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Volume 15, Issue 1, January-April

Osteochondral lesions of the talus in adults	
J. Batista, G. Joannas, L. Casola, L. Logioco, G. Arrondo	
1A	*Traumatic lesion* with isolated cartilage injury (flap) Tx: arthroscopy, curettage, and microfractures.
1B	*Traumatic lesion* (cartilage and subchondral bone injury)
1B.1	Lesion <10mm in diameter and <5mm of depth (superficial lesion) Tx: arthroscopy, curettage, and microfractures.
1B.2	Lesion >10mm in diameter and >5mm in depth Tx: fragment fixation with osteosynthesis, open surgery, osteochondral graft, or mosaicoplasty.
2A	*Non-traumatic* isolated bone injury, subchondral cyst. Tx: retrograde drilling.
2B	*Non-traumatic* open subchondral bone cyst with articular connection (progression of type 2A).
2B.1	Lesion measuring <10mm in diameter and <5mm in depth (superficial lesion). Tx: arthroscopy, curettage, and microfractures.
2B.2	Lesion measuring >10mm in diameter and >5mm in depth. Tx: open surgery, osteochondral graft, or mosaicoplasty.
3	*Type 1 or 2 lesions associated with lateral instability of the ankle* Tx: ligament repair.
4	*With limb deformities*
4A	*Types 1 or 2 lesions with hindfoot deformity* = varus or valgus calcaneus Tx: varus or valgus calcaneal osteotomy.
4B	*Type 1 or 2 lesion with supramalleolar deformity of distal tibia* (varus or valgus) Tx: varus or valgus supramalleolar osteotomy.

Tx: treatment.

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FLAMeCIPP up to date: achievements and future

Dear colleagues, as the end of our FLAMeCIPP presidency approaches, we would like to thank all of you for the support provided over these years, and we are honored to do so through this fantastic window, resulting from the fusion of our journals, ABTPe and Tobillo y Pie, to become stronger, one of the greatest achievements of our region in recent years.

FLAMeCIPP for Latin American foot and ankle surgeons represents integration, science, development, and friendship-a meeting point for our region, which keeps growing and expanding. Recently, Panama and Dominican Republic have joined us as new members, we have expanded in countries such as Peru and Costa Rica, El Salvador and Guatemala have reactivated, preparing their return to FLAMeCIPP. However, there is still work to be done, posing a great challenge to the upcoming authorities.

One of the main goals of the present administration was to make FLAMeCIPP more dynamic and closer to its members, and not only convening a congress every 2 or 3 years. To this end, we started to conduct monthly Instagram case discussions and webinars from the beginning of our administration in 2018. Initially, there was moderate engagement of our members, but interest gradually increased as we got used to these fantastic and interactive tools, thus achieving an outstanding participation.

FLAMeCIPP internationalization was an important objective for us. The webinars and case discussions brought us closer to other Foot and Ankle Federations. Currently, not only American, European, and Asian foot and ankle surgeons participate as speakers in our activities but also many Latin American surgeons are now often invited to participate in the activities of other Federations, showing the expertise and knowledge of this side of the world. It is very important to highlight that, by expanding the scientific influence of our region, FLAMeCIPP, as the institution, has been invited as a special guest by IFFAS, EFAS, SICOT, and SLARD to participate in their online activities.

We planned to give special attention to research in an attempt to figure out a path to organize it in the region. Although we have managed to take a few steps forward, we are still far from achieving what we are committing ourselves to and that is a matter of regret for us. We believe that our region has a high potential for research, we just need to find a way to stimulate and facilitate research mainly among the new generation of foot and ankle surgeons. That should be a major task in our region for the near future.

Finally, in these difficult times, we would like to speak a word of hope particularly for our region. Thankfully, we have managed to keep in touch through the different mechanisms brought to us by technology, thus keeping the FLAMeCIPP spirit alive, and we hope we can all embrace each other again in our IX Congress to be held in conjunction with IFFAS meeting in Santiago de Chile in April 2022. We wish you all the best.

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Original Article

External column lengthening with peek cage and modified single approach

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Abstract

Objective: To show the results obtained with the treatment of stage 2B flatfoot according to Myerson classification (reducible and flexible), through external column lengthening with interposition of a peek cage filled with spongious graft taken from the same calcaneus, without osteosynthesis, combined with medial slide calcaneal osteotomy with step plate, both using the a single approach. Medial time was associated with latero-lateral transfer of common flexor tendon of toes to posterior tibial.

Methods: Sixteen patients were assessed from 2015 to 2018, of which 11 were women and 5 were men. In all cases, surgery was performed with a first lateral time for osteotomies and a second time for tendon repair. Mean patients' follow-up was 28 months.

Results: All patients achieved consolidation of both osteotomies at nearly 12 postoperative weeks. No patient presented signs of peek cage migration due to lack of stability or dorsal cutaneous nerve branch injuries resulting from this modified single approach. Two patients evolved with wound dehiscence and only one with calcaneocuboid pain so far. No patient required reoperation.

Conclusion: The modified single tuberosity approach for the two osteotomies has shown to be a simple procedure that prevents damages to dorsal cutaneous nerve branches described with dorsal approach.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Flatfoot/surgery; Foot deformities, acquired; Osteotomy; Calcaneus/surgery; Bone Screws; Treatment outcome.

Introduction

Posterior tibial tendon is the primary dynamic stabilizer of the medial longitudinal plantar arch. Its function is to promote adduction and inversion of the hindfoot and plantar flexion of the tibiotalar joint. During gait, this tendon allow for the blockade of the internal column, thus providing a rigid lever for the transition from the intermediate phase of gait up to its propulsive phase[1]. In adult-acquired flatfoot, posterior tibial tendon dysfunction leads to collapse of internal longitudinal arch. It has a multifactorial etiology related to age, obesity, diabetes mellitus, hypertension, rheumatoid arthritis, and other congenital seronegative and autoimmune inflammatory rheumatic diseases, as well as to steroid therapies.

In stage II B of Myerson classification, patients present with functional deficit of the posterior tibial tendon, product of its elongation and/or rupture. The deformities we find in this group of patients are hindfoot valgus, Achilles tendon shortening, and forefoot abduction (Figure 1). All these deformities are reducible and flexible[2].

The implication of the external column in such deformities is well known, and many patients present with dysplasia in this column[3]. Its lengthening is part of treatment and allows to correct scaphoid uncoverage with respect to the talus and improve the clinical aspect of fore and middle foot. The procedure consists of an additive osteotomy in the lateral surface of the anterior calcaneal tuberosity. It is important to previously evaluate uncoverage and plan the adequate enlargement so as to prevent over or undercorrection[4].

The aim of this study is to present a surgical technique of external column enlargement for reducible flatfoot and its results.

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

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Methods

This study was approved by the Institutional Review Board and this project was conducted under the ethical rules that regulate investigation in humans, according to the national law of personal data protection No. 25326 (Habeas Data Law) and to the latest version of the Declaration of Helsinki.

The study was conducted by our team of specialists in the disease using specific selection criteria, predefined algorithms, and identical guidelines.

We operated 16 patients with flatfoot from 2015 to 2018, of which 11 were women (68.75%) and 5 were men (31.25%). All operated patients belonged to the subgroup 2B of Myerson classification[2]. Patients aged from 18 to 75 years were included, and all had symptoms of pain and altered gait related to the study disease. The study excluded all patients not belonging to this subgroup, as well as those who had another associated disease in the affected leg or foot. Patients with systemic diseases (rheumatoid arthritis, gout, etc.) and with several peripheral vascular disease were also excluded. Mean patients' follow-up was 28 months (22-33).

All surgeries were performed under spinal anesthesia and using a hemostatic cuff on the thigh. At a first moment, patients were placed in the lateral position for the lateral time and then, for medial time, they were let fall laterally until reaching the supine position.

Lateral time or osseous time: we performed a single approach starting with a proximal incision from behind the peritoneal tendons through the tuberosity up to its lower point, a semicurved dorsal incision was made distally, and then a 2-cm lengthening, on average, was achieved toward the central portion of the calcaneocuboid joint.

Figure 1. Clinical and radiographic aspect of a flexible valgus flatfoot.

In all cases, the calcaneus was displaced 1-cm medially by calcaneal osteotomy and fixed using a step plate with 4 screws (Figure 2).

Subsequently, osteotomy for external column lengthening were performed by interposing a 0.5cm peek cage filled with graft from the same calcaneus (taken from residual tissue of medial slide calcaneal osteotomy) with no fixation by osteosynthesis and no need for iliac crest graft (Figure 3). Six patients

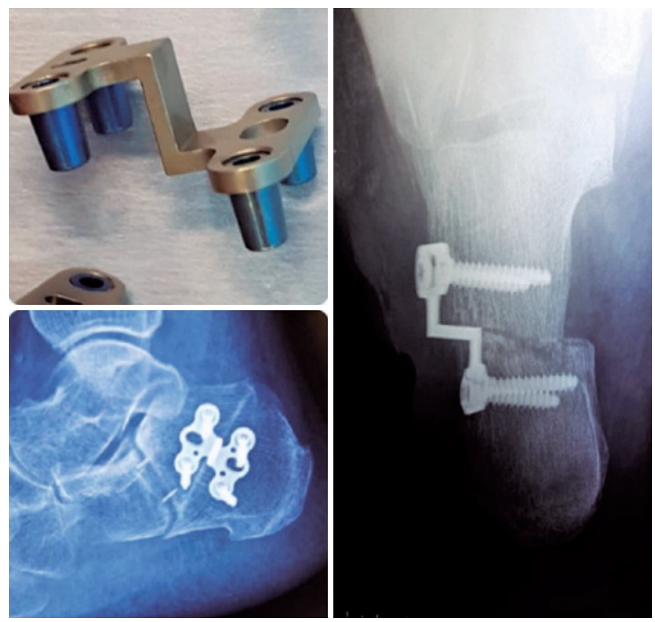

Figure 2. Radiographic view of the plate and of the achieved displacement.

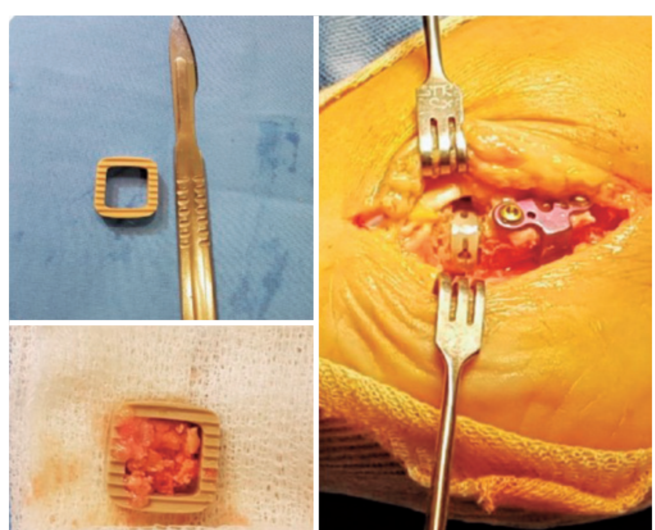

Figure 3. Peek cage filled with graft from the same calcaneus.

(37.5%) underwent Evans osteotomy, which is performed 1.5cm from the calcaneocuboid joint, and 10 patients underwent Hintermann osteotomy (62.5%), which is performed more proximally, at the heel level (Figure 4).

When performing the enlargement, we considered realign the facet joint to the medioplantar to correct flatfoot deformity[5].

Medial time or tendinous time: in all cases, we performed a medial approach for exploration of the posterior tibial tendon and sinovectomy, always combined with latero-lateral transfer of the common flexor tendons of the toes.

RESULTS

All patients achieved complete consolidation of both calcaneal osteotomies after 12 weeks[6] (Figure 5). There were no cases of peek cage migration due to lack of stability.

Two patients (12.5%) evolved with wound dehiscence, one was prescribed with antibiotics and a greater number of post-operative controls, and another patient required major follow-up, but no patient required surgical revision.

Only one patient (6.25%) persisted with pain on the lateral foot surface, resulting from irritation of the calcaneocuboid joint[7]. Up to date, she did not undergo reintervention.

No patient presented either with irritation or injury on peroneal tendons or with symptoms of dorsal cutaneous nerve branch injuries related to the surgical approach.

A VAS (visual analogue scale) was used, with a mean score of 9.125 (4-10). The patient who reported a VAS of 4 was the one with persistent calcaneocuboid pain, being actually the only patient who reported pain on the lateral foot surface in the long-term post-operative period.

Fifteen patients (93.75%) improved their activity and their quality of life soon after surgery. This included performing their daily and sports activities with no pain and no difficulties.

Only one patient (6.25%) was not able to take their feet off the ground after being operated; however, he reported a VAS of 10.

Finally, all patients reported achieving normal gait after surgery.

Discussion

There are many surgical treatments for adult-acquired flexible flatfoot that achieved good results, such as medializing calcaneal osteotomy, external column lengthening, double and triple arthrodesis[8]. There are also soft tissue techniques, such as posterior tibial plastic surgery and tightening, transfer of common flexor of the toes to the residual posterior tibial, or spring ligament suture. The latter procedures are hardly used alone, and it is currently discussed whether they should be associated with osseous time.

Many techniques of external column lengthening have been described in the treatment of flatfoot, either using the iliac crest bone, peek cage, or titanium Wedges[9]; and was also fixed with different implants, such as pins, screws, or screwed plates[10]. Any implant in the lengthening region usually causes direct irritation on peroneal tendons, and a high percentage of patients undergo reoperation for the removal of surgical material, due intolerance or tendinous injury[11].

Figure 4. Hintermann osteotomy and calcaneal slide osteotomy consolidated in the correct position.

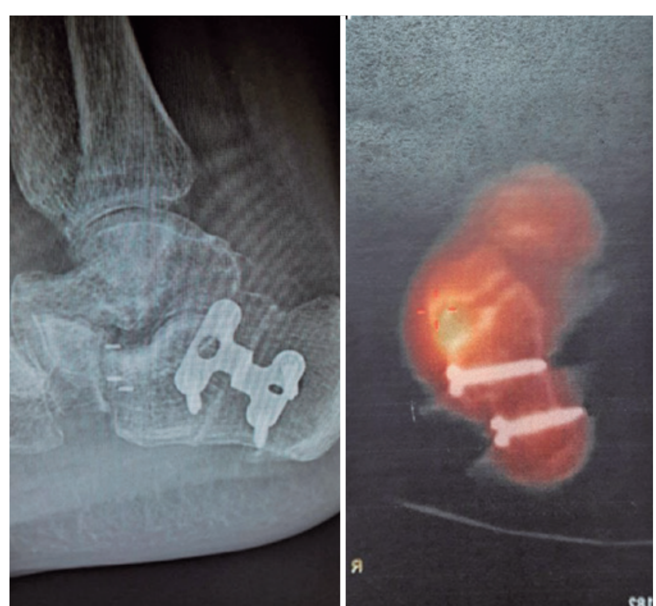

Figure 5. Left: image showing tuberosity after Evans osteotomy. Right: SPECT CT scan with hypercaptation at the calcaneocuboid joint.

Calcaneocuboid pain is frequent in patients who underwent external column lengthening. There is a discussion on where this procedure should be performed. In this study, Hintermann and Evans osteotomies were used. The first is performed on the heel, whereas the latter is performed 1.5cm from the calcaneocuboid joint. Studies comparing these two methods did not observe significant differences with regard to complications, although Hintermann osteotomy seemed to cause few degenerative injuries on the calcaneocuboid joint. The reported percentage of calcaneocuboid pain after Evans osteotomy is nearly 12%, and 36% of patients present with radiological degenerative changes on this joint(12). Although study duration was not very long, only one patient (6.25%), who underwent Evans osteotomy, reported pain on this site during the study period, but the patient did not require surgical revision (Figure 5).

We proposed to interpose a peek cage in external column lengthening, which remains fixed and stable due to the toothed structure of its wall and to the pressure exerted on the edges of the lengthening osteotomy. This material achieves a high consolidation rate, as shown in a preliminary series published in 2012 by the Instituto Dupuytren(13). It is not necessary to perform osteosynthesis when the external column is lengthened for the treatment of flexible flatfoot (Figure 6).

This type of discussion was not found in the literature, which only presents many studies with different fixation methods after external column lengthening was performed.

One of the limitation of the present study is its retrospective design and the fact that patients' follow-up was too short for achieving the expected results in treatment of any posterior tibial dysfunction. However, we believe that the time of presentation is appropriate for the technique presented here.

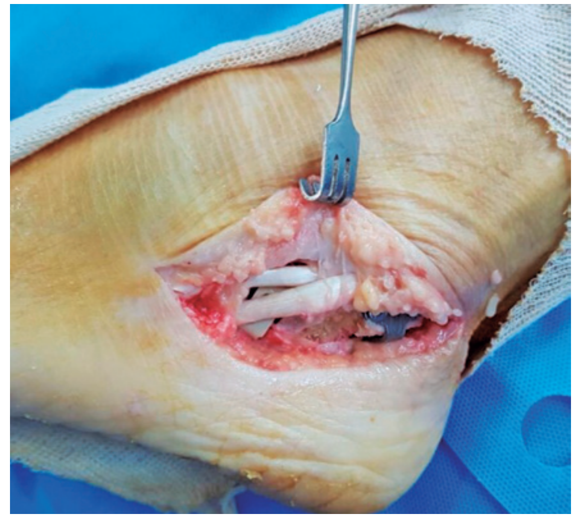

Figure 6. Postoperative image of peroneal tendons.

Conclusion

External column lengthening in flatfoot is a very important procedure that contributes for the improvement of clinical and radiographic results for this stage of the illness. We believe that use of only one lateral approach for both osteotomies, together with the use of a peek cage with a calcaneal graft, without osteosynthesis, has presented a high consolidation rate without leading to the complications described for this method with regard to osteosynthesis material resulting from peroneal tendon irritation and with no need for iliac crest graft.

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

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Original Article

A comparative study of single-vs. double-row technique in surgical treatment of insertional Achilles tendinopathy

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Abstract

Objective: This retrospective study compared the clinical and functional results of single- and double-row surgical techniques for insertional Achilles tendinopathy in the postoperative period.

Methods: In this case series, 29 patients who underwent surgery with one of the two techniques were followed up for one year postoperatively. Data were collected from medical records, imaging exams, and visual analog scale (VAS), Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire, 12-item Short Form Health Survey (SF-12), and Foot and Ankle Ability Measure (FAAM) scores.

Results: The following mean values (5% significance level) were found for single- and double-row techniques, respectively: postoperative VAS (2.9/2.2), FAAM-ADL (71.9/74.4), FAAM-Sports (28.3/29.8), SF-12 physical component (45.2/47.0), SF-12 mental component (44.9/48.2), and VISA-A (72.1/75.9). The complication rate did not differ significantly between the techniques.

Conclusion: No significant differences were found in any of the scores between the two surgical techniques.

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

Keywords: Achilles tendon/surgery; Tendinopathy/surgery; Suture anchors; Suture technique; Orthopedic procedures/methods; Treatment outcome.

Introduction

Insertional Achilles tendinopathy is attributed to overload, muscle imbalance, poor alignment, decreased blood supply, and tensile strength, and is currently considered multifactorial, involving mechanical, vascular, neural, and genetic factors. The presence of certain systemic diseases and the use of quinolones, statins, corticosteroids, anabolic steroids, and non-hormonal anti-inflammatory drugs also have an influence[1,2]. However, only alcohol abuse and ciprofloxacin have been identified as systemic risk factors for tendinopathy[3,4]. The population incidence of insertional Achilles tendinopathy is 3.7% (5 to 18% among runners), corresponding to 25% of all Achilles pathologies. It mainly affects young adults involved in high-demand activities and middle-aged adults with impaired healing potential, impacting performance and quality of life[1]. It is characterized by pain and edema along the tendon insertion that worsen during exercise.

Studies show that the initial treatment for insertional tendinopathy should be conservative[5-15]. Surgery should be considered only when conservative treatment (a maximum of six months) has failed or in cases of persistent pain and limitations in daily and sports activities[1,14,16]. Two of the surgical techniques cited in the literature for tendinopathy are single-row repair with two anchors[17] and double-row repair with four anchors[18].

Study performed at the Hospital Felicio Rocho; Hospital Madre Teresa and Hospital Mater Dei, Belo Horizonte, Brazil.

Correspondence: Ricardo Gomes Maciel. 255 Jequitiba St., Ipatinga, MG, Brazil, **Zip Code:** 35160-306. **E-mail:** ricardogomesmaciel@gmail.com. **Conflicts of interest:** Daniel Soares Baumfeld is a consultant and speaker for Arthrex (USA); Tiago Soares Baumfeld is a consultant and speaker for Medartis. The other authors disclaimed that there are no conflicts of interest. **Source of funding:** none. **Date received:** March 15, 2021. **Date accepted:** April 08, 2021. **Online:** April 30, 2021

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The double-row technique was developed to produce greater stability of the tendon insertion and allow earlier rehabilitation without increasing the complication rate[18,19]. However, the single-row method also has good functional results and a low rate of complications. McGarvey et al.[20] described a central access technique, finding satisfactory results for functional return and patient satisfaction. Nunley et al.[21] reported a high rate of satisfaction with a method that included central access and repair with two anchors. Therefore, the comparative benefits of single-row vs. double-row techniques are still debated in the literature.

The purpose of this study was to compare patients diagnosed with insertional Achilles tendinopathy who underwent single-row or double-row surgery with respect to pain and function. We hypothesized that, due to its more stable fixation, the double-row technique would provide a safer return to daily and sports activities without increasing the complication rate.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 33931420.8.0000.5128.

This retrospective comparative study assessed the results of single-row or double-row surgery in patients with insertional Achilles tendinopathy who underwent the procedure between July 2014 and January 2020.

The patients were diagnosed by orthopedic foot and ankle specialists and were subject to the following inclusion criteria: agreeing to participate, having been treated with one of the two aforementioned surgical techniques with a minimum follow-up of one year, and having adhered to postoperative guidelines. Patients who did not meet these criteria were excluded from the study. The following variables were evaluated: imaging examinations (radiography of the true anteroposterior projection of the ankle, profile and axial projections of the pre- and postoperative calcaneus, and magnetic resonance imaging of the preoperative ankle), type of postoperative immobilization, and postoperative complications (necrosis, infection, wound dehiscence, tendon rupture, paresthesia, and residual pain). The patients were also questioned about their physical activity (amateur, professional, or sedentary) before and after the procedure. The Visual Analog Scale (VAS) was applied pre- and postoperatively, while the Victorian Institute of Sport Assessment-Achilles (VISA-A)[22], Short Form Health Survey (SF-12), and the Foot and Ankle Ability Measure (FAAM)[23] were applied postoperatively.

Patient data were compared using quantitative statistical analysis to determine the main postoperative differences between the techniques. Statistical tests were performed using R version 4.0.3 with a significance level of 5%. The Shapiro-Wilk normality test was used for all scores, with the Wilcoxon test used when normality was rejected.

Surgical techniques

The two techniques are similar in preparation, positioning, and superficial and deep surgical access, differing only in the use of two or four anchors and their insertion sites. The patient underwent spinal anesthesia and sedation. A tourniquet was placed over the affected ipsilateral thigh and the patient was placed in the prone position. Antisepsis was performed, and the surgical fields were placed in the lower limb. The tourniquet was then inflated. In line with the Achilles tendon, a midline longitudinal incision was made from the calcaneus insertion to approximately 10cm proximally. The incision was continued through the subcutaneous tissue to the paratendon, which was opened to reach the Achilles tendon. The tendon was then split with a midline incision, partially released distally in an inverted ‘T’ figure, reflected medially and laterally, exposing the entire posterior tuberosity of the calcaneus and the Haglund deformity when present. The degenerated tissue of the Achilles tendon was then debrided. Using an oscillating saw, the calcaneal prominence was resected and the residual edges were smoothed with a file. After resecting the calcaneal prominence and debriding the degenerated Achilles tendon, it was reinserted[24].

In the single-row technique, two 4.5 mm suture anchors were positioned near the native insertion of the Achilles tendon in the medial and lateral calcaneal tuberosity. Using a free needle, each suture was threaded through the proximal-lateral and proximal-medial portions of the tendon. The anchors were tensioned with the foot in plantar flexion and each suture was tied, reinserting the Achilles tendon. After testing for stability, each suture was threaded through the distal portion of the tendon. The remaining sutures were tied, bringing the distal portion of the tendon closer to the calcaneus. The longitudinal split was sutured with 0-Vicryl™. Radiographs were taken to assess the position of the anchor and bone resection. The subcutaneous tissue and skin were closed with a single 2-0 Vicryl suture and a single 4-0 nylon monofilament suture, respectively. A sterile dressing was applied to the wound, and the leg was immobilized with a dorsal plaster splint or cast placed at 15-20o with the ankle in in the equinus position. The tourniquet was then deflated and the patient was placed in the supine position[13,17]. Non-functional immobilization was used during the postoperative period. Weightbearing was prohibited for 4 weeks. The dorsal plaster splint was worn in plantar flexion for the first 2 weeks, after which the sutures were removed. An immobilizing boot with 3 heel wedges was worn from the second to the fourth week. Movements in flexion and extension were then begun to increase the ankle’s range of motion, followed by active exercises. From the fourth to sixth week, weightbearing was gradually resumed while wearing the immobilizing boot with wedges. From the sixth to the eighth week, the wedges were gradually removed and physical therapy was begun. Finally, the boot was removed after the eighth week[17].

