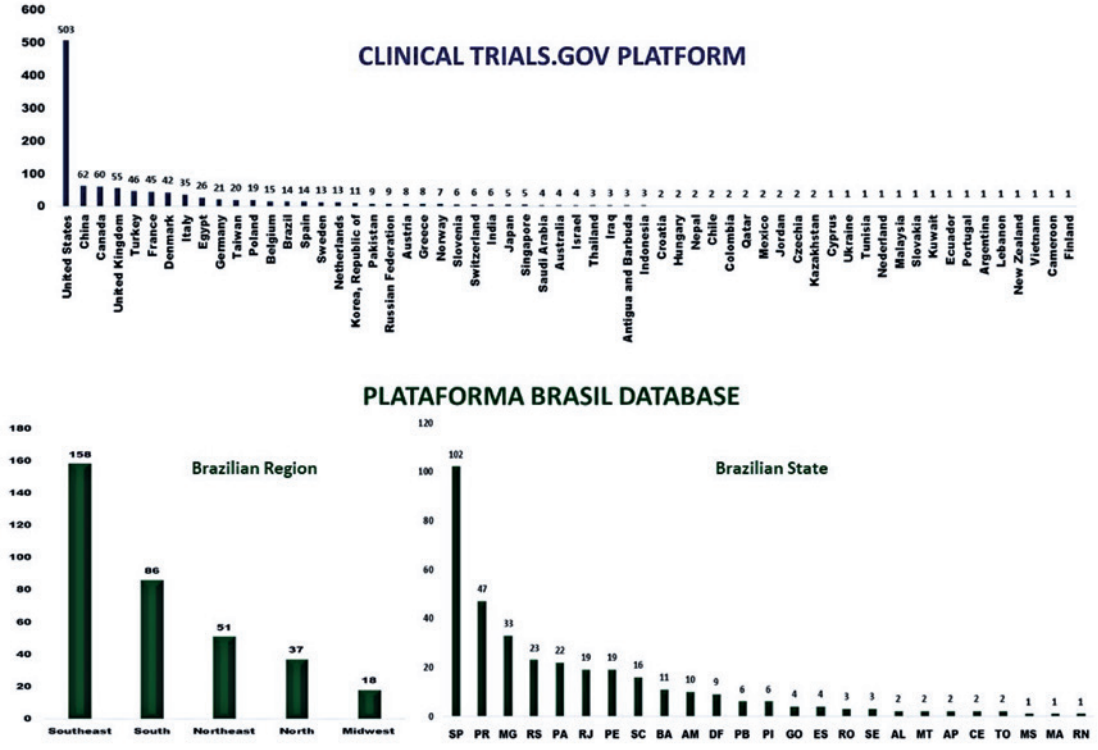


**Figure 2.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Main Country or State.

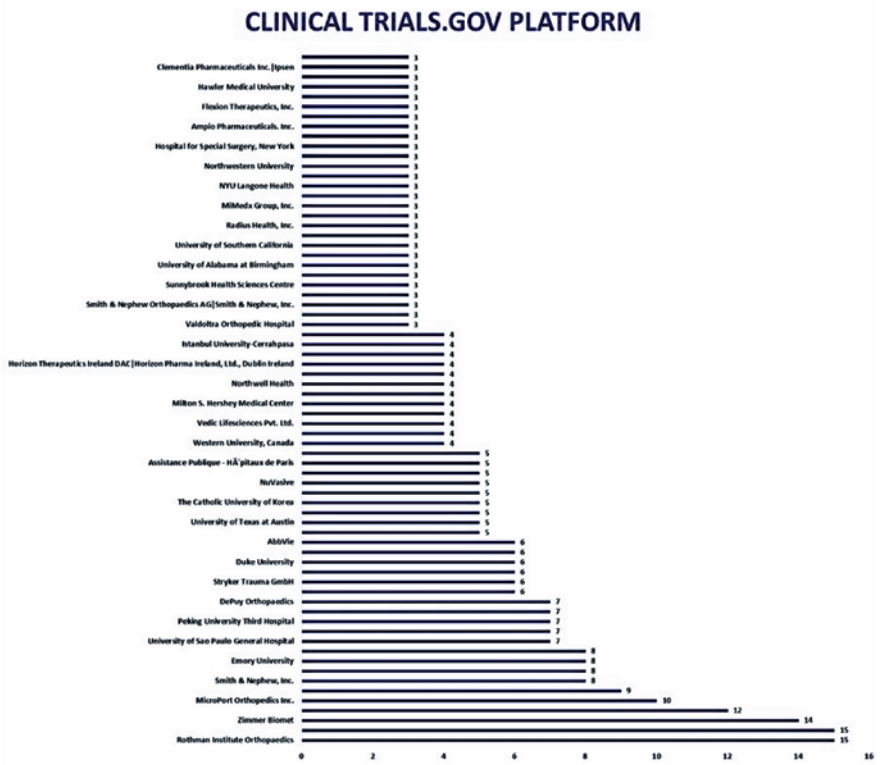


**Figure 3.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Top 50 sponsors or collaborators.

(Figure 4). Most of these studies target the adult and older adult population, involve devices, drugs, biological products, and were interventionist studies. On the other hand, in Brazil, these clinical trials target the pediatric and geriatric population, involve devices, diagnostic tests or drugs, and were observational studies (Figures 5, 6, and 7). In addition, phase I, II, III, and IV clinical trials were found in this area worldwide, while in Brazil, only phase III and IV (Figure 8).

According to data from the ClinicalTrials.gov platform, most clinical research related to orthopedic disorders received funding from medical industries or the pharmaceutical sector. According to data from the Plataforma Brasil database in Brazil, most clinical research related to orthopedic disorders involves private institutions (Figure 9).

## Discussion

When analyzing the number of clinical trials related to orthopedic disorders registered on the ClinicalTrials.gov platform, stagnation was observed in the number of studies in this area since 2018.

As expected, most clinical research related to orthopedic disorders registered on the ClinicalTrials.gov platform from January 2017 to July 2022 was performed in the USA. However, the growth in the number of clinical trials related to orthopedic disorders in China highlights the relevance of this country in the international scenario of clinical research.

Around 70 clinical trials related to orthopedic disorders are performed annually in Brazil. This corresponds to a little more than the mean studies performed in this area yearly worldwide. However, despite a small increase in the number of clinical trials related to orthopedic disorders performed in Brazil between 2017 and 2021, there are few studies in orthopedics and traumatology in Brazil.

However, even without an increase in the number of clinical trials in orthopedics and traumatology in the last five years, Brazil occupies the 14th position in the international ranking alongside 20 countries that most conducted clinical research related to orthopedic disorders worldwide.

According to data from the Plataforma Brasil database, clinical research related to orthopedic disorders in Brazil is concentrated in the southeast and Sao Paulo state.

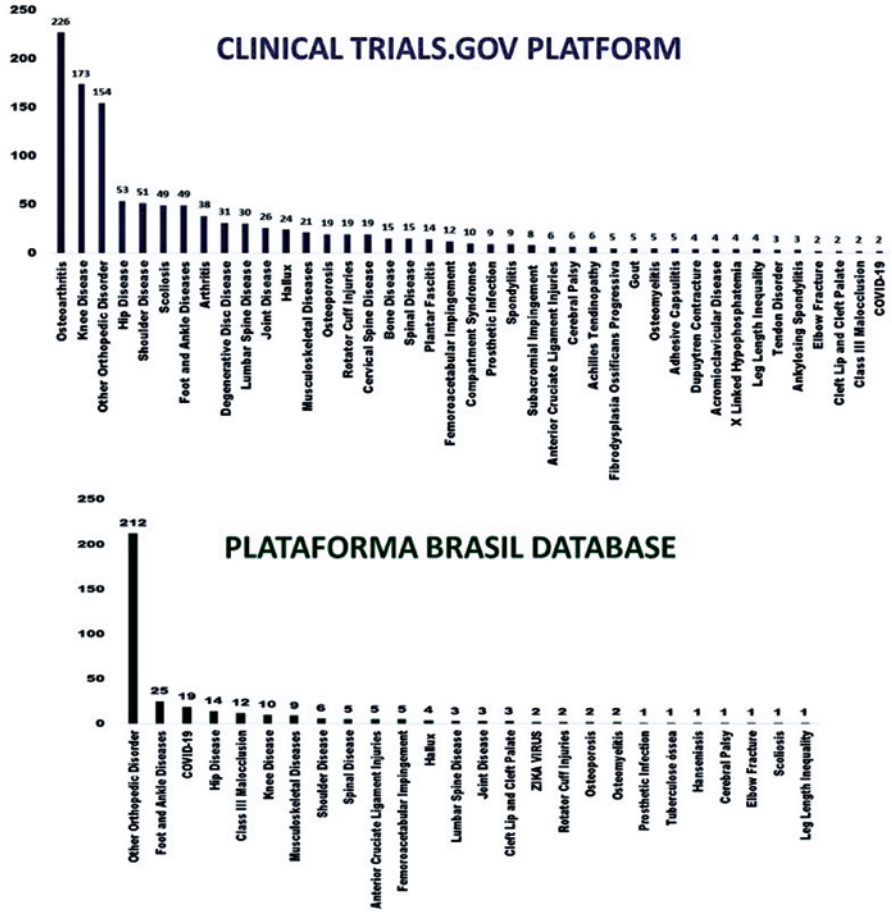


**Figure 4.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Conditions.

Universidade de Sao Paulo (USP) occupies the 6th position among sponsors/collaborators who conducted the most research in this area. This can be explained because USP is one of the top 150 universities in the world according to the Academic Ranking of World Universities 2022 (ARWU) published by the Chinese consultancy Shanghai Ranking Consultancy[9]. Another reason is the existence of the Fundação de Amparo à Pesquisa do Estado de Sao Paulo

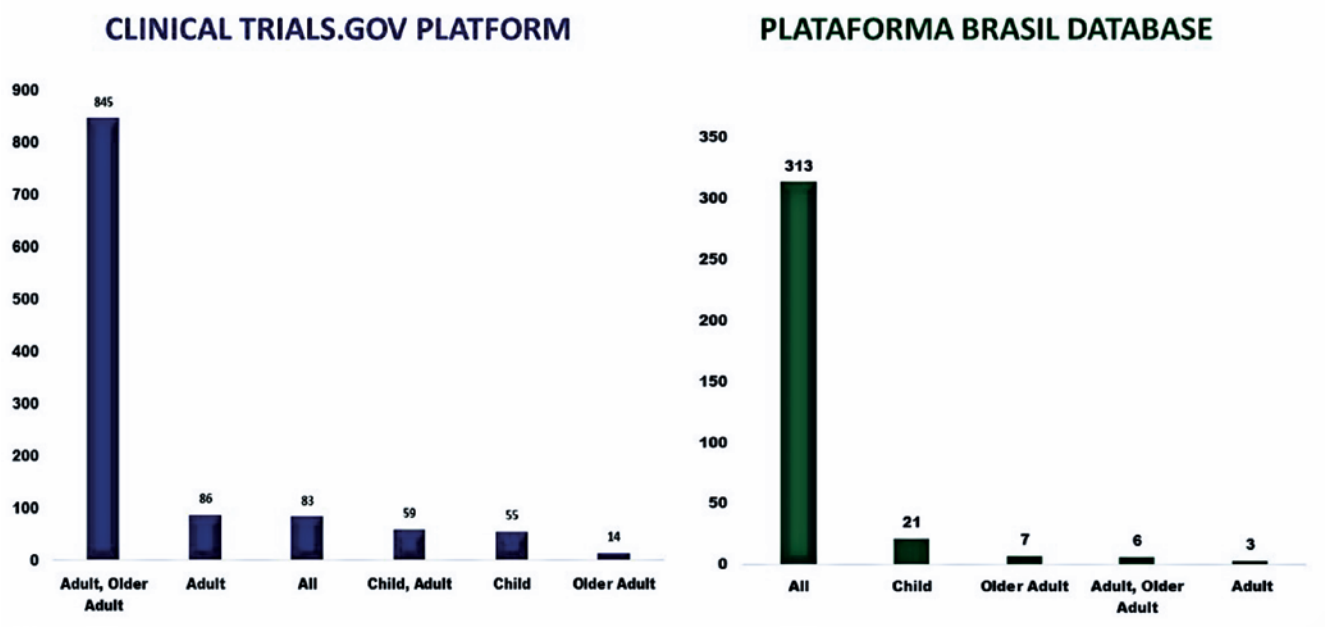


**Figure 5.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Age.

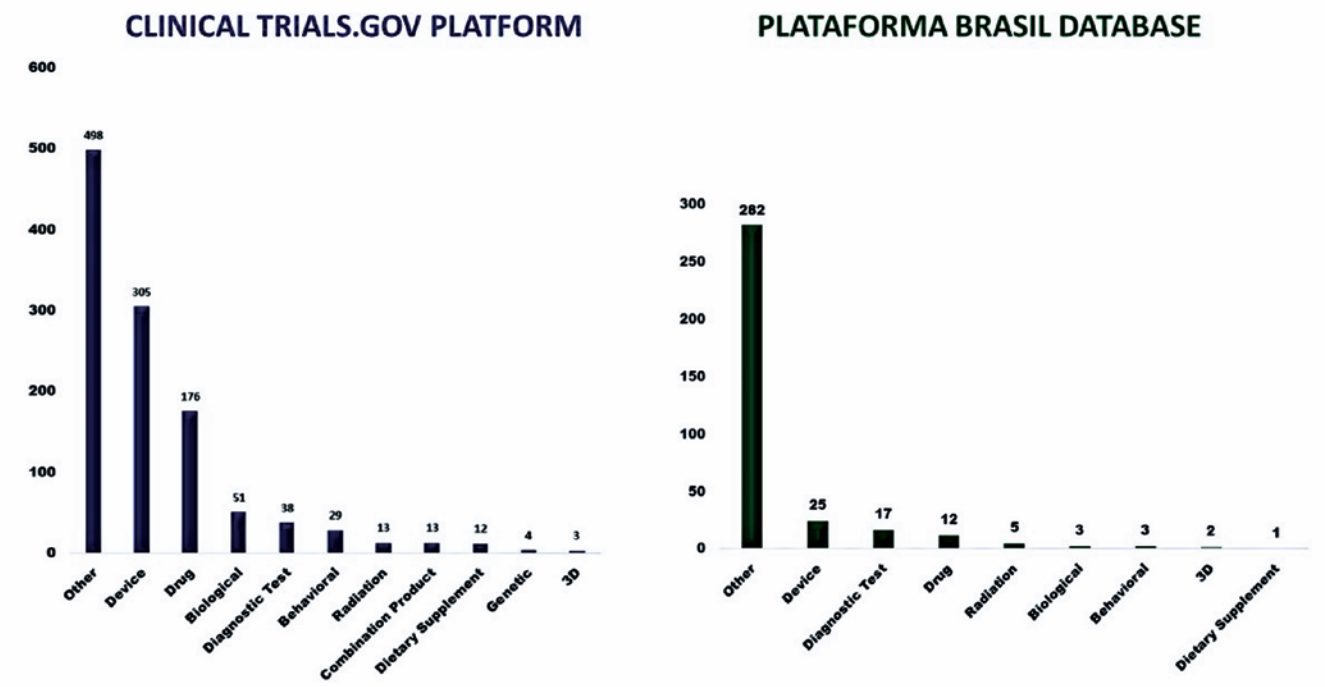


**Figure 6.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Target.

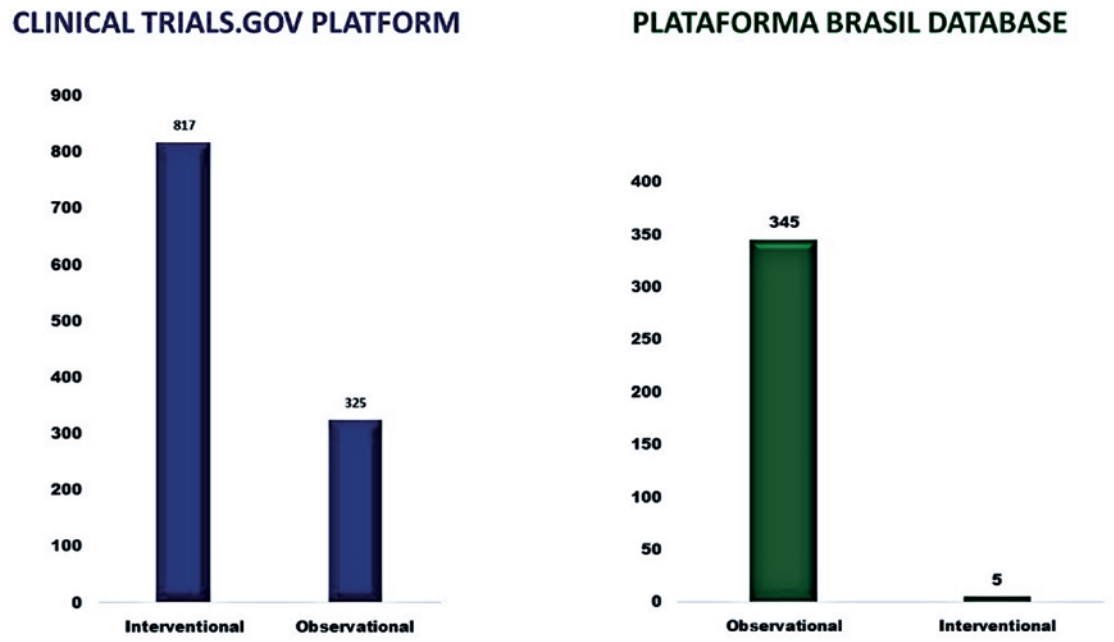


**Figure 7.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Study type**.**

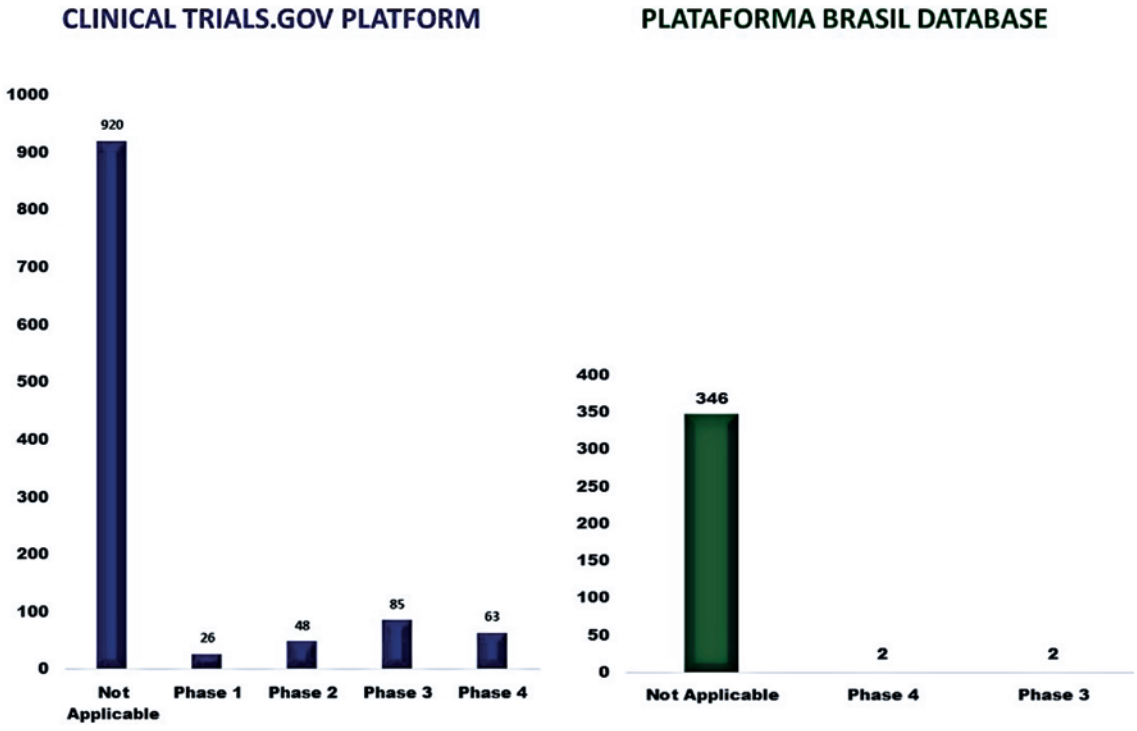


**Figure 8.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Phase.

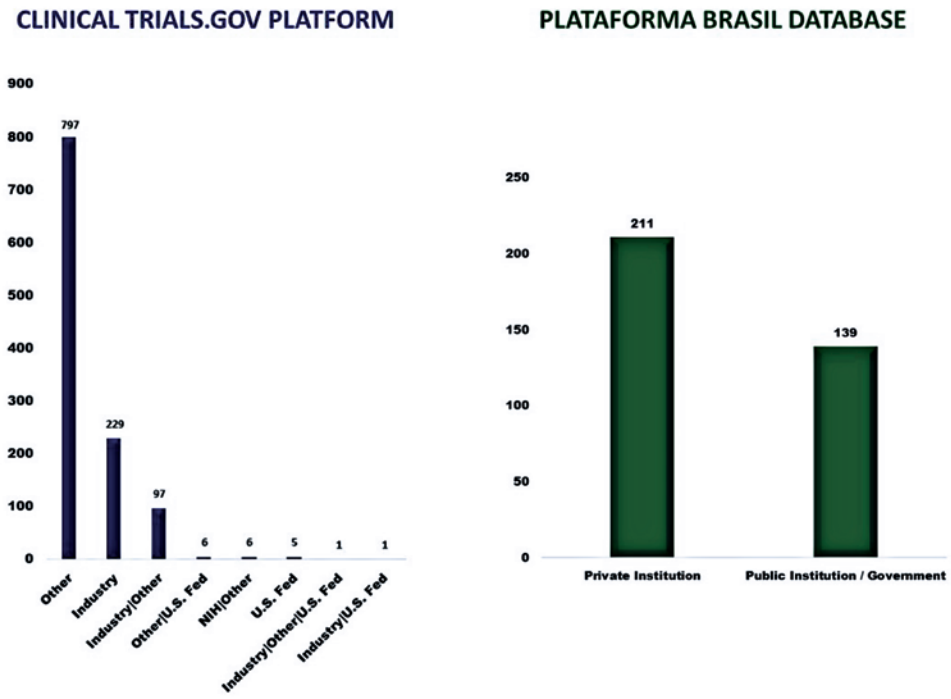


**Figure 9.** Clinical trials related to orthopedic disorders registered from January 2017 to July 2022. Funded by or institution type.

(FAPESP), one of the main research funding agencies in Brazil. With an annual budget corresponding to 1% of the total tax revenue of Sao Paulo state, FAPESP supports research and finances investigation, exchange, and dissemination of science and technology[10].