For the double-row technique, two 4.75-mm BioComposite SwiveLock anchors (Arthrex, Inc., Naples, FL, USA) were inserted into the calcaneus. Two holes were drilled about 1 cm proximal to the insertion of the Achilles tendon on the calcaneus and central to each half of the tendon. The two anchors, loaded with FiberTape (Arthrex) sutures (1 blue and 1 white/black), were inserted into the proximal holes. Both sutures were threaded through the proximal Achilles tendon on the medial and lateral sides. Two more holes, 2 cm distal to the proximal anchors, were drilled and threaded using the same technique. The split Achilles tendon was closed with resorbable sutures. The distal anchors were preloaded with a suture tip from the ipsilateral proximal anchor and a suture tail from the contralateral proximal anchor. With the foot in plantar flexion, the suture's tension was adjusted in the distal anchor eyelet. Both distal anchors were tensioned. This process was repeated for the other distal anchor using the remaining 2 suture tails from the proximal row (12,25,26). A single 0-Vicryl suture with was used to approximate the debrided area of the Achilles tendon. The subcutaneous tissue and the skin were closed with simple 2-0 Vicryl and 4-0 nylon sutures, respectively. Sterile dressing was applied to the wound, and a dorsal plaster splint or cast was placed at 15-20° with the ankle in in the equinus position. The tourniquet was then deflated and the patient was placed in the supine position. Functional immobilization was used during the postoperative period. The patients wore an immobilizing boot with 3 heel wedges, and weightbearing was allowed after 1 week. The wedges were gradually removed until the sixth week, when the boot was removed. The suture was removed after 2 weeks. Physical therapy was begun after approximately 3 to 4 weeks[24].

Results

This study included 29 patients with insertional Achilles tendinopathy, of whom 14 (48%) underwent surgery with the single-row technique and 15 (52%) with the double-row technique between July 2014 and January 2020. The sample included 15 (52%) women, the mean age was 54 years (33-79), and there was a minimum follow-up of one year after the procedure.

Regarding sports activities, 14 (48%) patients reported none, 14 reported an amateur level, and 1 reported a professional level. Only 5 patients had complications: there were 2 (7%) cases of residual pain (1 in each group), 1 (3%) case each of wound dehiscence and paresthesia in the double-row group, and 1 (3%) case of superficial infection in the single-row group. The remaining 24 (83%) patients had no complications.

The pre- and postoperative VAS values, as well as the difference observed between the two time points were graphed (Figure 1). The following values were obtained for the single- and double-row techniques, respectively: preoperative VAS (8.7/7.8) and postoperative VAS (2.9/2.2). There were no significant differences in VAS score between the groups.

The VISA-A (Figure 2), FAAM (Figure 3), the SF-12 physical (Figure 4) and SF-12 mental (Figure 5) components were distributed as follows for the single-row and double-row techniques, respectively: VISA-A (72.1/75.9); FAAM ADL (71.9/74.4); FAAM sports (28.3/29.8); the SF-12 physical (45.2/47.0) and SF-12 mental (44.9/48.2). Thus, there were no significant differences (at a significance level of 5%) in these scores between the procedures.

Discussion

This study compared the functional results of single-row and double-row surgical techniques for treating insertional tendinopathy of the Achilles tendon. No statistically significant differences were found between the techniques from a clinical and functional point of view.

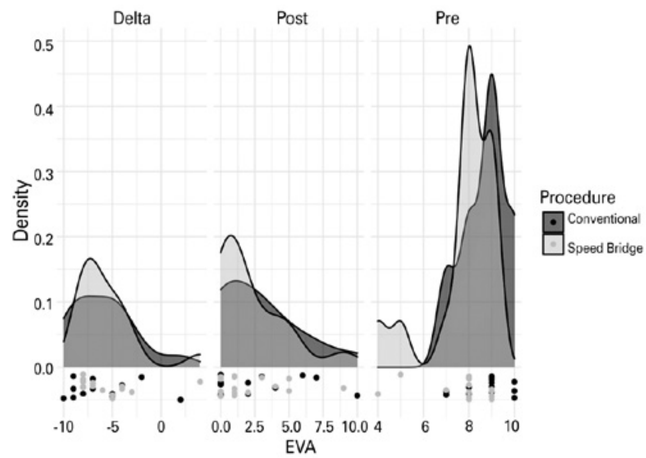

Figure 1. Visual Analog Scale results. The curves and darker points represent data collected from the single-row group, while the lighter tones represent the double-row group. The curves represent the density of the values according to row, while the points are the exact values collected.

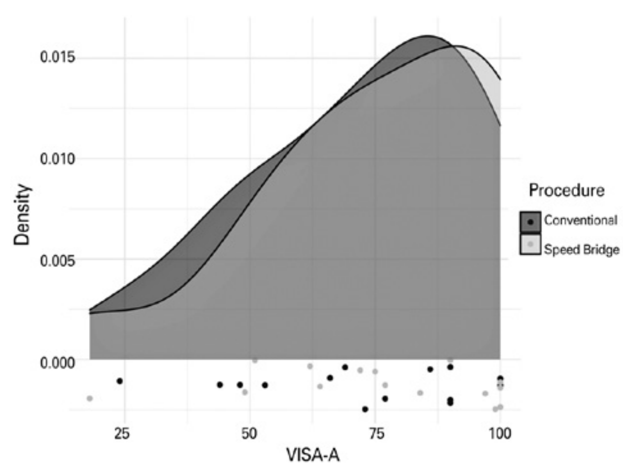

Figure 2. VISA-A results. The curves and darker points represent data collected from the single-row group, while the lighter tones represent the double-row group. The curves represent the density of the values according to row, while the points are the exact values collected.

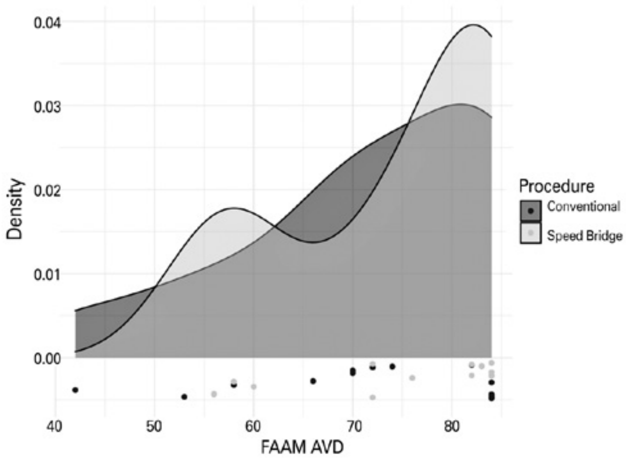

Figure 3. FAAM results. The curves and darker points represent data collected from the single-row group, while the lighter tones represent the double-row group. The curves represent the density of the values according to row, while the points are the exact values collected.

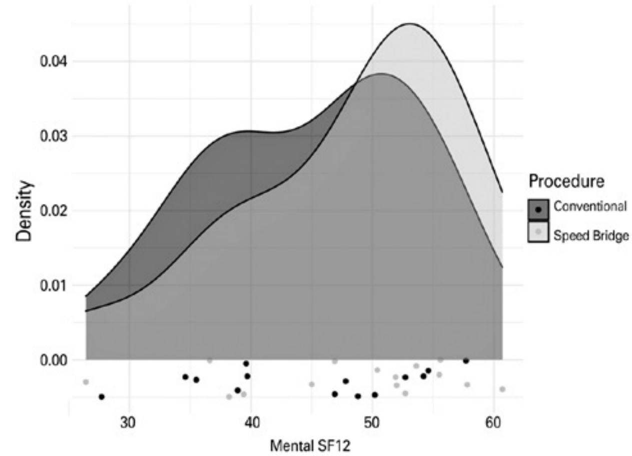

Figure 5. SF-12 mental component results. The curves and darker points represent data collected from the single-row group, while the lighter tones represent the double-row group. The curves represent the density of the values according to row, while the points are the exact values collected.

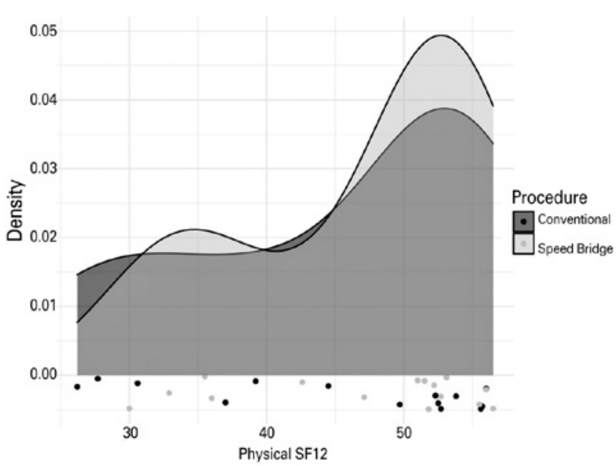

Figure 4. SF-12 physical component results. The curves and darker points represent data collected from the single-row group, while the lighter tones represent the double-row group. The curves represent the density of the values according to row, while the points are the exact values collected.

Table 1. Descriptive statistics of numerical variables according to surgical procedure

Variable	Procedure	Min.	Mean	Median	Max.	SD
VAS postoperative	Single-row	0	2.9	2	10	3.08
	Double-row	0	2.2	1	9	2.57
VAS preoperative	Single-row	7	8.7	9	10	0.99
	Double-row	4	7.8	8	9	1.47
FAAM ADL	Single-row	42	71.9	73	84	13.37
	Double-row	56	74.4	82	84	11.34
FAAM sports	Single-row	22	28.3	31	32	5.51
	Double-row	23	29.8	32	32	3.90
SF-12 physical	Single-row	26	45.2	51	56	11.00
	Double-row	30	47.0	52	56	9.10
SF-12 mental	Single-row	28	44.9	47	58	8.95
	Double-row	26	48.2	52	61	9.40
VISA-A	Single-row	24	72.1	75	100	22.92
	Double-row	18	75.9	77	100	23.95

ADL: activities of daily living; FAAM: Foot and Ankle Ability Measure; SD: Standard deviation; SF-12: 12-item Short Form Health Survey; VAS: Visual Analog Scale; VISA-A: Victorian Institute of Sports Assessment-Achilles questionnaire.

Regarding the VAS, Rigby et al.[24] carried out a study with 43 patients who underwent the double-row technique, finding mean values of 6.8 and 1.3 in the pre- and postoperative period, respectively. Using the single-row technique in 36 patients, Xia et al.[13] found mean pre- and postoperative VAS values of 7.8 and 1.8, respectively. In the current study, the mean pre- and postoperative VAS values for the single-row technique were 8.7 and 2.9, respectively, and 7.8 and 2.2 for the double-row technique, respectively. As in the above-mentioned studies, the techniques led to improved, but not significantly different, pain results in the postoperative period.

The VISA-A score, which is used to assess Achilles tendon disorders and their functional impact, is easy to apply clinically and provides a reliable index of the severity of tendinopathy[16,27,28]. Due to its brevity and performance, the SF-12 score, a general assessment of quality of life related to physical and mental health, is widely used in clinical trials and to assess routine results[29,30]. The FAAM score is a reliable and valid measure of physical function in individuals with musculoskeletal disorders of the foot and ankle[31,32]. There is a lack of studies in the scientific literature associating these scores and surgical techniques. In this study, no significant differences were found between the techniques in the postoperative period.

Biomechanical studies have found conflicting results about the best surgical technique. For example, Beitzel et al.[33] concluded that the double-row technique has a greater contact area and tolerates greater tension in stress testing than the single-row technique, which corroborates the results of a previous study by an orthopedic implant company[34]. However, a recent cadaver study[35], as well as Pilson et al.[36], found that the double-row technique could not tolerate a greater load before failure.

We found different types of postoperative immobilization protocols used in the literature. In Gillis and Lin[26], the patients went 4 weeks without weightbearing, progressively returned to weightbearing with immobilizing boots and wedges, followed by another 4 weeks of immobilizing boots without wedges. In Rigby et al.[24], the patients returned to weightbearing based on age, weight, comorbidities, activity level and concomitant procedures, varying from immediate weightbearing with an immobilizing boot to no weightbearing for several weeks. In Zhuang et al.[12] the patients went 4 weeks without weightbearing, followed by partial weightbearing with an immobilizing boot and wedges that were removed gradually over 6 weeks, after which full weightbearing was allowed. Thus, non-functional immobilization was used even with the double-row technique. Whereas, in Xia et al.[13], a study of the single-row technique, the patients went 2 weeks without weightbearing, followed by 4 weeks of partial weightbearing with an immobilizing boot, followed by boot removal and full weightbearing at 6 weeks. Despite their different immobilization protocols, all of these studies had good postoperative results. In the present study, postoperative immobilization was predominantly functional in the double-row group since this technique was expected to be more resistant. Therefore, these patients were prescribed earlier mobilization and weight bearing despite the conflicting results of the above-mentioned biomechanical studies.

Highlander and Greenhagen[37] conducted a systematic review on wound complications in posterior leg incisions, finding no difference in the incidence of complications between midline and medial incisions, with the medial incision allowing better visualization for tendon resection and reinsertion. Several studies have shown that central posterior access resulted in a low rate of complications for these techniques[12,20,25,38]. The present study also had a low rate of complications for both techniques: importantly, no cases of postoperative tendon rupture occurred.

This study's weaknesses include the small number of patients, its retrospective and non-randomized design, the fact that the postoperative immobilization type differed between techniques, the fact that all scores were not also collected in the preoperative period, and the inclusion of professional athletes, who may place greater stress on the tendon. Regarding its strengths, it was a comparative study, it included a minimum follow-up of one year, and it used validated scales, both general and specific.

According to the assessed scales and postoperative complication rates, neither technique was superior. Therefore, new studies with larger samples, participants with high functional demand, and use of similar postoperative immobilization for both techniques are needed to evaluate our hypothesis.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RGM *(https://orcid.org/0000-0002-5366-5394) participated in the review process, data collection; statistical analysis, bibliographic review, survey of medical records, article formatting; RSC *(https://orcid.org/0000-0002-8930-7046) participated in the review process, performed the surgeries; DSB *(https://orcid.org/0000-0001-5404-2132) conceived and planned the activities that led to the study, participated in the review process, performed the surgeries; TSB *(https://orcid.org/0000-0001-9244-5194) participated in the review process, performed the surgeries. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Neuropathic foot ulcer: microbiological assessment in chronic osteomyelitis

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Abstract

Objective: To determine the microbiological profile and antimicrobial susceptibility patterns of organisms isolated from chronic osteomyelitis secondary to neuropathic foot ulcers; secondarily, to describe the clinical outcomes of 52 patients admitted to a neuropathic foot referral center.

Methods: Retrospectively chart review of 52 patients with clinically infected neuropathic foot ulcers admitted to our service for treatment between 2005 and 2013. Tissue samples were collected for culture at the operating room after extensive debridement in order to determine the infectious agents and their resistance profile using the disk-diffusion technique, following CLSI criteria.

Results: A total of 52 patients were analyzed (40 males and 12 females). The mean age was 58 (37-72) years. Each patient presented with an average of 2.13 microorganisms, distributed as follows: 51% Gram-positive cocci, 43% Gram-negative bacilli. Among *Staphylococcus aureus* isolates, the prevalence of methicillin resistance was almost 50%, and the prevalence of coagulase-negative staphylococci (CoNS) was more than 75%.

Conclusion: *S. aureus*, *E. faecalis*, and CoNS were the most frequently isolated pathogens. Methicillin resistance was highly prevalent. A combination of extensive surgical debridement and prolonged antimicrobial therapy led to remission of infection in 77% of patients.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Antibiotics; Arthropathy, neurogenic/diagnosis; Foot/microbiology; Osteomyelitis; Ulcer.

Introduction

Neuropathic inflammatory osteoarthropathy of the foot, or simply neuropathic foot, is a syndrome first reported more than 100 years ago by Herbert William Page[(1)]. It was initially described as a complication of tabes dorsalis, but metabolic causes, such as diabetes and alcohol abuse, are now most frequently observed[(2)].

Symptoms vary from slight loss of sensitivity to total numbness and burning pain. Patients with this syndrome are at high risk of ulcers and infections of the foot, which may culminate in osteomyelitis and amputation[(2)].

Worldwide, diabetic foot ulcers are a major medical, social, and economic problem. They are the leading cause of hospitalization in diabetic patients. If not promptly treated, amputation of the infected foot is required[(3)]. It is estimated that 25% of patients with diabetes will present with a foot ulcer at some point in their lives[(4)].

Diabetic neuropathy causes damage to the peripheral nerves throughout the body, in particular the feet. In patients with neuropathic feet, injuries frequently go unnoticed, leading to severe infections and amputations, with a risk of amputation 25 times greater than in healthy individuals; indeed, diabetic neuropathy is the leading cause of non-traumatic amputations (57,000 per year)[(4)]. Even when amputation cannot be avoided, good quality of life may be obtained by good follow-up care from a multidisciplinary foot team[(5)].

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

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Proper management of infections in the neuropathic foot requires appropriate antibiotic selection based on culture and antimicrobial susceptibility. Several studies have found methicillin-resistant *Staphylococcus aureus* (MRSA) and polymicrobial infection present in as many as 15–30% of diabetic patients with chronic osteomyelitis secondary to neuropathic ulcers. Infection with multidrug-resistant organisms (MDROs) may increase the length of hospital stay, cost of management, and number of surgical procedures, and may cause additional morbidity and mortality(6-13). Although increasing antimicrobial resistance is a concerning problem in the BRICS countries, there is a paucity of data regarding the frequency of MDRO infections and the outcome of such infections among diabetic foot ulcers in these regions, especially Brazil(14).

Our hypothesis is that, since our service assists patients with diagnoses other than diabetes, and our population differs from the majority of others in which insensitive foot infections were studied, the microbiological profile and antimicrobial susceptibility patterns of organisms isolated from chronic osteomyelitis (CO) secondary to neuropathic foot ulcers will be different from the standard profile related in the literature(15).

Thus, the objective of this study is to determine the microbiological profile and antimicrobial susceptibility patterns of organisms isolated from CO secondary to neuropathic foot ulcers in patients treated at our tertiary neuropathic foot center.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 44731621.3.0000.0068.

Medical charts of 52 patients with clinically infected neuropathic foot ulcers admitted to our university-affiliated Diabetic Foot Center between January 2005 and December 2013 were reviewed.

Osteomyelitis was diagnosed on the basis of suggestive changes on plain radiographs and magnetic resonance imaging (MRI), and confirmed by microbiological examination (Figure 1). All cases were analyzed at 6 months of follow-up. Only results of bone culture obtained at the time of surgical debridement following antisepsis were considered for microbiological characterization.

Inclusion criteria

1. Patients admitted for treatment of chronic osteomyelitis secondary to neuropathic foot infection;
2. Surgical debridement performed between January 2005 and December 2013.

Exclusion criteria

Previous surgical manipulation of the affected foot.

Specimen acquisition and susceptibility testing

All bone specimens were collected from the clean surgical site, in the operating room, after extensive debridement or amputation (Figure 2). Samples were sent to the microbiology laboratory in bottles containing thioglycolate growth medium. Susceptibility tests were performed in all cases using the disk-diffusion technique; when required, minimum inhibitory concentrations were obtained using automatic methods or "e-test", and reported in accordance with the CLSI criteria(16).

Figure 1. A) Radiography showing signal abnormality in the head of the 5th metatarsus, B) T1-weighted MRI showing a lesion in the head of the 5th metatarsus. C) T2-weighted MRI of the same foot.

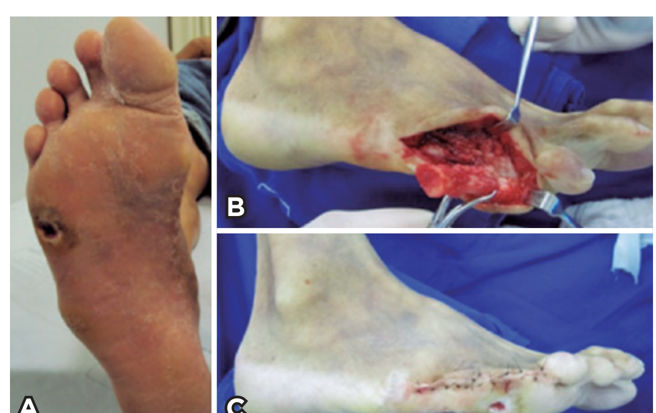

Figure 2. A) Ulcer on foot. B) Surgical debridement. C) Clinical outcome after surgery.

Statistical analysis

Quantitative variables were expressed as means ± standard deviation, while qualitative variables were expressed as percentages.

The association of study variables with MDRO and non-MDRO infections was tested using Student's *t* test or Fisher's exact test as appropriate.

Odds ratios (ORs) (with 95% CIs) for having MDRO-associated ulcers were calculated. Multiple logistic regressions were employed to identify independent predictors of MDRO infections and predictors of glycemic control.

Results

Fifty-two patients were treated during the period of analysis, 40 men (77%) and 12 women (23%). Mean age was 58 years (range, 37-72). Diabetes was the major cause of neuropathic foot (46 patients, 88%), followed by Hansen's disease (4 patients, 8%) and spinal cord injury and alcoholic neuropathy (2 cases each, 2%). Most ulcers (39, 75%) were located in the forefoot; the rest were located in the transition of the midfoot and hindfoot. Regarding surgical approach, 21 patients (41%) underwent debridement only, 27 (51%) underwent partial foot amputation, and 4 (8%) underwent below-knee amputation.

One-hundred and nine bacterial isolates were identified as causative agents of infection (mean, 2.13 isolates per patient). There was a predominance of Gram-positive cocci (51%), followed by Gram-negative bacilli (GNB) (43%). The most prevalent agents were *Staphylococcus aureus* (18%), *Enterococcus faecalis* (18%), and coagulase-negative staphylococci (CoNS) (14%). The profile of the isolated organisms is detailed in table 1.

Among *S. aureus* isolates, the prevalence of methicillin resistance (MRSA) was 48%, with 100% susceptibility to sulfamethoxazole/trimethoprim (SMX/TMP). Among CoNS, 77% were methicillin-resistant (MRCoNS), again with 100% susceptibility to SMX/TMP. All isolates of *E. faecalis* were susceptible to ampicillin and vancomycin. Among GNB, the Enterobacteriaceae predominated (77%), with 82% susceptibility to ciprofloxacin and piperacillin/tazobactam and 100% susceptibility to carbapenems. The results of susceptibility studies are summarized in table 2.

All patients received antimicrobial treatment guided by susceptibility tests for 6 months after debridement. Ciprofloxacin was the most frequently used drug (33%), followed by amoxicillin (21%) and SMX/TMP (19%) (Table 3).

At 6-month follow-up, 75% of patients were in remission, without signs of infection; 23% of patients presented recurrence of infection; and 2% had been lost to follow-up.

Discussion

In the present study, we described the microbiological profile and antimicrobial susceptibility patterns of organisms isolated from patients with neuropathic foot ulcers at a diabetic foot referral center. The organisms were isolated from bone cultures of patients with confirmed diagnosis of osteomyelitis, collected intraoperatively. As we hypothesized, the microbiological profile observed in this study differs from the standard profile described in the literature. This is consistent with the fact that our patients differed from those of most previous studies, as we also included non-diabetic neuropathic feet. Michalek et al.[15] postulated in their paper that different populations in different countries have different infections.

Previous reports have used swab cultures to describe the microbiological profile of patients with neuropathic ulcers[14,17-19]. However, this method is susceptible to contamination, possibly detecting organisms that are not actually sources of infection. Senneville et al.[20] compared superficial swab cultures with percutaneous bone biopsy cultures and found that swab cultures do not reliably identify bone organisms[8]. Peri-wound bone cultures have also been performed to identify osteomyelitis in neuropathic foot with ulcers. However, the reliability of this method and whether it avoids potential contaminants is unclear. By collecting intraoperative bone cultures, we could reliably describe the microbiological profile and antimicrobial susceptibility patterns of organisms in the diabetic foot center of a tertiary hospital[8,9]. Interestingly, we observed a high rate of isolates per specimen, despite thorough debridement and irrigation prior to collection of bone cultures. This finding suggests that osteomyelitis caused by multiple organisms may be an increasing issue that physicians should be prepared to deal when treating neuropathic foot infections[21].