According to another international ranking, Quacquarelli Symonds World University Ranking published by the British consultancy Quacquarelli Symonds specializing in higher education, USP is the 115th best university in the world. According to these data, Brazil is the Latin American country with the most institutions ranked in the ranking. In addition to USP, the highest-ranked Brazilian university, four other Brazilian institutions were among the top 500 in the world: Universidade de Campinas (Unicamp - 210th position), Universidade Federal do Rio de Janeiro (UFRJ - 333rd position), Universidade Federal de Sao Paulo (Unifesp - 441st position) and Universidade Estadual Paulista - Júlio de Mesquita Filho (Unesp 477th position). All these universities are located in the southeast region of Brazil[11].

Recently, the Resolution RDC No. 548, of August 30th, 2021, Ministry of Health/Brazilian, National Health Surveillance Agency/Collegiate Board, which provides for clinical trials with medical devices in Brazil, increased requirements to register these products in the country[12]. Therefore, Brazil expects more clinical trials related to orthopedic disorders in the coming years.

The importance of the foot and ankle area in clinical research related to orthopedic disorders is evident when it is the 7th most studied worldwide and the 2nd most studied in Brazil. On the other hand, many clinical trials related to orthopedic disorders registered on the ClinicalTrials.gov platform or Plataforma Brasil database were classified as "Other orthopedic disorder". This reinforces the importance of recording complete and specific information in public databases.

Our results showed that most clinical trials related to orthopedic disorders conducted worldwide targeted the adult or older adult population and involved devices, drugs, biological products, and were interventional studies. This fact, associated with the existence of phase I and II clinical studies, suggests that these clinical trials worldwide are aimed at treating patients.

On the other hand, most clinical trials related to orthopedic disorders performed in Brazil targeted the pediatric or geriatric population and involved devices, diagnostic tests, drugs, and were observational studies. This fact, associated with the predominance of phase III and IV clinical trials and the absence of tests involving biological products, suggests that these clinical trials focus on characterizing populations and diseases.

The results showed, as described in the literature, that there is a worldwide trend in which only when it acquires excellence in phase III studies does a country begin to be considered for more complex studies such as phase I and II.

According to the results, most of the clinical research related to orthopedic disorders performed worldwide and

in Brazil in the last five years depends on sponsorship and private institutions for their realization.

## Conclusion

In the last five years, the profile of clinical research related to orthopedic disorders worldwide showed that most clinical trials targeting the adult or older adult population aim to treat patients, not prevent diseases. In Brazil, targets were the pediatric or geriatric population focusing on characterizing populations and diseases. According to our results, most clinical research related to orthopedic disorders conducted worldwide and in Brazil depended on sponsorship and private institutions.

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**Authors' contributions:** Each author contributed individually and significantly to the development of this article: LLM *(https://orcid.org/0000-0002-1422-8597) 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; COC *(https://orcid.org/0000-0001-5483-0737), and VSN *(https://orcid.org/0000-0002-3212-9648), and BCL *(https://orcid.org/0000-0003-1106-1047) , and SLS *(https://orcid.org/0000-0002-0143-5095), and ALGS *(https://orcid.org/0000-0002-6672-1869) Data collection, interpreted the results of the study, participated in the review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Original Article

# Evaluation of range of motion of hallux metatarsophalangeal and interphalangeal joints after periarticular osteotomies

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## Abstract

**Objective:** Evaluate the impact of Chevron and extended Chevron techniques associated with Akin osteotomy on the range of motion (ROM) of hallux metatarsophalangeal joint (MPJ) and interphalangeal joint (IPJ) after three months and one year.

**Methods:** Sixteen patients (17 feet) were evaluated for the ROM of hallux MPJ and IPJ pre-and postoperatively, the flexion-extension measurements were performed using a goniometer.

**Results:** Comparing the pre-and postoperative measurements at three months and one year, the ROM decreased in MPJ extension and flexion, 9º and 5º, respectively, and IPJ flexion, 5º. The values presented statistical significance according to the analysis demonstrated ($p>0.05$). However, the decrease in IPJ extension was not statistically significant (decrease of 0.8º and $p<0.05$).

**Conclusions:** Periarticular osteotomies of hallux MPJ had a significant decrease in the ROM after three months and one year.

**Level of Evidence II; Therapeutic Studies - Investigating the Results of Treatment; Prospective Comparative Study.**

**Keywords:** Hallux valgus; Range of motion, articular; Metatarsophalangeal joint.

## Introduction

Hallux valgus affects 2-4% of the general population, especially between 18 and 65 years[1], mainly in women after the 5th decade of life, and the majority are bilateral[2]. It has intrinsic and extrinsic causes and can generate pain, progressive aesthetic deformity, and functional deficit[3].

Surgical indication depends mainly on functional deficit and pain. Several techniques can be used depending on the classification, which is graded according to the Coughlin and Shurnas classification[2,3]. This classification is based on the measurements of the hallux valgus angle (HAV) and intermetatarsal angle (IMA) associated with a sesamoid dislocation, and is divided into mild, moderate, and severe [3].

Other factors to be considered are arthrosis and unity in the first metatarsophalangeal joint (MPJ), the mobility of the metatarsal joint, and the patient's age. These factors are fundamental for surgical decisions[3].

In general, surgical techniques with a more distal approach and diaphyseal techniques in the first metatarsal are more indicated for moderate hallux valgus and proximal approaches for severe hallux valgus[4].

As proposed in this study, the Chevron technique is more indicated for mild hallux valgus, while extended Chevron osteotomy is more indicated for moderate hallux valgus. Akin osteotomy is mainly indicated for interphalangeal hallux valgus with joint congruence. It also helps reduce hallux pronation and shorten long proximal phalanges. It can be associated with any other osteotomy to improve aesthetic results[2,3].

However, these surgical procedures for correcting hallux valgus are not complications-free. One of the most common complications is MPJ stiffness[5], which may limit physical activities and require revision surgery[6]. In addition, the loss of range of motion (ROM) implies gait, especially the inefficiency observed in the propulsion phase[7,8].

Study performed at the Hospital de Base, Faculdade de Medicina de São José do Rio Preto, São José do Rio Preto, SP, Brazil.

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The objective of this study is to evaluate the impact of Chevron and extended Chevron techniques associated with Akin osteotomy on ROM of hallux MPJ and interphalangeal joint (IPJ) after three months and one year.

## Methods

The study was conducted from January 2019 to December 2019, and 16 patients (17 feet) were evaluated, 15 female and one male, with a mean of 57.8 years (range 33-70). The study was approved by the institution's ethics committee.

The MPJ and IPJ were evaluated and measured using a goniometer before, at three months, and one year after surgery. The measurements of the MPJ were performed with one hand immobilizing the first metatarsal head and the other mobilizing the proximal phalanx. The measurements on the IPJ were performed with one hand immobilizing the proximal phalanx and the other hand mobilizing the distal phalanx.

The patients had no deformities in the smaller toes, and the surgeries selected were the only ones performed. In addition, none of the patients underwent surgery due to recurrence of hallux valgus or had radiographic signs of MPJ arthrosis.

In nine feet, Chevron + Akin osteotomies were performed; in eight feet, extended Chevron + Akin osteotomies. The attending physician evaluated the patient during the pre-and postoperative and participated in all surgical procedures.

Table 1 shows the patient's demographic data.

### Surgical Technique

The patient was in decubitus position under spinal anesthesia, and a tourniquet was placed on the thigh. First, medial incision and careful dissection were performed for capsulotomy and resection of the medial eminence using a saw for small bones. Then, the Chevron or extended Chevron osteotomies were performed in a V-shape with a saw for small bones, with an apex starting around 8-10 mm from the articular surface, approximately in the center of the metatarsal head.

In Chevron osteotomy, its arms form a 60° angle to each other and target the dorsal and plantar cortical of the first metatarsal, from head center to proximal. In the extended Chevron, the arm is similar to the Chevron, and the extended cut is located dorsally in the first metatarsal, stretching to the proximal metaphyseal region, forming 30° of angulation with the plantar arm.

In our hospital, fixation is performed with a conical cannulated screw in Chevron osteotomy and two screws in extended Chevron. Regularization of the osteotomy edge was performed, followed by tension-free capsulorrhaphy and subcutaneous suture with absorbable wire and skin suture.

For the Akin osteotomy, a medial incision was made in the hallux, mid-diaphyseal osteotomy in the hallux proximal phalanx using a saw for small bones, leaving the lateral cortex intact and closing the medial wedge. The fixation was performed with a conical cannulated screw, proximal to distal and medial to lateral.

The postoperative performed in our institution is based on immobilization with gauze forming a "double H" between the hallux and the second toe. The patient was instructed to perform MPJ and IPJ extension and flexion early and immediate load with rigid postoperative shoes and no load in the forefoot. The dressing is changed every seven days, and the stitches were removed after three weeks. Patients were instructed to intensify the ROM exercises and were referred to physiotherapy at this time. The use of shoes was maintained for six to eight weeks when the patient was instructed to wear common shoes.

**Table 1.** Demographic data of the patients evaluated in the study.

| Patient | Sex | Age | Side | Surgery date | Surgery performed |
|---|---|---|---|---|---|
| 1 | Female | 70 | Right | 03/10/2019 | C + A |
| 2 | Female | 59 | Left | 03/25/2019 | EC + A |
| 3 | Female | 47 | Right | 04/11/2019 | EC + A |
| 4 | Female | 58 | Right | 04/17/2019 | C + A |
| 5 | Female | 64 | Left | 06/03/2019 | C + A |
| 6 | Female | 70 | Left | 06/10/2019 | C + A |
| 7 | Female | 78 | Right | 06/06/2019 | C + A |
| 8 | Female | 65 | Right | 06/12/2019 | C + A |
| 9 | Female | 46 | Left | 06/12/2019 | EC + A |
| 10 | Female | 44 | Left | 07/10/2019 | EC + A |
| 11 | Female | 60 | Left | 07/15/2019 | EC + A |
| 12 | Female | 33 | Bilateral | 08/07/2019 | EC + A Bilateral |
| 13 | Male | 52 | Right | 09/02/2019 | EC + A |
| 14 | Female | 66 | Right | 08/12/2019 | C + A |
| 15 | Female | 53 | Right | 10/10/2019 | C + A |
| 16 | Female | 60 | Right | 10/11/2019 | C + A |

C: Chevron ; EC: Extended Chevron; A: Akin

## Results

Table 2 shows the pre-and postoperative ROM measurements.

### Statistical analysis

The data was collected using Microsoft Excel® (Microsoft Corporation, Redmond, Washington, USA).

Descriptive statistical analysis was performed based on central tendency, dispersion, and frequency measures.

For the inferential statistical analysis of the quantitative variables, the Kolmogorov-Smirnov test was used to verify the data normality, and then the paired t-test and ANOVA test with repeated measures were applied.

In all analyses, $p<0.05$ and a test power of 80% were considered statistically significant.

Measures for MPJ flexion and extension and IPJ flexion were considered statistically significant ($p<0.05$). Thus, as the study is statistically significant, the decrease in hallux ROM is representative. Table 3 shows pre-and postoperative mean ROM. Tables 4 and 5 show the pre-and postoperative mean ROM of Chevron + Akin and extended Chevron + Akin, respectively.

## Discussion

There are several surgical techniques for correcting hallux valgus, depending on the severity and associated factors, such as arthrosis, but these techniques are not complications-free.

The most frequent surgical complications are rotational hallux deviation, pseudarthrosis, decreased ROM, infection, dehiscence and/or necrosis of the surgical wound, neurological lesion[6], hallux varus, avascular necrosis of the first metatarsal head[7], recurrence of hallux valgus, and implant failure[9]. In addition, in the literature, there are reports of stiffness between 7% and 38% of patients after surgery[10].

The ROM decrease of hallux MPJ and IPJ is one of the most common complications[5]. Some authors have demonstrated in their studies that the ROM decrease, especially the MPJ, leads to the reduction of the ankle plantar flexion during the gait, generating an inefficient propulsion movement[7,8], considering that it is necessary dorsiflexion between 40° and 60° of the first MPJ for the propulsion to occur properly [11]. In our study, the MPJ extension maintained a mean of 55° after one year of surgery.

In addition, adequate MPJ dorsiflexion is essential during the terminal phase of gait support and in the pre-swing phase

**Table 2.** Pre-and postoperative ROM measurements

| Patient | Pre ROM MPJ | Pre ROM IPJ | Post ROM MPJ | Post ROM IPJ | MPJ ROM 1 year | IPJ ROM 1 year |
|---|---|---|---|---|---|---|
| 1 | E60 F55 | E0 F40 | E50 F55 | E0 F40 | E50 F55 | E0 F35 |
| 2 | E70 F20 | E0 F75 | E60 F15 | E0 F65 | E55 F10 | E0 F70 |
| 3 | E50 F50 | E0 F50 | E40 F45 | E0 F40 | E45 F50 | E0 F50 |
| 4 | E80 F50 | E0 F50 | E65 F50 | E0 F40 | E70 F45 | E0 F50 |
| 5 | E60 F40 | E10 F70 | E50 F50 | E10 F70 | E55 F40 | E5 F60 |
| 6 | E50 F50 | E5 F60 | E45 F45 | E0 F55 | E50 F40 | E0 F50 |
| 7 | E70 F50 | E0 F65 | E50 F50 | E0 F60 | E55 F45 | E0 F60 |
| 8 | E40 F40 | E5 F60 | E40 F40 | E5 F55 | E40 F40 | E0 F60 |
| 9 | E60 F55 | E5 F60 | E50 F55 | E5 F55 | E60 F55 | E5 F60 |
| 10 | E50 F50 | E0 F50 | E45 F45 | E0 F45 | E45 F40 | E0 F45 |
| 11 | E80 F60 | E0 F70 | E65 F50 | E0 F60 | E65 F45 | E0 F60 |
| 12 | E90 F70 | E0 F70 | E65 F50 | E0 F65 | E75 F60 | E0 F70 |
| 12 | E90 F70 | E0 F70 | E65 F50 | E0 F65 | E75 F60 | E0 F65 |
| 13 | E50 F50 | E0 F70 | E40 F45 | E0 F70 | E40 F45 | E0 F60 |
| 14 | E60 F60 | E0 F60 | E50 F50 | E0 F60 | E55 F55 | E0 F60 |
| 15 | E70 F50 | E0 F65 | E65 F50 | E0 F65 | E60 F50 | E0 F60 |
| 16 | E70 F75 | E5 F80 | E50 F60 | E0 F75 | E50 F75 | E5 F70 |

ROM: range of motion; MPJ: Metatarsophalangeal joint; IPJ: Interphalangeal joint; E: extension; F: flexion.

**Table 3.** Pre-and postoperative mean ROM

| | Mean preop | Mean postop – 3 months | Mean postop – 1 year |
|---|---|---|---|
| MPJ extension | 64.7° | 52.64° | 55.58° |
| MPJ flexion | 52.64° | 47.35° | 47.64° |
| IPJ extension | 1.76° | 1.17° | 0.88° |
| IPJ tension | 62.64° | 57.94° | 57.94° |

MPJ: Metatarsophalangeal joint; IPJ: Interphalangeal joint.

to allow a smooth progression of the foot body[7]. Without the ideal amplitude, the gait presents reduced step length, shorter duration of the support phase, and decreased ankle plantar flexion at the tip of the foot[7,8]. There is also a delay in the calcaneus detachment and a displacement of the reaction forces to the ground before the first MPJ on the side of lower ROM[12].

It has been demonstrated that the Achilles-calcaneal-plantar system and the medial wedge are responsible for optimizing the support of the first MPJ so that there is adequate support of the foot during the third phase of the gait swing. Failure in plantar flexion of the first MPJ, which is accompanied by traction stress of the plantar fascia, limits the hallux dorsiflexion in the transition from the second to the third phase of gait balance[13].

The hallux MPJ dorsiflexion limitation often causes hyperextension of the hallux IPJ as a compensatory mechanism to avoid trauma of the distal phalanx against the ground, generating long-term arthrosis[12]. In a foot without changes, the hallux IPJ extension plays a role in the survey the calcaneus of the ground during propulsion[12]. Thus, the IPJ stiffness due to the decrease in MPJ dorsiflexion also contributes to the gait alteration.

On the other hand, some studies demonstrate that the ROM decrease of hallux MPJ and IPJ after arthrodesis did not significantly influence physical activities. For example, in the study by da Cunha et al.[14] in 2019, most patients submitted to arthrodesis of the first MPJ presented a satisfactory return to daily and sports activities, with approximately 16% of the patients showing restriction to gait and physical activities[14].

The study concluded that there was an objective ROM decrease hallux MPJ and IPJ after the analyzed techniques (Chevron and extended Chevron). According to the literature, this factor can be attributed to the surgical procedure or the postoperative period. The patients were instructed to perform early ROM to prevent stiffness. Despite this factor, most patients did not show ROM improvement after rehabilitation.

The literature highlighted that some intrinsic factors to the procedure might also alter the ROM of the first MPJ, such as hallux realignment, medial capsule repair, postoperative infection, and late rehabilitation[15]. In our procedures, medial capsulorrhaphy was performed without tension, and no postoperative infection was observed.

When evaluating each group separately, the patients submitted to the Chevron + Akin osteotomies presented a mean final MPJ ROM (after one year) higher than the group of extended Chevron + Akin; however, the same postoperative protocol was performed (Tables 4 and 5). The final IPJ ROM was similar in both groups. Thus, the ROM limitation can be attributed to the adherence generated in the healing process, which is worse in procedures requiring greater soft tissue dissection. In the study by Lee et al.[16], published in 2019, patients submitted to Chevron presented a more significant ROM decrease of hallux MPJ when osteotomies were associated with a soft tissue procedure[16].

The small number of cases in the study is a possible limitation. In addition, in our study, we preferred to make the measurement more accurate, specifying in degrees the postoperative limitation, and the function after surgery was not evaluated.

**Table 4.** Pre-and postoperative mean ROM in the Chevron + Akin osteotomies

| Chevron + Akin | Mean preop | Mean postop – 1 year |
|---|---|---|
| MPJ extension | 62° | 53.8° |
| MPJ flexion | 47° | 49.4° |
| IPJ extension | 2.7° | 1.1° |
| IPJ tension | 61° | 56° |

MPJ: Metatarsophalangeal joint; IPJ: Interphalangeal joint.

**Table 5.** Pre-and postoperative mean ROM in the extended Chevron + Akin osteotomies

| Extended Chevron + Akin | Mean preop | Mean postop – 1 year |
|---|---|---|
| MPJ extension | 67.5° | 57° |
| MPJ flexion | 53° | 45° |
| IPJ extension | 0.6° | 0.6° |
| IPJ tension | 64° | 60° |

MPJ: Metatarsophalangeal joint; IPJ: Interphalangeal joint.

## Conclusion

The surgical techniques used in this study (Chevron/Chevron Extended associated with akin) decreased ROM of hallux MPJ and IPJ as a complication in most patients. This was evidenced by the values obtained in the study and the statistical significance achieved.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: NCP *(https://orcid.org/0000-0002-0446-9725**)** Interpreted the results of the study, designed and wrote the manuscript, participated in the review process and approved the final version; DMM *(https://orcid.org/0000-0002-0159-9225) Conceived and planned the activities that led to the study; data collection TAPP *(https://orcid.org/0000-0003-1274-4421) Conceived and planned the activities that led to the study, approved the final version; MFG *(https://orcid.org/0000-0002-5163-1035) Performed the radiosynovectomy, participated in the reviewing process, approved the final version. HI *(https://orcid.org/0000-0002-1179-4809) Conceived and planned the activities that led to the study, formatting of the article, wrote the paper, participated in the reviewing process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Case Report

# Posterior tibial tendon dislocation after a medial ankle sprain: a case report

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## Abstract

Medial ankle sprains have a very low incidence (5% of ankle ligament injuries), and most of the time, the first structure involved is the deltoid ligament complex. However, other structures, such as the spring ligament, posterior tibial tendon, and flexor retinaculum, can also get damaged. A 32-year-old man who had an ankle sprain while performing sports activities showed magnetic resonance imaging findings compatible with a detachment of the flexor retinaculum and medial dislocation of the posterior tibial tendon. Surgical intervention was suggested to this patient; deepening of the medial retromalleolar groove and reattaching of the retinaculum were performed. It is very important to consider this rare injury after a medial ankle sprain and to think out of the box, not always assuming a deltoid ligament lesion.

**Level of Evidence V; Therapeutic Studies; Expert Opinion.**

**Keywords:** Posterior tibial tendon; Tendon injuries; Ankle injuries; Joint dislocations.

## Introduction

Medial ankle sprains have a relatively low incidence, accounting for 5% of ankle ligamentous injuries. In this scenario, the deltoid ligament complex is the most frequently damaged structure[1]; however, clinically determining which structures are injured is not an easy task. Clinical diagnosis is often insufficient due to poorly specific symptoms, such as pain, swelling, tenderness, instability, and ecchymosis[2]. Within this scope, the intimate anatomic relationship between the spring ligament, the posterior tibial tendon (PTT), or the flexor retinaculum and the superficial layer of the medial collateral ligament warrant further evaluation[1].

The evaluation of the PTT and its synovial sheath is paramount, given that both structures can explain medial-sided ankle pain. In this context, a high suspicion index is required to search for injuries other than those typically described after a medial ankle sprain-traumatic PTT lesions range from tears to complete ruptures, associated or not to a flexor retinaculum disruption. If the latter occurs, the tendon will probably dislocate[2], which is infrequent and neglected in most cases, becoming a chronic dislocation[2].

## Case description

This study was approved by the institution's ethics committee, and the patient was informed that data concerning the case would be submitted for publication, providing his consent.

A 32-year-old male patient presented with a history of a medial ankle sprain. Even though the patient could not recall the exact mechanism of the injury, he perceived a popping sensation elicited after the injury. His main symptoms were pain around the medial malleolus, ecchymosis, and swelling.

Under physical examination, the patient showed normal alignment of the lower limb and foot. We could identify a palpable cord on the medial aspect of the ankle joint, but neither active nor passive relocation was possible. Such cord

Study performed at the Clínica Universidad de los Andes, Santiago, Chile.

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was running during flexion-extension of the ankle and inversion of the foot, accomplishing the main function of the PTT, whose strength was considered normal. Nevertheless, the patient presented a full range of motion of the ankle joint but a limited, painful heel-rise test and subtalar motion. The patient was initially diagnosed with a medial ankle sprain and treated with a walking boot. Despite this initial treatment, symptoms persisted during the following week.

Normal weight-bearing radiographs were obtained. Magnetic resonance imaging (MRI) showed a low-grade deltoid ligament injury associated with detachment of the flexor retinaculum and medial luxation of the posterior tibial tendon (Figures 1 and 2), with moderate tenosynovitis and medial malleolar bone bruise.

With the patient in the supine position under regional anesthesia, hip rotated externally, and ischemia induction using a tourniquet, we performed a retromalleolar approach. We identified the flexor retinaculum detachment from the medial malleolus forming a false pouch with an intact PTT inside. Relocation of the tendon to the retromalleolar sulcus was possible but unstable due to an insufficient retinaculum.

The surgery goal was to relocate the tendon, restore a competent and functional flexor retinaculum, and deepen the shallow retromalleolar groove to avoid a recurrent dislocation. An approach similar to that applied in peroneal tendon dislocations was used in this case: we weakened the anterior wall of the sulcus by drilling it with increasing drill sizes. Then, we impacted the retromalleolar groove surface to deepen the groove and preserve the cartilage surface, allowing for a smoother tendon mobilization[3].

Finally, we reefed the remaining retinaculum using two anchors loaded with high-resistance sutures in the posterior border of the tibia. A 'pants-over-vest' repair of the retinaculum was performed to enhance the repair stability (Figures 3, 4, and 5).

Partial weight-bearing assisted by two crutches was allowed for one week. Antibiotic and venous thromboembolism prophylaxis were indicated for three and 30 days, respectively, and there were no complications or adverse outcomes.

After two weeks, stitches were removed, and rehabilitation began with progressive removal of the boot at four weeks.

The patient was asymptomatic at the one-year follow-up and after ten physiotherapy sessions. Clinical examination showed no signs of PTT instability. He was able to return to sports without contact at three months, satisfactorily taking part in such activities without any restriction at four months.

## Discussion

Traumatic PTT luxation has a very low incidence during medial ankle sprain. Although clinical diagnosis is simple with

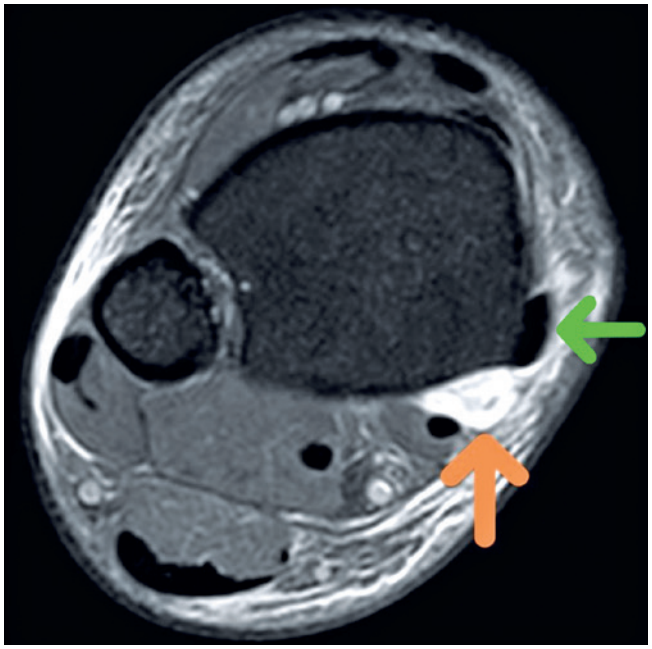

**Figure 1.** Axial MRI with the absence of the PTT in the retromalleolar groove associated with increased synovial fluid (orange arrow). Dislocated PTT location (green arrow).

**Figure 2.** Coronal MRI of the ankle showing the PTT presence (orange arrow) medial to the medial malleolus.

**Figure 3.** After the medial ankle approach, we could see the PTT dislocated out of the retromalleolar groove.

**Figure 5.** Retinaculum reefing after the PTT relocation into the retromalleolar groove.

**Figure 4.** Placement of two 3.5 anchors on the medial tibial side for retinaculum reattachment.

physical examination, it can be challenging due to the associated inflammation and a low suspicion index[2,4,5].

This injury rarely occurs as isolated lesions, being associated with an ankle fracture or a sports-related trauma in 58.5% of cases[4,5]. It was first described by Martins in 1874, and there are only a few case reports in the literature[5]. The complexity of this pathology lies in the nonspecific symptoms of a typical medial ankle sprain mechanism seen in the acute setting, with 53% of patients being misdiagnosed in the initial setting and a mean time to surgery of 17.3 weeks[5,6]. In a systematic review, 17 of 59 patients were initially treated for an ankle sprain, PTT dysfunction, or tarsal tunnel syndrome, and the mean delay in reaching the correct diagnosis was 4.4 ± 6.1 months[5].

Complications related to misdiagnosing and, thus, wrong treatment are a PTT unable to properly resist hindfoot eversion or a subtalar joint locking, directly leading to a dysfunctional gait that alters the foot biomechanics, recurrent dislocation, chronic pain, and poor functional results[7]. Also, a dislocated PTT can get damaged, leading to a tendon rupture[7].

Ouzounian et al.[8] reported seven patients with dislocation of the PTT, where six of them did not reach the correct diagnosis until nine months after injury.

The most common mechanism of injury is an involuntary, violent contraction of the PTT during dorsiflexion accompa-

nied by a forced inversion of the ankle[5,6]. Further, a relatively flat retromalleolar groove may predispose to dislocation[5].

Strydom classified these injuries into three categories: type 1 corresponds to an avulsion injury (most common and same as our patient), type 2 is a retinacular tear, and type 3 is related to a deficient retinacular tissue[6].

We confirmed our diagnosis by MRI and ultrasound. Magnetic resonance imaging shows specific findings in 75% of cases, compared to 14% of cases that could be detected by radiography, the latter being useful only to rule out medial malleolus fractures or avulsive lesions[5]. Ultrasound has 66% of specificity and is highly recommended for being a dynamic study that enables the elucidation of the non-anatomical position of the tendon through ankle mobilization[5].

Although we attempted a conservative treatment, literature has shown a very low success rate due to the obtainment of an insufficient retinaculum that is unable to retain the PTT in the retromalleolar groove. This is the main reason why the great majority of these injuries require surgical treatment (83%)[2].

Albeit several surgical techniques have been described, such as direct retinaculum repair, retinaculum reefing to the periosteum with anchors or intraosseous sutures, groove deepening or augmentation techniques with inverted periosteal flap, Achilles tendon flap, deltoid ligament flap, or sliding medial malleolus osteotomy, among others[6], there is no strong agreement on which is the best alternative for treating the luxation-options vary according to the state of the tendon, retinaculum, and retromalleolar groove[6]. We chose to treat the patient with the technique described above due to its simplicity and reproducibility.

Matsui et al.[9] reported a technique in which the pseudopouch was closed with suture tape and anchors. It showed beneficial results for cases of recurrent PTT dislocation, achieving a rigid fixation and a low profile implantation, with return to daily life and sports activities at 21 weeks.

In the presence of a partially torn and attenuated flexor retinaculum, Mullens et al[10]. proposed a plate buttressing technique for the flexor retinaculum associated with the closure of the potential space between the retinaculum and the periosteum[10]. They reported successful outcomes, with patients returning to preinjury levels of activity at one year. We consider this procedure to be much more aggressive than the one we offered to our patient, and that is the reason why it takes one year for patients to return to unpainfully physical activity, compared to four months as required by our patient.

Although the literature insists on long periods of immobilization with controlled ankle motion by walking boot or cast for approximately four weeks[4], we preferred early weight-bearing and rehabilitation to avoid calf atrophy and limited range of motion associated with ankle rigidity.

Limitations of this case report include its lack of generalizability and the danger of overinterpreting a single case, especially when it is a rare presentation of a common injury such as an ankle sprain.

## Conclusão

The strength of this report is that, through a safe, reproducible, and reliable surgical technique of groove deepening associated with anchor flexor retinaculum reconstruction, we present a high-success solution to this unusual problem.

Medial ankle sprains require a systematic evaluation due to the associated injuries that can be undiagnosed, such as injuries of the retinaculum and posterior tibial dislocations.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: FMZ *(https://orcid.org/0000-0002-6520-9775). Conceived and planned the activities that led to the study, approved the final version, ARC *(https://orcid.org/0000-0002-3442-8342) Interpreted the results of the study, participated in the review process, and approved the final version; GLL* (https://orcid.org/0000-0003-3749-5345), and FCR *(https://orcid.org/0000-0002-3524-0624) and GCU *(https://orcid.org/0000-0002-1993-6250) Performed the surgery, data collection and approved the final version, have conceived and planned the activities that led to the paper; MPP* (https://orcid.org/0000-0002-2820-5337) and COM* (https://orcid.org/0000-0003-2574-9010) Bibliographic review, survey of the medical records, formatting of the article and participated in the reviewing process; and have approved the final. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Case Report

# Achilles tendon reconstruction using a biosynthetic graft: a case report

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## Abstract

A 56-year-old male was admitted to an outpatient clinic five months after feeling a snap in his right heel while walking in the yard. Clinical and imaging evaluation demonstrated a discontinuity of Achilles tendon (AT). The measured gap between the insertion and the proximal stump was 13cm. The patient underwent reconstruction using a bio-absorbable synthetic graft associated with a Flexor Hallucis Longus (FHL) transfer. Good functional outcomes were noted. Achilles tendon reconstruction with the biosynthetic flexible band proved feasible for massive tendon defects by inserting a biological scaffold for native tendon healing, improving postoperative recovery and strength.

**Level of Evidence V; Therapeutic Studies; Expert Opinion.**

**Keywords:** Achilles tendon; Graft; Tendon injuries; Reconstruction; Rupture.

## Introduction

One of the definitions of a chronic Achilles Tendon (AT) rupture is the delay in diagnosis or treatment of at least four to six weeks after the initial event[1,2].

Management of patients with chronic Achilles ruptures involves both operative and nonoperative options. The choice between these options should be made after considering the patient's overall health status, assessment of risk factors for healing, and the patient's level of activity[3].

Surgical treatment aims to reestablish a stable connection between the triceps and its insertion and secure a proper tendon length and tensioning[1-4]. Several techniques have been described, depending on the size of the injury and the local conditions[5]. Ruptures smaller than 2cm can direct tendon repair[3].

For defects ranging from 2 to 5cm, tendon-lengthening procedures, with or without tendon transfer, are advised. Injuries greater than 5cm may require a tendon transfer, with or without a tendon-lengthening procedure. Patients with extensive chronic tears and healthy muscles can present a unique challenge for the surgeon to fill the defect[2].

The aim of the study was to report a chronic insertional AT rupture surgically treated with a bioabsorbable synthetic graft to insert a biological scaffold for native tendon healing, enhancing recovery and postoperative strength. The patient was informed that data concerning the case would be submitted for publication, and he provided consent.

Study performed at the UIOWA Orthopedic Functional Imaging Research Laboratory (OFIRL), University of Iowa, Carver College of Medicine, Department of Orthopedics and Rehabilitation. Iowa City, IA, USA.

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## Case description

The study was approved by the Research Ethics Committee of the institution and the patient signed the informed consent form.

### Preoperative evaluation

A 56-year-old male (BMI: 38.6Kg/m$^2$, height: 185.4cm, limb length: 42.1cm) was admitted to an outpatient clinic five months after feeling a snap in his right heel while walking in the yard.

The patient stated that the severity of pain, swelling, and weakness is progressively aggravating, limiting his activities, including golf. He denied any comorbidities or smoking. On physical examination, the patient presented with intact skin. There was moderate tenderness to palpation at mid-substance and insertion of the Achilles. A 4 out of 5 muscle strength in plantar flexion was noted. Dorsiflexion, inversion, and eversion had 5 out of 5 strength. The patient had a 15° increase in passive dorsiflexion of the right ankle compared to the left side. The double heel raise test was negative, and the single heel raise was positive.

The radiograph and the whole blood clotting test demonstrated a bone spur at Achilles insertion with no signs of avulsion (Figure 1 A-B). Magnetic resonance images (MRI) confirmed the Achilles discontinuity at the insertion site, scar tissue formation on the gap, and minor fatty infiltration of the gastrocsoleus complex (Goutalier 1) (Figure 1 C-J).

### Surgical technique

The patient received general anesthesia, a popliteal block, and was in supine position on the operating room table. No tourniquet was used.

First, we proceeded with a 10cm long longitudinal incision, starting 1cm proximal to the plantar pad and running medially and parallel to the trajectory of the residual AT.

The peritenon was incised in line with the residual AT that was confirmed ruptured at its insertion and retracted. A significant amount of scar tissue was filling the space of the old AT. The few distal remaining fibers were severely degenerated and were resected (Figure 2 A-B).

Achilles' degenerations and calcifications were removed with a sharp knife to the level of good tissue (pearly, shining, organized fibers) (Figure 2 C). The measured gap between the insertion and the proximal stump was 13 cm (Figure 2 D).

The Flexor Hallucis Longus (FHL) tendon and muscle belly were found at the deep crural fascia and carefully dissected (Figure 3A). A longitudinal 4 cm medial approach was then performed just to the plantar aspect of the first metatarsal base along the longitudinal arch of the foot. The FHL tendon was identified and cut distal to Henry's knot (Figure 3B) and retrieved proximally in the posteromedial wound. The FHL tendon was measured with a diameter of 5 mm, and its distal stump was prepared (Figure 3C).

A guidewire for an interference screw in a central position was then placed into the calcaneal tuberosity from dorsal to

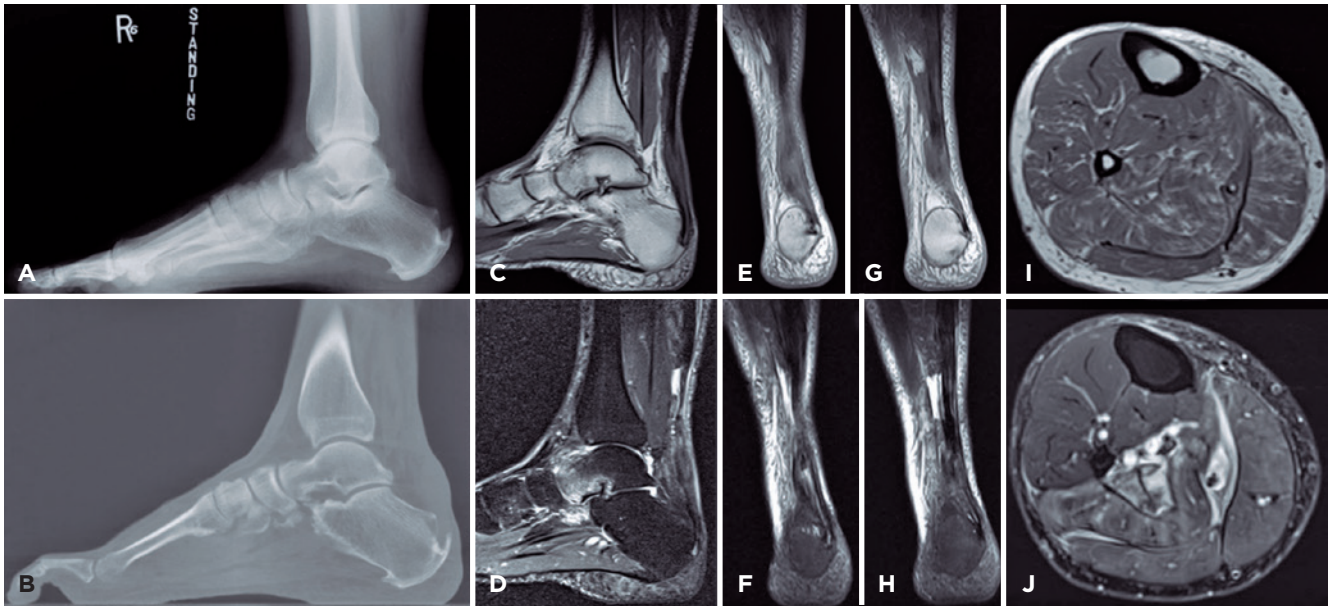


**Figure 1.** Preoperative imaging assessment. Lateral radiograph (A) and sagittal weight-bearing computed tomography scan (B) demonstrated a bone spur at Achilles insertion with no signs of avulsion. Sagittal (C, D) and coronal (E-H) MRI confirmed the Achilles discontinuity at the insertion site and scar tissue formation over the gap. Axial leg MRI showed minor fatty infiltration of the gastrosoleus complex (Goutalier 1) (I, J).

plantar at the Achilles insertion footprint (Figure 3D). Next, a 5.5mm tunnel was drilled into the calcaneal tuberosity (Figure 3E). Using the guidewire, the FHL tendon was inserted into the calcaneal tuberosity and delivered into the plantar aspect of the foot (Figure 3F).

While maintaining the foot in 30° of plantar flexion, the FHL tendon transfer was tensioned distally into the plantar aspect of the foot. A 5mm peek interference screw was inserted into the calcaneal tuberosity tunnel from dorsal to plantar. Adequate tensioning of the FHL tendon was maintained. Good deformity correction with maintained plantar flexion of the ankle joint was noted.

Two 2.9mm anchors were inserted medially and laterally into the central tunnel. A 7mm x 32cm bio-absorbable synthetic graft (Artelon™, Marietta, GA, USA) flex band was weaved into the Achilles proximal stump with 0 Vicryl™ sutures (Figure 4A). The construct was brought distally and sutured to the FHL tendon using three interrupted horizontal mattresses (Figure 4B). The biosynthetic graft was then sutured into the calcaneal tuberosity using the two anchors while maintaining the foot into 30° of plantar flexion (Figure 4 C-E). Tension was placed at the biosynthetic graft and brought back proximally into the proximal stump of the AT. Adequate ankle positioning, tensioning, and stability of the entire construct were noted (Figure 5).

Achilles peritendon was sutured with 3-0 Vicryl™, protected with a dehydrated human amnion/chorion membrane allograft (Figure 6A-C).

### Postoperative course

Prophylaxis for deep vein thrombosis was prescribed. The patient remained non-weight-bearing with a cast in a 15° plantar flexion position for two weeks. This was followed by two weeks of using a walking boot when weight-bearing was initiated. The rehabilitation program started six weeks after the surgery, consisting of a range of motion gain and progressive resistance exercises while taking care to avoid dorsiflexion stretching of the ankle above neutral until the 12th week. The boot was discontinued after 12 weeks of surgery when the patient progressed to a muscle training, balance, and proprioception program.

No medical or surgical complications have occurred to date, 12 months after surgery (Figure 7A-D). Postoperative radiographs showed the implant in a good position with no signs of loosening or osteolysis (Figure 8A). After 12 months, the MRI demonstrated complete healing of the biosynthetic graft at the muscular and bone attachments. The FHL tendon was also integrated, and its muscle hypertrophied (Figure 8 B-J). Incisions were healed, plantar flexion strength was 5 of 5, and the single heel raise test was positive. The ankle joint had 5° of dorsiflexion and 40° of plantar flexion.

Patient-Reported Outcomes Measurement Information System (PROMIS) consistently demonstrated positive changes in symptoms and function. PROMIS Global Physical Health T-score increased from 42 to 54 at 12 months. The Foot Function Index (Activity Limitation Score) reduced from 100 to 21 points, while PROMIS Pain T-Score reduced from 71 to 53[6].

## Discussion

The treatment for chronic AT ruptures remains a challenge for orthopedic surgeons. Several reconstructive strategies are described to reestablish the muscle-tendon unit and avoid potential complications[2]. We demonstrated a technique that can minimize soft-tissue dissection and the morbidity of

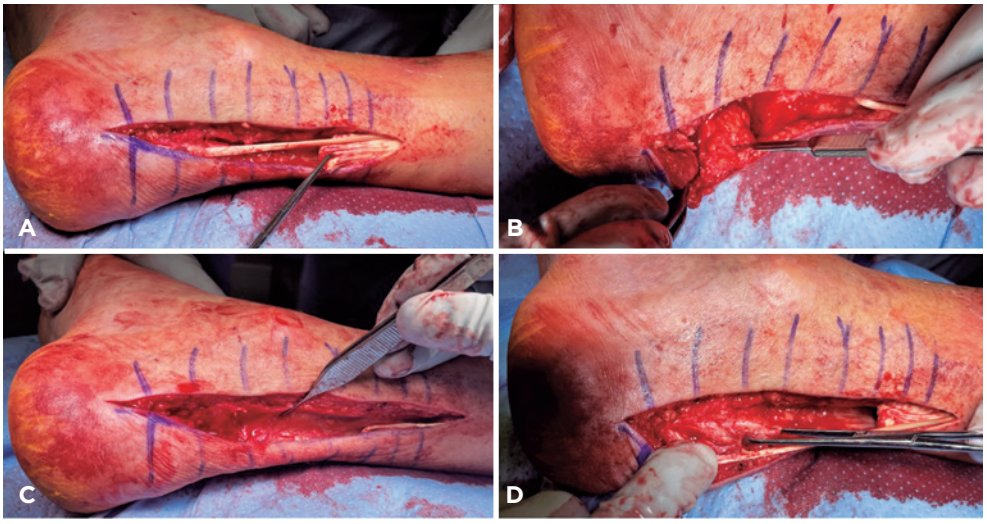


**Figure 2.** Remaining degenerated proximal fibers were resected (A). Scar tissue filling the space distally of the native ruptured AT was resected along with the plantaris (B). Achilles degenerations and calcifications were removed until good-quality tissue was found (pearly and shiny organized fibers) (C). The distance measured between the insertion and the proximal stump was 13cm (D).

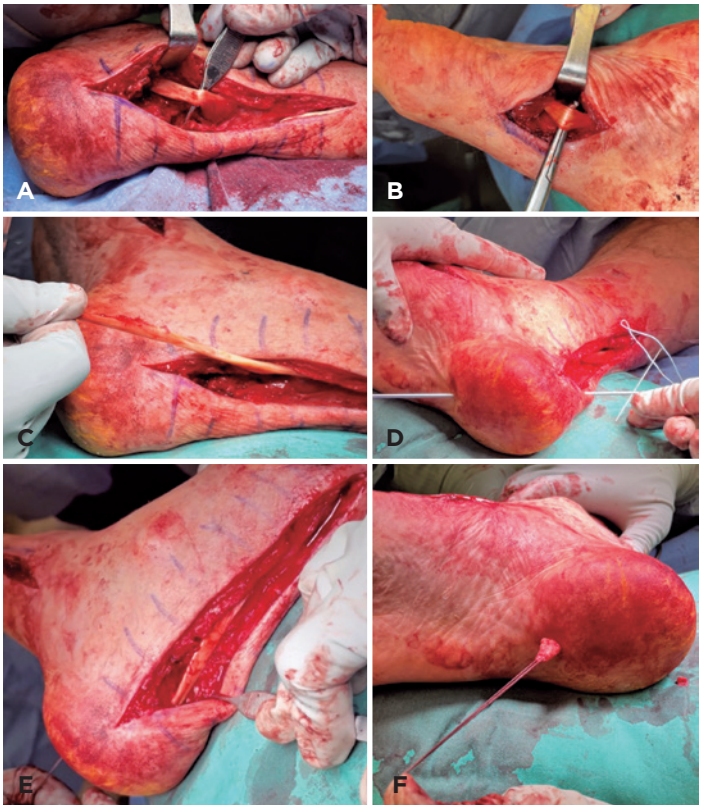


**Figure 3.** The FHL tendon and muscle belly were carefully dissected (A). The FHL tendon was identified and cut distally to Henry's knot (B) and retrieved proximally in the posteromedial wound measuring 5mm in diameter (C). The guidewire for an interference screw was placed centrally at the Achilles insertion footprint (D). The FHL tendon was inserted into the calcaneal tuberosity (E) and delivered to the plantar surface of the foot (F) while a 5.5mm interference screw secured its tensioned position.