Table 1. Microorganisms Isolated from the 52 patients with neuropathic foot osteomyelitis

Staphylococcus aureus	19 (17.43%)
Enterococcus faecalis	19 (17.43%)
Coagulase-negative *Staphylococcus* spp.	15 (13.76%)
Morganella morganii	10 (9.17%)
Proteus spp.	8 (7.34%)
Acinetobacter spp.	6 (5.50%)
Escherichia coli	5 (4.59%)
Serratia marcescens	5 (4.59%)
Pseudomonas aeruginosa	4 (3.67%)
Enterobacter cloacae	3 (2.75%)
Bacteroides spp.	3 (2.75%)
Finegoldia magna	2 (1.83%)
Klebsiella spp.	2 (1.83%)
Streptococcus spp.	2 (1.83%)
Sphingomonas paucimobilis	1 (0.92%)
Stenotrophomonas maltophilia	1 (0.92%)
Prevotella melaninogenica	1 (0.92%)
Eikenella corrodens	1 (0.92%)
Citrobacter koseri	1 (0.92%)
Clostridium spp.	1 (0.92%)
TOTAL	**109**

Table 2. Susceptibility of each microorganism

	Clinda	Levo	Sulfa	Teico	Vanco	Ampi	Cipro	Ceftri	Erta	Pip/Tazo	MR	MS
S. Aureus	12.50%	12.50%	100%	100%	100%	/	/	/	/	/	47.37%	52.63%
Coag Neg S.	0%	10%	100%	90%	100%	/	/	/	/	/	76.92%	23.08%
E. Faecalis	/	/	/	/	100%	100%	/	/	/	/	/	/
Enterobactéria	/	/	/	/	/	/	82.35%	88.24%	100.00%	88.24%	/	/

Clinda: Clindamycin; Levo: Levofloxacin; Sulfa: Sulfamethoxazole; Teico: Teicoplanin; Vanco: Vancomycin; Ampi: Ampicillin; Cipro: Ciprofloxacin; Ceftri: Ceftriaxone; Erta: Ertapenem; Pip/Tazo: Piperacillin/Tazobactam; MR: Multidrug resistant; MS: Multidrug sensitive.

Table 3. Antimicrobial agents used for treatment of neuropathic foot osteomyelitis

Antimicrobial agent	
Ciprofloxacin	17 (25.37%)
Sulfamethoxazole/Trimethoprim	10 (14.93%)
Ertapenem	8 (11.94%)
Teicoplanin	7 (10.45%)
Amoxicillin	6 (8.96%)
Amoxicillin/Clavulanic acid	5 (7.46%)
Levofloxacin	4 (5.97%)
Cefalexin	3 (4.48%)
Clindamycin	2 (2.99%)
Metronidazole	2 (2.99%)
Cefepime	1 (1.49%)
Moxifloxacin	1 (1.49%)
Vancomycin	1 (1.49%)

The distribution of isolates according to type of microorganism is highly variable in the literature[15]. This difference may be explained either by the intrinsic variations of microbiological profile among different centers or by the different methods used for collection of samples. *S. aureus* is considered the most prevalent pathogen in diabetic foot infections. In the present study, even though *S. aureus* was one of the most commonly observed gram-positive microorganism, *E. faecalis* was equally prevalent. In agreement with previous reports, we observed a 48% rate of MRSA, confirming the concern of increasing antimicrobial resistance in neuropathic foot infections[14,18,22]. On the other hand, vancomycin-resistant strains were not observed in this study, unlike in previous reports[23-25]. We also noted a high prevalence of CoNS, which may be attributed to the impaired host defenses observed in diabetic patients[26,27]. A previous study showed that the distribution of CoNS in bone and swab cultures were significantly different[8]. These findings indicate that bone cultures may be necessary to accurately identify this low-virulence organism. Therefore, this microorganism may be more prevalent than previously reported. Among GNB, Enterobacteriaceae were highly prevalent, representing 77% of these cultures.

The strength of the present study lies on the fact that all bone cultures were collected intra-operatively, using a relatively large population with confirmed diagnosis of osteomyelitis. This allowed us to collect bone samples precisely from the affected tissue by direct visualization. Collecting bone samples after debridement and antisepsis also decreased the risk of possible contaminant organisms.

However, this study was not without limitations. It was performed in a single tertiary care center, to which the most severe cases are referred, often after treatment failure and prior antimicrobial treatment. Therefore, the microorganism profile and resistance patterns described herein cannot be extrapolated to the general population or to other specialist diabetes centers.

Conclusion

In diabetic patients with chronic osteomyelitis secondary to neuropathic ulcers, *S. aureus*, *E. faecalis*, and CoNS were the most frequent pathogens isolated. Occurrence of MRSA and MRCoNS was high, but 100% susceptibility to SMX/TMP was preserved. A combination of extensive surgical debridement and prolonged antimicrobial therapy led to remission of infection in 77% of patients at 6 months of follow-up.

Authors' contributions: Each author contributed individually and significantly to the development of this article: ANLML*(https://orcid.org/0000-0002-2396-9880) Interpreted the results of the study, participated in the reviewing process; DLR *(https://orcid.org/0000-0003-0183-8641) Wrote the paper, interpreted the results of the study; PRDO *(https://orcid.org/0000-0003-1377-6556) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the reviewing process; GHS *(https://orcid.org/0000-0002-1211-9258) Interpreted the results of the study, participated in the reviewing process; RSM *(https://orcid.org/0000-0002-5025-4338) Participated in the reviewing process, approved the final version; RBS *(https://orcid.org/0000-0003-1085-0917) Participated in the reviewing process, approved the final version; ALGS *(https://orcid.org/0000-0002-6672-1869) Interpreted the results of the study, participated in the reviewing process; TDF *(https://orcid.org/0000-0002-9687-7143) 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

Efficacy of triple surgery for cavovarus foot in Charcot-Marie-Tooth disease

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Abstract

Objective: to evaluate the efficacy of surgical treatment to correct the main deformities associated with flexible cavovarus foot due to Charcot-Marie-Tooth disease.

Methods: Fifteen patients (18 feet) with flexible cavovarus feet due to Charcot-Marie-Tooth disease were evaluated and underwent surgery between 2000 and 2015. We used a "triple surgery" protocol: a combination of plantar fasciotomy, valgus-inducing osteotomy of the calcaneus, and lengthening osteotomy of the first metatarsal. After a mean follow-up time of 105 (48 to 198) months, we developed a numerical scale to assess the main aspects of patient complaints: pain (3 points), function (3 points) and deformity (4 points). The scale considered the results of the visual analog pain scale, the American Orthopedic Foot and Ankle Society Scale, and the Coleman block test, as well as clinical and radiographic evaluation of gait and cavovarus deformities.

Results: According to the numerical scale, the results were considered satisfactory in 15 of the 18 feet (84%) and unsatisfactory in 3 (16%).

Conclusion: In the medium term, the "triple surgery" protocol proved efficient for correcting cavovarus deformities, providing functional improvement while preserving mobility without pain complaints. In the final analysis, through the "triple surgery" protocol, early indication for arthrodesis can be avoided, postponing sacrifice of the hindfoot joints.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Charcot-Marie-Tooth disease/surgery; Foot deformities; Osteotomy/methods; Fasciotomy; Bone Lengthening/methods; Treatment outcome.

Introduction

Cavovarus foot is often caused by neurological disorders and is triggered by an imbalance between antagonistic muscle groups[1]. Among the neurological diseases related to cavovarus foot deformities, Charcot-Marie-Tooth disease (CMT) stands out since it is associated with approximately 80% of the reported cases[2]. A common feature of CMT is progressive motor paralysis, which results in worsening deformities and joint stiffness in the foot and ankle[3]. Initially mild and flexible deformities in childhood tend to become accentuated and rigid in adulthood[4-6].

In CMT, peripheral nerve involvement progresses from distal to proximal[7]. The intrinsic foot muscles are the first to suffer paralysis, followed by the tibialis anterior and fibularis brevis muscles[7]. On the other hand, the strength of tibialis posterior and fibularis longus muscles is affected later, causing their actions to occur without due opposition, which triggers typical cavovarus foot deformities[8].

The greatest treatment dilemma is choosing the most appropriate surgical intervention and the right time for it. Nevertheless, the surgery's corrective effect is not permanent due to the disease's progressive character, ie, as it evolves, other muscles may be affected[9].

Since some degree of flexibility remains in the joints in the initial stage of the deformities, surgeries are aimed at both correcting the deformities and preserving joint mobility. The main procedures indicated at this stage are: releasing the plantar fascia (popularized by Steindler)[10]; hindfoot realignment by calcaneal osteotomy (described by Dwyer)[11];

Study performed at the Santa Casa de Misericórdia de São Paulo, São Paulo, SP, Brazil.

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and lowering the medial longitudinal arch with a dorsal closing wedge osteotomy at the first metatarsal head. When correcting deformities, it is also necessary to consider adding procedures that rebalance the deforming forces[12]. Given that no single surgery can correct of all cavovarus foot deformities, an association of procedures is frequently needed[7]. Since the literature is not specific about the best combination of surgeries for correcting flexible cavovarus foot associated with CMT disease, we developed a specific treatment protocol that combines the following three procedures: 1) plantar fasciotomy; 2) valgus-inducing osteotomy of the calcaneus; and 3) lengthening osteotomy of the first metatarsal.

The aim of this study was to evaluate our protocol's effectiveness for treating flexible cavovarus feet associated with CMT disease.

Methods

This retrospective observational study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 03686718.1.0000.5479.

In this series, the diagnosis of CMT disease was essentially clinical, based on a family history of progressive foot deformity, atrophy of the intrinsic musculature of the hands and feet, peripheral vibratory sense deficit, and decreased muscle strength of the tibialis anterior and fibularis brevis muscles. Foot flexibility was clinically determined by the Coleman block test[13].

Between 2000 and 2015, 18 patients (21 feet) with flexible cavovarus foot and CMT disease underwent "triple surgery" (TS), a name our service coined for a combination of: 1) plantar fasciotomy; 2) valgus-inducing osteotomy of the calcaneus; and 3) lengthening osteotomy at the head of the first metatarsal. In 12 feet, additional soft-tissue procedures were associated with TS according to individual needs. For study inclusion, a minimum follow-up of 48 months was required.

The 15 included patients returned for clinical-functional and radiographic evaluation, three of whom underwent TS in both feet, totaling 18 feet. There were eight female and seven male patients, whose mean age at the time of surgery was 22 years (9 to 60 years). The mean postoperative follow-up time was 105 months (48 to 198 months).

We considered three criteria when assessing the TS results: pain, function and residual cavovarus deformity. To objectively compare the results, we developed a numerical scale with maximum score of 10 points. The pain and function criteria were assigned a maximum score of three points each and residual deformity was assigned a maximum score of four points. The scores were classified as follows: ≥8 points was considered good, 5-7 normal, and ≤4 poor. Good and normal results were considered satisfactory, while poor results were considered unsatisfactory.

We used two scales to assess pain: a visual-analog pain scale (range 0 to 10 points), and a subscale from the American Orthopedic Foot and Ankle Society (AOFAS) rating system[14] (range 0 to 40). In our numerical scale, visual-analog pain scores from 0-2 were scored as 2 points, scores from 3-7 were scored as 1 point, and scores from 8-10 were scored as 0. For the AOFAS pain subscale, scores ≤20 and >20 were scored as 0 and 1, respectively.

We used three clinical parameters for functional assessment: 1) the AOFAS function subscale (range 0-50); 2) the presence or absence of claudication during gait; and 3) residual flexibility in the foot joints. In our numerical scale, AOFAS subscale scores ≥36 (equivalent to 70% functionality) were scored as 1 and lower scores as 0. Regarding gait, the absence and presence of claudication were scored as 1 and 0, respectively. Regarding foot flexibility, positive and negative Coleman test results were scored as 1 and 0, respectively.

We used two parameters to evaluate residual cavovarus deformities, one clinical and one radiographic. Of the 4 total points in this area, 2 points each could be scored for varus and cavus deformity correction.

Regarding residual varus, the clinical evaluation (1 point) was performed with the patient standing, and the angle between the axes of the heel and leg was measured. Radiographic evaluation (1 point) was performed by measuring the angle between the axes of the calcaneus and tibia, using radiographs according to Saltzman's method[15]. In both evaluations, angular values of up to 4 degrees of varus were considered satisfactory and were scored as 1, while values ≥5 degrees of varus were considered unsatisfactory and were scored as 0 (Figure 1).

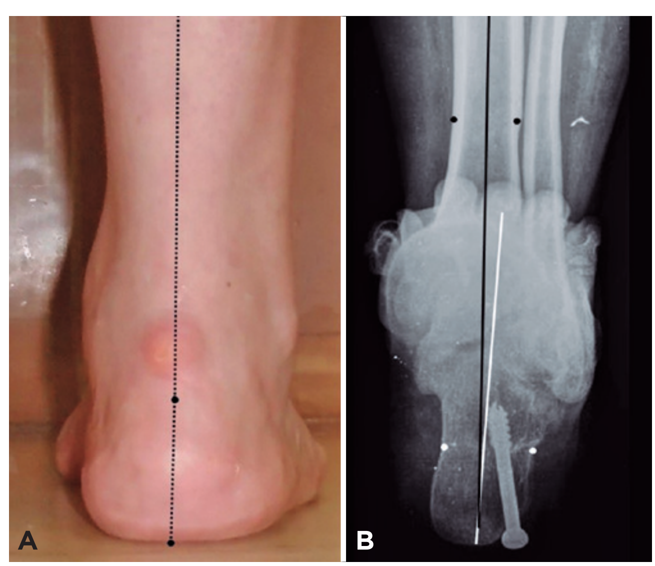

Figure 1. Posterior view of the right leg-foot (Saltzman) of patient 8, showing the clinical (1A) and radiographic (1B) methods for measuring the tibial and hindfoot axes, which are used to assess residual varus after surgical treatment.

For clinical measurement of cavus deformity (1 point), we used photographs of a medial weight-bearing view of the foot (Figure 2). We proposed a ratio with the height of the medial longitudinal arch (measured from the ground to the highest point of the curve in the midfoot) as the numerator (X) and the length of the foot (measured from the head of the first metatarsal to the heel where they contact the ground) as the denominator (Y). When the ratio was ≥50% lower in the postoperative image than the preoperative image, the result was considered satisfactory and 1 point was awarded. When the reduction was <50%, the result was considered unsatisfactory and 0 points were awarded.

For radiographic measurement of the cavus deformity, we used only postoperative lateral weight-bearing radiographs of the foot (Figure 3). Considering the distance from the lower edge of the navicular bone to the ground as the numerator (A) and the length of the longitudinal axis of the navicular bone as the denominator (N), we applied the ratio A/2N as an evaluation method. When the height of the navicular bone ≤ twice its length, the result was considered satisfactory and scored as 1. When the value was > twice its length, the result was considered unsatisfactory and scored as 0.

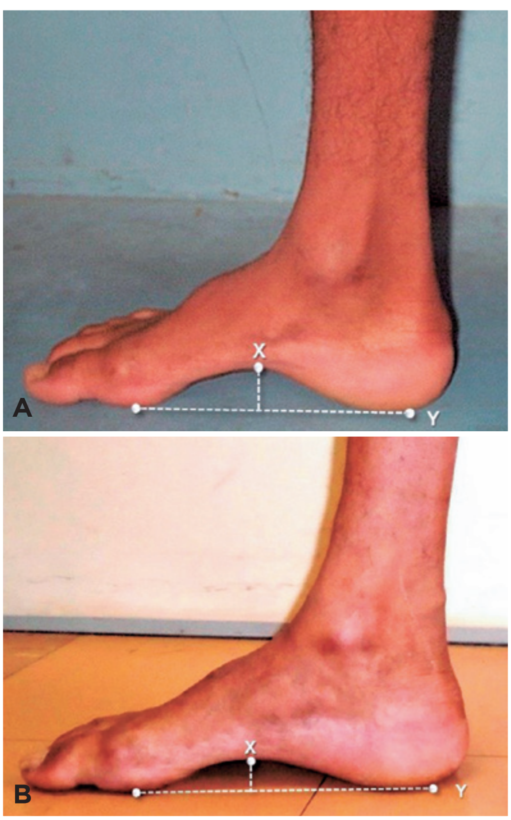

Figure 2. Pre- (2A) and postoperative (2B) medial view of the right foot of patient 5 in our series, showing the method used to assess the height of the medial longitudinal arch (X) in reference to the ground line (Y) . Arch height variation was compared using a ratio of the lengths of X and Y.

Results

Table 1 shows the demographic data and the clinical-functional and radiographic results of TS for cavovarus foot associated with CMT disease.

According to the numerical scale, after a mean follow-up of 105 months (48 to 198 months), we obtained good results in 10 feet, normal results in 5 feet, and poor results in 3 feet. Thus, the final results were considered satisfactory in 15 of 18 feet (84%) (Figures 4 and 5).

Regarding residual pain, the mean visual-analog pain score was 1 (0 to 7) point and the mean AOFAS pain score was 37 (20 to 40) points. Regarding functional analysis, the mean AOFAS subscale score was 41 (20 to 50) points. Claudication was identified in 4 feet, and satisfactory flexibility was maintained in 17 feet after surgery.

Regarding whether TS could correct hindfoot varus, means of 2 (14° to -12°) and 3 (9° to -8°) degrees were found in the clinical and radiographic measurements, respectively. Regarding cavus deformity, a reduction ≥50% in the height of the medial longitudinal arch occurred in only 2 feet according to the clinical measurement, while in radiographic measurement, the height of the medial arch was two times higher the length of the navicular bone in only 1 foot.

Figure 3. Postoperative lateral view of the left foot (weight-bearing) of patient 10, showing the lines used in our radiographic method for evaluating the height of the medial arch. Line N represents the largest longitudinal axis of the navicular bone, while the line A measures the height of the navicular bone in relation to the ground. In this study, we used the ratio of N to A to calculate the magnitude of the residual cavus deformity after surgery.

In a separate analysis of the 3 (all unilateral) cases with poor results, the mean age was 42 (37 to 46) years at TS. The mean time between the initial and rescue surgery (triple arthrodesis) was 39 (16 to 74) months. Of the five patients (five feet) with normal results, the mean age at TS was 21 (9 to 60 years) years and the mean follow-up time was 122 (48 to 198) months. In the 7 patients (10 feet) with good results, the mean age at TS was 17 (10 to 28) years and the mean follow-up was 116 (48 to 192) months.

Discussion

CMT is a progressive neurological disease that causes muscle paralysis and affects the motor function of the foot[16,17]. Surgical interventions cannot permanently correct the associated deformities. Instead, soft tissue surgeries associated with osteotomies[17-21] attempt to preserve joint mobility and postpone larger procedures, such as modeling arthrodesis[22].

The fundamental concepts of surgical treatment include correcting deformities, eliminating deforming forces, and

Table 1. Demographic data and clinical-functional and radiographic results for 15 patients (18 feet) who underwent triple-surgery treatment for cavovarus foot associated with Charcot-Marie-Tooth disease

Case	Sex, age, side	Additional surgeries/ rescue surgeries (Y/N)	Follow-up (months)	Pain vaps (0-10) AOFAS (0-40)	Function AOFAS (0-50) coleman (Y/N) claudication (Y/N)	Varus deformity clinical/ radiographic angle measurement	Cavus deformity clinical/radiographic qualitative measurements (satisfactory/ unsatisfactory)	Decimal scale score (0-10) good/normal/ poor
1	F, 58, L	Jones + FHLT/Y	27	7/20	20/N/Y	7°/4°	Unsatisfactory/ satisfactory	3/poor
2	F, 33, R	Jones + TFL/N	155	3/30	40/Y/N	8°/3°	Unsatisfactory/ satisfactory	7/normal
3	F, 26, L	LCT + TPTT + FHLT/N	198	0/40	27/Y/Y	14°/4°	Unsatisfactory/ satisfactory	6/normal
4	F, 53, R	FHLT/Y	86	7/20	20/N/Y	14°/3°	Unsatisfactory/ satisfactory	3/poor
5	M, 36, R	N/N	176	0/40	41/Y/N	-12°/3°	Unsatisfactory/ satisfactory	9/good
	L	N/N	100	0/40	41/Y/N	-2°/2°	Unsatisfactory/ satisfactory	9/good
6	M, 28, R	N/N	192	0/40	36/Y/N	5°/5°	Unsatisfactory/ satisfactory	8/good
	L	N/N	175	0/40	36/Y/N	-9°/5°	Unsatisfactory/ satisfactory	8/good
7	F, 23, L	Jones + FHLT/N	162	0/40	29/N/Y	-5°/8°	Unsatisfactory/ satisfactory	6/normal
8	F, 30, R	Jones + TPTT/N	146	0/40	44/Y/Y	0°/4°	Unsatisfactory/ satisfactory	8/good
9	F, 53 , R	Jones + FHLT + LALR/Y	18	8/20	20/N/Y	6°/4°	Unsatisfactory/ satisfactory	2/poor
10	M, 20, L	TFL/N	110	0/40	50/Y/N	-8°/-8°	Unsatisfactory/ satisfactory	9/good
11	M, 26, R	TFL + LCT + LALR/N	90	0/40	50/Y/N	-8°/4°	Satisfactory/ satisfactory	10/good
	L	TFL + LCT + LALR/N	76	0/40	50/Y/N	-5°/5°	Unsatisfactory/ satisfactory	9/good
12	M, 14, L	TPTT/N	48	0/40	50/Y/N	-4°/1°	Satisfactory/ satisfactory	9/good
13	M, 64, L	TFL + LALR/N	48	2/30	48/Y/N	4°/7°	Unsatisfactory/ unsatisfactory	7/normal
14	F, 18, L	N/N	48	3/30	50/Y/N	2°/9°	Unsatisfactory/ satisfactory	7/normal
15	M, 18, R	N/N	48	2/40	50/Y/N	3°/2°	Unsatisfactory/ satisfactory	9/good

M: male; F: female; Y: yes; N: no; AOFAS: American Orthopedic Foot and Ankle Society Scale; COLEMAN: Coleman block test; FHLT: flexor hallucis longus tendon transfer to the fibularis brevis; Jones: extensor hallucis longus tendon transfer from the hallux to the first metatarsal bone; LALR: lateral ankle ligament reconstruction; LCT: lengthening of the calcaneal tendon; TFL: tenodesis of the fibularis longus to the fibularis brevis; TPTT: tibialis posterior tendon transfer to the dorsum of the foot; VAPS: visual analog pain scale.

attempting to restore the force of paralyzed muscles by performing muscle transfers. Occasionally, it is necessary to reconstruct incompetent lateral ligaments that are associated with muscle imbalance and gait instability[23-28].

Although several surgical techniques have been described for cavovarus foot due to CMT disease, it is necessary to combine procedures to address multiple deformities[16-23]. The literature does not clearly define how to select the best combination of procedures[28-30]. In this study, we attempted to develop a systematized surgical protocol for correcting the main flexible deformities of the cavovarus foot.

In our series of 15 patients (18 feet), the 3 feet with poor results were operated on later in the course of the disease (mean age at intervention 42 years vs. 22 years overall). It would seem that, due to the progressive nature of the disease, there has been a neurological deterioration over the years, leading to greater muscle imbalance and more pronounced deformities. Thus, the point at which surgery is performed would directly influence the outcome. Better clinical-functional results would be expected of younger patients, whose deformities are less severe and rigid and whose degree of muscle impairment is lower.

Given that all patients with flexible deformities underwent the three combined procedures in our service, we cannot separately assess the corrections achieved by each procedure. Some authors consider calcaneus osteotomy unnecessary to correct deformities of the flexible cavovarus foot. They perform only lengthening osteotomy of the first metatarsal associated with plantar fasciotomy, reporting that they can correct the foot and prevent arthrodesis in most cases[5,6,29,30]. We believe that due to the varus component in the deformity, calcaneus osteotomy is important for complete correction in the hindfoot. It could be that feet which respond well to lengthening osteotomy of the first metatarsal associated

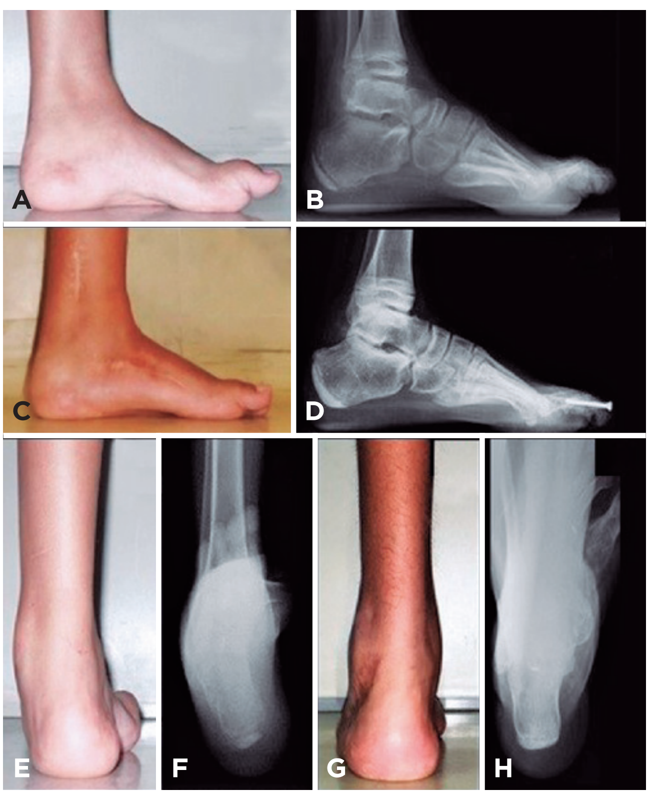

Figure 4. According to these clinical and radiographic images of the left foot and ankle of patient 12, the main deformities in the preoperative period were significantly corrected after surgery. Note the decrease in medial arch height before (4A) and 48 months after surgery (4C), which can also be seen in pre- (4B) and postoperative (4D) lateral weight-bearing radiographic images. Also note the correction of varus deformity of the hindfoot by comparing the pre- (4E) and postoperative (4G) clinical images. The correction can be better appreciated by comparing pre- (4F) and postoperative (4G) radiographic images in the axial leg-foot view. (Source: SAME Santa Casa de São Paulo).