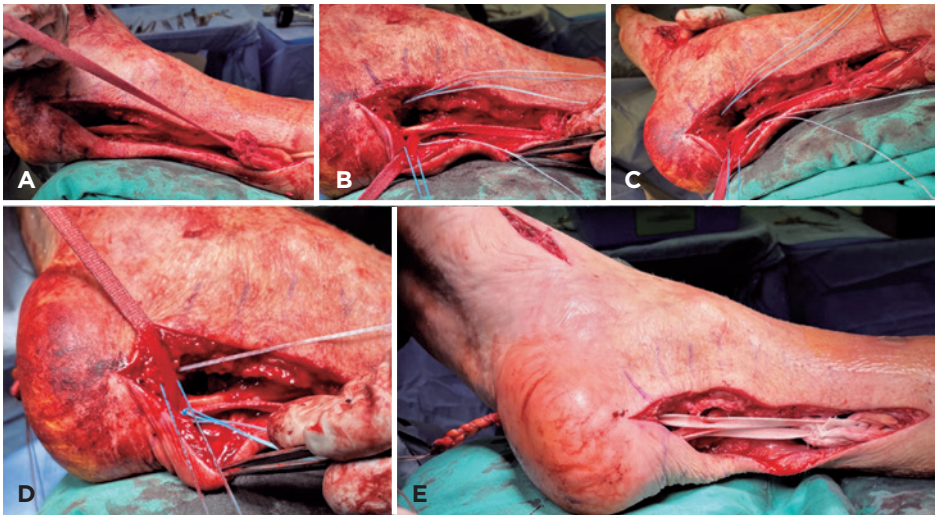


**Figure 4.** A flexible 7mm x 32cm bioabsorbable synthetic graft band (Artelon™, Marietta, GA, USA) was woven into the proximal stump of Achilles with 0 Vicryl™ stitches (A). The construct was brought distally and sutured to the FHL tendon in tension with three interrupted horizontal mattresses (B). The biosynthetic graft was inserted to the calcaneal tuberosity (C) using two 2.9mm anchors, keeping the foot at 30° of plantar flexion (D). The remaining Artelon stump was then returned to the proximal Achilles native stump, where new Vycril™ sutures were used to complete the construction (E).

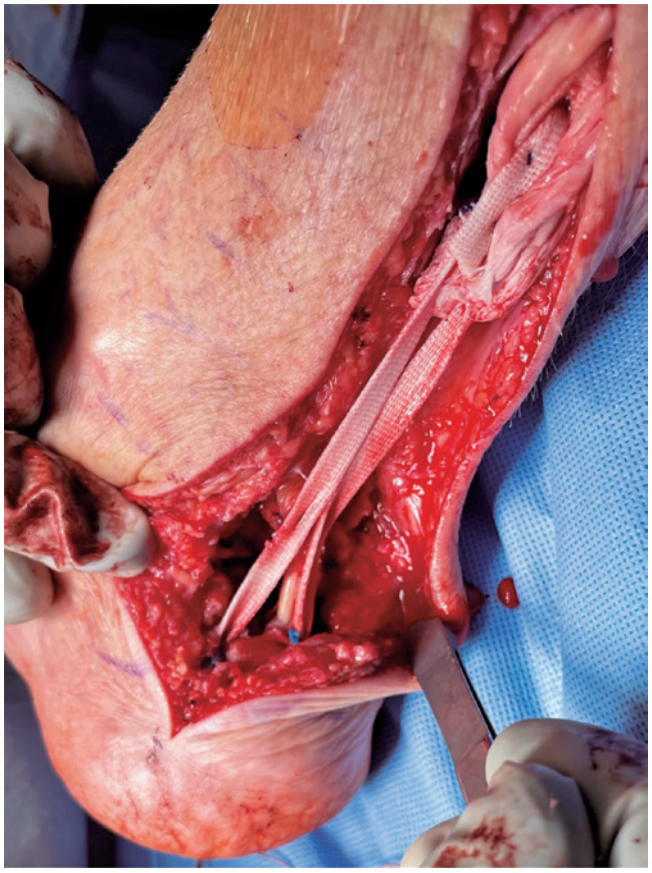

**Figure 5.** Final appearance of the entire reconstruction with the proper ankle positioning.

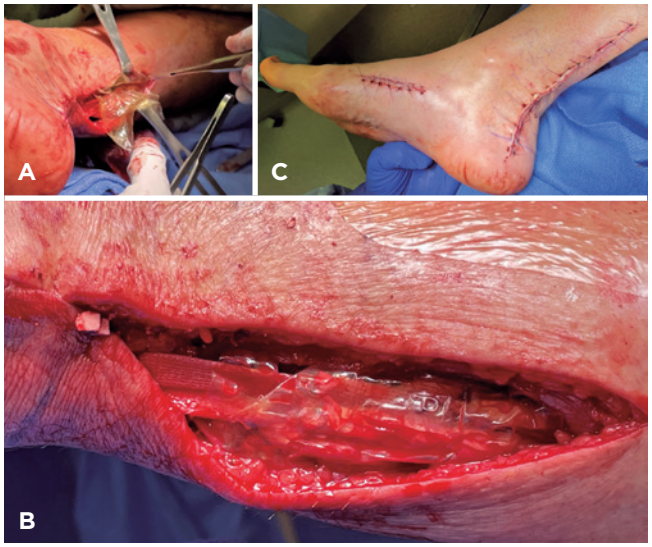


**Figure 6.** The Achilles peritendon was protected (A) with a dehydrated human amnion/chorion membrane allograft (B). The subcutaneous tissue was closed with 3-0 Vicryl™ suture, and the skin with 4-0 nylon sutures in horizontal mattress fashion (C).

autograft harvesting while inserting a biological scaffold for native tendon healing.

Choosing a treatment strategy historically relies on the quality of the existing tendon, the gap size, muscle status, and the surgeon's comfort with each technique[1]. However, treatment algorithms focus solely on defect size[7,8]. Myerson[7] and Kuwada[8] developed two classification systems based on the tendon gap with a therapeutic impact. In chronic cases, the tendon gap corresponds to what remains after the complete debridement of the fibrous tissue to the viable ends of the tendon.

The primary goal of surgery is to restore proper length and tension to the triceps surae with healthy tissue[9]. In patients with chronic tears, tendon retraction, muscle atrophy, and severe tissue degeneration present an extra challenge to treatment, sometimes requiring augmentation with endogenous or exogenous material[2]. Preliminary studies suggest that tendon augmentation is an effective method to improve the strength of the repaired tendon. Using autografts or biological scaffolds of an allogenic or xenogenic base could be an option in this scenario[4,10].

While autografts are associated with donor-site morbidity, there have been conflicting reports regarding the use of xenogenic scaffolds[4]. In addition, there are multiple reports of problems related to adverse reactions to this construction, failing the primary surgery, and the potential for multiple reoperations[4,10]. Synthetic scaffolds have thus been developed to overcome the disadvantages of existing biological scaffolds and to provide an alternative for tendon augmentation. In our case, with 12 months postop outcome, we used a flexible biocompatible, knitted mesh synthetic scaffold band derived from poly (urethane urea)[11].

In a biomechanical study, Giza et al.[1] evaluated the strength added to an AT repair reinforced with this biosynthetic scaffold. The authors demonstrated superior mechanical properties of the group that used synthetic augmentation compared to the non-augmented group. The study argued that the biosynthetic is thinner, has the potential for fibroblast ingrowth, and has improved handling characteristics compared to a xenograft. Additionally, the graft has been included to facilitate healing via internal cell growth, angiogenesis, and neocollagenesis[1].

Many authors advocate using a tendon transfer to protect the healing Achilles, bringing vascularity to the region and enhancing plantar flexion power[12].

The FHL tendon is the most used donor for tendon transfer due to its biomechanical strength, phase of action, and line of pull[13]. Wapner et al.[14] described transferring the FHL tendon through a medial midfoot incision to the calcaneus, anterior to the Achilles insertion, with satisfactory results. Multiple techniques for fixation of the tendon to the calcaneus are described, including using bone tunnels, suture anchors, or an interference screw[14].

Martin et al.[15] observed that patients with chronic Achilles tendinosis treated with complete excision of the AT (distal 4

to 6 cm from the tendon), transfer, and anastomosis of the FLH tendon to the proximal stump of the AT, had a significant reduction in the level of pain and improved function. However, they had deficits in strength and range of motion in plantar flexion.

Schweitzer et al.[16], in a literature review, found studies that support the use of synthetic materials in cases of extensive tearing because, according to these studies, the additional strength provided by the initial reconstruction may allow earlier mobilization and a faster return to activity. However, there are still minimal long-term data in the current literature on the specific application of these materials in the foot and ankle[16].

In addition, we must consider the costs of using these materials and concerns about using unabsorbable material in a region prone to contracture and soft-tissue compromise, wound formation, and infection.

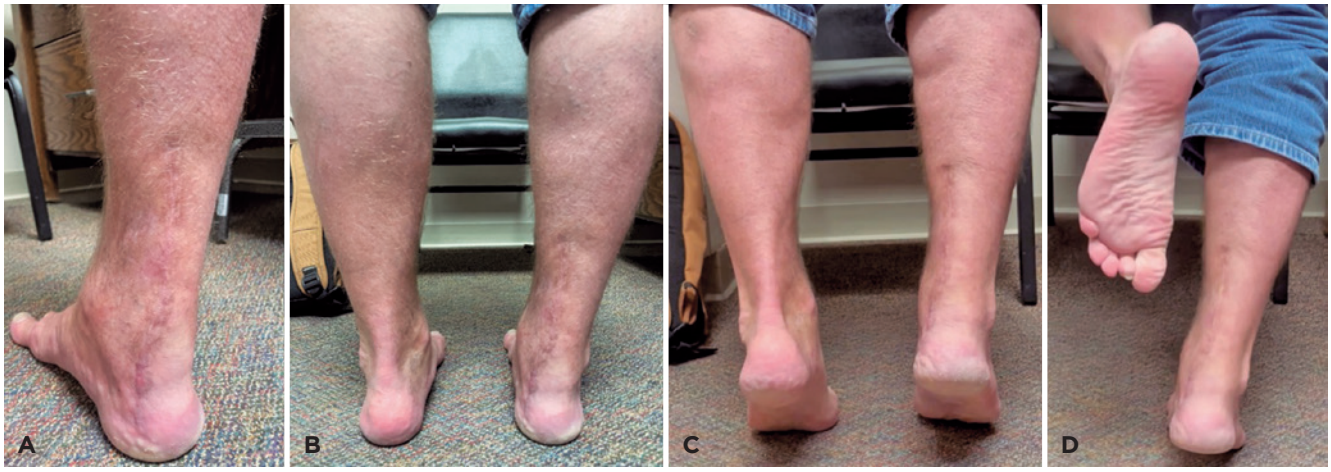


**Figure 7.** Clinical images with 12 months follow-up. Posteromedial view of the right hindfoot (operated side) (A). Bilateral standing posterior view (B). Posterior view with the patient in heel-raise position and with a right-side monopodal support (D).

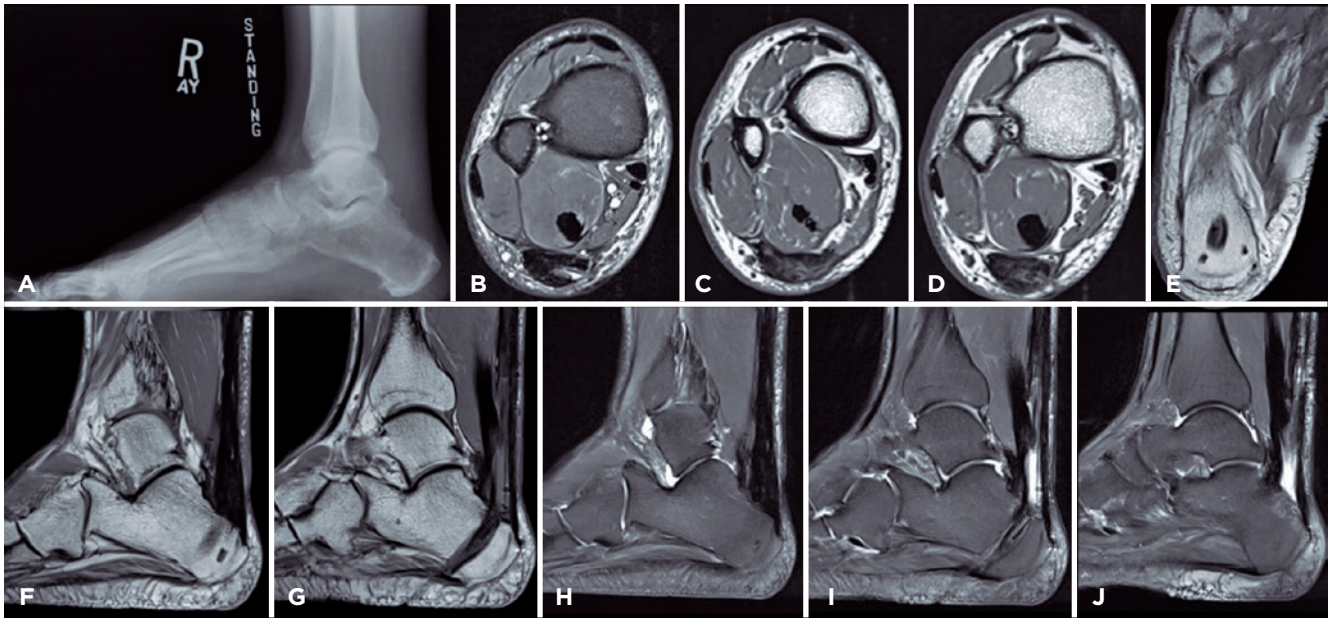


**Figure 8.** Postoperative imaging assessment. The three months postoperative lateral radiograph (A) demonstrated good tunnel position and no lysis. The MRI after 12 months depicted good gastrocnemius appearance and FHL muscle hypertrophy on axial views (B, C, D). Tunnel and anchors positioning are also shown (E). Sagittal MRI demonstrates good healing on proximal and distal attachments of the biosynthetic graft (F, H, J). FHL placement and its relationship with the reconstructed AT are also exhibited (G, I).

We added FHL transfer anteriorly to the biosynthetic graft reconstruction in our technique to potentialize healing and postoperative strength. There were no complications, and the patient presented a good recovery, showing good functional results.

## Conclusion

Achilles tendon reconstruction with the biosynthetic flexible band proved feasible for massive tendon defects by inserting a biological scaffold for native tendon healing, improving postoperative recovery and strength.

**Authors' Contribution:** Each author contributed individually and significantly to the development of this article: KAMC *(https://orcid.org/0000-0003-1082-6490) Conceived and planned the activities that led to the study, wrote the paper, interpreted the results of the study, statistical analysis, formatting of the article, participated in the reviewing process, bibliographic review, approved the final version; ES *(https://orcid.org/0000-0002-6922-5238) Data collection, interpreted the results of the study, participated in the reviewing process; AE *(https://orcid.org/0000-0001-6180-4780) Data collection, interpreted the results of the study, participated in the reviewing process; KCK *(https://orcid.org/0000-0002-3731-8448) Interpreted the results of the study, participated in the reviewing process; NSBM *(https://orcid.org/0000-0003-1067-727X) and CCN* (https://orcid.org/0000-0001-6037-0685) Data collection, participated in the reviewing process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Case Report

# Ankle desarthrodesis: report of three cases

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## Abstract

The good results of primary ankle arthroplasty and long-term dissatisfaction with arthrodesis have made arthrodesis, that is, the conversion of an arthrodesis into arthroplasty, an option for patients with a painful ankle fusion. This study presents the results of three patients submitted to ankle desarthrodesis in Brazil between 2019 and 2021. Two men and one woman, aged between 48 and 52 years and with an arthrodesis-prosthetic interval between two and 30 years, presented satisfactory results after arthroplasty. Pain reduction and increased functional capacity were observed, representing an improvement in the visual analog scale (VAS) between 5 and 6 points, range of motion (ROM) gain between 20° and 45° and progress in the American Orthopaedic Foot & Ankle Society (AOFAS) score between 17 and 54 points in the postoperative follow-up. Although it is a procedure with a long learning curve, desarthrodesis should be considered a therapeutic alternative to painful ankle arthrodesis.

**Level of Evidence IV; Case Series; Therapeutic Studies - investigating the results of treatment.**

**Keywords:** Arthrodesis; Arthroplasty; Osteoarthritis; Ankle.

## Introduction

Osteoarthrosis (OA) is a chronic, progressive and irreversible disease associated with pain, mobility limitation, and reduction in quality of life that affects 15% of the population worldwide, totaling approximately 250 million people[1-3]. Among these, the ankle represents 1% of the total cases. Unlike the large joints of the lower limb, where the primary origin is the main etiology[3], the ankle is predominantly post-traumatic (78%), followed by other systemic secondary causes (13%), such as rheumatoid arthritis and hemophilia. The primary etiology is rare and represents only 9% of the cases[4,5].

Due to the global increase of OA, among the ten leading causes of disability in developed countries, and the repercussion of using economic resources in health and absenteeism at work[6,7], great effort has been made to improve the treatment of this disease. Previously considered the gold standard for OA in advanced stages[8], ankle arthrodesis is associated with medium and long-term complications, especially arthrosis of adjacent joints, making total ankle arthroplasty (TAA) an option highly indicated as primary treatment[5,9,10] and a therapeutic alternative for cases of painful joint fusions.

## Case descriptions

The study was approved by the institution's ethics committee, and all patients signed an informed consent form to be included in the study.

Three patients underwent conversion of painful tibiotarsal arthrodesis into TAA with the Infinity implant (Wright Medical, Memphis, TN, USA), in Brazil, from 2019 to 2021.

Case 1: A 51-year-old female patient diagnosed with undetermined inflammatory arthritis with polyarticular involvement without other comorbidities. The patient presented mixed pain (mechanical and inflammatory) and sporadic incapacitation for daily activities with decreased ankle range of motion (ROM). Due to a traumatic fracture of the medial malleolus, it evolved into severe ankle OA. The patient underwent arthrodesis of the right ankle and then developed ankle pseudarthrosis (sagittal alignment in neutral and coronal with 6° of valgus) and chronic pain. After three years, due to disabling ankle pain, arthrodesis was converted to TAA with satisfactory results: a 5-point reduction in the visual analog scale (VAS) [interval: preoperative 8 to postoperative 3], a

Study performed at the Hospital Felício Rocho, Belo Horizonte, MG, Brazil and Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

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gain of 45° in active ROM [interval: 15° of equine to 30° dorsiflexion], measured by closed kinetic chain goniometry by one of the authors and an improvement of 54 points [interval: 18 to 72] in The American Orthopaedic Foot and Ankle Society (AOFAS) score (Ankle-Hindfoot Score) after 12 months of postoperative follow-up.

Case 2: 48-year-old male patient, obese (Body mass index (BMI = 30)), with post-traumatic arthrosis due to bimalleolar ankle fracture (medial and lateral malleolus). The patient underwent tibiotarsal arthrodesis to treat chronic pain, a mechanical pattern of strong intensity and functional limitation presenting poor postoperative evolution. However, consolidation of the arthrodesis with good angular parameters and radiographic consolidation was obtained. After five years of conservative treatment failure using optimized analgesia, physiotherapy, and orthopedic shoes, it was decided to convert the tibiotarsal arthrodesis, performed 12 years ago, into TAA and obtaining the following results: a 6-point reduction in VAS [interval: 8 to 2], a gain of 20° in active ROM [interval: 0° to 20°], measured by closed kinetic chain goniometry by one of the authors and an improvement of 52 points in the AOFAS score [interval: 33 to 85] after nine months of postoperative follow-up (Figures 1, 2 and 3).

Case 3: A 52-year-old female patient with poliomyelitis in the lower limb without other comorbidities, with 20 years of evolution of panarthrodesis (tibiotarsal, subtalar, and talonavicular) that resulted in chronic ankle pain of mechanical pattern and functional limitation. The tibiotarsal joint showed no angular or rotational deviations. The alignment of the hindfoot was 5°. Then, the tibiotarsal arthrodesis, performed 20 years ago, was converted into TAA, associated with calcaneal valgus osteotomy and elongation of the hook-type Achilles tendon (triple hemisection). Significant postoperative improvement was observed with a 6-point reduction in VAS [interval: 8 to 2], a gain of 20° in ROM [range: 0° to 20°], measured by closed kinetic chain goniometry by one of the authors and an improvement of 17 points in the AOFAS score [interval: 48 to 65] after eight months of postoperative follow-up (Table 1).

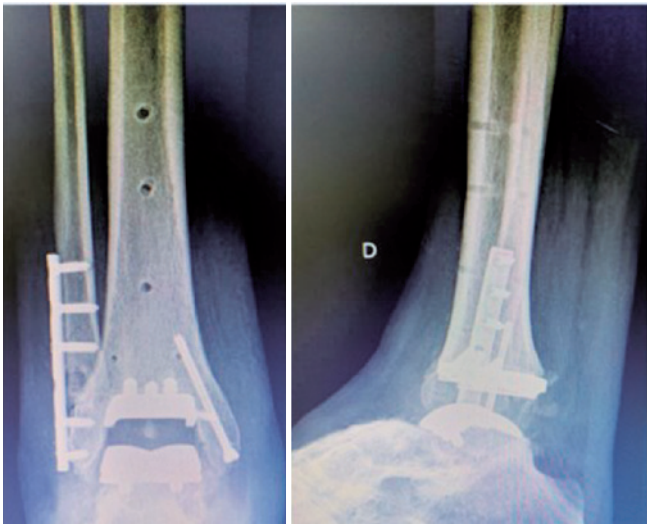


**Figure 2.** Case 2: Postoperative right ankle radiographs in anteroposterior (left) and lateral (right) views where TAA is observed with adequate component positioning and prophylactic malleolar fixation.

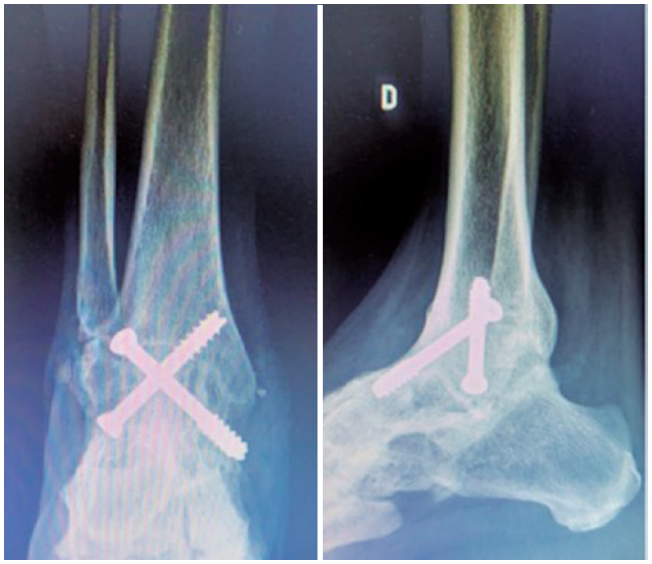


**Figure 1.** Case 2: Preoperative right ankle radiographs in anteroposterior (left) and lateral (right) view with consolidated arthrodesis and without angular deviations.