Figure 5. Clinical and radiographic images of the left foot of patient 14 pre-and 48 months postoperatively. The decrease in medial arch height can be seen by comparing the pre- (5A) and postoperative (5C) images. In the weight-bearing lateral view, the reduction in medial arch height between the pre- (5B) postoperative (5D) periods is evident. Significant correction of the hindfoot varus deformity can be seen by comparing the preoperative clinical (5E) and radiographic (5F) images with those of postoperative period (5G and 5H). (Source: SAME Santa Casa de São Paulo).

with plantar fasciotomy are still in a very early stage deformity and have no major changes in the hindfoot, unlike some of the feet in our series. In addition, our clinical evaluation showed that there was no significant correction of the cavus deformity despite the lengthening osteotomy of the first metatarsal.

Due to the lack of a classification system to quantify deformities in the cavovarus foot, there are currently no formal indications regarding the ideal procedure for each type of deformity. There is not even a standardized system for evaluating the results of surgical treatment. Thus, we attempted to formulate a method for evaluating the main points we seek to improve with the surgical intervention. We developed a scale to more accurately evaluate the results and created objective parameters that allow a comparison of the initial and the post-surgery states for the main cavovarus foot deformities. This scale could also be used to assess different treatment modalities, allowing a comparison of the results of different techniques for correcting cavovarus foot.

Regarding study limitations, we point out that our preoperative documentation did not allow a complete comparison between pre- and postoperative deformities in some cases. Thus, we could not accurately determine whether the cases that obtained satisfactory results were initially less severe than those that did not. Another important point is that the evaluation did not include soft tissue procedures performed in conjunction with TS.

Although we obtained satisfactory results with TS, it should be pointed out that these patients have a progressive neurological disease that can result in significant disability in foot function. The purpose of this protocol is not definitive treatment but rather to improve the symptoms and quality of life of these patients, reestablishing better foot support and possibly improved walking[3].

Conclusion

As a proposal for cavovarus foot treatment in patients with CMT disease, our TS protocol efficiently corrected the hindfoot varus deformity in the medium term. The method can provide functional improvement while preserving mobility without pain complaints.

Authors' contributions: Each author contributed individually and significantly to the development of this article: LM (https://orcid.org/0000-0001-5967-0541)* data collection, clinical examination, wrote the article, interpreted the results of the study, participated in the review process; NMN (https://orcid.org/0000-0001-7696-2220)* wrote the article and interpreted the results of the study; RCF (https://orcid.org/0000-0002-9886-5082)* conceived and planned the activities that led to the study, wrote the article, participated in the review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Peripheral talus fractures: epidemiology and short-term outcomes

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Abstract

Objective: To present the epidemiology and assess short-term clinical and radiological outcomes of peripheral talus fractures treated between 2013 and 2019 at a secondary hospital.

Methods: This is a retrospective study based on a series of 21 cases of peripheral talus fractures. Out of these 21 cases, 11 underwent functional assessment using the ankle-hindfoot scale of the American Orthopaedic Foot and Ankle Society (AOFAS) and radiological assessment after a mean period of 24.5 months.

Results: Regarding the epidemiology of the 21 reported cases, the mean age was 28.7 years and 76.2% of the patients were male. The left foot was affected in 71.4% of the cases, and the most frequent type of trauma was motorcycle accident (47.6%); 23.8% of the cases had open fractures. Complete peritalar dislocation occurred in 38.0% of the cases and the most common fracture was that of the lateral process of the talus, in 42.8% of the cases. Eleven patients returned for reassessment and presented a mean AOFAS score of 80.9 points. All fractures were consolidated at the moment of assessment, and one of them progressed to subtalar and talonavicular osteoarthritis, requiring triple arthrodesis.

Conclusion: The peripheral fractures studied here were caused by high-energy traumas with open fractures in one-quarter of the cases and were frequently associated with other fractures. The short-term functional outcome is good but has potential for severe complications such as stiffness and persistent pain.

Level of Evidence IV, Therapeutic Studies; Case Series.

Keywords: Talus/injuries; Ankle Fractures/diagnostic imaging; Fractures, bone/epidemiology; Treatment outcomes.

Introduction

Peripheral talus fractures affect the following segments of the talus: head, middle facet, and lateral, posterolateral, and posteromedial processes[1]. Overall, talus fractures are rare and comprise less than 2.5% of all fractures[2]. An incidence of only 4.6 cases per year was observed at a tertiary hospital in the city of São Paulo[3].

Among peripheral talus fractures, the lateral process fracture is the most frequent and has snowboarding accidents as its main cause. These fractures are overlooked in around 33% of initial assessments and present better functional outcomes when treated surgcally[4,5].

Literature on fractures of the posteromedial process of the talus and the talar head is based on limited case series and there are no significant conclusions regarding the best treatment[6,7].

Posterolateral process fractures usually have hindfoot stiffness and mild pain during physical activities as after effects[2].

The aim of the present study is to present the epidemiology and short-term clinical and radiographic outcomes of peripheral talus fractures treated between 2013 and 2019 at a secondary hospital in an inland city of the state of São Paulo.

Study performed at the Hospital Municipal Dr. José de Carvalho Florence, São José dos Campos, São Paulo, Brazil.

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Methods

This is a retrospective, single-centered, case series study and was approved by by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 19163819.8.0000.5451.

We selected adult patients (over 17 years old) who received treatment due to peripheral talus fractures between 2013 and 2019. All patients signed a free and informed consent form.

All cases in this study were treated and followed up by the hospital's Foot and Ankle Group, which consists of 4 specialist physicians accredited by the Brazilian Association of Medicine and Surgery of the Ankle and Foot, in addition to a physician in training in this specialty. The diagnosis of peripheral fractures was based on radiographic images and complemented by computed tomography images in all cases. Surgical treatment, when applicable, was performed by the 2 most experienced members of the Group and was based on the guidelines summarized by Berkowits et al. Small extra-articular avulsions, fragments measuring less than 1cm with displacements of less than 2mm, and non-displaced fractures were treated conservatively. Large fragments with articular displacement were treated with reduction and osteosynthesis. Simple resection was an option for large, comminuted fractures that did not allow fixation[8]. All cases were postoperatively followed up in an outpatient basis at the hospital by members of the Foot and Ankle group.

The epidemiology study was performed through the assessment of the following variables: age, sex, associated diseases, trauma mechanism, and fracture type.

Patients with at least a year of treatment follow-up were selected and underwent functional and radiographic assessment of the affected foot. Functional assessment was performed according to the ankle-hindfoot scale of the American Orhtopaedic Foot & Ankle Society (AOFAS); results varied from 0 to 100 points, and the higher the result, the better the outcome[9]. At the radiographic assessment, the following criteria were analyzed: fracture consolidation, signs of osteoarthritis on the ankle and hindfoot joints (considering joint space narrowing in weight-bearing radiography), and complications such as osteonecrosis (due to bone sclerosis) and disuse osteopenia, without applying a specific classification for each of them. Both assessments were performed by the Foot and Hindfoot Group after patient recruitment by the hospital. During the visit, radiographic images of the foot and ankle were updated, and the functional assessment scale was applied.

Results

Twenty-one patients with peripheral talus fractures were treated between November 2013 and March 2019. Of these, 11 had functional and radiographic assessments performed according to the methodology proposed by this study and 10 were not available for the final assessment but were included in the study's epidemiological assessment. The characterization of cases and treated fractures was performed with all 21 patients and is described in the following paragraphs.

Mean age was 28.7 years (minimum 17, maximum 48); 16 patients (76.2%) were male and 5 (23.8) were female. The left foot was affected in 15 (71.4%) patients and the right foot, in 6 (28.6%) cases. The most common trauma mechanism was motorcycle accident, in 10 (47.6%) cases, followed by fall from height in 5 (23.8%) cases, sprain in 4 (19.0%) cases, and bicycle and car accidents in 1 case each (4.8%).

Eight (38.0%) patients had complete peritalar dislocations associated with the fracture, of which 5 (62.5%) were medial and 3 (37.5%) were lateral. Five patients (23.8%) had open peripheral talus fractures. Fractures of the lateral process of the talus were the most common, in 9 (42.8%) cases, followed by posteromedial process fractures in 8 (30.8%) cases, posterolateral process fractures in 5 (23.8%) cases, talar head fractures in 5 (23.8%) cases, and middle facet fractures in 2 (9.6%) cases, totaling 29 fractures. Six patients had more than one type of concomitant peripheral talus fracture. Associated fractures in the ankle and ipsilateral foot regions were found in 7 (33.3%) patients; 3 patients had more than 1 type of fracture. The diagnosed fractures were: cuboid (3 cases), sustentaculum tali (2 cases), metatarsus (2 cases), navicular (1 case), anterior process of the calcaneus (1 case), and lateral malleolus (1 case).

When considering only the 11 patients who underwent final functional and radiographic assessments, the mean follow-up period was 24.5 months, with a minimum of 12 months and a maximum of 63 months. The distribution of fractures and treatments performed in this group is exhibited in table 1. Overall, 16 fractures (6 fractures of the lateral process of the talus, 3 of the posterolateral process of the talus, 3 talar head fractures, and 2 middle facet fractures). Three patients had complete peritalar traumatic dislocation associated with the fracture. Ten fractures were surgically treated, of which 7 were treated by reduction and osteosynthesis and 3, by resection of the fractured fragment. The other 6 fractures were treated conservatively.

The AOFAS score varied between 22 and 100, with a mean value of 80.9 points (median 84.4; standard deviation 22.7). All fractures were consolidated at the moment of assessment, and we did not evaluate time to consolidation. There were no cases of tibiotalar osteoarthritis, 2 cases progressed to subtalar osteoarthritis, and 1 case presented talonavicular osteoarthritis. There were no cases of talar necrosis and only 1 case of disuse osteopenia at final assessment (Table 2). One case required a triple arthrodesis due to stiffness and persistent pain.

Discussion

In this study, the left foot was affected in 71.4% of the patients, which was similar to results found by von Knoch et al.[10]. We attempted to correlate this finding with motorcycle accidents as the trauma mechanism, since a fixed left foot is required for shifting gears, but the distribution of cases among those who suffered this type of accident was of 6 fractures of the left foot vs 4 of the right foot (p=0.08 according to Fisher's exact test), thus not showing a statistically significant difference.

Table 1. Study of cases and fractures of patients who underwent final functional and radiographic assessments

Case	Age	Sex	Side	Trauma mechanism	Open fracture	Peritalar dislocation	Treatment of dislocations	Type of fracture	Treatment of fractures
1	39	Female	Left	Motorcycle accident	No	Yes, medial	Closed reduction, plaster splint	Posteromedial	Conservative
2	31	Female	Left	Sprain	No	No	-	Posteromedial and posterolateral	Osteosynthesis
3	41	Female	Left	Bicycle accident	Yes	Yes, lateral	Closed reduction, plaster splint	Posteromedial and talar head	Posteromedial resection, conservative treatment of the talar head
4	30	Male	Left	Fall from height	No	No	-	Lateral and middle facet of the talus	Conservative treatment of the lateral fracture, osteosynthesis of the middle facet
5	20	Male	Right	Motorcycle accident	No	No	-	Lateral	Osteosynthesis
6	17	Male	Right	Sprain	No	No	-	Posterolateral	Conservative
7	21	Male	Right	Motorcycle accident	Yes	Yes, medial	Closed reduction, external fixation	Lateral	Conservative
8	24	Male	Left	Car accident	No	No	-	Lateral, middle facet, and talar head	Osteosynthesis of the 3 fractures
9	19	Male	Left	Motorcycle accident	No	No	-	Posterolateral	Conservative
10	28	Male	Left	Motorcycle accident	Yes	No	-	Talar head	Resection
11	22	Male	Left	Motorcycle accident	No	No	-	Lateral	Resection

Table 2. Final functional and radiographic assessments

Case	Follow-up time (months)	AOFAS score	Consolidation	Tibiotalar osteoarthritis	Subtalar osteoarthritis	Talonavicular osteoarthritis	Osteonecrosis	Disuse osteopenia
1	63	85	yes	No	No	No	No	No
2	51	67	yes	No	No	No	No	No
3	34	22	yes	No	Yes	Yes	No	No
4	22	82	yes	No	No	No	No	No
5	13	82	yes	No	No	No	No	No
6	13	100	yes	No	No	No	No	No
7	17	84	yes	No	No	No	No	Yes
8	13	97	yes	No	No	No	No	No
9	12	100	yes	No	No	No	No	No
10	14	71	yes	No	No	No	No	No
11	18	100	yes	No	Yes	No	No	No

AOFAS: American Orthopaedic Foot and Ankle Society.

The high rates of open fractures observed in this study (23.8% of all cases and 50% of the cases with peritalar dislocation) were larger than those described by Bibbo et al.[11], who reported 28.0% of open peritalar dislocations, and by Hoexum and Heetveld, who observed 22.5% of open injuries[7]. The high frequency of open injuries in this study may be explained by the fact that 76.2% of the cases were caused by high-energy traumas. Much lower incidences are found in studies that only consider fractures of the lateral process of the talus, which in European and North American countries are predominantly caused by snowboarding accidents[4,12]. Another consequence related to high-energy traumas are associated fractures in the ankle and foot regions, which were present in one-third of our cases (7 patients). Out of these 7 patients with associated fractures, 5 had motorcycle accident as cause.

Among our cases, we had 2 patients with a rare pattern of peripheral fracture. These presented fractures with impaction of the middle articular facet towards the subtalar and, from this impaction focus, a fracture line was extended to the talar head; this injury was incomplete in one case and complete in the other. Both cases had an associated fracture of the lateral process of the talus (Figures 1 and 2), and both impaction fractures were treated surgically. The diagnosis of this type of injury demands much attention in the analysis of images initially obtained for assessing trauma and can easily be overlooked. Computed tomography imaging is fundamental in understanding this type of injury, and even magnetic resonance may be necessary[13,14].

The outcome achieved in our cases, with a mean AOFAS score of 80.9 points, was below that reported by Valderrabano et al.[4] in the treatment of fractures of the lateral process of the talus. These authors reported AOFAS scores of 97 and 85 points, respectively, for cases treated surgically and conservatively. However, Wijers et al.[15] reported an AOFAS score of 78.7 points when treating fractures of the posterior process of the talus. Our result was negatively influenced by a case (number 3) that developed stiffness of the hindfoot and intense pain, requiring a triple arthrodesis with 34 months of follow-up. Regardless of this case, the fact that most patients had suffered high-energy traumas (of which 3 resulted in open fractures) led to a decrease in the expectation of good functional outcomes.

Some limitations of this study are the inclusion of different types of peripheral talus fractures, which could not be compared with each other due to the small number of cases. The retrospective and single-centered design of the study was also a negative aspect. Since this is a rare type of fracture, the inclusion of other centers that provide care to patients with this injury could have contributed to a larger number of cases. Another aspect to be considered is that final assessment was performed with only 11 patients, with a relatively short follow-up period to demonstrate the incidence of osteoarthritis.

Conclusion

The peripheral talus fractures observed in our environment were predominantly of the left foot, caused by high-energy traumas, open, and frequently associated with other fractures. Short-term functional outcomes are good, but there is potential for severe complications such as stiffness and persistent pain.

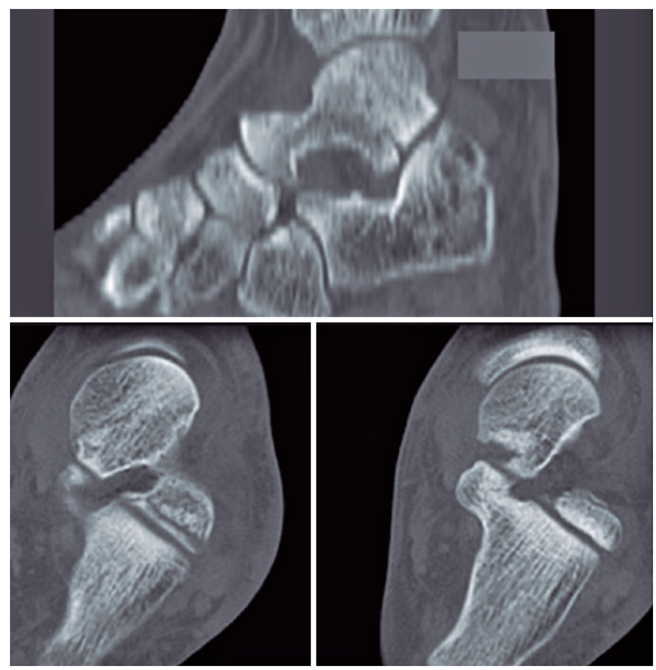

Figure 1. Fracture of the lateral process associated with a fracture of the middle facet of the talus.

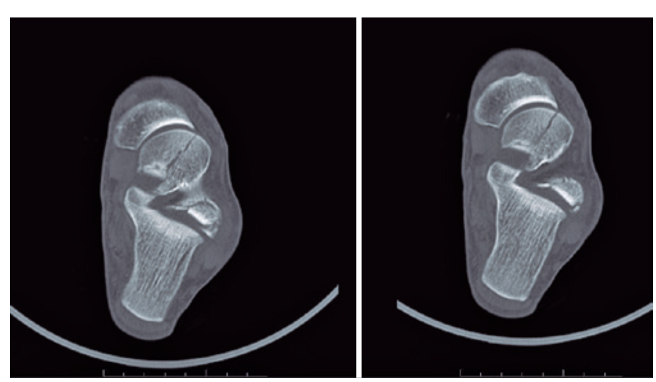

Figure 2. Fracture extension to the talar head and impaction of the middle facet.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MHS *(https://orcid.org/0000-0001-7969-0515) conceived and planned the activities that led to the study, interpreted the results of the study, performed the surgeries; JMPB *(https://orcid.org/0000-0002-5280-1673) conceived and planned the activities that led to the study, bibliographic review; LNSP *(https://orcid.org/0000-0003-3711-0695) participated in the review process; CMRS *(https://orcid.org/0000-0002-0077-4087) data collection, clinical examination; KMM *(https://orcid.org/0000-0003-0804-4078) data collection, clinical examination. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Radiographic assessment of AO 44-B1 and -B2 ankle fractures

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Abstract

Objective: To verify if there is a type of image that guides the surgeon in recommending surgical treatment for ankle fractures and assess whether this decision is associated with the evaluator's age and experience, considering surgeons of different nationalities. **Methods:** We analyzed 3 different presentations of radiographic images of ankle fractures in 36 patients: anteroposterior and lateral views, true anteroposterior and lateral views, as well as the 3 grouped images. Images were assessed randomly and independently by 89 professionals of different nationalities, ages, and experience.

Results: Among professionals from Ecuador, Argentina, Mexico, and Chile, surgery recommendations were more frequent when images were presented in true anteroposterior and lateral views. For professionals from Peru, Venezuela, Bolivia, Paraguay, Brazil, Colombia, Uruguay, and Guatemala, as well as globally, recommendations for surgery were more frequent when grouped images of the 3 positions were presented. In all countries and globally, we verified lower frequencies of surgery recommendations when presenting only anteroposterior and lateral views.

Conclusion: In most countries, surgery recommendations were more frequent when grouped images of all 3 views were presented. On the other hand, the highest frequencies of surgery recommendations were observed when images were presented only in true anteroposterior and lateral views. Surgery recommendations were not associated with the experience (years since graduation) of the evaluating physician.

Level of Evidence IV; Prognostic Studies; Case Series.

Keywords: Ankle fractures/epidemiology; Radiography/methods; Observer variation; Reproducibility of Results; Attitude of health personnel.

Introduction

Ankle fractures are among the most frequent injuries of the musculoskeletal system and correspond to approximately 9% of all fractures[1]; the radiographic study of these pathologies represents 10%-12% of all radiographs captured in emergency settings, resulting in significant expenses[2-12].

Radiographic assessment is essential in ankle fractures. The Ottawa ankle rules represented an attempt to reduce the recommendation of imaging examinations. However, the small dose of radiation and low cost of radiographic procedures favor the performance of such tests[6]. Radiographic views classically requested for diagnosing ankle fractures are anteroposterior (AP), AP with internal rotation of 20° (true AP), and lateral. However, many studies have challenged the need for 3 radiographic images when diagnosing ankle fractures[2,4,9,10]. Various authors have suggested that 2 views may be enough for diagnosing this pathology[2,4,9,11]. These studies suggest that only the AP and lateral views could be used for diagnosing fractures[2,10]. Conversely, other authors recommend only the true AP and lateral views, since these could provide "95% precision" in the diagnosis of ankle fractures when compared to the 3-view series[4,9]. In most of these studies, the combination of 2 images was compared to the standard 3-image series, selected according to the researcher's preference.

This work aimed to verify if there is a type of image that leads the surgeon to recommend surgical treatment of ankle fractures and to assess whether the surgeon's decision is associated with his or her age and experience, considering surgeons of different nationalities.

Study performed at the Hospital Santa Teresa, Petrópolis, RJ, Brazil.

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Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 82503418.6.0000.5245.

This is an observational cross-sectional study was performed between March 01 and June 30, 2019, involving 89 evaluating professionals and 36 patients with ankle fractures treated at a tertiary hospital. Patients were randomly selected and no sampling analysis was performed.

Inclusion criteria were: patients over 18 years old, diagnosed with 44-B1 and -B2 supination external rotation ankle fractures, who had radiographic images in 3 views in the studied period. Exclusion criteria were: patients with open fractures (since these are normally caused by more intense trauma and may present different patterns), patients with history of previous ankle fractures or of fractures due to metabolic or tumor-derived alterations.

For achieving the aim of this study, radiographic images were randomly and independently assessed by 89 professionals of different nationalities, ages, and experience (time since graduation). Inclusion criteria for evaluators were: physicians graduated more than 1 year before in orthopaedics and traumatology and who were registered at orthopaedic associations in their countries of work. Exclusion criteria for evaluators were: physicians who did not work with traumatology and who did not belong to any orthopaedic association.

Three different presentations of radiographic images of the ankles of 36 patients were shown to the evaluators.

Each of the 36 cases was presented to the evaluators as follows:

- Presentation 1: radiographic image of the ankle in AP and lateral views;
- Presentation 2: radiographic image of the ankle in AP with internal rotation of 20° (mortise) and lateral views;
- Presentation 3: radiographic image of the ankle with all 3 grouped images (AP, mortise, and lateral).

The 108 presentations were independently provided to the evaluators in a random order via a digital platform under control of the researchers only. For each presentation, the evaluator indicated his or her decision of surgical or conservative treatment. Once the evaluator chose a type of treatment, the program did not allow changes to previously assigned answers. This was determined so as the evaluator could not change his or her opinion when identifying the case in presentations containing all 3 images. We did not control the time spent by each evaluator examining the radiographic images.

Statistical analysis

Data on the evaluators (age, time since graduation, and country of work) and their answers regarding surgery recommendations for each of the 180 evaluations formed the database for our research.

Quantitative variables (age and time since graduation) were described using minimum and maximum values, means, medians, standard deviations, and coefficients of variation. The variability of a quantitative variable distribution was considered low if; moderate and high if: for each of the 3 presentations; results of the selected outcome (surgery recommendations) were presented in tables and graphs as absolute and percentage frequencies (relative surgery recommendation index).

We used the Mann-Whitney test for comparing ages and time since graduation of professionals who recommended surgery or not, since the distribution of these variables in this study was not normal. The normality of data distribution regarding age and time since graduation was verified by a Shapiro-Wilk test.

Since variables were not normally distributed, the correlation between quantitative variables was assessed by Spearman's rank correlation coefficient, and the significance of the correlation coefficient was tested.

All discussions were performed with a maximum significance level of 5% (0.05).

Results

Profile of the professionals

Table 1 presents the distribution of frequencies regarding the evaluators' countries of work and main age statistics, per country and globally (Figure 1). The sample contains professionals from 12 countries in South, Central, and North America, of which Brazil and Mexico are the most represented countries (33.7% and 15.7% of the sample, respectively) (Table 1).

Table 2 presents the distribution of frequencies regarding the evaluators' countries of work and main statistics of time since graduation, per country and globally (Table 2, Figure 2).

Decisions of the professionals

Table 3 demonstrates the distribution of frequencies of professional recommendations to operate on the evaluated cases and the relative surgery recommendation index, per country, type of presented image, and globally. Figure 3 presents, for each type of presented image and globally, frequencies and relative indices of surgery recommendations, per country and globally.

Considering professionals from Ecuador, Argentina, Mexico, and Chile, surgery recommendations were more frequent when images were presented in true AP view. For professionals from Peru, Venezuela, Bolivia, Paraguay, Brazil, Colombia, Uruguay, and Guatemala, as well as globally, surgery recommendations were more frequent when the 3 grouped images were presented. For all countries and globally, we verified the lowest frequencies of surgery recommendations when only the normal AP view was presented (Figure 3).

Only in 2 out of 108 evaluations (1.9%), we verified a significant association between the decision to operate and the age of the evaluating physician. In both cases, physicians who decided on surgical treatment were significantly more experienced than

Table 1. Distribution of frequencies of evaluators' countries of work and main age statistics, per country and globally

Country	Number of cases	Age of the professionals					
		Minimum	Maximum	Mean	Median	Standard deviation	Coefficient of variation
Argentina	8	27	54	40.8	41	8.7	0.21
Bolivia	2	33	36	34.5	35	2.1	0.06
Brazil	30	28	62	41.0	40	8.7	0.21
Chile	3	32	63	43.7	36	16.9	0.39
Colombia	9	33	52	40.0	39	6.7	0.17
Ecuador	2	44	45	44.5	45	0.7	0.02
Guatemala	1	28	28	28.0	28	-	-
Mexico	14	27	58	39.4	39	10.2	0.26
Paraguay	3	28	42	33.3	30	7.6	0.23
Peru	4	32	82	54.3	52	21.5	0.40
Uruguay	1	34	34	34.0	34	-	
Venezuela	12	30	58	36.3	33	8.6	0.24
Global	89	27	82	40.1	38.0	10.0	0.25

Table 2. Distribution of frequencies of evaluators' countries of work and main statistics of time since graduation, per country and globally

Country	Number of cases	Time since graduation					
		Minimum	Maximum	Mean	Median	Standard deviation	Coefficient of variation
Argentina	8	3	29	13.0	12	9.0	0.69
Bolivia	2	2	5	3.5	4	2.1	0.61
Brazil	30	2	34	13.1	13	9.0	0.69
Chile	3	4	39	16.0	5	19.9	1.25
Colombia	9	2	22	8.8	6	7.3	0.83
Ecuador	2	10	15	12.5	13	3.5	0.28
Guatemala	1	2	2	2.0	2	-	-
Mexico	14	2	33	11.8	9	10.0	0.85
Paraguay	3	1	12	5.0	2	6.1	1.22
Peru	4	4	50	21.3	16	21.1	0.99
Uruguay	1	5	5	5.0	5	-	-
Venezuela	12	3	28	7.8	6	6.7	0.86
Global	89	1	50	11.5	7	9.8	0.85

Table 3. Distribution of frequencies of evaluators' surgery recommendations on the evaluated cases and relative surgery recommendation indices, per country, type of image, and globally

Country	Presenting image in normal anteroposterior view			Presenting image in true anteroposterior view			Presenting all 3 images			Global		
	Evaluations	Number of surgery recommendations	Relative surgery recommendation index	Evaluations	Number of surgery recommendations	Relative surgery recommendation index	Evaluations	Number of surgery recommendations	Relative surgery recommendation index	Evaluations	Number of surgery recommendations	Relative surgery recommendation index
Argentina	288	182	63.2%	288	224	77.8%	288	204	70.8%	864	610	70.6%
Bolivia	72	42	58.3%	72	56	77.8%	72	57	79.2%	216	155	71.8%
Brazil	1080	663	61.4%	1080	713	66.0%	1080	740	68.5%	3240	2116	65.3%
Chile	108	55	50.9%	108	72	66.7%	108	69	63.9%	324	196	60.5%
Colombia	324	183	56.5%	324	201	62.0%	324	210	64.8%	972	594	61.1%
Ecuador	72	57	79.2%	72	62	86.1%	72	57	79.2%	216	176	81.5%
Guatemala	36	9	25.0%	36	7	19.4%	36	13	36.1%	108	29	26.9%
Mexico	504	273	54.2%	504	329	65.3%	504	322	63.9%	1512	924	61.1%
Paraguay	108	72	66.7%	108	71	65.7%	108	76	70.4%	324	219	67.6%
Peru	144	102	70.8%	144	106	73.6%	144	115	79.9%	432	323	74.8%
Uruguay	36	20	55.6%	36	17	47.2%	36	24	66.7%	108	61	56.5%
Venezuela	432	283	65.5%	432	332	76.9%	432	345	79.9%	1296	960	74.1%
Global	3204	1941	60.6%	3204	2190	68.4%	3204	2232	69.7%	9612	6363	66.2%

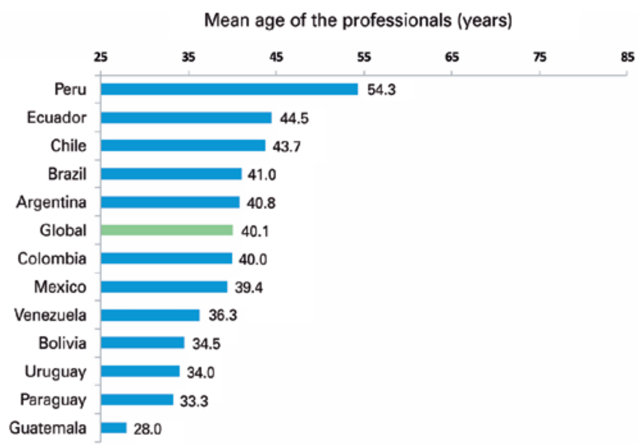

Figure 1. Mean age of professionals per country (ascending order).

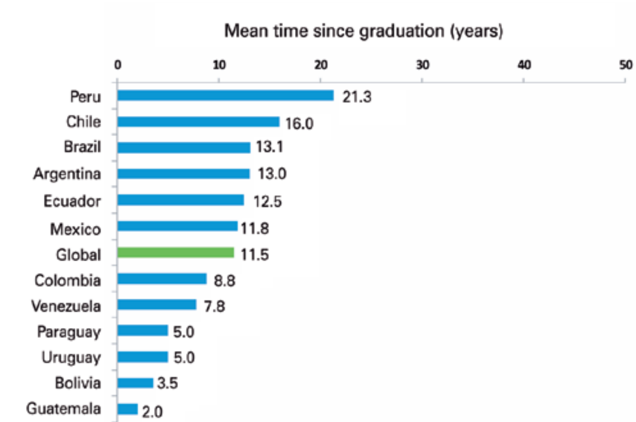

Figure 2. Mean time since graduation for professionals in each country (ascending order).

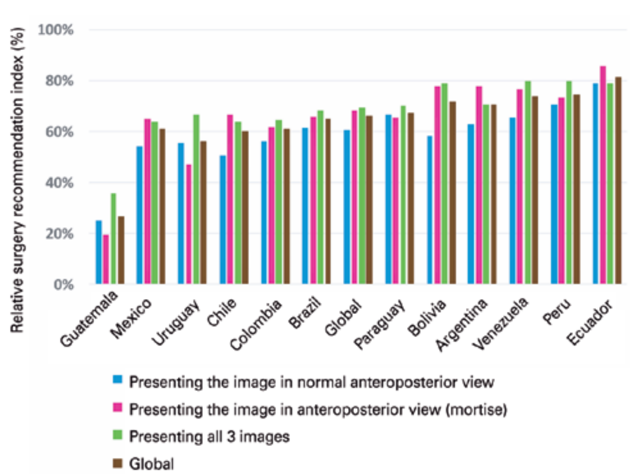

Figure 3. Relative surgery recommendation indices per country and type of presented image and globally.

those who decided on conservative treatment. In the other evaluations and globally, we did not verify a significant association between the decision to operate and the age of the evaluating physician (p-values over 5% in the Mann-Whitney test when comparing age distributions of those who decided to operate and those who decided not to). As the association between the decision to operate and the age of the evaluating physician was present only in a nonrelevant fraction of the cases (1.9%), we concluded that the decision to operate was not significantly associated with the age of the evaluating physician.

In 5 out of the 108 evaluations (4.6%), we verified a significant association between the decision to operate and the time since graduation of the evaluating physician. In these 5 cases, professionals who decided on surgical treatment were significantly more experienced than those who decided on conservative treatment. In the remaining evaluations and globally, we did not verify a significant association between the decision to operate and the time since graduation of the evaluating physician (p-values over 5% in the Mann-Whitney test when comparing time since graduation of those who decided to operate and those who decided not to). Since the association between the decision to operate and the time since graduation of the evaluating physician was observed with a nonrelevant frequency (4.6% of the evaluations), we concluded that the decision to operate was not significantly associated with the time since graduation of the evaluating physician.

Additionally, we investigated whether the total number of surgery recommendations (regarding the 3 presentations and globally) was correlated with the professional's age and time since graduation. Because data were not normally distributed, correlations were assessed using Spearman's rank correlation coefficient. Correlations presented on Table 4 are small and not significantly different from zero (p-values of significance over 5%).

Table 4. Correlation analysis between the number of surgery recommendations by the evaluator and his or her age and time since graduation

Correlation coefficient between variables in lines and columns (p-value of significance of the correlation coefficient)	Age	Time since graduation
Number of surgery recommendations by the evaluator for the presentation of lateral and normal anteroposterior images	0.06 (0.559)	0.09 (0.400)
Number of surgery recommendations by the evaluator for the presentation of lateral and true anteroposterior images	0.06 (0.534)	0.12 (0.246)
Number of surgery recommendations by the evaluator for the presentation of all 3 images	0.07 (0.534)	0.09 (0.427)
Total number of surgery recommendations by the evaluator	0.06 (0.563)	0.11 (0.320)

Discussion

According to the literature, various studies have demonstrated different numbers of views that would be required for diagnosing ankle fractures[1,4,9,10,16].

In emergency departments, radiographic examinations of the ankle represent 10%–12% of all requested radiographs[2-12].

Auletta et al.[13] reported that 50% of ankle radiographs were not necessary and other studies demonstrated that they are unnecessary[3,14,15]. Cockshott et al.[2] stated that fractures were present in only 29% of the radiographed patients. Auletta et al.[13] found fractures in 30% of patient radiographs and Brandser et al.[11] found a 28% fracture prevalence.

In our study, we observed that ankle fractures should be diagnosed and classified for their correct treatment, and the ideal setting would include 3 radiographic images: AP, true AP, and lateral views.

This study demonstrated that, even in different medical scenarios (different countries), most evaluators opted for using 3 images of ankle fractures for recommending surgical treatment. However, images in true AP and lateral views, when compared with the 3 grouped images, also provided more information such as: type of fracture, classification, and surgical treatment.

Cockshott et al.[2], in a review with 242 ankle radiographs, observed that the AP and lateral views detected all fractures and that true AP images did not provide additional information. Wallis[9], when analyzing 945 ankle radiographs, found 128 fractures (13.5%). This author studied AP and lateral radiographs and compared them with true AP images; although 4.7% of the cases presented fractures that had not been detected in the AP radiograph, he determined that true AP images would not be necessary because the undiagnosed fractures were fibula avulsion fractures that would not alter the established line of treatment. Brandser et al.[12] compared images used for diagnosing ankle fractures and combined individual results for comparing the performance of 2 and 3 images.

Vangsness et al.[4] examined 123 cases of ankle fractures and compared fracture detection using true AP and lateral views with the 3 images. They observed 95% "precision" with this combination and reported that the choice of the true AP and lateral views over the AP and lateral views was a decision of the authors for performing the study. Brage et al.[10] studied intra and interobserver agreement in the classification of 99 ankle fractures using 2 and 3 images and found that agreement was better with 2 images. The authors recommended the use of the true AP and lateral images for classifying ankle fractures. However, authors did not focus on the fracture diagnosis.

Brandser et al.[11] observed that the combination of both images (AP and true AP) was similar for diagnosing fractures and did not find a reason for choosing one over the other. However, they analyzed only the fracture diagnosis and did not verify whether the 3 images were necessary for classifying fractures or deciding on treatment.

This study demonstrated that, globally, surgeons recommended surgery more frequently when provided with 3 images (69.7% of surgery recommendations when 3 images were provided). However, this is not the standard for groups of surgeons in all countries, since when observing the surgery recommendation indices in each separate country, some differences were verified. When comparing the surgery recommendation indices regarding images in AP, lateral, and true AP views, we observed that, in general, these were higher when the true AP image was shown (68.4% vs 60.6% when the normal AP image was shown). It is important to note that this study aimed to assess surgery recommendations for each image and did not study classification and diagnosis.

For the first time in the literature, physicians from 12 different countries participated in evaluations of ankle fracture images, allowing us to identify and alert for differences between indices of surgery recommendation between countries. Considering evaluators from Ecuador, Argentina, Mexico, and Chile, surgery recommendations were more frequent when true AP images were presented. For professionals from Peru, Venezuela, Bolivia, Paraguay, Brazil, Colombia, Uruguay, and Guatemala, as in the global results, surgery recommendations were more frequent when images in all 3 views were presented. In all countries and globally, we verified the lowest frequencies of surgery recommendations when the image was in normal AP view. The variety of patterns in different countries demonstrates the need to provide as many images as possible.

This study also identified that the decision to operate was not significantly associated with the age and time since graduation of the evaluator. The total number of surgery recommendations by each professional, in all 3 presentations and globally, was also not correlated with his or her age and time in the profession.

An important limitation of this work was the difficulty in obtaining larger samples of evaluators in some countries. It is worth noting that the study recruitment was widely distributed in all participating countries, but adherence was lower than the expected or needed. By dividing the sample with 89 evaluators per country of work of the evaluator, we had small subsamples for some countries, hampering an unbiased statistical inference from our results. However, this does not prevent our results from being used in comparison with other studies with larger subsamples. Moreover, the results of the global analysis presented more validity and provided important conclusions, since this analysis was performed with a broader (89 evaluators) and diverse sample, contemplating many countries of origin.

Another limiting factor of this study was the absence of a categorization of evaluators into 2 groups: those with training on ankle and foot surgery and those who were general trauma specialists.

Conclusion

In most countries, surgery recommendations were more frequent when images of all 3 views were presented. However, the highest frequencies of surgery recommendations were observed when only true AP and lateral images were presented.

Surgery recommendations were not associated with the time since the surgeon's graduation.

Authors' contributions: Each author contributed individually and significantly to the development of this article: PJL *(https://orcid.org/0000-0003-4967-7576) 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, survey of the medical records, formatting of the article, approved the final version; FF *(https://orcid.org/0000-0002-6495-3383) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, statistical analysis, bibliographic review, approved the final version; WDB *(https://orcid.org/0000-0003-1838-1473) Interpreted the results of the study, participated in the review process, statistical analysis, bibliographic review, approved the final version; LEA *(https://orcid.org/0000-0002-8488-184X) Interpreted the results of the study, participated in the review process, bibliographic review, formatting of the article, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Peroneus brevis tendon injury in chronic ankle instability. A comparative study

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Abstract

Objective: To compare the surgical outcome of patients with chronic lateral ligament injury of the ankle, with and without an associated peroneus brevis tendon injury.

Methods: This retrospective comparative study was based on epidemiological analysis and the American Orthopedic Foot and Ankle Society (AOFAS) scores of patients diagnosed with chronic ankle instability who were treated surgically with the Broström-Gould technique. The medical records of 50 patients treated in an orthopedics service between January 2012 and January 2020 were analyzed. The patients were divided into two groups: those with and without a peroneus brevis tendon injury. The following data were also collected: sex, age, comorbidities, and AOFAS score in the pre- and postoperative period (between 90-120 days), as well as other epidemiological data.

Results: Sixteen patients (32%), whose mean age was 43 years and 76% of whom were female, presented with a peroneus brevis tendon injury. The right side (54%) was more commonly affected. The main comorbidities were obesity (14%), slight pes cavus (12%), diabetes mellitus (4%) and depression (4%). The mean improvement in AOFAS score was 41 points. There was a marginal difference in final AOFAS score (p=0.03) between the groups.

Conclusion: The Broström-Gould Technique proved effective for treating chronic lateral ligament injury regardless of an associated peroneus brevis tendon injury. However, the final postoperative results were significantly worse in patients with a peroneus brevis tendon injury than in those without one.

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

Keywords: Ankle joint; Joint instability; Ligaments, articular/injuries; Tendon Injuries.

Introduction

Lateral ankle sprain is one of the most common orthopedic injuries[1]. The lateral ligaments limit the ankle's inversion, keeping it firm in its function and balance[2]. The lateral ligament complex of the ankle is also the most frequently injured structure in sports, with an index varying from 13-56% of all injuries that involve running and jumping, such as soccer, basketball and volleyball[2]. Although patients generally do not remember a specific episode of trauma, they often mention symptoms of chronic lateral ankle instability, which persist for years[3].

The mechanism of this type of injury is forced supination of the hindfoot when initial ankle dorsiflexion changes to plantar flexion[1]. The severity of the injury is classified as grade 1, 2, or 3. Grade 1 is a mild damage to a ligament that does not result in joint instability, grade 2 involves a partial tear and mild joint instability, and grade 3 involves a complete ligament tear and joint instability[4].

Ankle injuries can affect the medial and lateral ligament complexes, but lateral ligament injuries are more common (85% of the cases). Problems associated with lateral ligament injuries include: peroneus brevis tendon injuries, hindfoot varus, alignment abnormalities, retinacular pathology, and anterior ankle impingement[5]. These ankle ligament injuries are responsible for up to 25% of orthopedic consultations[6]. Approximately 20% of these injuries can progress to chronic instability, with anterior talofibular ligament damage occurring in 60 to 70% and calcaneofibular ligament damage in 30%[7].

Study performed at the Conjunto Hospitalar do Mandaqui, São Paulo, SP, Brazil.

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Researchers have correlated peroneus brevis tendon injury (PBTI) and chronic lateral ligament injury of the ankle (CLLI). Thus, an ankle inversion injury can not only damage the anterior talofibular and calcaneofibular ligaments, but the peroneal tendons and superior peroneal retinaculum as well. The central portion of the tendon is almost always injured. In foot eversion during the swing phase, the peroneus longus pulls the peroneus brevis tendon into the retrofibular groove, which is on the posterior border of the fibula. This leads to displacement of the most anterior part of the injured tendon and almost invariably to pain in the posterior aspect of the fibula. In most cases, the damaged tendon goes unnoticed and the diagnosis can be delayed or even overlooked. Due to superior peroneal retinaculum damage, peroneus brevis tendon instability, and tendon tissue degeneration, these cases are usually refractory to non-surgical treatment, and tendon rupture progresses(8). Although considered uncommon, some cases of PBTI with hypertrophied peroneal tubercle have been described in the literature(9). Acute post-traumatic PBT injuries have also been reported but are rarer than chronic injuries(10).

CLLI of the ankle occurs when the torn ligament regenerates with weak fibrous tissue or in an elongated state, in addition to proprioceptive deficit or weakness of the peroneus brevis muscle(11). When not treated correctly, it can cause chronic lateral pain, synovitis with recurrent edema, instability, and loss of function (frequent sprains)(12).

Recovery from an ankle sprain depends on the severity of the injury and the concomitant pathology. Although most sprains recover uneventfully, there is a high rate of new injuries after an initial sprain; up to 34% of patients will suffer a second sprain within 3 years of the initial injury(7).

In addition to a physical examination, magnetic resonance imaging is a useful for visualizing the PBT, allowing anterior talofibular ligament injury and other lateral pathologies of the ankle to be ruled out. In addition, it can be used to assess anatomical variations and bone or soft tissue changes before surgery, such as peroneus quartus, convex fibular groove, bone spur and tendon subluxation(13).

Conservative treatment in the acute phase includes anti-inflammatories, physical therapy, or immobilization for an average of three to six weeks(14). While 80% of acute ankle sprains can be satisfactorily treated with muscle rehabilitation and strengthening, the remaining 20% of patients continue to suffer from chronic ankle instability and new injuries(15). Moreover, conservative treatment may not be able to prevent recurrent episodes of PBT dislocation or subluxation(16).

In cases where the patient has not responded favorably to conservative treatment (eg, adequate physical therapy and/or orthosis), surgical stabilization may be appropriate for restoring function, depending on the patient's needs and expectations(17).

There are several surgical techniques for recovering ankle stability, including non-anatomical reconstruction (tenodesis), anatomical reconstruction, and anatomical repair, such as Broström-Gould surgery(7,12). Broström's anatomical repair, later modified by Gould, was described in 1966 and has since become the gold standard for anatomical repair. It restores the original anatomy of the anterior talofibular ligament, which helps stabilize the subtalar region without restricting its movement(18).

Non-anatomical lateral ankle tendon reconstruction involves transposition of the tendon, such as in the Watson-Jones procedure, the Evans procedure, and the Chrisman-Snook procedure, and is often reserved for patients with generalized ligament laxity or as a revision surgery, since it can sacrifice normal tendons and restrict movement in the tibiotalar and subtalar ankle joints. There is also an increased risk of injury to adjacent cutaneous nerves and of medial degenerative joint disease of the ankle(15).

The present study is relevant due to the high prevalence of this pathology in orthopedic practice, as well as the fact that we could find no other studies directly comparing cases of isolated lateral ligament injuries and those associated with PBTI. Therefore, our objective was to determine whether PBTI associated with ankle ligament instability impacts the results of Broström-Gould surgery regarding quality of life, as well as to obtain an epidemiological sample of patients diagnosed with CLLI.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 38111120.4.0000.5551. The patients were informed about the purpose of the study and provided written consent prior to enrollment.

The CLLI and PBTI diagnoses were confirmed through magnetic resonance imaging. The medical records of 50 patients treated at a public orthopedic reference service between January 2012 and January 2020 were examined regarding the inclusion/exclusion criteria.

The inclusion criteria were: patients aged 18 years or older with CLLI of the ankle who underwent Broström-Gould reconstruction. The exclusion criteria were: refusal to grant access to the medical records, age under 18 years, cognitive inability to provide informed consent, acute ligament injury of the ankle (up to 30 days after the trauma), or severe foot injury.

The surgical technique (described below) was performed on all participants by the same surgeon (JMN). The patient was placed in the supine position with a cushion under the ipsilateral hip and a tourniquet was applied at the root of the thigh of the affected leg. When a PBTI was not diagnosed, the incision was a 3-4cm curve over the lateral malleolus of the ankle, which was followed by dissection of the distal fibula and the remaining stump of the anterior talofibular ligament. The lateral talus process was then inspected and any free bodies and/or meniscus were removed. The anterior talofibular ligament was then reinserted into the distal fibula with an appropriate anchor and was reinforced with the periosteal flap and the inferior retinaculum of the extensors. Injured calcaneofibular ligaments were inserted into the fibula using an anchor or a transosseous suture.

When there was a previous diagnosis of associated PBTI, the incision was curved approximately 8cm proximal to the tip of the fibular malleolus and 2cm toward the fifth metatarsal. When there was no previous injury, debridement was performed after opening the superior retinaculum, followed by tunneling the PBT. When the lesion was extensive and the tendon was not viable, proximal and distal tenodesis of the PBT with the peroneus longus tendon was performed, including exeresis of the damaged segment. A 2.0mm anchor was used to reinsert the superior peroneal retinaculum.

In the first 4 postoperative weeks, the patients wore a walking boot and were instructed to avoid weight-bearing. From the 30th to the 45th day, partial weight-bearing was allowed with crutches. Afterwards, the orthosis was removed and the patient began physical therapy with gait training and exercise to regain range of motion. Normal activities of daily living were allowed during this period and contact sports and distance running could be resumed 4 to 6 months later.

The study was based on medical record analysis. In addition to sex and age, the following epidemiological data were collected in the preoperative (approximately 7 days prior to the procedure) and postoperative (between 90 and 120 days after the procedure) periods: laterality, comorbidities, clinical signs, complications, and AOFAS score. AOFAS is a standardized system for evaluating treatment results in individuals with foot and ankle disorders. The instrument has been translated and validated for Brazilian Portuguese. The instrument was applied to all patients during regular consultations.

The patients were divided into two groups: those without a peroneus brevis tendon injury (PBTI-) and those with a peroneus brevis tendon injury (PBTI+). The groups were compared regarding pre- and postoperative AOFAS scores and the improvement index (ie, the difference between the scores). In addition to the direct comparison between groups, an age-corrected comparison was performed with cut-offs below the minimum age of the older group and above the maximum age of the younger group.

Data analysis was performed after compilation in a Microsoft Excel spreadsheet. The large number of medical records analyzed was due to the eight-year data collection period. The Shapiro-Wilk test was used to determine normal distribution. The groups were compared using Student's *t*-test for normally distributed values or the Mann-Whitney U test for nonparametric distribution. The significance level was set at $p<0.05$ (95% confidence interval [CI], $\alpha=0.05$). Age and AOFAS scores were rounded to the nearest whole number.