**Figure 3.** Case 2: Ectoscopy with maximum ROM obtained after six months postoperatively.

**Table 1.** Patient demographics and clinical data

| Gender | age | Etiology | VAS | | AOFAS | | ROM | |
|---|---|---|---|---|---|---|---|---|
| | | | Pre-op | Post-op | Pre-op | Post-op | Pre-op | Post-op |
| F | 51 | Inflammatory | 8 | 3 | 18 | 72 | <15 | 30° |
| M | 48 | Post-traumatic | 8 | 2 | 33 | 85 | 0° | 20° |
| F | 52 | Secondary to poliomyelitis | 8 | 2 | 48 | 65 | 0° | 20° |

*VAS: Visual analog scale; AOFAS: American Orthopaedic Foot & Ankle Society; ROM: Range of motion.

The three patients complained of mechanical ankle pain, with no predominant symptoms in adjacent joints, and underwent removal of the synthesis material and single-stage TAA via anterior access to the ankle. In addition, prophylactic malleolar fixation, bone cuts through the extramedullary guide, and TAA with the Infinity implant (Wright Medical, Memphis, TN, USA) was performed, as originally described in the literature[9,11].

The patients were submitted to the same postoperative protocol with immobilization with a cast without support and ROM training during the first four weeks, in which the dressing was changed weekly. In the fourth week, the stitches were removed, and the patients were referred to functional rehabilitation with individualized physical therapy aiming at a progressive ROM gain, gait training, muscle strengthening, balance, and proprioception. The support was performed in a protected manner with an immobilizer boot until the sixth week and removed later. Activities in the open kinetic chain academy and indoor bicycle training were allowed after this period. In addition, closed kinetic chain walks and exercises were allowed after three months postoperatively.

## Discussion

The prevalence and biopsychosocial impact of ankle OA have resulted in improved therapeutic modalities in recent years. In the final stage, the surgical treatment of OA, until recently, as a gold standard, was based on pain control at the expense of mobility and joint preservation through arthrodesis[3,8]. This treatment was associated with a high rate of arthrosis in adjacent joints in the medium and long-term, especially in the hindfoot[4,12], requiring additional surgical procedures and decreasing patient satisfaction[2].

Total ankle arthroplasty, an alternative to joint fusion in severe cases, was little used until the mid-2000s due to higher complication rates than arthrodesis[4,10]. For this reason, improvements were sought to enable the performance of TAA and reduce its high complication rates. These improvements were obtained with a 3rd generation system and allowed greater use of the technique with more satisfactory results[4].

Therefore, the good results with primary arthroplasty and decrease in late satisfaction after arthrodesis, related to secondary arthrosis or due to complications, such as non-union or vicious consolidation, raise the possibility of converting an arthrodesis to TAA[6,8]. Unfortunately, this procedure, of great technical difficulty, although described in 2004 by Greisberg et al.[9] in a cases series involving 18 patients with a mean follow-up of 39 months, has not been reported in Brazil until the publication of this study.

Commun indications for conversion of arthrodesis into TAA include pseudarthrosis, vicious consolidation, or arthrodesis with symptoms in adjacent joints. The absolute contraindications are the presence of active infection, severe peripheral vascular disease, inadequate soft tissues for coverage, and Charcot arthropathy; the relative ones are the absence of distal fibula, talar osteonecrosis, extensive ligament injury, active smoking, and anticipation of inadequate postoperative alignment[2,7].

Schuberth et al.[13] were responsible for the largest case series ever published, involving 77 ankles in a mean follow-up of 101 months, finding encouraging functional results with statistical significance ($p<0.05$). Despite a lower ROM gain than expected in a primary arthroplasty (16-20° versus 34-40°), the reduction or absence of pain and the mobility restoration improved the AOFAS score for ankle and hindfoot and VAS[2,3,12].

These results are compatible with other studies available in the literature. Pellegrini et al.[14], in a study involving 23 ankles with a mean follow-up of 33 months and a minimum of 12, obtained a reduction in VAS and improved quality of life through the Short Form-36 (SF-36). Preis et al.[15] evaluated 18 patients for a mean follow-up of 54 months and a minimum of 27 and also found statistically significant results for pain reduction and increased quality of life and mental health, represented by VAS and SF-36, respectively. Hintermann et al.[11], evaluating the same parameters in 29 ankles of 27 patients for a mean follow-up of 55 months and a minimum of 36, reached 82% of patient satisfaction and a mean of 24° ankle ROM gain.

Therefore, as described above, the patients in this study met the procedure's formal indications and had no absolute contraindications. Furthermore, the results obtained about the improvement of pain, quality of life, and important ROM gain, combined with the possibility of performing daily living activities, such as walking on uneven surfaces, climbing stairs, or low-impact sports practice, met the patient's expectations and are favorable to the proposal of desarthrodesis followed by TAA.

However, the study has limitations. The study is a case report with a short number of patients and a limited follow-up time of 12 months. In addition, the ROM evaluation was performed by goniometry and not by serial radiography, resulting in a tibiopodal and not a tibiotarsal angle.

Thus, a greater number of cases is necessary to objectively evaluate the results of desarthrodesis followed by TAA in Brazil with long-term follow-up.

## Conclusion

Desarthrodesis is a treatment option with good results for painful ankle arthrodesis.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: TSB *(https://orcid.org/0000-0001-9244-5194), BMG *(https://orcid.org/0000-0002-7428-2798) CASN *(https://orcid.org/0000-0002-9286-1750) and DSB *(https://orcid.org/0000-0001-5404-2132) Conceived and planned the activity that led to the study, wrote the article, participated in the review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID)  .

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## Case Report

# Subungual tumor of the hallux: a diagnostic challenge

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## Abstract

Subungual tumors of the hallux are rare, with a varied spectrum of differential diagnoses, and it may be challenging to reach the correct diagnosis. Depending on the health system where the patient will be treated, the specialist physician may follow different paths in the search for pathological definitions, which may lead to delays in obtaining the diagnosis and even to mistaken results. We present a case of a patient with a subungual tumor of the hallux, which represents the singular process above, aiming to demonstrate relevant differential diagnoses, determining factors for the correct diagnosis, and the importance of pathological elucidation for its proper treatment so that the outcomes for the patient are prevented.

**Level of Evidence V; Case Report; Expert Opinion.**

**Keywords:** Bone neoplasms; Hallux; Oncology; Orthopedic.

## Introduction

Subungual tumors of the hallux are rare, with a varied spectrum of differential diagnoses, and it may be challenging to reach the correct diagnosis. Depending on the health system where the patient will be treated, the specialist physician may follow different paths in the search for pathological definitions, which may lead to delays in obtaining the diagnosis and even to mistaken results[1,2].

We present a case of a patient with a subungual tumor of the hallux initially diagnosed and treated as superficial acral fibromyxoma. After an unsatisfactory outcome with recurrence and progressive nail deformity, suspicions of subungual exostosis and bizarre parosteal osteochondromatous proliferation (BPOP), or Nora's lesion, were raised.

The objective of this report is to present relevant differential diagnoses of subungual tumors of the hallux, determining factors for the correct diagnosis, and the importance of pathological elucidation for its appropriate treatment so that the outcomes for the patient, such as onychodystrophy and even amputation, are prevented.

## Case description

The study was approved by the institution's ethics committee, and the informed consent form was signed.

A 15-year-old male presented to a dermatologist's office complaining of a subungual lesion in the left hallux. The patient denied episodes of trauma and reported rapid lesion growth, with nail deformity due to elevation of subungual mass, without pain. A biopsy was performed by superficial scraping, with an anatomopathological result of the fibroblastic proliferation of reaction pattern, with myxoid areas without atypia. The immunohistochemical profile was positive for CD99 and smooth muscle actin, suggestive of superficial acral fibromyxoma (Figure 1).

Initially treated with superficial excision, the lesion presented new growth with progressive nail deformity. The patient underwent a radiographic examination and was referred for consultation with a foot specialist orthopedic surgeon. The radiograph showed ossification near the hallux's dorsomedial end of the distal phalanx, measuring 1cm, associated with sclerosis and phalanx irregularities (Figure 2).

The clinical evolution associated with imaging suggested differential diagnoses, such as subungual exostosis, Nora's lesion, and subungual osteochondroma. Therefore, surgical treatment was then performed with excision of the lesion (Figures 3 and 4), as follows: 1) incision of the medial, anterior, and lateral region of the left hallux, above the midline in the longitudinal plane; 2) dissection of the tissues to the tumor's base in the phalanx and the subungual bed superiorly; 3) dis-

Study performed at the Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

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section of the whole exostosis base; 4) control with radioscopy and osteotomy with microdrill of the exostosis base; 5) lesion resection; 6) intraoperative histopathological analysis of the lesion - without malignancy characteristics; 7) regularization of the phalanx base; 8) skin and flap closing between the nail and the skin; 9) dressing; and 10) use of footwear with forefoot wedge in the postoperative period.

The detailed anatomopathological report characterized the lesion as bone neoformation partially covered by cartilage without atypia, with nail erosion, associated acute inflammatory process, histiocytic reaction around hemorrhage (previous biopsy site), foci of fibrosis, myxoid degeneration and ischemic necrosis in adjacent connective tissue, without morphological evidence of malignancy, concluding by bone exostosis.

The patient evolved well, with good wound healing and no lesion recurrence to date (Figure 5).

**Figure 1.** Subungual lesion of the left hallux at the time of the first biopsy by superficial scraping.

**Figure 2.** Left hallux radiograph.

## Discussion

Subungual tumors of the hallux are uncommon lesions that present a wide spectrum of differential diagnoses, such as subungual exostosis, subungual osteochondroma, BPOP or Nora's lesion, superficial acral fibromyxoma, glomus tumor, onychomycosis, and pyogenic granuloma. The patient can seek help in different areas of medicine, such as dermatology, orthopedics, and oncology, or from non-medical health professionals, such as podiatrists. Therefore, varied approaches

**Figure 3.** Steps of the surgical approach.

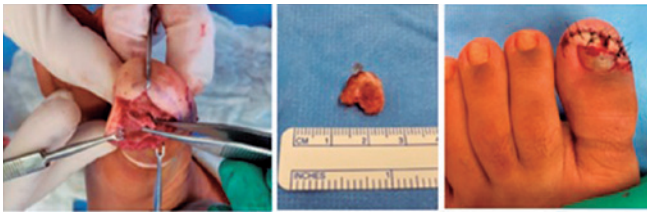

**Figure 4.** Lesion resection and wound regularization.

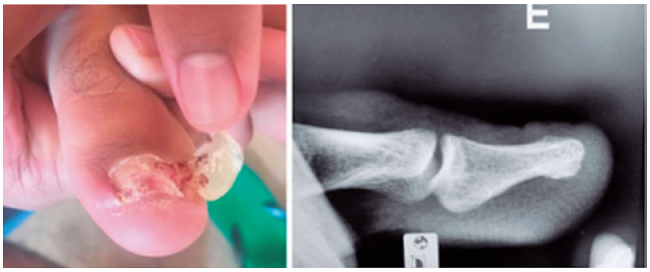

**Figure 5.** Two months postoperative.

can lead to delayed diagnosis or even mistaken results. It is relevant to analyze the main differential diagnoses for subungual lesions of the hallux that were investigated in this case report and determine factors in the investigative process.

## Superficial acral fibromyxoma

Superficial acral fibromyxoma is a rare benign soft tissue tumor, more common in patients in the fifth decade of life, with a mean age of 43 years, affecting more males in a 2:1 ratio to females[1,2]. It is usually located on the tips of the fingers and toes, preferably subungual or periungual, and the hallux is the most affected digit[3].

It appears as a slow-growing solitary nodule, reaching mean dimensions of 0.6 to 5 cm, and painless in most cases[1,4]. On histological analysis, it is described as a myxoid tumor with spindle-shaped, stellate cells and fibroblasts, usually confined to the dermis and subcutaneous tissue. It may also involve deeper tissues, causing erosion of the underlying bone limited to the cortical bone, without tumor calcification, a characteristic lesion that can be visualized on radiographs[2,4]. Magnetic resonance imaging usually presents hypointense signal on T1-weighted sequences and a hyperintense signal on T2-weighted[3]. On immunohistochemical analysis, it is reactive for CD34, CD99, and epithelial membrane antigen, being negative for S100, which distinguishes it from myxoid neurofibroma[1].

The treatment of superficial acral fibromyxoma should be conducted with its complete excision to prevent recurrence[1].

## Nora's lesion

Bizarre parosteal osteochondromatous proliferation, described by Nora in 1983, is a rare benign tumor lesion, with just over 100 cases reported in the literature. Although its etiology is not yet fully defined, it is believed to be associated with genetic alterations, such as translocation t(1:17)(q32;q21)[5]. It usually presents as a fast-growing nodule for weeks to months, painless or slightly painful. It is preferentially located in the hands and feet of young adults in the third decade of life, especially in the phalanges, metacarpals and metatarsals, with no preference for gender[5,6].

Morphologically, it appears as a mass of heterotopic mineralization that rises from the periosteal or intact cortex without medullary involvement, presenting a nodular surface covered by metaplastic cartilage[7]. There are osteoblasts irregularly disposed in the bony trabeculae, along with bizarre fibroblasts between the trabeculae[6]. Magnetic resonance imaging is characterized as a low-signal lesion on T1-weighted sequences and a low-intermediate signal on T2-weighted, without periosteal reaction and gadolinium enhancement. When it is not completely resected, it presents a high local recurrence rate, reaching up to 55% of the cases[5,6].

## Subungual exostosis

An important diagnosis is a subungual exostosis, a rare benign tumor late diagnosed in about 10% of cases, with reports in the literature showing a significant interval of two months to four years from the onset of symptoms until the correct lesion elucidation[8].

Initially described by Dupuytren in 1817, this benign tumor affects patients more frequently in the second and third decades of life, with no difference between genders. It is a slow-growing solitary mass, usually painful, with progressive involvement of the nail and nail bed and a preference for hallux in about 80% of cases. There are no reports of malignant transformation[9].

Its etiology is still uncertain, and its development may be related to traumas, infections, tumors, hereditary factors, and the translocation t(X;6)(q22; q13-14)[8,9].

On physical examination, it may present as a fixed subungual nodule with a hyperkeratotic surface in the distal region of the nail[8]. In subungual exostosis, the formed bone originates from fibrous tissue and does not present continuity with the cortical or medullary bone, having a fibrocartilage cover, an important characteristic that differentiates it from osteochondroma[8,9]. On radiographical examination, there is no bone destruction or periosteal reaction[10].

## Subungual osteochondroma

An important differential diagnosis of subungual exostosis is subungual osteochondroma. Osteochondroma is the most common benign bone neoplasm, corresponding to 10-15% of all bone tumors; however, its subungual form is rare[10]. The latter affects the hallux in 45% of cases and the other toes in most other cases.

It is presented as a bone mass derived from endochondral ossification, pedunculated or sessile, continuous with the cortical and bone marrow, and hyaline cartilage[9,10].

For both subungual exostosis and osteochondroma, removing the entire lesion to its base, with its curettage until visualization of the cancellous bone, is recommended to avoid recurrence. The nail bed should be preserved whenever possible[9,10].

# Conclusion

Subungual tumors are rare lesions with a wide spectrum of differential diagnoses. For diagnostic investigation, imaging exams and pathological examinations are of great value and should be used to perform early appropriate treatment and prevent harm to the patient.

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## Case Report

# Traumatic hallux sesamoid fracture: a case report

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## Abstract

The authors describe an extremely rare case of traumatic fracture of both hallux sesamoid bones, which was treated non-surgically, and the indications, contraindications, and unfavorable outcomes analyzed.

**Level of Evidence V; Therapeutic Studies; Expert Opinion.**

**Keywords:** Sesamoid bones; Fractures, bone; Hallux.

## Introduction

The sesamoid bones lie lateral and medial to the flexor hallucis longus, developing a similar function to the pulleys, allowing a better load distribution in the first ray, besides participating in the functionalities of flexor hallucis brevis tendons and the protection of flexor hallucis longus[1]. They are located on the plantar aspect, suffering the impact of the body weight against the ground, especially when jumping or during a race. There are two sesamoid bones, the tibial sesamoid is larger and more medial, and the fibular sesamoid is smaller and more rounded[1,2].

Sesamoid bone fractures usually occur due to dorsiflexion trauma of the hallux and direct trauma in landing, for example[3]. Usually, tibial sesamoid fracture occurs because it is more fixed and larger, thus making it more susceptible to trauma. In addition, fractures generally present a more transverse feature, differing from pseudarthroses, which are more irregular and acute[4].

Treatment options are conservative and surgical. Conservative treatment includes immobilization with a suropodalic cast or non-weight-bearing footwear for four to six weeks. On the other hand, the surgical treatment recommends implants such as screws or even sesamoid resection, that is, sesamoidectomy[1,2,5], partially or totally, which has demonstrated in some studies an earlier return to sports activities in athletes[5].

We emphasize that surgical treatment is contraindicated due to the patient's clinical or poor local skin conditions, and in fractures without deviation and without compromising the function of the plantar glenosesamoid complex of the first metatarsophalangeal joint.

We report a case with a fracture in both sesamoids where conservative treatment was indicated because the patient did not meet the criteria for surgical treatment, which is an extremely rare with almost no publication in the literature.

## Case description

A 42-year-old female patient had a history of falling down the stairs with approximately 15 steps on 10/22/2021 with axial trauma to the foot in equinus and dorsiflexion in the first ray evolving with severe pain in the left forefoot, limitation to ambulation, and inability to support body weight. The patient attended the Emergency Department of the Hospital do Servidor Público do Estado de São Paulo on the same date.

Radiographs (Figure 1) were performed, demonstrating a transverse lateral sesamoid fracture and a transverse and comminuted medial sesamoid fracture, confirmed by computed tomography (Figure 2), revealing relative integrity of the plantar glenosesamoid complex, and was opted for conservative treatment with cast and follow-up with serial radiographs every two weeks. The reasons to choose conservative treatment were: the tibial sesamoid fracture was comminu-

Study performed at the Serviço de Ortopedia e Traumatologia do Hospital do Servidor Público Estadual (HSPE), São Paulo, SP, Brazil.

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ted, which would practically preclude the synthesis, and the fibular sesamoid fracture presented a transverse feature, that is, stable, showing good results in the non-surgical treatment.

The patient evolved with satisfactory results and consolidation after six weeks of cast immobilization (Figure 3) and was instructed to wear shoes with rigid soles for another four weeks. After that, the patient was referred to rehabilitation with good evolution, painless gait, weight-bearing capacity, daily activities without any limitation, and recovery of the range of motion, mainly from the first ray compared to the contralateral limb.

## Discussion

As discussed by Bichara et al.[6] and Tan et al.[3], the hallux sesamoid bones play a crucial role in the first metatarsal joint, performing a pulley function and imparting most of the force to the first ray. Due to their location, they are subject to trauma or repetitive stress, presenting clinically with pain and limitation of physical activities since injuries to these bones, especially fractures, often affect athletes. In addition, York et al.[7] also cite the high susceptibility of sesamoid bone fracture in athletes.

Sesamoid fractures can be classified as acute or stress fractures. In acute cases, they usually affect the tibial sesamoid because it is larger and more fixed, presenting a more transverse feature. In contrast, the fibular sesamoid tends to be less affected due to its high mobility and the ability to slide between the first and second rays in the first intermetatarsal space. It should be noted that fractures involving both sesamoids are extremely rare events.

As treatment options, Cohen[4] suggests conservative management with a cast for four to six weeks and another four to six weeks with an immobilizer boot. Surgical cases are reserved for deviated fractures or those that evolve with pseudarthrosis or delayed consolidation. However, Stein et al.[2] and Robertson et al.[5] mention that high-performance athletes patients submitted to surgical treatment had an earlier return to activities, but the fracture time did not imply the result and/or fracture consolidation, as described by Robertson et al.[5], that some athletes started with conservative treatment and after the poor evolution or worsening of symptoms underwent surgical treatment and returned to the same level of activity before fractures[2,5,8].


**Figure 1.** Radiographs from the day of the fracture (10/22/2021).

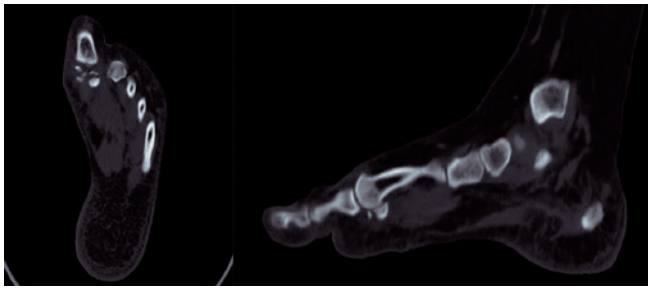

**Figure 2.** Computed tomography on 10/22/2021.

## Conclusion

Conservative treatment proved efficient and allowed the return to daily activities, even with the rare fracture of the two sesamoids, according to the evolution of the case described in this study.

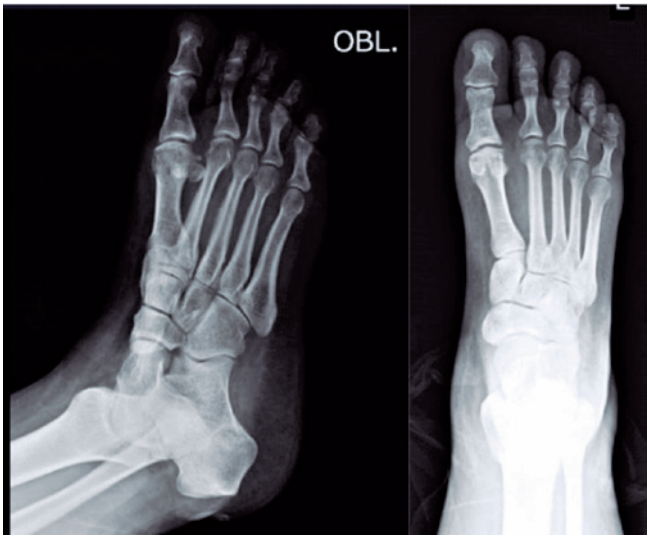


**Figure 3.** Radiographs after six weeks using a cast.

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Systematic Review

# Minimally invasive surgery for pedal digital deformity: a systematic review

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## Abstract

**Objective:** The interest and application of minimally invasive surgery (MIS) in treating lesser toe deformities have increased worldwide. The symptoms are often attributed to callosities and localized pressure. Conservative treatment may improve comfort, but its success largely depends on the level of deformity. When conservative treatment fails, surgery may be indicated. This study explores the available evidence and reviews in the literature seeking to examine the efficacy of MIS in lesser toe pathology.