Results

Since all medical records contained sufficient data and met the necessary criteria, no cases were excluded. Table 1 shows the epidemiological data of the 50 patients, of whom 38 (76%) were female. The mean age was 42 years and 9 months, ranging from 21 to 70 years. Regarding laterality, 27 patients (54%) were affected on the right side.

Regarding ligament injuries that resulted in ankle instability: 26 (52%) patients had an isolated anterior talofibular ligament injury, while in 24 (48%) the anterior talofibular ligament injury was associated with the calcaneofibular ligament. It should be pointed out that 34 (68%) of the 50 patients did not have a PBTI.

Among the complications, superficial dehiscence of the surgical wound occurred in one patient, while a deep infection that required debridement and surgical cleaning occurred in another.

As shown in figure 1, the most common comorbidity was obesity (7 patients, 14%), followed by the slight pes cavus (6 patients, 12%), diabetes mellitus (2 patients, 4%), and depression (2 patients, 4%). The other comorbidities occurred in only 1 patient (2%) each: chondral lesion of the talus, fibromyalgia, anterior ankle impingement, breast cancer (2%) and meniscoid lesion of the ankle (2%).

In relation to relevant clinical tests and symptoms: a positive anterior ankle drawer test was present in all participants. All of the patients with a PBTI had pain on palpation of the peroneal tendons and 90% had perimalleolar edema. These findings reinforce the importance of clinical examination during the preoperative phase.

Half of the patients were physically active (Figure 2): 8 (16%) were runners, 6 (12%) played soccer, 6 (12%) were walkers, 2 (4%) played volleyball, 2 (4%) played handball, 2 (4%) were martial artists and 1 (2%) was a circus acrobat. All patients returned to their regular physical activities after the surgical procedure.

The mean AOFAS score in PBTI- patients ranged from 52 (SD, 9) points preoperatively to 95 (SD, 5) points ($P<0.001$) postoperatively (Table 2). The same pattern of improvement was seen in PBTI+ patients, whose mean AOFAS score ranged from 50 (SD, 7) points preoperatively to 92 (SD, 5) points ($P<0.001$) postoperatively. Thus, the scores of both groups improved after Broström-Gould surgery.

As shown in table 3, the mean postoperative AOFAS score was 92 (SD, 5) for PBTI+ patients and 95 (SD, 5) for PBTI- patients. There was a marginally significant difference ($P=0.03$) in final scores between the groups, which shows that the improvement in the PBTI+ group, although good, was less than that of the PBTI- group. Given the high final scores in both groups, this result was not normally distributed.

Regarding variation in AOFAS scores (Table 3), variations of 42 (SD, 8) and 41 (SD, 7) points occurred in the PBTI- and PBTI+ groups, respectively ($P=0.02$). These data were normally distributed. PBTI had a marginally significant negative impact on both the initial and final scores.

The mean age of the PBTI- and PBTI+ groups was 39 (SD, 13) and 49 (SD, 11) years, respectively ($P=0.019$) (Table 3).

Table 1. Patient epidemiological data

Name	Sex	Age	Laterality	Affected Ligament	PBT lesion	AOFAS Score	Comorbidities	Follow-up	Complications
S.A.D	F	54	R	ATL+CF	No	26-79	Obesity	3 years	-
R.D.L.A	F	37	L	ATL	No	57-100	None	3 years	-
L.I.L	F	52	R	ATL	No	48-92	Obesity	3 years	-
D.S	F	62	R	ATL+CF	No	48-92	None	4 years	-
P.B.D	F	33	R	ATL+CF	No	48-100	Slight pes cavus	2 years	Deep suture dehiscence
C.T.S	F	58	R	ATL+CF	No	30-90	None	3 years	-
C.S.A.D.S	F	38	L	ATL+CF	No	57-90	Obesity, depression	4 years	-
L.M.S.S	F	63	L	ATL+CF	No	48-100	Obesity	4 years	-
D.R.D.B	F	57	L	ATL	No	48-100	None	4 years	-
W.B.P	M	35	L	ATL	No	48-100	None	6 years	-
V.L.D.S.O	F	50	L	ATL	Yes	50-95	None	4 years	-
S.N.D.S	F	53	R	ATL	No	58-95	Depression, Fibromyalgia	5 years	
W.I.M	M	53	L	ATL+CF	No	48-100	None	4 years	-
M.S.D.M.A	F	28	R	ATL	Yes	50-95	None	6 years	-
S.M.B	F	26	R	ATL+CF	No	53-100	None	4 years	-
N.M.D.S.B	F	42	R	ATL	Yes	53-95	None	4 years	-
A.D.S.F	F	26	L	ATL+CF	No	48-95	None	4 years	-
N.M.S	F	60	L	ATL+CF	Yes	48-95	Slight pes cavus	5 years	-
J.M.D.S.A.C	F	29	L	ATL	No	49-95	None	5 years	-
M.A.F.S	F	47	R	ATL+CF	No	49-95	None	5 years	-
M.D.A	M	24	L	ATL	No	48-95	None	5 years	-
L.S.D.B	M	33	R	ATL	No	48-100	None	5 years	-
L.M.M	M	24	L	ATL	No	57-100	None	5 years	-
F.H.C	M	48	L	ATL+CF	No	50-100	None	5 years	-
K.F.T	F	46	R	ATL+CF	Yes	26-90	Obesity, Diabetes mellitus	5 years	-
B.R.B	F	30	R	ATL+CF	No	58-95	None	5 years	-
R.D.P.C	M	38	L	ATL	Yes	58-95	Slight pes cavus	1 years	-
A.A.L	F	43	R	ATL	No	50-80	None	2 years	-
M.A.B	F	49	R	ATL	Yes	50-80	Smoking	18 months	-
S.T	F	40	R	ATL+CF	No	58-95	None	9 months	-
T.A.D.C	F	39	L	ATL+CF	No	50-80	Smoking	6 months	Superficial dehiscence
J.A.F	F	57	R	ATL+CF	Yes	50-90	None	6 months	-
M.A.DB.C	F	40	L	ATL	No	58-95	None	4 months	-
R.B.D.D	F	26	L	ATL+CF	No	73-95	None	6 months	-
L.M.P	M	21	R	ATL+CF	No	73-100	Slight pes cavus	6 months	-
B.P	F	23	L	ATL	No	58-100	None	1 year	-
D.G.B.O	F	63	R	ATL	Yes	50-95	None	2 years	-
G.L.R.S	F	38	R	ATL	Yes	58-95	Slight pes cavus	2 years	-
A.M.G.N	F	70	R	ATL+CF	Yes	50-80	Slight pes cavus	3 years	-
N.M	M	43	L	ATL	No	58-95	Anterior ankle impingement	2 years	-
L.P.M.B	F	27	L	ATL+CF	No	58-95	Meniscoid lesion of the ankle	2 years	-
M.S.B.R	F	55	R	ATL+CF	Yes	50-95	None	2 years	-
V.O.N	M	29	L	ATL+CF	No	58-100	None	3 years	-
C.A.F.K	F	51	R	ATL	No	58-95	Breast cancer	3 years	-
J.A.M	F	39	R	ATL+CF	Yes	58-95	Obesity, Slight pes cavus	3 years	-
C.D	F	64	L	ATL	Yes	50-95	None	3 years	-
F.L	M	60	L	ATL	No	50-90	Chondral lesion of the ipsilateral talus	3 years	-
C.C.M.B	F	42	R	ATL+CF	Yes	50-90	None	5 years	-
H.R.D.A	M	25	R	ATL+CF	No	58-95	None	5 years	-
R.C.R	F	50	R	ATL+CF	Yes	50-90	Obesity	5 years	-

* PBT: peroneus brevis tendon; * ATL: Anterior talofibular ligament; * CF: Calcaneofibular Ligament

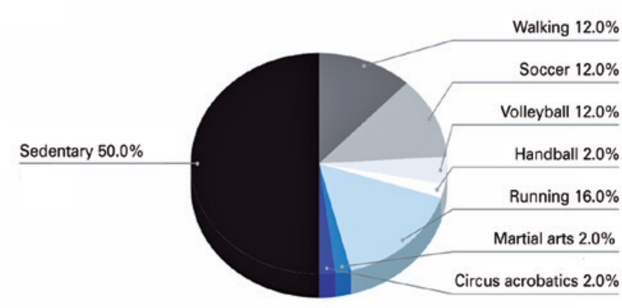

Figure 1. Patient comorbidities.

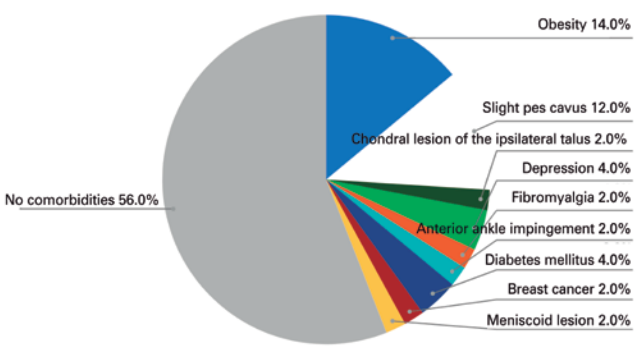

Figure 2. Patient physical activity.

Table 2. Comparison of pre- and postoperative AOFAS scores in patients with or without a peroneus brevis tendon injury; Means and Standard Deviations

	Pre AOFAS	Post AOFAS	P-value
PBTI-	52 ± 9	95 ± 5	<0.001*
PBTI+	50 ± 7	92 ± 5	<0.001*

PBTI-: group without a peroneus brevis tendon injury; PBTI+: group with a peroneus brevis tendon injury; AOFAS: American Orthopedic Foot & Ankle Society score; Pre: preoperative; Post: postoperative.
*: significant P-values for 95% CI.

Table 3. Comparison of AOFAS scores and age between groups of patients with and without a peroneus brevis tendon injury; Means and Standard Deviations

	PBTI-	PBTI+	P-value
Age	39 ± 13	49 ± 11	0.019*
Preoperative AOFAS score	52 ± 9	50 ± 7	0.92
Postoperative AOFAS score	95 ± 5	92 ± 5	0.03*
Score difference (pre vs. post)	42 ± 8	41 ± 7	0.02*

PBTI-: group without a peroneus brevis tendon injury; PBTI+: group with a peroneus brevis tendon injury; AOFAS: American Orthopedic Foot & Ankle Society score.
*: significant P-values for 95% CI.

Discussion

Although the association between PBTI and chronic lateral ligament injury of the ankle has been extensively described in the literature[2,4,14,17], we found no study comparing the effectiveness of Broström-Gould surgery in ligament ankle injuries that specifically assessed the role of PBTI in ankle instability. Due to this lack of data, we developed a comparative study to investigate the impact of associated PBTI in Broström-Gould surgery results.

To calculate the sample size, we initially selected studies by Nery et al.[14] and Gomes-Carlin et al.[18] due to their methodological similarities. However, since the number of cases in our study was higher, we decided to use a convenience sample. We used the AOFAS score to evaluate the results because it encompasses both direct clinical results and the subjective impressions of patients regarding quality of life. Since the final AOFAS scores are quite high, both in the literature and in our study, we used an improvement index based on the difference between the scores, rather than the final scores, to obtain normally distributed values, which did not occur for postoperative period values alone.

Approximately one-third of all assessed CLLI cases had a PBTI, which demonstrates the importance of understanding whether this combination of injuries impacts the final result of the surgical procedure.

Our results corroborate the literature in that Broström-Gould surgery is a very effective treatment for patients with chronic ankle instability. There was important improvement in the mean AOFAS score in all patients, which demonstrates the effectiveness of this surgical technique. The results were good even when there was an associated PBTI[2,4,14,17]. However, more detailed analysis showed that an associated PBTI had a negative impact on postoperative results, since the final postoperative score for the PBTI+ group was significantly lower than that of the PBTI- group. The mean age of the PBTI+ group was approximately 10 years higher than the PBTI- group, which might also explain the difference between groups. Considering that AOFAS scores are sensitive to patient age, analyses that eliminate this confounding factor have become necessary. Although the mean age of the PBTI+ group was higher than that of the PBTI- group, there was a coincident age range of 28 to 63 years old between the groups. The corrected analysis for this age range revealed no difference in score variation or final score between the groups. However, it should be pointed out that there this corrected analysis lost statistical power, since 11 individuals (more than 20% of the initial sample) were eliminated and the PBTI+ score variation data lost normal distribution. Due to this reduction in statistical power, we chose not to publish the age-corrected results. This finding, however, could indicate that age affects the outcome more than a surgically treated PBTI. It should be pointed out that all cases of PBTI received specific treatment for this injury in addition to Broström-Gould surgery to correct CLLI, which may explain the parity of results between the groups.

Without correction for age, the P-values in the AOFAS score comparison between the groups, although significant, were very close to the 0.05 α-value. This study included 50 cases, which is a satisfactory sample compared to previous studies. However, its retrospective observational design reduced the level of evidence. To better understand the role of PBTI in chronic ankle instability, prospective comparative studies (or, preferably, meta-analyses) are necessary, to which this study can contribute.

Conclusion

PBTI associated with chronic lateral ligament instability of the ankle negatively impacts quality of life (AOFAS score) after Broström-Gould surgery. Nevertheless, there was significant improvement in AOFAS scores in both groups, regardless of an associated PBTI.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RSD *(https://orcid.org/0000-0003-2007-2557) Data collection, bibliographic review, formatting of the article, participated in the review process; JMN *(https://orcid.org/0000-0003-2007-2557) Conceived and planned the activities that led to the study, bibliographic review, performed examination, performed the surgeries, survey of the medical records, participated in the review process, approved the final version ; AMO *(https://orcid.org/0000-0003-2364-3183) Statistical analysis, interpreted the results of the study, participated in the review process, approved the final version; CASA * (https://orcid.org/0000-0002-2533-5793) participated in the review process, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Radiographic analysis of the effects of first metatarsal rotation in hallux valgus surgery

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Abstract

Objective: To evaluate whether the initial degree of metatarsal rotation interferes with the surgical correction of severe hallux valgus.

Methods: A retrospective study was performed using weight-bearing AP radiographs to measure first metatarsal rotation based on the shape of the lateral edge of the metatarsal head and the hallux valgus (HVA) and intermetatarsal (IMA) angles. Participants were then classified into two groups. Those with less rotational deformity were placed in the negative pronation group, while those with greater rotational deformity were placed in the positive pronation group. Mean HVA and IMA correction were calculated and compared between groups. Participants underwent the modified Lapidus procedure with correction of pronation.

Results: Data were collected for 26 feet with hallux valgus. The negative and positive pronation groups contained 14 and 12 feet, respectively. Successful surgical correction of pronation was observed in 11 of the 12 feet, which were ultimately classified in the negative pronation group based on postoperative radiographs. The negative pronation group showed a mean difference of 15.05° in the HVA and 4.20° in the IMA. The positive pronation group showed a mean difference of 14.22° in the HVA and 3.2° in the IMA. These values did not significantly differ between groups.

Conclusion: The initial degree of pronation does not affect the degree of angular correction as long as metatarsal rotation is also addressed.

Level of Evidence IV; Diagnostic Studies; Case Series.

Keywords: Hallux valgus/diagnostic imaging; Hallux valgus/surgery; Metatarsal bones/diagnostic imaging; Rotation; Pronation; Range of motion, articular.

Introduction

Hallux valgus is a common condition of the foot consisting of a multiplanar deformity that occurs most frequently in women starting in the fourth decade of life. Up to 90% of patients with hallux valgus show deformities in the coronal plane, with metatarsal rotation and, consequently, pronation of the hallux[1]. This deformity plays an important role in disease progression, as it is frequently accompanied by sesamoid subluxation and an imbalance in muscle forces in the first phalangeal-metatarsal joint[2]. If uncorrected, metatarsal rotation can increase the likelihood of recurrence after surgery, as demonstrated by studies of hallux pronation and its impact on disease recurrence after surgical treatment[3-5].

The shape of the lateral cortical surface of the metatarsal head has been identified as an important factor to be considered in pre- and postoperative anteroposterior (AP) radiographs of the foot in orthostasis since a rounded metatarsal head is associated with higher rates of hallux valgus recurrence, as identified by Okuda et al.[6]. The author also noted that alterations in the lateral cortical surface of the metatarsal head could be related to the degree of metatarsal pronation, with rounder surfaces indicating a higher degree of pronation[6]. The method described by Okuda et al.[7] to classify the shape of the lateral cortical surface was adopted in subsequent studies, such as that of Yamaguchi et al.[8], who found this variable to be associated with metatarsal rotation, confirming the correlation between these factors using digitally reconstructed radiographs from axial computed tomography (CT) scans.

Study performed at the Faculdade de Medicina de São José do Rio Preto, São Paulo, Brazil.

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The surgical correction of these rotational deformities has been described in previous studies[9-11]. Dayton et al. described improvement in the angular measurements of hallux valgus with the modified Lapidus procedure[12] where the original technique was altered to focus specifically on the correction of metatarsal rotation[11].

The aim of this study was to evaluate whether the degree of pronation observed in preoperative radiographs of severe hallux valgus interferes with the corrective effects of the modified Lapidus procedure on the hallux valgus (HVA) and intermetatarsal (IMA) angles[12].

Methods

Patients

A study was conducted based on the weight-bearing AP radiographs of the foot of patients submitted to surgical treatment of hallux valgus using the Lapidus technique. The study was approved by a research ethics committee. All patients had severe hallux valgus with HVA >40º or IMA >16º. Pre- and postoperative images, obtained two months to one year after surgery, were evaluated. Surgeries were performed by the same foot and ankle surgery team, including two senior foot and ankle surgeons, between 2012 and 2019. After reviewing medical records, the research team identified 26 feet treated using the modified Lapidus technique. The feet belonged to 23 patients, 22 female and 1 male, with a mean age of 60.18 years (SD, ± 15.58).

The technique involves a dorsal approach to the tarsometatarsal joint, with careful dissection to preserve vascularization. An osteotomy was performed at the base of the first metatarsal with the resection of all cartilage to allow for the correction of deformities in the sagittal and transverse planes. Rotational deformities can be corrected by inserting a 2.0mm Kirschner wire perpendicular to the first metatarsal to be used as a joystick to control supination of the first metatarsal while correcting the transverse plane. The wire is then positioned and fixed to the lateral surface of the second metatarsal. This metatarsal de-rotation technique was first used by the surgical team in 2016. Prior to this point, the primary goal of the perpendicular placement of the Kirschner wire was not to achieve de-rotation but to increase stability and allow for early ambulation. The radiographic analysis of cases of severe hallux valgus that received surgical treatment before 2016 did consider the possibility of inadvertent de-rotation of metatarsal pronation. Four of the feet included in this study had undergone surgery prior to 2016.

Radiographic analysis

The radiographic assessment of first metatarsal rotation, which corresponds to the degree of hallux pronation, was performed as described by Okuda et al.[7] with modifications by Yamaguchi et al.[8]. Printed radiographic images and a goniometer were used to measure the distance from the center to the lateral edge of the metatarsal head. The goniometer was placed over the center of the metatarsal head, with the concentric circles outlining the metatarsophalangeal joint. The maximum distance of the circle to the lateral edge of the metatarsal head was measured. Cases in which this distance was greater than 2mm were classified as group A, or angular. When this distance was between 1 and 2mm, the case was classified as intermediate, or group B. If the circle perfectly outlined the metatarsal head or the distance was smaller than 1 mm, the case was classified as group C, or round.

Patients were divided into groups A, B, and C based on the shape of the metatarsal head in preoperative weight-bearing AP radiographs. Group C patients had a rounded metatarsal head, corresponding to the greatest degree of rotation of the first metatarsal. These individuals were classified in a positive pronation group, while patients in groups A and B were combined into a negative pronation category due to their smaller degree of hallux pronation (Figure 1). The two groups were subsequently compared using statistical methods.

Participants were classified into positive and negative pronation groups based on the degree of pronation observed in preoperative and postoperative images. The degree of surgical correction was calculated based on the HVA and IMA values determined using preoperative and postoperative weight-bearing AP radiographs. The mean values of preoperative and postoperative measurements were then calculated for each group. The correlation between the degree of correction and the degree of metatarsal rotation was also examined.

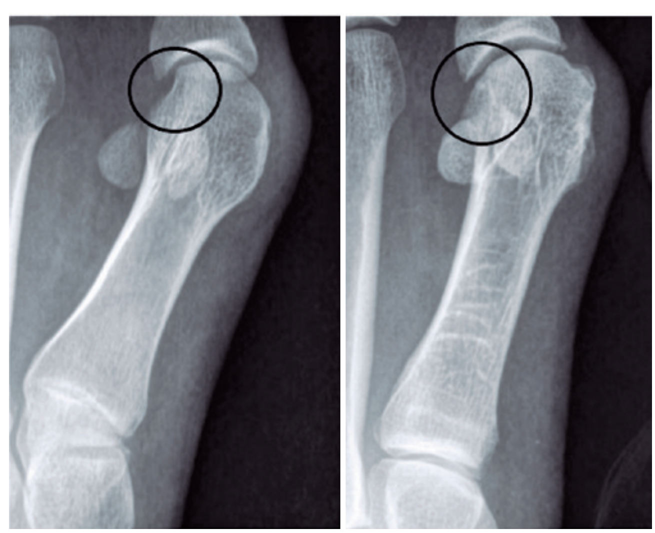

Figure 1. On the left, the lateral edge has an angular shape, indicating less pronation (negative pronation). On the right, the lateral edge is rounded, indicating greater pronation (positive pronation).

Statistical analysis

Preoperative and postoperative HVA and IMA values were calculated for all patients. The difference between pre- and postoperative values was then determined, and mean values were compared between the negative (A+B) and positive (C) pronation groups using statistical methods.

Data were analyzed using the Statistical Package for the Social Sciences (SPSS, IBM, version 24.0) and GraphPad Instat 3.10 (2009).

Categorical variables were summarized as frequencies and percentages. Quantitative variables were analyzed using measures of central tendency and dispersion. Normality was tested using the Kolmogorov-Smirnov test. Inferential analysis was conducted using Student's T-tests and Chi-square tests. Associations between quantitative variables were examined using Pearson correlation coefficients. The coefficients (r) were classified as described by Dancey and Reidy (2005), in the following categories:

r=0.10 to 0.30 (weak)

r=0.40 to 0.60 (moderate)

r=0.70 to 1 (strong)

In all analyses, results were considered significant at $p \leq 0.05$.

Results

Measurements of metatarsal rotation revealed that 12 feet with hallux valgus had a high degree of pronation. These were placed in the positive pronation group (group C), while the remaining 14 feet were placed in the negative pronation group (groups A+B). Eleven of the 12 feet originally classified as group C were reclassified as group B after the analysis of postoperative radiographs, which demonstrated a less rounded metatarsal head (Figure 2). One foot in group C did not show radiographic improvement of the metatarsal head shape after surgery and retained its classification. One patient in group B was reclassified to group A. All patients in group A maintained their classification. The analysis of postoperative radiographs of the 4 feet treated prior to 2016 resulted in 3 feet being classified into the negative pronation group and 1 in the positive pronation group. After surgery, however, the latter was reclassified into the negative pronation group.

Figure 2. Rotational correction, as shown in pre- and postoperative radiographs, demonstrated by the less rounded appearance of the metatarsal head.

Preoperative measurements for the sample as a whole revealed a mean HVA of 36.58° (SD, ± 9.22°) and a mean IMA of 14.98° (SD, ± 3.40°). On postoperative measurements, the mean HVA was 21.91° (SD, ± 10.20°) and the mean IMA was 11° (SD, ± 3.25°). Preoperative measurements were then calculated for each group of participants. Those in the pronation-positive group had a mean HVA of 39.99° (SD, ± 8.93°) and an IMA of 15.62° (SD, ± 3.43°) while those in the pronation-negative group had a mean HVA of 34.28° (SD, ± 8.48°) and an IMA of 14.42° (SD, ± 3.40°). Preoperative HVA and IMA values did not significantly differ between groups (p=0.058 and p=0.1915, respectively).

In the pronation-negative group (A+B), the mean difference between pre- and postoperative HVA was 15.05° while that of IMA was 4.20°. The pronation-positive group (C) showed a mean difference of 14.22° in the HVA and 3.2° in the IMA. A Student's T-test of the differences in pre- and postoperative HVA between pronation negative (A+B) and positive (C) groups yielded p=0.7343, indicating that these values did not significantly differ from one another. The results of between-group comparisons of changes in IMA values was similarly nonsignificant, with p=0.8419. The results of the statistical analysis are shown in table 1.

Table 1. Statistical analysis of the results obtained from the calculation of angle improvement in patients with less pronation (negative pronation) and greater pronation (positive pronation)

Col. title	Negative pronation group (IMA)	Negative pronation group (HVA)	Positive pronation group (IMA)	Positive pronation group (HVA)
Mean	-4.207142857	15.05	-3.716666667	14.225
Standard deviation (SD)	2.542	8.271	4.596	12.461
Std. error of mean (SEM)	0.6794	2.211	1.327	3.597
95%CI lower limit	-5.675	10.275	-6.637	6.308
95%CI upper limit	-2.74	19.825	-0.7965	22.142
Minimum	-8.5	1.2	-11.4	0.1
Median (50th percentile)	-3.65	14.8	-2.8	11.75
Maximum	-0.5	27.8	3.4	40.5
Normality test KS	0.135	0.1235	0.1696	0.1654
Normality test p value	>0.10	>0.10	>0.10	>0.10
Passed normality test?	Yes	Yes	Yes	Yes

Pearson correlations were used to evaluate the association between pronation-positive and pronation-negative groups, and the difference in pre- and postoperative IMA and VHA values. The pronation-negative group was assigned a value of 1 while the pronation-positive group was given a value of 2. The correlation between IMA values and the degree of pronation was approximated by an ascending line (Figure 3). The correlation between pronation and HVA values, on the other hand, yielded a descending line (Figure 4). The r values for these correlations were 0.06992 (p=0.7343) for the IMA and 0.04111 (p=0.84190) for the HVA values.

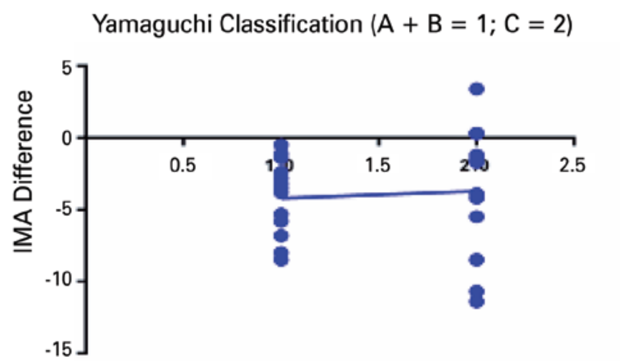

Figure 3. Upward-sloping line demonstrating differences in the IMA. The A+B group corresponds to the negative pronation group. Group C had greater pronation.

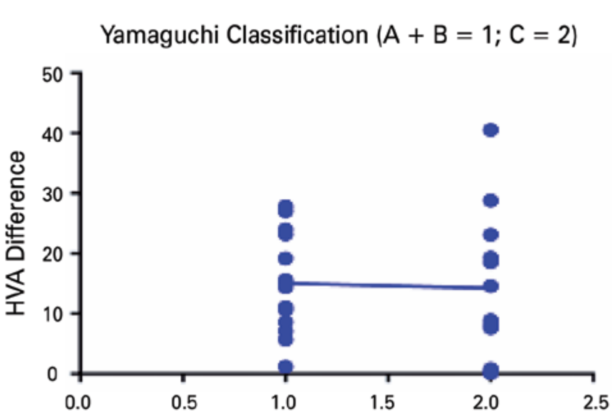

Figure 4. Downward-sloping line demonstrating differences in the HVA. The A+B group corresponds to the negative pronation group. Group C had greater pronation.

Discussion

Hallux valgus is an illness with a multifactorial pathogenesis, and the degree of rotation of the first metatarsal has become an increasingly important issue in the surgical treatment of this condition[4,7,13]. We agree with other authors that the careful evaluation and surgical treatment planning of hallux valgus must consider its three-dimensional nature[14]. The presence of a rounded metatarsal head in preoperative radiographs can indicate that a significant degree of pronation is present and must be corrected during surgery. Residual pronation is a risk factor for hallux valgus recurrence, and the presence of a rounded metatarsal head on postoperative radiographs can indicate that the pronation deformity was not corrected[8,9,15]. Incomplete sesamoid reduction with lateral subluxation of the sesamoid complex is also associated with higher rates of recurrence and may be directly linked to the incomplete correction of metatarsal rotation, as shown in previous studies[10,16]. The surgical technique used in this study aimed to reduce the sesamoid complex under the metatarsal head simultaneously with metatarsal derotation. Sesamoid reduction was not evaluated in this study, as our focus was on the association between metatarsal derotation and angle correction. Nevertheless, in future studies, we plan on evaluating the correlation between incomplete sesamoid reduction and uncorrected rotation.

In the present investigation, we evaluated the results of 8 years of use of the modified Lapidus technique in the treatment of hallux valgus[12]. Starting in 2016, the correction of metatarsal rotation garnered special attention as a means of improving angle correction rates. Dayton et al.[11] demonstrated the potential of first metatarsal rotation as a standalone treatment for hallux valgus, and our findings support this hypothesis, as both groups achieved similar correction rates regardless of preoperative differences, especially in HVA values.

The rotation of the first metatarsus was evaluated based on pre- and postoperative weight-bearing AP radiographs of the foot, a method that is simple and inexpensive, and involves the analysis of the shape of the lateral edge of the first metatarsal head, as described in previous studies, such as those of Okuda et al. and Yamaguchi et al.[7,8] The degree of rotation of the first metatarsal can be evaluated using computed tomography[8] or axial radiographs of the first metatarsal[17,18] as described in the literature.

In this study, the results obtained in the two pronation groups did not significantly differ from one another. In the intraoperative period, one of our main concerns is the correction of the rotational deformity of the metatarsal bone. This was achieved in 11 of the 12 cases of hallux valgus with significant pronation (pronation-positive group) in the present study. Since this approach has only been used since 2016, it can be assumed that any rotational correction observed in cases treated before this date was unintentional. In recent years, special attention has also been paid to sesamoid reduction. While this was not evaluated in the present study, as the analysis focused on rotational correction, the authors intend to evaluate this variable in future studies. According to a study by Lee et al.[16], incomplete sesamoid reduction is associated with worse radiographic outcomes and increased recurrence. Zitouna et al.[19] concluded that incomplete sesamoid reduction does not necessarily predict poor clinical outcome.

We believe that the length of follow-up in the present study may have been too short to assess recurrence rates in patients submitted to surgical treatment, and suggest that future studies evaluate these rates in longer follow-up periods. Our main goal in this study was to observe whether the initial degree of metatarsal rotation had a negative impact on the outcome of the modified Lapidus technique. In a review on metatarsal pronation, Wagner and Wagner[20] found that the recurrence rate of hallux valgus ranged from 2 to 50%, describing this as a multifactorial complication citing incomplete sesamoid reduction as a main contributing factor. The study in question also found that in 86% of cases, tibial sesamoid position depended on the degree of metatarsal rotation, further emphasizing the importance of rotational correction in the prevention of recurrence.

The negative trend between the degree of metatarsal rotation and the correction of the HVA in the present study (Figure 2) may indicate an association between the correction of the HVA and metatarsal de-rotation, since the presence of significant pronation may increase the difficulty of surgical correction of the valgus angle. This must be verified in larger samples, since the degree of correction did not differ between groups in the present study, despite the trend toward lower correction rates in patients with greater pronation. Mortier et al.[17] have also demonstrated a possible correlation between pronation and lower correction rates in hallux valgus. We believe that the similarity in IMA and HVA correction between the two groups in the present study is attributable to the correction of pronation in most patients in the positive pronation group.

The upward line corresponding to the association between pronation and IMA correction (Figure 3) suggests that greater pronation is associated with a larger increase in IMA, and consequently, greater potential for correction of this deformity[21-23].

The short follow-up period and small number of cases are possible limitations of this study, as is the potential bias of unintentional correction in cases treated prior to 2016.

Conclusion

Patients with severe hallux valgus with different degrees of pronation displayed similar degrees of IMA and HVA correction after modified Lapidus surgery.

Authors' contributions: Each author contributed individually and significantly to the development of this article: AAB *(https://orcid.org/0000-0002-1358-7950) Wrote the article, data collection, survey of the medical records; HI *(https://orcid.org/0000-0002-1179-4809) Wrote the article, approved the final version MGF *(https://orcid.org/0000-0002-5163-1035) Wrote the article, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Surgical treatment of hallux valgus using a modified Reverdin-Isham technique

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Abstract

Objective: To evaluate the postoperative results of patients who underwent surgical treatment of hallux valgus with a modified Reverdin-Isham (RI) technique and to compare the achieved correction with that reported by studies using the original technique.

Methods: This is a retrospective study including patients with mild to moderate hallux valgus who underwent surgery from June 2010 to July 2019. All patients were operated using the modified RI technique. Data were collected through the American Orthopaedic Foot and Ankle Society (AOFAS) questionnaire, in addition to pre and postoperative radiographic studies of the intermetatarsal angle (IMA), the hallux valgus angle (HVA), and the distal metatarsal articular angle (DMAA).

Results: The mean postoperative follow-up was 30.1 months, and the mean age of patients was 56.4 years. The median AOFAS score in the postoperative period was increased by 56 points. The mean HVA was reduced in 16.5°, the mean IMA was reduced in 4.3°, and the mean DMAA was reduced in 10°. There were no cases of displacement or deviation of the first metatarsal head during the postoperative follow-up.

Conclusion: The modified RI technique provided considerable stability to the osteotomy, in addition to a significant correction of the measured angles and an improvement in AOFAS scores, demonstrating itself as an effective technique for correcting mild to moderate hallux valgus.

Level of Evidence IV, Therapeutic Studies, Case Series.

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

Introduction

Hallux valgus is the most common deformity of the forefoot and is frequently accompanied by pain complaints, especially with the use of shoes with a narrow toe box. In symptomatic cases, surgical treatment is recommended, aiming to correct the alignment of the first radius. Recent studies have demonstrated that minimally invasive techniques present similar results to open surgery techniques, with less aggression to soft tissues(1-3).

The Reverdin-Isham (RI) percutaneous surgical technique for correcting the hallux valgus deformity was developed by Stephen Isham(3), modifying the osteotomy performed in the first metatarsal (M1) proposed by Louis Reverdin(4). The RI technique is performed through incisions of less than a centimeter(5), following a series of surgical gestures for correcting the deformities: exostectomy, M1 osteotomy, lateral capsulotomy, adductor tenotomy, and wedge osteotomy of the base of the proximal phalanx (Akin osteotomy).

During the learning curve of the use of the RI technique, in some cases the M1 osteotomy became unstable, progressing to medial displacement of the metatarsal head. By analyzing these cases, we decided to change the way the M1 osteotomy was performed(6), seeking better stability. Other instances of the original technique were maintained as proposed by Isham(3).

The aim of this study was to evaluate postoperative results of patients who underwent surgical treatment of hallux valgus through a modified RI technique and to compare the achieved correction with that reported by studies using the original technique.

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

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Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 32408320.5.0000.5501.

From June 2010 to July 2019, 76 patients with mild to moderate hallux valgus underwent surgery at our institution's university hospital and one of the author's private practice. The procedure was performed percutaneously, according to Isham[3], with our modification[6].

We included patients with symptomatic hallux valgus classified as mild or moderate[7] and who had a postoperative follow-up of at least 6 months.

Patients with severe hallux valgus, rheumatic diseases, neurological disorders, radiographic evidence of osteoarthritis in the metatarsophalangeal joint of the hallux[7], history of previous surgery, or previous fractures of the assessed forefoot were excluded.

Patients were contacted by telephone and 69 individuals (90.79% of the total) attended outpatient visits, totaling 79 feet. All participating patients were informed of the objectives of this work and signed a free and informed consent form. Radiographs were performed in a weight-bearing manner in anteroposterior (AP) and lateral views, as routine. Angles were manually measured with a goniometer using the AP radiograph in the pre and postoperative periods. We measured the hallux valgus angle (HVA), the intermetatarsal angle (IMA), and the distal metatarsal articular angle (DMAA)[8].

All measurements were performed by orthopaedic specialists of the foot and ankle surgical team of our service.

Clinical assessment was performed using a translated version of the American Orthopaedic Foot and Ankle Society (AOFAS) questionnaire for hallux deformities[9]. The range of motion of the first interphalangeal and metatarsophalangeal joints was measured with a goniometer, both pre and postoperatively.

All complications after the procedure were documented in the medical records. These included complications of the surgical wound, sensitivity or motor alterations of the hallux, residual calluses or deformities or of the smaller toes, unpredicted displacements of the metatarsal osteotomy, delayed union (absence of consolidation after 8 weeks), recurrences, or progression to osteodegenerative changes.

Surgical technique

The procedures were performed by a team comprising 2 orthopaedists specialized in foot and ankle surgery. Patients were positioned in the dorsal decubitus position with their feet protruding from the operating table, without the use of a tourniquet, and were subjected to locoregional anesthesia (ankle block) at the ankle[10].

The special material used for surgery included a MIS Beaver 64 scalpel blade, a Wedge 4.1mm burr, a long Shannon burr, and rasps. For the movement of the percutaneous burrs, we used a motor drill at 6000 rpm.

All patients were subjected to the RI technique, which included exostectomy, lateral capsulotomy, adductor tenotomy, and Akin osteotomy, performed according to the literature[3,4,11]. Our modification was on the distal M1 osteotomy.

Exostectomy – this procedure was performed via a 5-8mm incision on the medial plantar surface of the M1. Firstly, a single-plane incision was made, reaching the end of the exostosis. The articular capsule was detached from the bone. Then, the Wedge burr was used for removing the exostosis. The bony detritus was removed manually and by washing with saline solution.

Modified RI osteotomy – after removing the exostosis and under fluoroscopy guidance, the Shannon burr was positioned through the same incision on the medial surface of the M1, at an angle of 45° to the ground and immediately proximal to the medial sesamoid bone, pointing to the second metatarsal head. The osteotomy was initiated until reaching one-third of the metatarsal width. At this point, the direction of the burr was changed to a position perpendicular to the long axis of the metatarsal bone, maintaining the transversal cut until it reached the final third of the bone width. The direction of the burr was again changed to proximal and oblique until the lateral cortex osteotomy was completed. The aim was to create a notch where, when laterally translating the M1 head, a natural fit of the bone fragments occured (Figure 1A and B), providing more stability to the osteotomy.

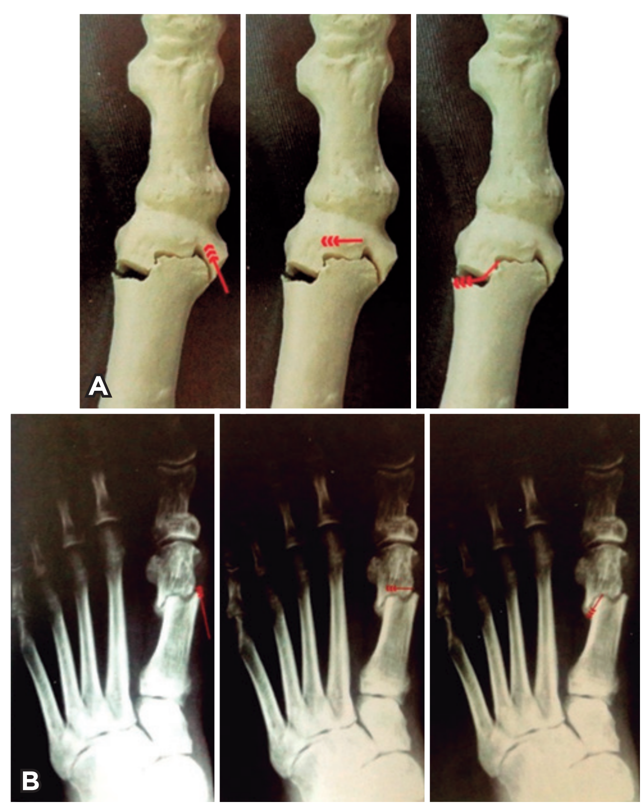

Figure 1. A. Sequence of M1 osteotomy planes in Sawbones. B. Same sequence demonstrated in radiographs.

Tenotomy of the adductor hallucis tendon and lateral capsulotomy – Through a new 2 mm incision in the dorsal lateral surface of the first metatarsophalangeal joint, the adductor hallucis tendon and the lateral capsule were sectioned.

Hallux proximal phalanx base osteotomy (Akin osteotomy)[11] – through another 3-5mm incision in the dorsal medial surface of the base of the first phalanx, medial osteotomy was performed with a long Shannon burr without reaching the lateral cortex, maintaining higher stability with the osteoclasis after varus movement of the toe.

Immobilization and postoperative care

At the end of the procedure, we applied an elastic bandage for maintaining the achieved position in a slight hypercorrection of the hallux. This immobilization should be changed weekly by the team during the first 4 weeks, and by the patient in the 2 following weeks. Deambulation was allowed with the use of shoes with stiff soles from the first day until the second month after the procedure. The patient was instructed to mobilize the hallux from the first week. Physiotherapy was recommended after the sixth postoperative week.

Statistics

Initially, the demographic and clinical characteristics were descriptively analyzed. Categorical variables were presented as absolute and relative frequencies, and numerical variables were presented as summary statistics (mean, median, standard deviation [SD], minimum, maximum).

For comparing means before and after intervention, we used a Student's t-test for paired samples. The Student's t-test assumes a normal distribution, which was verified using a Kolmogorov-Smirnov test. All statistical tests used a significance level of 5%.

Statistical analyses were performed with SPSS 20.0.

Results

We analyzed information from 69 patients and 79 feet. The mean age was 56.4 years (SD = 11.9 years), minimum age was 27 years, and maximum age was 82 years.

As shown in table 1, 91.3% of the patients were female, 14.5% had both their feet affected, and 51.9% of the cases were of the left foot. Mean follow-up was 30.1 months (SD=20 months), with a minimum period of 6 months and a maximum of 98 months (a little over 8 years).

As shown in table 2, significant reductions were observed in the HVA (p<0.001), the IMA (p<0.001), and the DMAA (p<0.001). An improvement of the AOFAS score was also observed (p<0.001). This way, mean reductions of 16.5° (SD=7.3°), 4.3° (SD=2.7°), and 10.0° (SD=7.7°) were observed in the HVA, IMA, and DMAA, respectively. Considering the AOFAS score, we verified a significant increase in the median value, with a variation of 56 points (p<0.001).

Regarding complications, 79.7% of the feet (63) did not present any type of complication. The most frequent occurrence was a limitation of the range of motion of the metatarsophalangeal joint, in only 6.3% (5) of the feet, followed by hypoesthesia, reflex sympathetic dystrophy, and persistent edema, with 2 cases each. Transfer metatarsalgia and second metatarsal stress fracture occurred only in one patient each, as well as one recurrence and one hypercorrection (hallux varus).

Table 1. Sample characteristics

Patients (N=69)	
Sex, N (%)	
Female	63 (91.3)
Male	6 (8.7)
Age (years)	
Mean ± SD	56.4 ± 11.9
Median (minimum - maximum)	57.0 (27.0 to 82.0)
Involvement, N (%)	
Unilateral	59 (85.5)
Bilateral	10 (14.5)
Feet (N=79)	
Laterality, N (%)	
Right	38 (48.1)
Left	41 (51.9)
Follow-up (months)	
Mean ± SD	30.1 ± 20.0
Median (minimum - maximum)	24.0 (6.0 to 98.0)

Table 2. Measured variables

	Time points			p
	Before surgery	After surgery	Before - after surgery	
Hallux valgus angle (o)				<0.001
Mean ± SD	27.5 ± 6.9	10.9 ± 5.6	-16.5 ± 7.3	
Median (minimum - maximum)	27.0 (10.0 to 45.0)	10.0 (-10.0 to 25.0)	-16.0 (-36.0 to -2.0)	
Intermetatarsal angle (o)				<0.001
Mean ± SD	14.6 ± 2.7	10.2 ± 2.5	-4.3 ± 2.7	
Median (minimum - maximum)	14.0 (8.0 to 20.0)	10.0 (5.0 to 19.0)	-4.0 (-11.0 to 6.0)	
Distal metatarsal articular angle (o)				<0.001
Mean ± SD	17.7 ± 8.1	7.6 ± 4.2	-10.0 ± 7.7	
Median (minimum - maximum)	17.0 (0.0 to 50.0)	6.0 (0.0 to 20.0)	-10.0 (-32.0 to 5.0)	
AOFAS score				<0.001
Mean ± SD	40.2 ± 12.8	92.9 ± 6.0	52.7 ± 13.2	
Median (minimum - maximum)	35.0 (23.0 to 74.0)	95.0 (74.0 to 100.0)	56.0 (13.0 to 72.0)	

AOFAS: American Orthopaedic Foot and Ankle Society.

Discussion

Mean AOFAS scores were significantly increased, going from a median of 35 points before surgery to 95 points after the procedure, demonstrating a median variation of 56 points; this is similar to what was reported by studies using the classical RI technique[12,13]. On the other hand, scores were slightly inferior to what was reported by Restuccia et al. [14] and Liuini et al.[2]. We believe that our AOFAS score variation was lower because we did not include patients with severe hallux valgus, which are generally associated with lower preoperative AOFAS scores.

We observed a significant decrease in the measured radiological angles. The mean HVA was decreased by 16.5°, indicating good correction of this parameter when compared to results of authors using the traditional technique[12,13,15].

In this study, we performed complete osteotomy of M1 and lateral displacement of the distal fragment. We reckon that this is the reason why we achieved a higher correction of the IMA when considering studies that used the classical RI procedure[12,13,15]. The mean DMAA was decreased by 10°, which is in line with values observed in the literature[4,12-18].

The modified RI technique maintained the intracapsular aspect of the original description[1]. Therefore, we do not recommend this procedure for cases of severe hallux valgus, where there is a need for increased angular correction.

The most frequent complication of percutaneous intracapsular techniques and open surgeries tends to be the decrease of the range of motion of the hallux metatarsophalangeal joint[4,12,15,19]. Although all patients were instructed to actively mobilize the joint in the immediate postoperative period, the results of this study were also in line with the literature, showing a decrease in mobility as the most frequent complication (6.3%).

Even though it is not frequent with the classical RI technique, displacement of the M1 osteotomy may occur, leading to the loss of the achieved correction[1,10,15,20,21]. We aimed to modify the RI technique so that the M1 osteotomy would promote the fit of the bone fragments, providing better stability[5]. With this modification, we did not observe any cases of osteotomy displacement.

Hallux hypoesthesia was observed in 2 patients (2.5%), with a low incidence when compared to the literature, where some studies report indices of up to 30%[6]. We believe that this type of complication occurs due to overheating of the burrs and its potential aggression to soft tissues. To reduce the risk of injury, one should maintain motor rotation below 8000 rpm, avoid continuous and prolonged use of the burr, and perform intermittent irrigation with physiological saline. These measures help cooling the burrs, avoiding burns to the skin and soft tissues[22].

We had a case of transfer metatarsalgia and a third metatarsal stress fracture. We believe that these complications are due to the association between the shortening caused by the M1 osteotomy and the long second and third metatarsals. This combination can lead to the inbalance of the metatarsal formula, leading to an overload of the neighboring radiuses[4,23].

We had only one case of recurrence, where the patient opted to not undergo a new correction procedure since she was not having symptoms.

Three patients (3.8%) had type 1 complex regional pain syndrome (PRPS) after the procedure, reaching spontaneous resolution up to 6 months into the postoperative period[24]. This result was in line with the literature, where a systematic review of foot and ankle surgeries reported an incidence of PRPS of 4.36%[25]. Bauer et al. had an incidence of 2.67% with percutaneous surgeries, but of type 2 PRPS, with neurological injury[13].

In the literature, infection rates for percutaneous foot surgeries vary from 0% to 3.5%[16,22,26]. We did not report any infections in the present study and we believe that this could be justified by a low aggression to tissues and minimal bone exposure, as described by Prado et al.[4].

Some of the positive aspects of our work include a satisfactory sample size, where we managed to perform a 6-month follow-up with approximately 90% of the patients and the mean follow-up lasted 30.1 months. Our pre and postoperative assessments approached both objective radiographic measurements (angle variations) and the functional assessment of patients (clinical assessment and AOFAS questionnaire).

Despite being one of the most widely used questionnaires, the AOFAS score has little validation in the literature due to its limitations in clinical assessment[18,27]. We decided to use this instrument because it provided us with a wider bibliographic study for analyzing the obtained clinical results.

As limitations of this study, we should cite that data were collected by more than one examinator. All pre and postoperative assessments were executed by the same team of surgeons that performed the experiments, which could be a source or performance bias. We did not assess shortening of the metatarsal after osteotomy, which could be useful for discussing possible transfer metatarsalgias. Angle measurements were performed manually, which could result in interobserver variations. Since this is a retrospective study for evaluating the results of a single surgical technique, we did not have a control group for comparing results. For future studies, we suggest the comparison between patients who underwent the original surgical technique and our modified procedure, evaluating their capacity to avoid displacements of the M1 head.

In percutaneous foot surgery, in addition to an adequate indication and specific material, it is crucial that the surgeon undergoes training for familiarizing him or herself with the technique and for the progression of the learning curve. The learning curve is known to be long[28], but as one progresses, the level of complications inherent to the surgeon decreases.

Conclusion

The modification of the M1 osteotomy in the RI technique evidenced significant results regarding its stability, since there were no displacements or deviations in the postoperative period. We observed a significant improvement in AOFAS scores and in the correction of the measured angles. Therefore, the modification was shown to be effective for correcting mild to moderate hallux valgus.