**Methods:** A systematic review was performed, and the search included the following databases: Cochrane Library, CINAHL, MEDLINE®, PUBMED, Science Direct, and other relevant peer-reviewed sources between September 2019 and June 2022. In addition, a manual search was conducted in Australian, American, British, and European orthopedic and podiatric scientific data for relevant studies.

**Results:** The search for potentially eligible information for this systematic review yielded 92 unique studies. All studies identified were obtained and reviewed. An updated search was performed in July 2022, resulting in no additional studies that satisfied the inclusion criteria. After considering all potentially eligible studies, five (5.4%) met the inclusion criteria. One thousand one hundred eighty-six lesser toe procedures (500 patients) were included. The overwhelming majority of patients were female (80.5%). The patient's mean age was 56.9 (range 18-91) years, and the mean follow-up was 19.6 (range 6-33) months. All of the studies included early mobilization in the postoperative protocol.

**Conclusion:** There is a need for more research using a combination of validated patient-reported outcomes to evaluate the effectiveness of MIS procedures in treating lesser toe deformities alongside the development of validated and tested treatment algorithms to guide surgical decision-making.

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

**Keywords:** Minimally invasive surgery; Hammer toe syndrome; Systematic review.

## Introduction

The interest and application of minimally invasive foot surgery (MIS) continue to grow worldwide, yet the most appropriate surgical treatment for lesser toe deformities is controversial[1-8]. MIS has been defined as surgery performed through small portals without direct visualization of anatomical structures. Its use has increased due to the belief that it reduces soft-tissue damage, smaller scars, shorter surgery time and hospital stay, lower postoperative pain, and reduces infection risk. However, there is limited evidence to support these assertions[9].

The aim of lesser toe surgery is to correct the deformity and preserve the foot biomechanics. There is no consensus regarding the best surgical approach[9]. Surgeons have historically focused on anatomical structures and contractures to guide their decision-making[10]. The ambiguous definitions and treatment options for diagnosing and managing lesser toe deformities have been well documented and may further confound the confusion surrounding appropriate surgical approaches[11].

The symptoms of lesser toe deformities are often attributed to callosities and localized pressure[3]. Conservative treatment

Study performed at the Australasian College of Podiatric Surgeons, Victoria, Australia.

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may improve comfort, but its success depends on the level of deformity. Orthoses, special footwear, protective devices, and various injection techniques have been employed as non-operative management[12]. When conservative treatment fails, surgery may be indicated. The aim of this systematic review is to determine whether MIS approaches for the correction of lesser toe deformities provide a safe and reproducible approach.

## Methods

A systematic review was performed, and the search included the following databases: Cochrane Library, CINAHL, MEDLINE®, PUBMED, Science Direct, and other relevant peer-reviewed sources between September 2019 and June 2022. In addition, a manual search was conducted in Australian, American, British, and European orthopedic and podiatric scientific data for relevant studies, including but not limited to the Journal of Foot & Ankle Research, the Journal of Foot & Ankle Surgery, the Journal of the American Podiatric Medical Association, the American Journal of Sports Medicine, the British Journal of Sports Medicine, Foot and Ankle International, the Journal of Bone and Joint Surgery, and International Orthopaedics.

The abstract of each study was assessed to ensure it met the inclusion criteria outlined in Table 1. The hierarchy of evidence was considered for this review; however, given the small number of studies concerning the treatment and informing MIS decision-making, narrative reviews were included despite their low standing due to the mention of surgical algorithms.

Given MIS for lesser toe deformities is a relatively modern field of practice, few filters and limitations were applied to ensure the largest pool of research articles. Boolean operators searched for specific terms and established associations between keywords. A PRISMA flow chart is outlined in Figure 1.

## Results

The search for potentially eligible information for this systematic review yielded 92 unique studies. All studies identified were obtained and reviewed. An updated search was performed in July 2022, resulting in no additional studies that satisfied the inclusion criteria. After considering all potentially eligible studies, five (5.4%) met the inclusion criteria. One thousand one hundred eighty-six lesser toe procedures (500 patients) were included (Table 2). The overwhelming majority of patients were female (80.5%). The patient's mean age was 56.9 (range 18-91) years, and the mean follow-up was 19.6 (range 6-33) months. All of the studies included early mobilization in the postoperative protocol.

Favorable postoperative results using MIS for lesser toe deformities were seen across all studies, irrespective of the postoperative outcome measures used. A prospective cohort study by Yassin et al.[13] reported a postoperative Visual Analog Scale (VAS) score of 1.9 for MIS compared to 3.5 for open Kirschner wire (K-wire) fixation.

**Table 1.** The inclusion and exclusion criteria

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| Empirical research | Concomitant hallux valgus surgery |
| Minimally invasive techniques<br>- Lesser toe deformities<br>- Toe and Deformity<br>- Guidelines or Algorithms | Traditional open |
| Research using patient-reported outcome measures | |
| Research completed between 2008-2021 | |
| Studies examining MIS in patients with existing medical conditions | |
| Narrative reviews | |

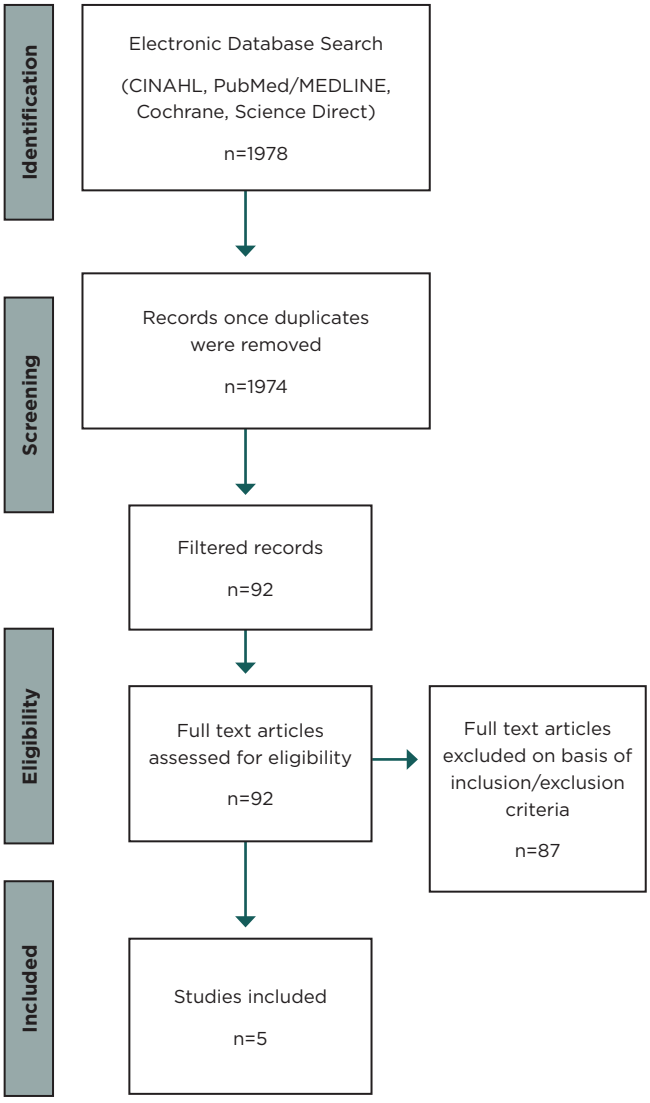


**Figure 1.** A PRISMA Flow chart of the included studies.

**Table 2.** Characteristics of the included studies

| Author | Sample size | No. of procedures | Level of evidence | Surgical technique | Outcome measure | Follow-up |
|---|---|---|---|---|---|---|
| Nieto-Garcia et al.[14] | 223 | 723 | III | Incomplete phalangeal osteotomies with or without tenotomies for lesser toe deformities alongside HAV surgery | AOFAS pre- and postoperatively | 6, 12 months |
| Yassin et al.[13] | 87 (MIS), 265 (Open) | 221 (MIS), 454 (Open) | III | Open K-wire fixation compared to percutaneous fixation | Radiographic assessment<br>ASEPSIS score<br>VAS | 2, 3 months |
| Malhotra et al.[11] | N/A | N/A | V | N/A | N/A | N/A |
| Gilheany et al.[9] | 179 | 299 | III | Simple deformity: MIS phalangeal osteotomies and/or ostectomy with/without lengthening/release to flexor/extensor tendons and capsular releases as required.<br>Complex deformity: MIS reconstructive procedures of the MTPJ | An audit of comnplications using national benchmark indicators | 12 months |
| Lui[15] | 11 | 13 | III | MIS combined plantar plate tenodesis and EDB transfer | Radiological assessment | 33 months |

*HAV: Hallux abductus valgus; AOFAS: American Orthopaedic Foot & Ankle scale; MIS: Minimally invasive surgery; K-wire: Kirschen wire; ASEPSIS: Additional treatment, the presence of Serous discharge, Erythema, Purulent exudate, and Separation of the deep tissues, the Isolation of bacteria, and the duration of inpatient Stay; VAS: Visual Analog Scale; MTPJ: Metatarsophalangeal joint; EDB: Extensor digitorum brevis.

Four studies[9,13-15] provide commentary on postoperative complications in their respective studies. Gilheany et al.[9] reported low complication rates when performing MIS on pedal deformities through tenotomies, capsular releases, and osteotomies, with an observed infection rate of 0.53% and under correction of 0.67%. This complication rate contrasts with Nieto-Garcia et al.[14], who found significantly higher postoperative complication rates when comparing the impact of tenotomies on the outcome of incomplete osteotomies. They reported a complication rate of 13.9% following an incomplete phalangeal osteotomy which increased to 38.6% when a tenotomy was performed concurrently. Yassin et al.[13] found an increase in abnormal wound healing following MIS (20.7%) compared with open K-wire fixation (7.1%). However, a high number of co-morbid patients diagnosed with peripheral vascular disease in the MIS could impact the validity of their findings and explain the increase in postoperative complications.

## Discussion

The aim of this systematic review was to evaluate the effectiveness of MIS procedures in treating lesser toe deformities. All studies included aimed to assess the effectiveness and management of MIS for lesser toe deformities; however, several different MIS techniques and lesser toe deformities were evaluated. Nieto-Garcia et al.[14] and Yassin et al.[13] approached this through comparative studies, with the latter comparing MIS to open surgery. Gilheany et al.[9] assessed the surgical and medical complication rates associated with MIS for pedal toe deformities. Results were then compared against national benchmark indicators to determine whether MIS could prove advantageous or comparable to traditional open surgery. The final study by Lui[15] examined the lateral and dorsal metatarsal phalangeal angles pre- and postoperatively through plain radiographs to assess the effectiveness of MIS in correcting cross-over toe deformity.

The study by Nieto-Garcia et al.[14] was the largest, including 723 procedures performed on 223 patients. The study with the smallest sample size was conducted by Lui[15] with 11 patients and 13 percutaneous procedures for lesser toe deformities. It is expected that a larger sample size would provide a better representation of a population, whereas small sample sizes may not capture the full range of results.

Gilheany et al.[9] focused on postoperative complication rates where a longer-term follow-up may be considered advantageous when assessing deformity reoccurrence. This is in contrast to studies that compared pre- and postoperative pain scores where shorter follow-up periods focused on how pain levels change following the surgical intervention. Given the vast variation in postoperative follow-up periods recorded, direct comparisons between the studies included in this review may be invalid.

All studies included in this review concluded that their respective results favor using MIS in treating lesser toe deformities. However, it is difficult to draw direct conclusions due to the variance and limitations across the methods, data collection, and analysis.

Several complications were described across the studies identified, with all studies describing MIS as providing low complication rates. The variance was observed across all studies regarding the methodologies and patient-reported outcome measures used to identify adverse events. Nieto-Garcia et al.[14] assessed the effectiveness of incomplete osteotomies using MIS techniques. Complications were higher

when the osteotomies were used alongside tenotomies, specifically those of delayed union, hypertrophic callous, and postoperative phalangeal fractures. Yassin et al.[13] compared MIS osteotomies to traditional K-wire fixation. Adverse events were lower in the percutaneous group than those treated with traditional K-wire fixation.

## Conclusion

There is a need for more research using a combination of validated patient-reported outcomes to evaluate the effectiveness of MIS procedures in treating lesser toe deformities alongside the development of validated and tested treatment algorithms to guide surgical decision-making.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: SRE *(https://orcid.org/0000-0002-9866-0327) Interpreted the results of the study, designed and wrote the manuscript, participated in the review process and approved the final version; MGM *(https://orcid.org/0000-0001-9533-7797) Conceived and planned the activities that led to the study, approved the final version; MFG *(https://orcid.org/0000-0002-8179-7992) Performed the surgeries, data collection and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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## Systematic Review

# Reconstruction of the extensor hallucis longus with a hamstring tendon autograft: a systematic review

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## Abstract

**Objective:** The purpose of this study was to systematically review the literature regarding the use of hamstring tendon (HT) autograft for extensor hallucis longus (EHL) reconstruction.

**Methods:** A systematic search for studies addressing the use of HT autograft for reconstruction of nonrepairable EHL tendon injuries was performed in December 2021. The databases searched include Embase, Medline, Europe PMC, Cochrane, and Scopus. Predetermined inclusion and exclusion criteria were implemented, and appropriate studies were selected for review.

**Results:** The database search resulted in one study that met the inclusion and exclusion criteria. Three additional studies met inclusion and exclusion criteria after screening the references of the selected study. A total of four studies were included in the final review. Clinical presentation, surgical technique, postoperative rehabilitation, clinical follow-up, and outcomes were recorded. All four studies reported single cases of EHL tendon reconstruction using a semitendinosus autograft with satisfactory clinical results and no complications. Patients may experience a five degrees decrease in range of motion or minimal decrease in hallux extension strength; however, all patients were asymptomatic and reported no limitations.

**Conclusion:** Four case reports regarding EHL tendon reconstruction were reviewed and demonstrated using a semitendinosus autograft as a viable option with favorable outcomes and no complications.

**Level of Evidence IV; Systematic Review**

**Keywords:** Autograft; Extensor hallucis longus; Hamstring tendons; Tendon injuries.

## Introduction

The extensor hallucis longus (EHL) muscle originates along the anterior fibula, travels distally under the extensor retinaculum of the ankle, and courses superficially along the dorsal foot where the distal tendon inserts on the base of the distal phalanx of the hallux[1]. The primary function of the EHL is the extension of the hallux interphalangeal (IP) joint, and it works with the extensor hallucis brevis (EHB) to extend the metatarsophalangeal (MP) joint. In addition, it contributes to dorsiflexion of the ankle and inversion of the foot, but other muscles, such as the tibialis anterior, can also perform these functions.

The overall incidence of EHL rupture has not been well-defined. Anzel et al.[2] reviewed 1,014 cases of various muscle and tendon injuries, noting 16 cases (1.5%) were injuries to the toes extensors. Open laceration is the most commonly described injury mechanism for EHL tendon injury[3]; however, closed traumatic rupture[4,5], attritional rupture[6], and iatrogenic injury have also been reported[7]. In addition, a higher prevalence of EHL pathology has been observed in martial

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art practitioners compared to the general population[8]. When patients present with an acute tendon rupture, surgical treatment is indicated in the acute setting with direct end-to-end primary repair of the tendon[9–11]. These patients have favorable outcomes with restoring function and returning to their previous activity levels[3,12–15]. Nonoperative treatment can be considered in ruptures distal to the extensor expansion, patients with limited activity levels, or patients with medical comorbidities precluding operative intervention[9,16].

Some patients may present to a medical provider in a delayed fashion with a chronic injury, which cannot undergo direct repair secondary to tendon retraction and scar tissue formation[9,17,18]. For this situation, local tendon transfers or tendon reconstruction procedures using allograft or autograft have been described[6,17,19–27]. The use of hamstring tendon (HT) autograft has been reported for various foot and ankle reconstruction surgeries with minimal donor site morbidity[28]. The purpose of this study is to perform a systematic literature review regarding EHL tendon reconstruction using HT autograft.

## Methods

### Database search

A systematic literature search was performed in December 2021 to evaluate the use of HT autograft for EHL reconstruction. The search was conducted in the following databases: Embase, Medline, Europe PMC, Cochrane, Scopus, and Scielo. The search terms used include ((ankle) OR (foot)) AND (autograft) AND (hamstring) AND (tendon reconstruction) NOT (ligament).

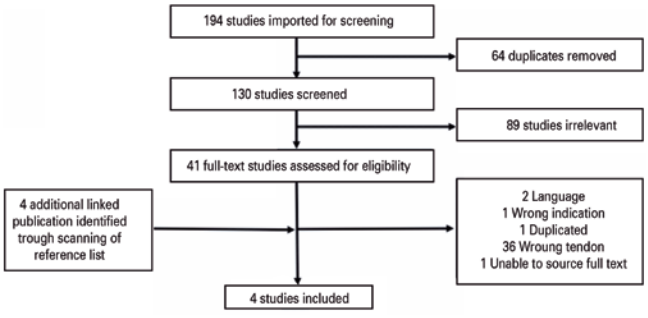


**Figure 1.** Flow chart of literature search and study selection procedure.

### Study selection criteria

After performing the database search, duplicate articles were eliminated. The remaining studies were reviewed to be considered in the systematic review. Inclusion criteria were the use of an HT autograft for EHL reconstruction. For this study, the gracilis tendon and semitendinosus tendon were considered. The exclusion criteria include EHL reconstruction with grafts other than HT autograft, use of the HT autograft in other tendons reconstruction, use of HT autograft for ligament reconstruction, absence of the surgical technique description, and articles not available in the authors' primary language. Additionally, the references of the selected studies were screened and included in the final review if inclusion and exclusion criteria were met.

### Study review

The selected studies were reviewed. Patient clinical presentation, surgical technique, postoperative protocol, clinical follow-up, and outcomes were recorded.

## Results

### Study selection

After performing the described database search, 194 articles were identified for review (Figure 1). Sixty-four were duplicates, remaining 130 unique studies for review. After applying the inclusion and exclusion criteria, a single study was selected for full-text analysis. The references from this study were reviewed, and four additional studies were identified for further analysis. Among the additional studies, one full-text was unable to be obtained, and the study was excluded[29]. For the final review, four studies were included (Table 1)[7,17,24,30]

**Table 1.** Details of the selected studies included in the review

| Author | Year | Age | Sex | Mechanism of Injury | Chronicity | Follow-up (months) | Outcome |
|---|---|---|---|---|---|---|---|
| Park et al. | 2003 | 15 | Male | Taekwondo | 1 year of symptoms,<br>Inability to extend hallux for 2 weeks | 6 | Slightly decreased extension strength<br>Normal range of motion |
| Tuncer et al. | 2010 | 40 | Male | Iatrogenic | 4 months after ankle arthroscopy,<br>6 weeks after acute rupture | 12 | No symptoms |
| Lohrer et al. | 2012 | 32 | Female | Sprinting,<br>Roller Skating | 3 years of symptoms,<br>6 previous surgeries for EHL tenosynovitis | 19 | Full Strength<br>Limited flexion of 5° |
| Kwapisz et al. | 2017 | 18 | Male | Kickboxing | 2 years of symptoms,<br>Inability to extend hallux for 10 months | 8 | Minimal limitation of extension strength<br>Limited extension of 5° |

Regarding the study where the full-text article could not be obtained, the abstract was reviewed. The abstract describes a case report regarding a 61-year-old female who presented with a chronic EHL tendon laceration that failed a previous repair and subsequently underwent tendon reconstruction using a gracilis tendon autograft and IP joint arthrodesis[29]. No surgical technique description, patient follow-up, or postoperative outcomes were available for review. Thus, this study was excluded from the final review.

## Clinical Presentations

The studies selected for review include four case reports describing using a semitendinosus autograft for EHL reconstruction. Park et al.[24] reported a case of a 15-year-old male who experienced three or four episodes of a painful pop in his foot over one year and presented with an inability to extend his hallux for two weeks. Examination revealed an inability to extend the IP joint of the hallux with associated flexion deformity, but passive range of motion (ROM) was preserved. Ultrasound imaging showed multifocal partial ruptures of the EHL tendon with associated tendon thickening and increased fluid within the tendon sheath.

Tuncer et al.[7] described a case of iatrogenic injury to the EHL in a 40-year-old male submitted to arthroscopic debridement for early degeneration of the tibiotalar joint where the anterior joint capsule was breeched using a radiofrequency probe and the extensor tendons were exposed, but no tendon injury was noted. The patient experienced a painful pop in the anterior ankle ten weeks postoperatively. Clinical examination revealed an inability to extend the first three toes. Rupture of the EHL, second, and third extensor digitorum longus (EDL) tendons was diagnosed. The diagnosis was confirmed with magnetic resonance imaging (MRI). The patient initially deferred surgical treatment, but he ultimately underwent EHL reconstruction with a semitendinosus graft and direct repair of the EDL tendons six weeks later.

Lohrer and Nauck.[30] presented a case of a 32-year-old female who was a former world champion in roller skating with a history of six prior surgeries in the previous three years for EHL tenosynovitis. The patient experienced a painful pop in the foot when sprinting two days before evaluation. Physical examination revealed a flexion deformity of the hallux, an inability to extend the IP joint of the hallux, and normal passive ROM. No advanced imaging was reported for further evaluation of the injury.

Kwapisz et al.[17] reported a case of an 18-year-old male kickboxer who experienced two years of pain over the dorsum of his foot and ten months of inability to extend the hallux. Exam revealed an inability to extend the IP joint of the hallux and weakness with extension at the MP joint. Normal passive ROM was observed. The diagnosis of EHL tendon rupture was confirmed with ultrasound and MRI.

## Surgical Technique

Three authors described using a two-incision technique to isolate the EHL tendon stumps[7,24,30], while Kwapisz et al.[17] did not describe the incisions used. In general, a longitudinal incision over the dorsal aspect of the hallux IP joint is used to identify the distal stump of the EHL tendon. The second incision is used to identify the proximal stump of the EHL tendon and is based on the proximal aspect of the anterior ankle to expose the extensor retinaculum and associated tendons. Once the tendon stumps were identified proximally and distally, areas of obvious nonviable and degenerative tendons were debrided[7,17]. A description of semitendinosus autograft harvest was not reported in any of the studies.

After identification of the tendon stumps, the semitendinosus autograft was passed between the two incisions for reconstruction. Kwapisz et al.[17] established tension of the EHL tendon reconstruction with the ankle in a neutral position and the hallux joints in dorsiflexion, then performed an end-to--end suturing technique for graft fixation distally and circumferential repair to the stump proximally. Lohrer and Nauck.[30] defined the tension of the tendon reconstruction with both the ankle and hallux held in dorsiflexion. Distal fixation of the HT autograft was performed using a transosseous technique at the hallux's distal phalanx, and proximal fixation was performed with a side-to-side anastomosis to the proximal EHL stump. In addition, the position of the hallux IP joint was held with temporary Kirschner wire fixation that was removed at four weeks postoperatively. The remaining two studies did not provide details regarding setting tension of the reconstruction, and both opted to perform the Pulvertaft suture technique proximally and distally for fixation[7,24].

In our practice, a single longitudinal incision over the anterior ankle and dorsal aspect of the foot is performed to evaluate the entirety of the tendon and identify the zone of injury (Figures 2A and 2B). Next, tendon stumps are isolated and held within the surgical field using hypodermic needles while the ankle and first MP joint are held in maximal dorsiflexion, and the nonviable tissue is debrided (Figures 2C and 2D). Once debridement was completed, a braided absorbable suture was placed in a continuous locking loop configuration in both the proximal and distal stumps to bridge the resulting tendon gap (Figures 3A and 3B). The harvested semitendinosus tendon autograft is prepared in a triple-bundle fashion to increase the maximal load of graft failure. The prepared graft is then used to reconstruct the EHL using a Pulvertaft technique for fixation into the proximal and distal tendon stumps (Figures 3C and 3D).

## Post-Operative Protocol

Two studies used a short leg splint for postoperative immobilization[7,24]. In addition to the splint, Park et al.[24] used a hook over the nail of the hallux, which was attached to a rubber string fixed to the upper portion of the ankle to allow passive extension and limit tension across the reconstruction. Tuncer et al.[7] immobilized the patient in a neutral position in a short leg splint with the ankle and toes. Kwapisz et al.[17] used a short leg cast for immobilization with plantar support beneath the hallux. Lohrer and Nauck[30] also used a short leg cast fitted with plantar support beneath the hallux but also

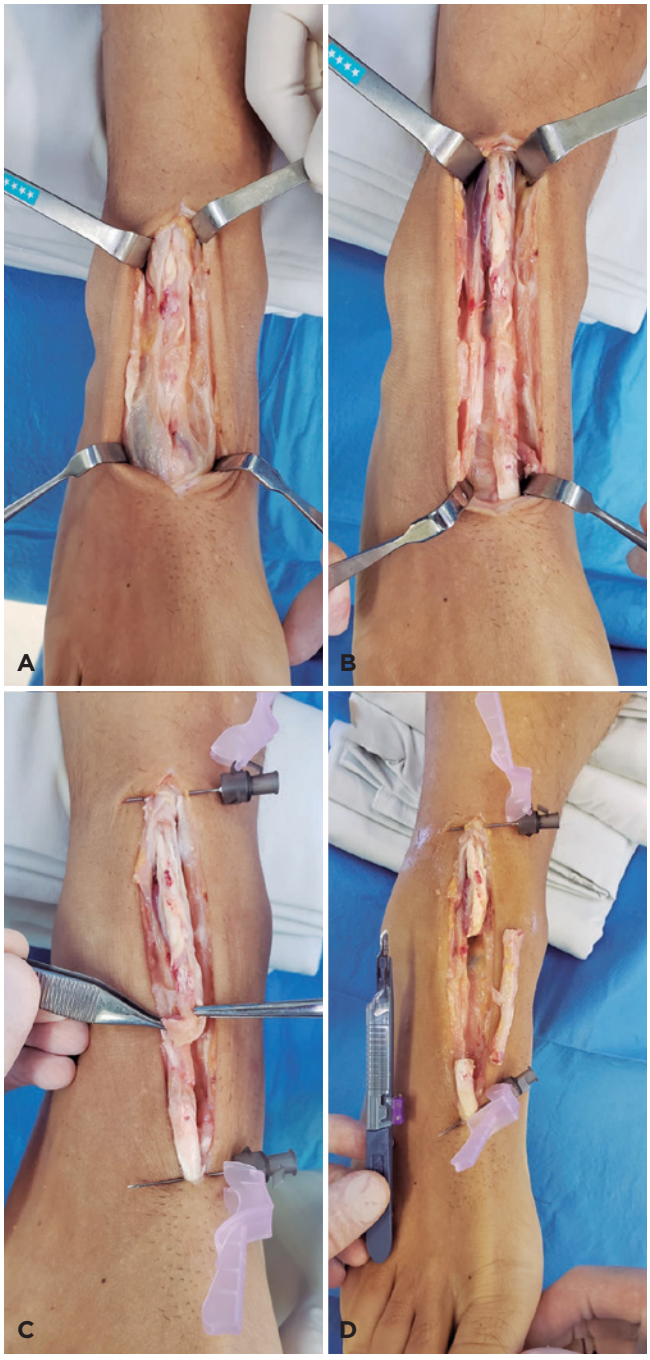


**Figure 2.** (A) Incision on the anterior ankle and dorsal aspect of the foot showing the diseasedextensor hallux longus (EHL). (B) Further exposure of the EHL tendon to identify the extent of pathology. (C) Viable tendon is identified proximally and distally and pinned in place using hypodermic needles with the ankle and first metatarsophalangeal joint in maximal dorsiflexion. The viable tendon is held in maximum tension, which also demonstrates the redundancy and poor quality of the chronic EHL tendon injury. (D) Nonviable tissue is debrided and the tendon stumps are seen with the resulting tendon gap.

used a hallux suspension sling and temporary Kirschner wire fixed across the hallux IP joint to maintain a dorsiflexed position.

Park et al.[24] allowed for passive extension and active flexion of the hallux within the splint during the first six weeks, then transitioned to active extension and flexion exercises


**Figure 3.** (A and B) Suture bridge between the proximal and distal stumps creating a pathway to put the autograft. (C and D) Fixation of the autograft in the tendon defect and final reconstruction.

out of the splint. Kwapisz et al.[17] transitioned patients out of the cast into a boot with plantar support postoperatively for six weeks while remaining non-weight bearing. Passive ROM was initiated at three weeks. Active ROM and free ambulation were allowed starting in the seventh week. Tuncer et al.[7] also allowed for passive ROM at three weeks in a removable splint and transitioned to active extension at 12 weeks postoperatively. Lohrer and Nauck[30] restricted weight-bearing for seven weeks, and the patient was transitioned to a walking boot with a 30-degree plantar wedge for the hallux. The wedge was weaned and removed at 14 weeks postoperatively. A night splint was utilized until five months, jogging was allowed at seven months, and release to full sports was achieved at nine months postoperatively.

### Follow-up and outcomes

Park et al.[24] reported the shortest follow-up period of six months. The patient was doing well, with no discomfort during activities. Examination revealed normal ROM and a slight decrease in extension strength compared to the contralateral side.

Kwapisz et al.[17] reported eight months of follow-up where the patient had full function without pain. Examination revealed minimal limitation in extension strength and five degrees of limited extension at the MP joint compared to ROM of the contralateral side. In addition, a dynamic ultrasound was obtained that showed smooth gliding of the reconstructed EHL tendon, and pedobarography revealed symmetric pressure distributions.

Lohrer and Nauck[30] reported 19 months of follow-up where the patient had postoperative improvement in Foot Function Index and American Orthopedic Foot and Ankle Society Hallux metatarsophalangeal-interphalangeal joint scores when compared to preoperative state. Examination demonstrated full strength and five degrees of limited plantar flexion.

Tuncer et al.[7] reported the absence of any symptoms at one year of follow-up, but no postoperative examination was reported.

## Discussion

While there appears to be a consensus regarding treating acute EHL tendon rupture with direct primary repair, there is limited evidence regarding the best method for the treatment of nonrepairable EHL tendon injuries[9–11]. The current study performed a systematic literature review and presented four cases of EHL tendon reconstruction using a semitendinosus autograft. All patients are reported to have satisfactory outcome with no complications. However, there may be a minimal decrease in hallux extension strength or a decrease in overall ROM of approximately five degrees[17,24,30]. These findings may not be clinically relevant as each patient reported no symptoms or limitations.

Indications for pursuing an EHL reconstruction have not been established. When possible, direct end-to-end primary repair of an acute EHL tendon rupture yields satisfactory results[3,12–15]. However, chronic rupture of greater than six weeks may result in tendon retraction and scar tissue formation[9,18]. In addition, patients with antecedent symptoms before rupture or previous failed primary repair may require extensive tendon debridement during the surgical intervention[7,17,25,29,30]. These historical factors may indicate an injury resulting in a large tendon gap that cannot be directly repaired. Clinical examination of an EHL tendon rupture will often demonstrate a lack of extension at the IP joint of the hallux with an associated flexion deformity and normal passive ROM. Plain radiographs should be obtained to exclude the possibility of an osseous avulsion injury. Further evaluation with advanced imaging, such as ultrasound or MRI can be used to confirm the rupture, evaluate for concomitant injuries, define the size of the tendon gap, and evaluate the quality of the tissue that remains[7,17,24].

When indicated, an HT autograft for EHL reconstruction appears to be a viable treatment option. The major disadvantage of using an autograft for tendon reconstruction is donor site morbidity. Cody et al.[28] demonstrated minimal donor site morbidity when using HT autograft for various foot and ankle reconstructive procedures. Also, many autograft choices are available and have been described for EHL reconstruction, including the EDL[3,25], EHB[20], extensor hallucis capsularis[22], split peroneal longus[18], and palmaris tendons[12]. It is unknown what the best choice for EHL reconstruction is, but some argue that the semitendinosus autograft better matches the caliber of the EHL tendon and provides substantial length to reconstruct large defects[7,17,24].

In addition to autograft EHL reconstruction, the allograft is another treatment option. EHL reconstruction using a tensor fascia lata allograft in combination with IP joint arthrodesis has been reported and resulted in weakness with minimal active extension of the hallux at ten months[26]. The major advantages of allograft reconstruction are the ability to avoid donor site morbidity and reduce surgical times. The possible disadvantages of allograft include limited graft availability, increased costs, immunologic reaction to the graft, sterilization process affecting graft integrity, and risk of disease transmission[31–34].

If tendon reconstruction is not desired or unable to be performed, a tendon transfer or side-to-side tenodesis to the neighboring EDL tendon has been described for treating nonrepairable EHL injuries[6,19,21,23]. Tendon transfers most commonly use the EDL tendon[19,23], but a transfer of the peroneus tertius has also been reported[4]. These procedures can be used routinely but may be particularly useful in scenarios where the proximal tendon stump cannot be identified for reconstruction. In addition, some small tendon defects may be amenable to lengthening the healthy EHL tendon stump to bridge the defect for repair[35], similar to techniques described for tibialis anterior ruptures[36]. However, this repair may require augmentation with additional material, such as an acellular dermal scaffold[27]. Lastly, IP joint arthrodesis may have a role in treating nonrepairable EHL injuries, but there is a lack of evidence regarding indications and outcomes of this procedure for nonrepairable EHL injuries[17,26,29,30].

Regarding tendon fixation strategies, it is important to distinguish the need for a direct tendon repair versus a tendon reconstruction procedure. A direct tendon repair is often performed as an end-to-end repair as there is minimal tendon retraction resulting in acceptable tension at the repair site; however, increased strength is often needed when performing a tendon reconstruction with a graft such as side-to-side or Pulvertaft weave techniques, which allows increased suture fixation between the tendons[37]. However, there is concern that an increased suture can compromise the vascular supply to the tendon and limit healing[25]. Gabuza et al. compared the Pulvertaft weave to the side-to-side technique and found that the weave technique has greater resistance, which increases with the number of weaves[38]. Conversely, other investigations have found no difference between these two techniques, while others have demonstrated greater repair strength with the side-to-side method. Wagner et al.[39] analyzed the strength of various side-to-side tenorrhaphy configurations using porcine flexor digitorum longus tendons and found a significantly lower failure load with a vertical mattress configuration compared to a running locked, eight simple, and pulley suture configurations. While the Pulvertaft weave is our preferred method, a side-to-side repair is another viable option.

The decision between using a tendon transfer, tendon tenodesis, reconstruction with autograft, or reconstruction with allograft is controversial. However, if tendon reconstruction is performed, the postoperative protocol and rehabilitation are critical for optimization of outcomes. Initial use of plantar support to prevent flexion of the hallux and limit tension on the reconstruction is recommended. If immobilization is prolonged, formation of adhesions and scar tissue may develop. It results in limited tendon excursion, decreased ROM, and possible need for tenolysis. To combat adhesion and scar formation, rehabilitation principles from the upper extremity have been adopted, including early passive ROM[40]. The use of a dynamic splint for the hallux following EHL tendon repair or reconstruction to provide an early passive extension to prevent scarring and adhesions has been described[15,24].

The main limitation of the present study is the lack of data available on this clinical topic. Only four case reports could be obtained for evaluating EHL reconstruction using an HT autograft. The differences in preoperative evaluation, surgical technique, postoperative rehabilitation, and reporting of outcomes created a heterogeneous sample of patients making it difficult to evaluate these reports collectively. In addition, there are no comparison studies evaluating outcomes and complications between the available procedures for a nonrepairable EHL injury. This limits our ability to make recommendations regarding indications for the various treatment options or to assess treatment superiority. The major strength of the study is the consolidation of the available case reports regarding EHL reconstruction using HT autograft to evaluate the efficacy of this treatment modality.

## Conclusion

There is limited evidence to guide the treatment of nonrepairable EHL tendon ruptures. A systematic review was performed to evaluate the use of HT autograft for EHL reconstruction. Four cases of EHL tendon reconstruction using a semitendinosus autograft were reviewed, and it appears to be a viable treatment with satisfactory outcomes and no complications reported. Further investigation is needed to determine the indications and efficacy of the various treatment modalities for nonrepairable EHL injuries.

**Author's contributions:** Each author contributed individually and significantly to the development of this article: DLR*( https://orcid.org/0000-0003-0183-8641) Conceived and planned the activities that led to the study, data collection, statistical analysis, wrote the article; ESH *(https://orcid.org/0000-0002-6261-3617) Conceived and planned the activities that led to the study, data collection, statistical analysis, wrote the article; GB*(https://orcid.org/0000-0001-5273-4303) Conceived and planned the activities that led to the study, data collection, statistical analysis; DDB*(https://orcid.org/0000-0002-7599-4244) Participated in review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID)

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Systematic Review

# Hallux valgus and percutaneous surgery: treatment evaluation

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## Abstract

**Objective:** Evaluate the treatment of hallux valgus through percutaneous surgery.

**Methods:** This is a systematic review, and the search was conducted on PubMed/Medline and Virtual Health Library (VHL) databases. The search included studies that addressed percutaneous surgery and analyzed the American Orthopaedic Foot & Ankle Society (AOFAS) score, published between 2013 and 2018, as original studies, in English, Portuguese and Spanish.

**Results:** One-hundred and eighty-five articles were identified in the databases, 19 were selected for STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) application, and five were included in the systematic review. The majority of the studies were European; the age of the patient was from 17 to 78 years, who suffered from mild to severe deformities, which were evaluated radiographically and through the AOFAS scale, then submitted to minimally invasive surgeries. Postoperative follow-up was from six months to ten years.

**Conclusion:** The percutaneous technique for hallux valgus correction has shown good results, little surgical trauma, few complications, rapid recovery, return to activities and high satisfaction with the result.

**Level of Evidence I; Systematic Review of Level I Studies.**

**Keywords:** Hallux valgus/surgery; Osteotomy; Metatarsophalangeal joint.

## Introduction

The hallux valgus (HV) is a multifactorial deformity characterized by a 5° deviation of the first ray and 10° of the first metatarsal, commonly associated with medial exostosis of the first metatarsal and pain in its prominence, being more frequent in women (88%), with a mean age of 55 years[1].

Hallux valgus can result from extrinsic factors, such as inadequate footwear (shoes with narrow anterior chamber), heredity, gender, age, and foot anatomy[1]. It presents with pain in the medial eminence of the first ray of the forefoot (70%), associated with metatarsalgia (40% of cases). It can also be associated with "bunion" (medial bone exostosis) and other foot comorbidities, which are evaluated on physical examination[1,2].

The HV classification and the treatment method choice are made considering radiological evaluation. It will allow the measurement of the altered main angles and assist in classifying the pathology as mild, moderate, or severe[1].

From the classification, the treatment method can be decided, whether conservative, in which the patient will try to acquire new habits, using more appropriate footwear or surgical, which can be open or closed (percutaneous). In this systematic review, the closed treatment will be addressed, represented by percutaneous surgery, which is a minimally invasive treatment, and brings with it the advantage of less surgical time, less surgical trauma (small incisions), and consequently, minor complications and faster recovery[3].

Percutaneous surgeries are osteotomies, exostectomy, and soft tissue release through incisions of 1-3mm length, under intraoperative fluoroscopy, using a mini-blade[4] scalpel[5,6].

Two main osteotomies are described in the percutaneous approach: Reverdin-Isham and Bösch osteotomies. The first is a distal osteotomy, which corrects mild to moderate deformities. The second is a metaphysis distal osteotomy that corrects severe deformities[7-16].

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In the literature, few studies address percutaneous techniques associated with HV, as they are relatively new techniques, requiring greater comparations, studies, and clarifications. In addition, most studies address the method, not considering patient improvement. Therefore, it is necessary to evaluate the percutaneous surgery for HV through an extensive and comparative literature review that confirms the technique's efficacy compared with traditional treatment.

## Methods

The question chosen was made through the PICO strategy:

P - POPULATION: people affected by the hallux valgus

I - INTERVENTION: percutaneous surgeries

C - CONTROL: open surgeries or conservative treatment

O - OUTCOME: patient improvement and satisfaction

A systematic review was conducted by searching for articles in the literature on HV associated with percutaneous surgery (observational and cross-sectional studies), where the evidence was synthesized and critically evaluated to determine whether the data were relevant and beneficial enough to apply this technique to the patient.

After data searching, the affected population was separated by age, gender, prevalence of unilateral or bilateral foot involvement, follow-up period, and any withdrawal from the studies due to complications.

It was noted that the percutaneous technique might be different regarding the surgeon's choice. The correction of the main foot angles was also examined by analyzing radiographic data that followed the pre-and postoperative periods. As a result, corrections were verified: hallux valgus angle (HVA), intermetatarsal angle (IMA), and distal metatarsal articular angle (DMAA).

The American Orthopaedic Foot & Ankle Society (AOFAS) score was also analyzed, and the complications of percutaneous surgery were considered.

Systematic data research was performed in PubMed/Medline and Virtual Health Library (VHL) databases from 2013 to 2018, searching for original articles that used percutaneous surgery in HV treatment.

"Hallux valgus" and "percutaneous surgery" were the two terms used in the search, and 185 articles were found. After identifying the titles, the abstract was read, all relevant studies were included to confirm eligibility through the full-text read.

The inclusion criteria were original articles that addressed HV correction through percutaneous surgery, published within the last five years. In addition, articles that included AOFAS score, level of evidence I to IV, and compared open surgical techniques.

The exclusion criteria were systematic reviews, articles describing only the surgical technique or that did not report the perception, improvement, and satisfaction of patients, articles that addressed the open technique exclusively, articles with publication over five years, and studies not available for a full-text read. In addition, studies with children, cadavers, and animals.

After the selection process, 22 articles were included in the eligibility criteria. Then, the PRISMA protocol was applied, which helped to improve the quality of data extraction. Once the eligible studies were identified, data were extracted and compared following the protocol:

1) number of participants; 2) number of feet on which the surgery was performed; 3) age; 4) gender; 5) surgical techniques and indications (mild, moderate, or severe deformity); 6) follow-up time; 7) improvement of HVA, IMA, and DMAA; and 8) AOFAS score.

The methodology quality was evaluated using STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) application.

## Results

The strategies mentioned above were applied to identify and select the studies. In the first stage, the search identified 185 articles, of which 94 were excluded, leaving 91 articles. Then, the title and abstract of each study were read.

In the second stage, 41 duplicates were identified, one was in German, one in Italian, 11 review articles, four experts opinion, and two were excluded, leaving 31 articles to advance to the eligibility stage, where the full-text read was completed. Of these, eight were excluded because they did not use the AOFAS score, and four were not fully available. Thus, 19 articles were selected for STROBE, and five were included in the systematic review after STROBE evaluation.

### General characteristics of the selected studies

The study by Faour-Martín et al.[17] was conducted in 2013 in Spain, with 87 patients (115 feet) affected with HV unilaterally and bilaterally. This prospective study aimed to show ten years of follow-up of patients submitted to percutaneous surgery techniques. The same surgeon performed the surgeries using a technique first described by Bösch (percutaneous subcapital osteotomy). The results showed improvement in the AOFAS score, from a mean of 47.1 points in the preoperative to a mean of 89.3 points ten years after surgery. It was also evidenced that there was pain improvement (0 - 40 points) from 18.4 to 36.5 points, functional capacity improvement (0 - 45 points) from 22.5 to 40.6 points, and alignment improvement (0 - 15 points) from 6.2 to 12.2 points. There was also radiographic analysis that showed IMA improvement from a mean of 17.6° (mild deformity) to 8.1° (no deformity/mild deformity), HVA improvement from a mean of 34.2° (moderate deformity) to 14.6° (no deformity/mild deformity), and DMAA improvement from a mean of 15.4° to 7.2°. The study did not indicate limitations in its development.

The study by Biz et al.[18] was conducted in 2016 in Italy, with 80 patients submitted to unilateral surgeries. This prospective longitudinal study aimed to clinically and radiologically evaluate patients affected with mild to severe HV submitted

to minimally invasive surgeries. A sequence of techniques was applied, Reverdin-Isham procedure was the first, followed by Akin osteotomy, and finished with a lateral soft tissue release. The study showed improvement in the AOFAS score, from a mean of 54.1 points in the preoperative to a mean of 87.1 points 45 months after surgery. It also showed pain improvement, angle alignment, and daily activities. There was also radiographic analysis showing IMA improvement from a mean of 12.9° (moderate deformity) to 9.0° (no deformity/mild deformity), HVA improvement from a mean of 26.4° (moderate deformity) to 13.9° (no deformity/mild deformity), and DMAA improvement from a mean of 10.12° to 5.2°. The limitation of the study was the lack of a control group to compare the results of the techniques.

The study by Lucas y Hernandez et al.[19] was conducted in 2016 in France, with 38 patients (45 feet) submitted to percutaneous extra-articular reverse-L Chevron (PERC) osteotomy. This prospective study aimed to describe the prognostic factors and results of PERC in treating moderate HV. The results showed improvement in the AOFAS score, from a mean of 62.5 points in the preoperative to a mean of 97.1 points five years after surgery. There was also radiographic analysis that showed IMA improvement from a mean of 11.8° (moderate deformity) to 7.9° (no deformity/mild deformity), HVA improvement from a mean of 26.2° (moderate deformity) to 9.6° (no deformity/mild deformity), the DMAA analysis was not performed in the study. On the other hand, results were analyzed for proximal articular set angle ( PASA), tangential angle of the second axis (TASA), and interphalangeal angle (IPA). The study did not indicate limitations in its development.

The study by Lee et al.[20] was conducted in 2017 in Australia. A randomized prospective study comparing the Chevron/Akin percutaneous technique (PECA) and open Scarf/Akin (SA) osteotomies. The study included 50 patients with moderate or severe HV, randomized into two groups. The objective of this study was to observe the results and complications of both techniques. The AOFAS questionnaire, visual analog scale (VAS), and radiographic follow-up were performed to assess the change of angles. The PECA results showed an improvement in the AOFAS score, from a mean of 61.3 points in the preoperative to a mean of 88.7 points six months after surgery. Radiographic evaluation showed IMA improvement from 15.6° to 6.4° and HVA from 31.4° to 7.6°. In comparison, the SA technique showed an improvement in the AOFAS score, from a mean of 58.5 points in the preoperative to a mean of 83.0 points six months after surgery. Radiographic evaluation showed IMA improvement from 15.7° to 7.6° and HVA from 31.2° to 10.1°. The DMAA was not analyzed in any of the techniques. The limitations of the study were a limited sample, with few participants in each group, the non-validation of the analysis method, and the use of a "popular" procedure in the control group; the ideal would have been compared with known techniques for more reliable data.

The study by Kaufmann et al.[21] was conducted between 2017 and 2018 in Austria. A randomized prospective study comparing the Open Chevron (OC) technique and the minimally invasive Chevron technique (MIS). The study included 42 patients (47 feet) affected with moderate or severe HV, randomized into two groups. The study aimed to compare the two techniques, and the hypothesis was to find significant differences between the clinical and radiographic results in the range of motion of the first metatarsophalangeal joint and patient satisfaction. The AOFAS score, the VAS score, and the follow-up radiographic evaluation were applied. The OC results showed an improvement in the AOFAS score, from a mean of 66.5 points in the preoperative to a mean of 90 points nine months after surgery. Radiographic evaluation showed IMA improvement from 15.15° to 5.85° and HVA from 28.25° to 8.5°. In comparison, the MIS technique showed an improvement in AOFAS score, from a mean of 65.0 points in the preoperative to a mean of 85.0 points nine months after surgery. Radiographic evaluation showed IMA improvement from 14.0° to 6.8° and HVA from 26.4° to 7.6°. The DMAA was not analyzed in any of the techniques. The limitations of the study were the inclusion of one center with a single surgeon and the preliminary result of nine months of follow-up.

The quality of the selected studies was evaluated based on the STROBE initiative's criteria. Of the 19 articles analyzed by STROBE, ten achieved a 16.5 score, higher than the average. The 2.5 standard deviation was calculated and applied to refine the study better. Thus, five articles were selected to be evaluated in this systematic review. For the selection, 1 point was assigned to articles that fully met the STROBE analyzed criterion, 0.5 to which partially attended, and 0 to those that did not meet the criterion or were not well elucidated.

## Discussion

The HV is a multifactorial deformity affecting the forefoot, which is more frequent in women, with a mean age of 55.

To classify HV, a classification system is used and considered mild deformity (HVA <20°, IMA ≤11° and less than 50% of medial sesamoid subluxation), moderate deformity (HVA between 20° and 40o, IMA >11o and <16°, with 50 to 75% tibial sesamoid subluxation), and severe deformity (HVA > 40o, IMA ≥16° and more than 75% tibial sesamoid subluxation)[1].

Clinical evaluation of HV can be done using the AOFAS score, assessing pain, functional capacity, and hallux alignment. This scale ranges from 0 to 100 points, and 100 is the best result[5].

Radiographic results, in conjunction with the AOFAS score, lead to a conclusion about whether patients improved through conservative or surgical treatments.

In this review, three studies aimed at first analyzing the results of long-term percutaneous surgery with follow-up of at least four years[17-19]. Two studies analyzed the results of percutaneous surgery compared with open surgery, including immediate and a minimum period of six months[20,21].

When comparing the studies, the best mean HVA correction was obtained by Lee et al.[20] with 23.8° variation. The best mean IMA correction was obtained by Faour-Martín et al.[17] with 9.5° of variation. The best mean DMAA correction was

obtained by Faour-Martín et al.[17] with 8.2° variation. The highest mean AOFAS score was obtained by Faour-Martín et al.[17], with a variation of 42.2 points from preoperative to postoperative. All results were satisfactory.

The best immediate radiographic/surgical response was found by Lee et al.[20]. However, in this study, the population sample was limited, including 50 patients submitted to surgery, with 25 patients in each group. The same in Kaufmann et al.[21], with an improvement of more than 70% in hallux correction, however, its sample was limited to 42 patients, divided into percutaneous and open techniques, and its follow-up time was also short (nine months).

Faour-Martín et al.[17], Biz et al.[18], and Lucas y Hernandez et al.[19] had the best response of AOFAS scores which were the longest follow-up period. As it is a more subjective scale, which has the patient's opinion, it is understandable that the best results are from those with the longest period, because, despite the percutaneous surgery obtaining satisfactory immediate results, it is necessary time to evaluate the improvement of quality of life and functional capacity.

Faour-Martín et al.[17] obtained the best AOFAS score with a ten-year follow-up, achieving a mean improvement of 42.2 points, corresponding to 42.2% on a scale of 100 points. Biz et al.[18] and Lucas y Hernandez et al.[19], in turn, followed for four and five years, respectively, and obtained mean variations above 33% of the preoperative value.

Comparing Lee et al.[20] and Kaufmann's[21] AOFAS, the improvement was significant but represented only 20 to 27%, and perhaps with a longer study period, they would prove that the percutaneous technique used has better long-term results, after all, both were published in 2017 and 2018.

In the pain assessment, the best response was Faour-Martín et al.[17], with 93% of patients without any or little pain.

The best satisfaction response, which is tied to aesthetics and improved functional capacity, pain, and complications over time, was noticed by Lucas y Hernandez et al.[19], with 97% satisfaction of their patients. However, his sample was small, and paradoxically, many complications were reported in his study.

The limitations of the study were no significant studies included the local population, so the hallux valgus improvement through percutaneous surgery in the Brazilian population could not be studied. In addition, understanding the various techniques in the studies, due to the variety of more than 100 techniques described in the literature, and the choice varies according to the surgeon's abilities, only practice and long-term study can show which is the "best" technique.

## Conclusion

Percutaneous surgery techniques for hallux valgus correction have good results regarding the procedure and patient satisfaction. Nevertheless, there are still few studies with a high level of evidence, thus having to use more time and resources to prove this treatment's better efficacy.

**Authors' contributions**: Each author contributed individually and significantly to the development of this article: ATCN *(https://orcid.org/0000-0003-1888-7212), and VPN *(https://orcid.org/0000-0002-9028-0637) Conceived and planned the activity that led to the study, interpreted the results of the study and approved the final version; LAAS *(https://orcid.org/0000-0002-2443-3324) Interpreted the results of the study, bibliographic review, data collection and formatting of the article; JESJ *(https://orcid.org/0000-0001-8810-4127), and FD (https://orcid.org/0000-0001-8681-9428), and MAM *(https://orcid.org/0000-0002-3592-986X) Participated in the review process; JAA *(https://orcid.org/0000-0003-3248-580X) Did the bibliographic review. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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Technical Tips

# Posterior femoral hemiepiphysiodesis for genu recurvatum with equinus foot deformity: a novel surgical proposal

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## Abstract

*Genu recurvatum* is characterized as an hyperextension deformity of the knee in the sagittal plane and can be associated to structured equinus deformity of the ankle and foot. Amongst its causes are conditions like arthrogryposis, cerebral palsy, tibial tuberosity arrest, poliomyelitis and syndromes with generalized ligamentous hyperlaxity. The treatment of this condition can be challenging, specially when associated with equinus of the foot and, to date, aggressive methods such as femur or tibia osteotomies are the most used for its correction. We describe here a safe and minimally invasive technique with posterior hemiepiphysiodesis of the distal femur performed with transphyseal screws for correction of the *genu recurvatum* with apex on the distal femur associated with rigid equinus of the foot due to tarsal coalition. This technique has great potential for correcting the recurvate knee in the immature skeleton and can be an excellent alternative to the more aggressive methods currently used for the treatment of this deformity.

**Level of Evidence V; Therapeutic Studies; Expert Opinion.**

**Keywords:** Child; Knee; Joint deformities, acquired; Orthopedic procedures/methods.

## Introduction

*Genu recurvatum* is characterized as an hyperextension deformity of the knee in the sagittal plane. When untreated, it is associated with short and long-term complications, such as joint pain and early gonarthrosis, especially when associated with ipsilateral foot deformity. In extreme cases, there may even be anterior knee dislocation[1-3].

Recurvatum is an unusual deformity of the knee in children and amongst its causes are conditions such as arthrogryposis[4], cerebral palsy [5-7], poliomyelitis, sequelae of the tibial tuberosity fracture[8,9], and some syndromes with generalized joint hypermobility[1,10]. When there is a structured equinus deformity of the ankle and foot, the knee with joint hypermobility can deform into recurvatum due to the vector resulting from the relative posteriorization of the proximal tibia and anteriorization of the load axis to the knee.

It is important to highlight that the genu recurvatum's treatment is challenging, especially when associated with structured equinus of the foot. When the deformity is significant and surgical correction is indicated, soft tissue procedures can be used, such as quadricepsplasty[11] and hamstrings lengthening[6,12], as well as osteotomies of the distal femur and proximal tibia with internal[13] or external fixation[14,15] to correct bone alignment. The aforementioned surgical procedures are aggressive and require a long recovery time, and are subject to risks like neurovascular injury, compartment syndrome and infections.

Study performed at the Hospital Israelita Albert Einstein, São Paulo, SP, Brazil.

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Considering this scenario and searching for less aggressive methods with excellent potential for correcting this angular deformity, we have used the guided growth with posterior hemiepiphysiodesis of the distal femur to correct the genu recurvatum. In this study, we present a novel surgical technique performed on a patient with genu recurvatum resulting from joint hypermobility associated with structured equinus deformity of the ankle. The procedure has been performed with two cannulated transphyseal screws inserted in the posterior portion of the distal femoral physis. The clinical and radiographical results showed significant improvement in the deformity and in ankle and foot biomechanics.

## Surgical Technique

The patient was positioned in horizontal dorsal decubitus. Two 1cm longitudinal incisions were made on the anterior face of the distal thigh, and blunt dissection was performed through the quadriceps muscle to the anterior face of the distal femur in an area proximal to the epiphyseal disc.

Percutaneously and using fluoroscopic images in the coronal and sagittal planes, two guide wires were inserted (one for each incision) in anterior to posterior and proximal to distal directions, crossing the distal femoral epiphyseal disc in its posterior third, close to the subchondral edge of the medial and lateral femoral condyles. Two 4.5mm cannulated fully threaded screws were inserted through the guide wires, with the tips of the screws placed completely in the distal femoral epiphysis (Figure 1). Subcutaneous and skin sutures were then performed.

## Clinical Case

A nine-year-old patient with a unilateral 32° recurvatum knee deformity caused by joint hypermobility associated with fixed equinus deformity of the ankle due to tibiotarsal and subtalar ankylosis, calcaneocuboid and talonavicular coalition (Figures 2 and 3). Surgical treatment was performed and the patient was followed until achieving complete correction of the deformity. Immediate weight bearing was allowed after surgery. Every four months, the degree of the deformity was evaluated clinically and radiographically until its complete correction, and then the screws were removed. The time to correct the deformity was 15 months, with a follow-up of 23 months.

There were no perioperative complications, and there was no recurrence of the deformity measured by the femorotibial angle in the sagittal plane since the bone alignment of the lower limb in the sagittal plane was corrected.

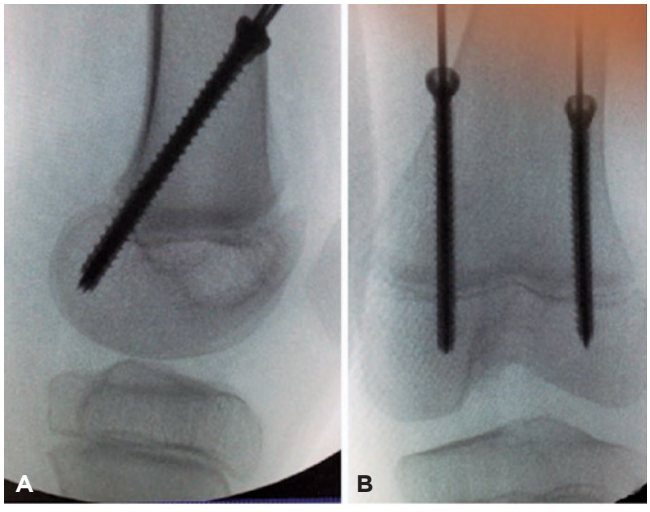


**Figure 1.** Intraoperative control of posterior hemiepiphysiodesis of the distal femur with two cannulated screws guided by metallic wires (A) lateral view; (B) anteroposterior view.

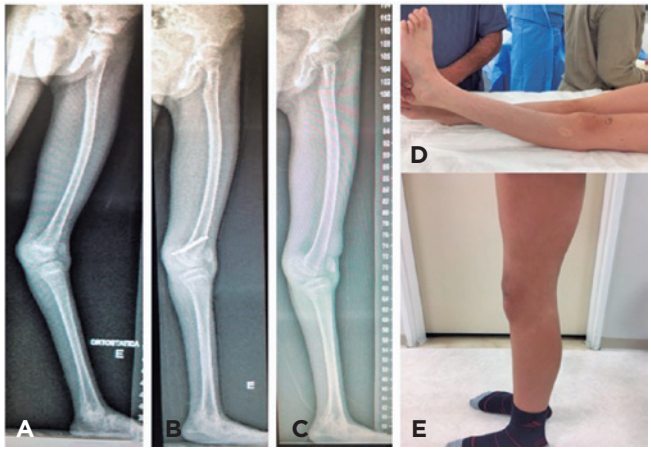


**Figure 2.** (A) Lateral panoramic radiograph of the left lower limb, demonstrating genu recurvatum deformity of 32o, due to joint hypermobility. (B) Lateral panoramic radiograph of the left lower limb, 13 months after posterior distal femoral hemiepiphysiodesis, correcting genu recurvatum deformity. (C) Lateral panoramic radiograph 14 months after screw removal, maintening the correction of genu recurvatum. (D) Preoperative lateral photograph of the left lower limb, demonstrating genu recurvatum deformity. (E) Photograph after 12 months of genu recurvatum correction.


**Figure 3.** Radiographs in the orthostatic profile of the right and left feet showing ankylosis of the left ankle and hindfoot.

## Discussion

The knee recurvatum, or in hyperextension (genu recurvatum), may have its origin in bone deformities affecting the tibia or femur, neuro-orthopedic diseases[6], traumatic fracture or epiphysiodesis of the tibial tuberosity, infections, iatrogenic[9], capsule-ligament malformations by arthrogryposis and syndromes with joint hypermobility. The clinical characteristics are posterior knee angulation, unilateral or bilateral, depending on the etiology. During the patient's walk, there may be claudication, especially when unilateral or asymmetrical. The orthostatic radiographic analysis with the knees in maximum extension defines the origin of the deformity (bone, joint or mixed); it allows the angle calculation of the femorotibial deformity. The association with equinus deformity of the foot increases the deforming force at the knee level in the sagittal plane, resulting from the load axis anterior to this joint. The treatment of genu recurvatum depends on the clinical and functional repercussions and the degree of deformity.

Arthrogryposis, an important cause of genu recurvatum, is a condition that has existed since birth, with the rigidity of multiple joint deformities. The clinical presentation varies, which differentiates therapeutic options. In arthrogryposis, knee involvement is very common (38-90% of patients with amyoplasia), ranging from soft tissue contractions (in flexion or hyperextension) with instability, subluxation, or tibial femoral dislocation. Flexion contractures are more common and disabling, with significant resistance to treatment and a high recurrence rate[4]. Recurvatum deformities have a better prognosis for the ability to walk. According to the literature, the non-surgical treatment of genu recurvatum in arthrogryposis, with passive mobilization and orthoses, has failed in about one-third of cases. Therefore, surgical treatment is indicated when associated with the equinus deformity of the foot. According to Lampasi et al.[16], the most used methods to date are quadricepsplasty and femoral shortening-flexion osteotomies, which imply a higher complication rate than the percutaneous hemiepiphysiodesis with transphyseal screws described here.

The non-surgical treatment modalities of the genu recurvatum include physiotherapy, serial casting, and orthoses[16,17]. Surgery is for cases where the deformity is more resistant and part of the overall treatment plan, which may include correcting foot[18] and hip[6] deformities. Among the available surgical options, quadricepsplasty and other soft tissue procedures can be considered. In cases of bone deformities, supracondylar femur osteotomies with a posterior wedge removal, aiming at the angle normalization between the diaphysis and the intercondylar sulcus, is a surgical option described. Another treatment option is tibial osteotomy with anterior opening wedge, above the tibial tuberosity and with bone graft insertion[8]. Osteotomies can be combined with posterior capsular repair[19], mainly indicated in cases where premature closure of the anterior portion of the epiphyseal disc has occurred[9,15].

The most commonly used surgical treatment for genu recurvatum is performed with distal femur or proximal tibial osteotomies[13]. However, such procedures present high morbidity and risk of complications, demanding the search for less invasive, safer, and effective methods.

Guided growth is a treatment method for lower limb deformities in the sagittal plane. Jorneau[20] and Klatt et al.[21] described knee correction in flexion with guided growth by anterior distal femoral hemiepiphysiodesis with two plates (eight plates).

In 2021, Stevens et al.[22] described guided growth for tibial recurvatum by posterior proximal tibial epiphysiodesis using eight plates, obtaining excellent results. Kievit et al.[23] reported a case in which genu recurvatum was a complication of the treatment of lower limb length discrepancy through temporary epiphysiodesis of the distal femur and proximal tibia with eight plates. The hypothesis is that recurvatum was caused by the very anterior positioning of the plates. Then the recurvatum deformity was corrected with the surgical reapproach and posterior replacement of the plates on the distal femur.

To date, no surgical approach for treating genu recurvatum with posterior hemiepiphysiodesis of the distal femur with transphyseal screws has been described in the literature, as described here.

In this study, we report the surgical treatment of genu recurvatum with a novel technique performed through guided growth with the posterior hemiepiphysiodesis of the distal femur with two screws, indicated for deformities caused by capsule-ligament hyperextension associated with equinus deformity of the foot. However, this treatment is not indicated for situations with early closure of the anterior, femoral, or tibial epiphyseal plate by any etiology[15]. Eventually, in these situations, the posterior distal femur epiphysiodesis could only be indicated to reduce the deformity's progression during the residual growth.

Based on the study by Metaizeau et al.[24] on the techniques of guided growth, described for correction of deformities in the coronal plane (varus and valgus), we used two transphyseal cannulated screws positioned in the sagittal plane generating provisional posterior hemiepiphysiodesis of the distal femur to allow anterior distal femur growth, aiming to correct the deformity in genu recurvatum. In addition, a factor associated with genu recurvatum and equinus deformity of the foot can also be treated by the method described herein.

It is a minimally invasive, reversible method with a low complication rate, not requiring postoperative immobilization, and the patient can walk after the procedure and return to normal activities. However, it is important to emphasize the need for monitoring at short intervals to define the exact moment of screw removal, avoiding overcorrection with deformity inversion.

Patients with genu recurvatum due to ligament laxity have few options for physiotherapeutic or surgical treatment with soft tissue repair. Osteotomy treatment is reserved when there is great clinical involvement. The posterior hemiepiphysiodesis of the distal femur presented here is undoubtedly a less aggressive surgical alternative with lower risks, showing progressive and perennial correction after screw removal.

## Conclusion

The posterior hemiepiphysiodesis of the distal femur with transphyseal screws proved to be a safe and very useful method for genu recurvatum deformities whose apex is present in the femur, associated with joint hypermobility and fixed equinus deformity of the foot. This technique has great potential for correcting the genu recurvatum in the immature skeleton, being an excellent alternative to the more aggressive methods currently used to treat this deformity.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: NBM *(https://orcid.org/0000-0002-0705-1623) and, TOG *(https://orcid.org/0000-0001-9277-7746), and ARJ *(https://orcid.org/0000-0003-4267-4567) Conceived and planned the activities that led to the study, participated in the review process, approved the final version. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) .

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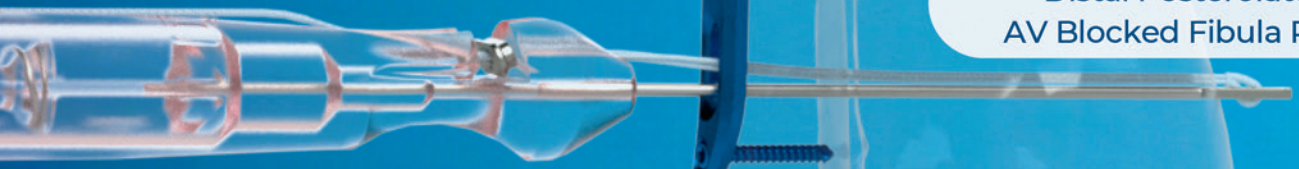

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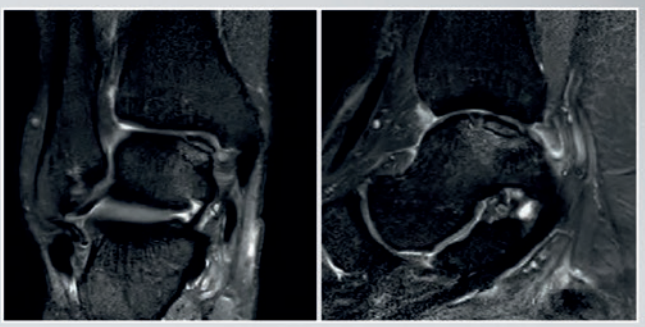
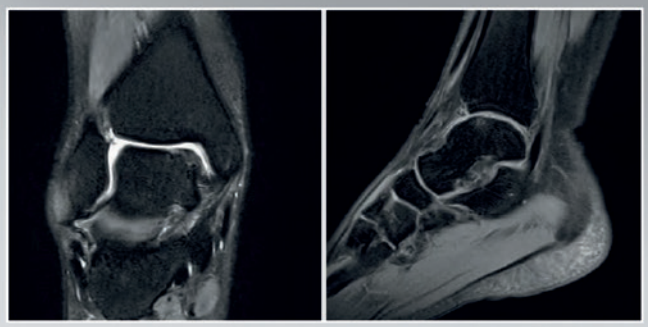


› The preoperative MRT-diagnostic image shows an osteochondral lesion >1.5 $cm^2$ on the medial edge of the talus. Images courtesy of Prof. Dr. Markus Walther



› After 3 years, the cancellous bone graft has been partially resorbed and the defect area is filled completely with regenerated cartilage. In comparison to the lateral talus, the edge on the radial side is slightly rounded. Images courtesy of Prof. Dr. Markus Walther

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