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

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Original Article

Calcaneal stress fractures in civilian patients: an epidemiological study

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Abstract

Objective: To conduct a retrospective magnetic resonance imaging (MRI) analysis of calcaneal stress fractures and construct an epidemiological profile of these injuries.

Methods: Of 258 MRIs analyzed, nine were consistent with calcaneal stress fractures. These were evaluated by two investigators to confirm the diagnosis. The calcaneus was divided into three anatomical regions: anterior calcaneus (delimited by the angle of Gissane), mid-calcaneus (delimited by the angle of Gissane and tuberosity of the posterior facet), and posterior calcaneus (delimited by the tuberosity of the posterior facet). Fractures were classified as low-grade (grade I, when associated with periosteal edema; II, endosteal; III, muscular) or high-grade (grade IV, when there was a visible fracture line on MRI).

Results: The average patient with a calcaneal stress fracture was an overweight (66.7%) female (66.7%) amateur athlete (66.7%), with a left-sided (55.6%) grade IV fracture (77.8%) of the posterior portion of the calcaneus (66.7%), sustained while running (77.8%), and took 1 to 2 years to be diagnosed (66.7%).

Conclusion: Calcaneal stress fractures are more frequent in women, amateur athletes, middle age, and in those with overweight. Younger patients usually present with grade I, II, or III fractures, while middle-aged patients present most often with grade IV fractures; lesions tend to be more common in the anterior region than in the mid- or posterior calcaneus.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Fractures, stress/epidemiology; Calcaneus/injuries; Magnetic resonance imaging.

Introduction

Calcaneal stress injuries were first reported in the German literature in 1937[1,2]. Stress fractures are the result of repetitive microtrauma to normal bone, and have an incidence of 1% to 7% among all sports activities. They are considered the second most common foot injury, accounting for 20% of all fatigue-induced fractures[3-5]. These injuries occur primarily in military recruits, long-distance runners, and the obese. Women have a particularly high prevalence, with reports that these lesions may account for up to 39% of all fractures in females[3,4,6-11].

Heel pain is a common complaint in adults, and can cause discomfort and disability. However, due to the low incidence of this type of fracture and low level of suspicion, it is diagnosed rarely as compared to other conditions, such as hindfoot tendinopathy, plantar fasciitis, neuropathies, retrocalcaneal bursitis, and calcaneal (Achilles) tendinopathy[4].

Several risk factors have been associated with development of calcaneal stress fracture, including insufficient physical activity and inadequate footwear[12,13]. Conventional radiography, especially in the early stages of these lesions, cannot establish a definitive diagnosis. Instead, bone scintigraphy and magnetic resonance imaging (MRI) are considered the most reliable imaging methods for the diagnosis of stress fracture. Both modalities have excellent sensitivity, but MRI also offers high specificity and is considered the optimal imaging method for diagnosis of stress fractures[11].

Study performed at the Hospital Santa Teresa, Petrópolis, RJ, Brazil.
Correspondence: Luiz Eduardo Cardoso Amorim. 4801 das Américas Av., Loja A. Barra da Tijuca, Rio de Janeiro, RJ, Brazil. **Zip Code:** 22631-004. **E-mail:** luizeanarj@uol.com.br **Conflicts of interest:** none. **Source of funding:** none. **Date received:** March 12, 2021. **Date accepted:** March 30, 2021. **Online:** April 30, 2021.

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The objective of this study was to conduct a retrospective MRI analysis of stress fractures and outline the epidemiological profile of this injury.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 82503418.6.0000.5245. An informed consent form was signed by the patients involved.

From January 2015 to December 2017, all MRI scans of patients presenting to the study hospital with hindfoot pain were retrospectively evaluated.

The exclusion criteria were patients who presented with acute calcaneal fracture or with any infection involving the ankle and/or foot. Patient charts were analyzed to collect data on demographic parameters and clinical history, including time from symptom onset until definitive diagnosis and type of activity that triggered heel pain. Of 258 MRIs analyzed, 11 were consistent with stress fracture, but two were excluded because the patients presented with acute trauma. Therefore, the sample consisted of nine patients (Table 1).

Magnetic resonance imaging of the ankle was obtained in at least two different planes. Of these, the sagittal and axial planes, in T1-weighed spin-echo and fast-spin T2-weighed sequences with fat suppression, were the most common. Additional sequences were also requested, such as STIR (short-tau-inversion-recovery). All MRIs were evaluated by two investigators to certify that they represented stress fractures. To determine the location of the lesion, as proposed by Sormaalaet al.[14], the calcaneus was divided into three anatomical regions: The anterior calcaneus (delimited by the angle of Gissane), mid-calcaneus (delimited by the angle of Gissane and tuberosity of the posterior facet), and posterior calcaneus (delimited by the tuberosity of the posterior facet) (Figure 1).

Calcaneal stress fractures were classified as low-grade (grade I, when associated with periosteal edema; grade II, endosteal edema; grade III, muscle edema) or high-grade (grade IV) when there was a visible fracture line on MRI[15-17] (Figures 2A, 2B). Because the calcaneus is an essentially trabecular bone, the low-grade fractures were pooled for analysis by the two investigators, as these lesions are difficult to assess.

Statistical analysis

Due to the small sample size, no inferential analysis of significance could be performed; the statistical analysis was descriptive, based on graphs, frequency distributions, and calculation of (mean, median, standard deviation, coefficient of variation – *CV* – for the age variable). The variability of age distribution was considered low if , moderate if , and high if.

Graphs were plotted in Microsoft Excel 2007. All other analyses were carried out in SPSS Statistics for Windows, Version 22.0.

Results

The baseline sample of this study is composed of nine patients with calcaneal stress fractures, six women (67.7%) and three men (33.3%), as shown in figure 3.

The age distribution of the patients, overall and by gender, is described in table 2. Patient age ranged from 36 to 74 years (mean, 50.8 years; median, 48.0 years; standard deviation, 11.8 years), and variability was moderate (CV=0.23). The variability of age distributions in the female and male subgroups was also moderate. Women with calcaneal stress fractures were generally older than men (4.2 years on average). A comparison of mean and median age in the male and female subgroups is shown in figure 4.

The frequency distribution of variables that characterize patients and their fractures, overall and stratified by gender, is shown in table 3. The frequency distribution of age shows that the most typical age groups for calcaneal stress fractures are between 36 and 56 years (66.6%). The typical patient with a calcaneal stress fracture was an overweight (66.7%) female (66.7%) amateur athlete (66.7%), with a left-sided (55.6%) grade IV fracture (77.8%) of the posterior portion of

Table 1. Demographic data and clinical history of the included patients

Code	Age (years)	Gender	Site of fracture	Side	Meters	Weight	Bmi	Time elapsed from symptoms to diagnosis	Athlete	Cause	Level
1	43	Female	Posterior portion	Right	1,68	62	22,0	About 1 year	Amateur	Running	I, II, III
2	41	Female	Posterior portion	Left	1,72	75	25,4	About 1,5 year	Amateur	Running	IV
3	46	Male	Posterior portion	Right	1,78	86	27,1	About 2 years	Amateur	Running	IV
4	62	Male	Media portion	Right	1,7	84	29,1	About 1 year	No	Walking	IV
5	36	Male	Posterior portion	Left	1,76	68	22,0	One week	Amateur	Running	IV
6	50	Female	Posterior portion	Left	1,67	70	25,1	About 10 months	No	Running	IV
7	57	Female	Posterior portion	Right	1,72	73	24,7	1 Year	Amateur	Running	IV
8	48	Female	Media portion	Left	1,74	69	22,8	About 6 months	Amateur	Running	IV
9	74	Female	Anterior portion	Left	1,69	74	25,9	About 1 year	No	Walking	I, II, III

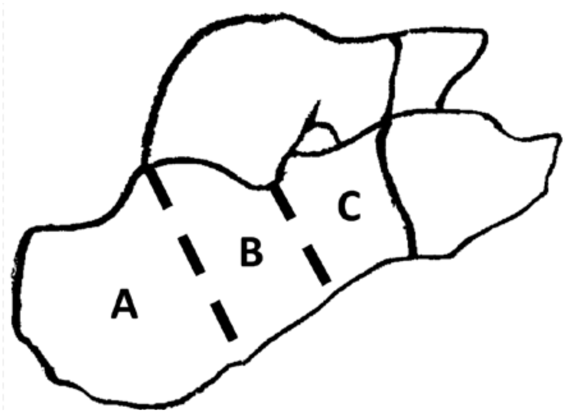

Figure 1. Calcaneus divided into three anatomical regions: A – posterior; B – medial; C – anterior.

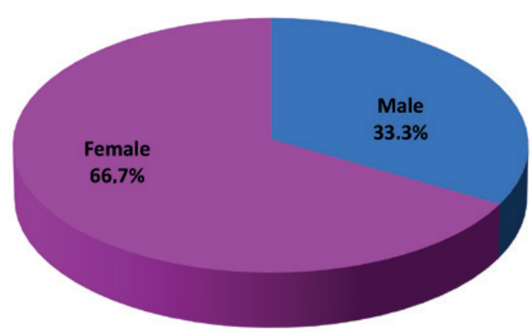

Figure 3. Gender distribution of the sample.

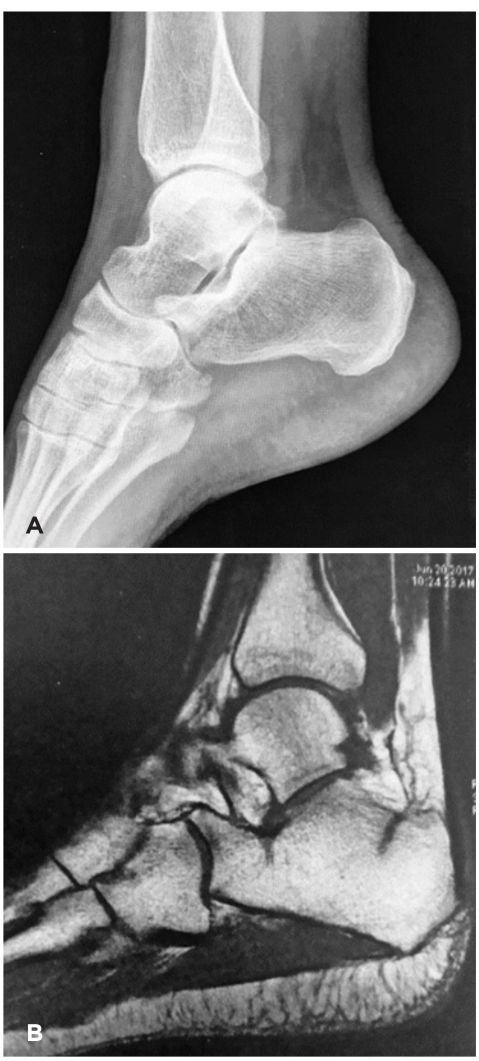

Figure 2. A and B – Plain radiographs and MRI of a grade IV calcaneal stress fracture.

Table 2. Key statistics for the patient age variable, overall and stratified by gender

Statistic	Overall	Female	Male
Minimum	36	41	36.0
Maximum	74	74	62.0
Mean	50.8	52.2	48.0
Standard deviation	11.8	12.1	13.1
CV	0.23	0.23	0.27
Median	48.0	49.0	46.0

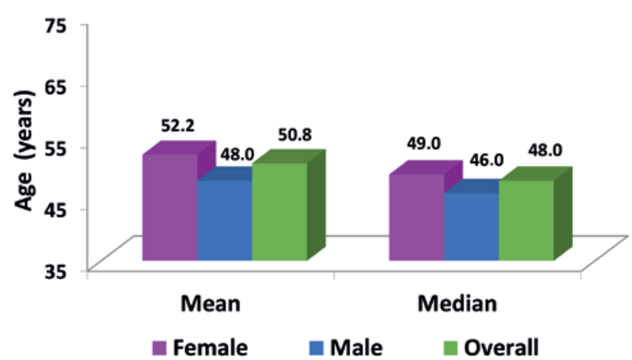

Figure 4. Mean and median patient age, overall and stratified by gender.

the calcaneus (66.7%), sustained while running (77.8%), which took 1 to 2 years to be diagnosed (66.7%).

Table 4 shows the main statistics related patient age, stratified into subgroups determined by the variables. These findings suggest that, among patients with calcaneal stress fractures, amateur athletes are older than non-athletes; those who are overweight are older than patients with normal

Table 3. Characteristics of patients and their injuries

Variable	Overall n=9		Female n=6		Male n=3	
	F	%	F	%	F	%
Age (years)						
36 |— 46	3	33,30%	2	33,30%	1	33,30%
46 |— 56	3	33,30%	2	33,30%	1	33,30%
56 |— 66	2	22,20%	1	16,70%	1	33,30%
66 |— 76	1	11,10%	1	16,70%	0	0,00%
Athlete						
No	3	33,30%	2	33,30%	1	33,30%
Amateur	6	66,70%	4	66,70%	2	66,60%
Classification of BMI						
Normal	3	33,30%	2	33,30%	1	33,30%
Overweigth	6	66,70%	4	66,70%	2	66,60%
Fracture's cause						
Walking	2	22,20%	1	16,70%	1	33,30%
Running	7	77,80%	5	83,30%	2	66,60%
Level of fracture						
I, II e III	2	22,20%	2	33,30%	0	0,00%
IV	7	77,80%	4	66,70%	3	100,00%
Side of fracture						
Right	4	44,40%	2	33,30%	2	66,70%
Left	5	55,60%	4	66,70%	1	33,30%
Site of fracture						
Anterior portion	1	11,10%	1	16,70%	0	0,00%
Media portion	2	22,20%	1	16,70%	1	33,30%
Posterior portion	6	66,70%	4	66,70%	2	66,70%
Time elapsed from symptoms to diagnosis						
Less than 1 year	3	33,30%	2	33,30%	1	33,30%
1 to 2 years	6	66,70%	4	66,70%	2	66,60%

Table 4. Key statistics for the patient age variable, stratified by subgroup

Subgroup	Mean	Median	Standard deviation	Minimum	Maximum	CV
Athlete						
No	45.2	44.5	7.1	36	57	0.16
Amateur	62.0	62.0	12	50	74	0.19
BMI classification						
Normal	42.3	43	6	36	48	0.14
Overweight	55.0	53.5	12	41	74	0.22
Cause of fracture						
Walking	68.0	68	8.5	62	74	0.12
Running	45.9	46	6.8	36	57	0.15
Fracture grade						
I, II, III	58.5	58.5	21.9	43	74	0.37
IV	48.6	48	8.9	36	62	0.18
Affected side						
Right	44.7	48	7.6	36	50	0.17
Left	53.8	51.5	12.9	41	74	0.24
Fracture site						
Anterior calcaneus	74.0	74	-	74	74	-
Mid calcaneus	55.0	55	9.9	48	62	0.18
Posterior calcaneus	45.5	44.5	7.3	36	57	0.16
Time elapsed from symptom onset to diagnosis						
Less than 1 year	52.0	51.5	9	43	62	0.17
1 to 2 years	49.8	48	14.6	36	74	0.29

weight; those who walk are older than those who run; those with grade I, II, and III fractures are older than those with grade IV lesions; those who presented with lesions on the left side were older than those who had lesions on the right side; the oldest patient of the sample had an injury of the anterior calcaneus, while those who presented with mid-calcaneus injuries were older than those who presented with lesions in the posterior portion. There was no substantial age difference between patients with a symptom-to-diagnosis interval of less than 1 year versus 1 to 2 years.

Figure 5 shows the frequency and mean age of patients in subgroups stratified by gender and BMI classification. The highest frequency of calcaneal stress fractures (44.4%) was found in overweight women with a mean age of 55.5 years, while the lowest frequency (11.1%) was in men with normal weight and a mean age of 36 years. Therefore, based on this sample, we estimate that an overweight woman is four times more likely to experience a calcaneal fracture than a man of normal weight.

Discussion

Although calcaneal stress fractures are considered unusual injuries, MRI should be considered for early diagnosis in patients with heel pain, especially in overweight, physically active women.

The diagnosis of calcaneal stress fractures can be a challenge for the orthopedic surgeon. Localization of pain and tenderness in the plantar and/or posterior region will often induce diagnostic suspicion of plantar fasciitis or other soft-tissue conditions. Due to its relatively uncommon incidence when compared to other stress fractures and other causes of heel pain, calcaneal stress fractures are often misdiagnosed or neglected[18,19]. Although the literature shows that, on physical examination, pain is usually located in the plantar or posterior

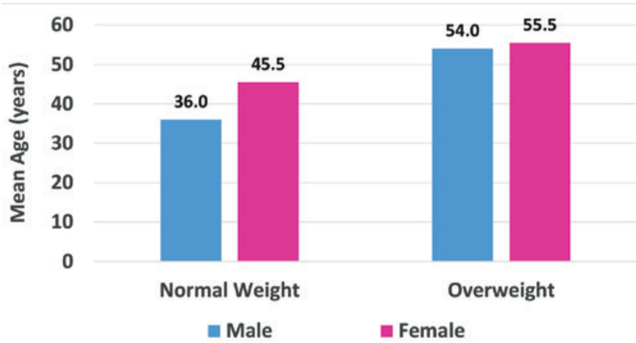

Figure 5. Frequency and mean age in patient subgroups stratified by gender and BMI classification.

region of the calcaneus[3], most of our patients reported pain in the lateral aspect of the heel. This may be due to the course of the branches of the posterior tibial nerve (lateral plantar nerve and calcaneal branch).

According to the literature, several different imaging modalities, such as plain-film radiography, computed tomography, bone scintigraphy, and MRI, are frequently used for the diagnosis of stress fractures[20,21]. Conventional ankle radiographs show a dense line of sclerosis; however, this sign only becomes visible several weeks after the onset of injury[20]. Conversely, MRI and bone scintigraphy allow more accurate documentation and characterization of stress fractures[11]. Fredericson et al.[22] compared MRI to technetium scans in 14 runners with symptoms of leg pain, and found that MRI was more accurate than bone scintigraphy. These findings were confirmed by Miller et al.[23]. Bone scintigraphy has demonstrated high sensitivity but low specificity for the diagnosis of stress fractures[24]. Therefore, MRI has proved ideal test for the diagnosis of stress fractures, since it combines high sensitivity and specificity for the assessment of medullary edema, periosteal inflammatory reaction, and fracture lines[25,26]. In addition, it is worth noting that, according to Kanstrup[27], the radiation dose effect of bone scintigraphy lasts up to 2 years, which makes MRI an even more attractive modality.

This study analyzed MRI scans of 258 patients with heel pain, nine of whom were diagnosed with a stress fracture. Regarding the time elapsed between first complaint and imaging, 33.3% of the patients were diagnosed in the first year since symptom onset and 66.7% between the first and second year of symptoms. Thus, although MRI was the most appropriate modality to establish the diagnosis, there was still a delay in requesting imaging, which consequently delayed the diagnosis.

According to the literature, calcaneal stress injuries are usually located in the posterior region[7,9]. Sormaala et al.[14] observed that 56% of injuries were located in the posterior region, 26% in the anterior region, and 18% in the mid-calcaneus. Other studies have observed that 95 to 100% of these lesions were located in the posterior region[7,9]. However, these studies were restricted to conventional radiography. The disparity in results was attributed to the high sensitivity of MRI in locating fractures in different portions of the calcaneus. Our study confirmed the findings of Sormaala et al.[14], with a predominance of lesions in the posterior tuberosity (66.7%). Despite the small number of patients in our study, we observed that lesions of the anterior calcaneus (11.1%) occurred mainly in elderly patients (median age 74 years), followed by mid-calcaneal injuries (22.2%) at a median age of 55 years and posterior injuries (66.7%) at a median of 44 years.

Sormaala et al.[14] analyzed MRIs and classified 41% of lesions as low-grade, while only 15% of calcaneus fractures were detected on plain radiographs. Therefore, they concluded that, in order to ensure early diagnosis, MRI should be requested in patients who present with a complaint of heel pain, especially in military recruits, athletes, and the obese, even when radiographs are normal. In this study, probably due to the delay in obtaining MRI and consequent late diagnosis, seven of the nine analyzed patients (77.8%) had grade IV lesions. Perhaps earlier diagnosis might have led us to observe a greater number of grade I, I, and III stress lesions.

According to the literature, stress injuries of the calcaneus are more common in female and obese patients (BMI≥30). Our study showed a higher prevalence in female and overweight, though not obese, patients (44.4%), as determined by BMI. However, due to the small sample size, we cannot rule obesity out as a risk factor.

This study has some limitations. We did not analyze some variables that could interfere with the development of stress fractures of the calcaneus, such as flat feet and limb discrepancies, and did not obtain data on bone mineral density or history of menopause for female patients. In addition, the small sample size is an issue, as mentioned above.

Conclusion

In civilians, calcaneal stress fractures are more frequent in women, amateur athletes, middle-aged non-athletes, and those with overweight. Younger patients usually present with grade I, II, or III fractures, while middle-aged patients present most often with grade IV fractures. Lesions tend to be more common in the anterior region than in the mid- or posterior calcaneus.

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Original Article

Translation, Cross-Cultural Adaptation, Reproducibility, and Validation: Brazilian Version of the Olerud-Molander Ankle Score (OMAS-BrP)

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Abstract

Objective: The aim of this study was to perform the translation and cultural adaptation of the Olerud-Molander Ankle Score (OMAS) in Brazilian Portuguese, in addition to determining its validity and reliability.

Method: This was a cross-sectional case-series study. The translation and adaptation processes were conducted in 5 stages: initial translation (2 bilingual Brazilians); synthesis of translations; back translation (2 bilingual Brazilians not involved in the first part of the study); consensus version and assessment (technical committee); and testing phase. The test-retest reliability and construct validity of the Brazilian Portuguese version of the OMAS (OMAS-BrP) were evaluated in a sample of 40 participants. Construct validity was determined based on the correlations of the OMAS-BrP to the Foot Function Index (FFI) and Short-Form 12 (SF-12).

Results: The OMAS-BrP had excellent test-retest reliability (ICC=0.99). The OMAS-BrP showed moderate and weak correlations with the SF-12 PCS and SF-12 MCS (r=0.68 and p<0.001; r=0.38 and p=0.014, respectively). The correlation coefficient between the OMAS-BrP and the FFI was graded as excellent (r=-0.846 and p<0.001). There was a strong correlation between the OMAS-BrP, the SF-12 PCS, and the FFI.

Conclusion: The OMAS-BrP is a valid and reliable questionnaire, with psychometric parameters that are similar to those of its original version and other cross-cultural adaptations. The OMAS-BrP is a useful patient-reported outcome (PRO) measure to evaluate Brazilian Portuguese-speaking patients with ankle fractures.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Ankle fractures/classification; Reproducibility of results; Surveys and questionnaires; Translations; Outcome assessment, health care/methods; Cross-sectional studies.

Introduction

Ankle fractures are common injuries in orthopedic practice. In recent years, their incidence has reached 101–174 fractures per 100,000 person-years[1,2], and the most frequently affected individuals are young men, and women aged 50 years or older[3-5]. In older adults, the ankle is the third most common fracture site after the hip and wrist[3].

Given the impact of ankle fractures on overall health and quality of life, health care professionals have paid increasing attention to the analysis of postoperative outcomes from the patient's perspective[6]. According to the International Classification of Functioning, Disability, and Health (ICF), the assessment of impairment, disability, and quality of life should be based on the patients' perception[7]. This can be achieved using self-report questionnaires and similar instruments.

Several measures of functioning and quality of life after foot and ankle injuries have been developed and validated for use in Portuguese, such as the Foot and Ankle Outcome Score (FAOS)[8], the Foot Function Index (FFI)[9], and the Short-Form 12 (SF-12)[10]. However, these are general questionnaires and do not evaluate a specific type of injury.

Study performed at the Hospital Mater Dei, Belo Horizonte, MG, Brazil

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In 1984, the Olerud-Molander Ankle Score (OMAS) was developed specifically to evaluate functioning after ankle fractures[11]. The questionnaire was originally written in English[12] and was later translated to Turkish[11] and Swedish[13]. A literature review did not identify any reports of the translation and/or validation of this instrument to Brazilian Portuguese.

To facilitate cross-cultural comparisons, it is crucial to adapt this instrument to the Brazilian population and establish its equivalence to the original instrument [9,14]. This will include adjusting the OMAS to a different language, population, culture, and setting. Evaluations of validity, reproducibility, and sensitivity to change are also important in determining that the new version of the instrument has retained the characteristics of the original[9].

The aim of this study was to perform the translation and cultural adaptation of the OMAS Brazilian Portuguese, in addition to determining its validity and reliability.

Method

Study Design

This cross-sectional study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 00789318.6.0000.5128.

Translation and Cross-cultural Adaptation

The OMAS is a patient-reported outcome (PRO) measure designed specifically for individuals with ankle fractures. The instrument contains 9 questions, each with a different maximum score, allowing for the assessment of the following domains: pain (25 points), stiffness (10 points), edema (10 points), stair climbing (10 points), running (5 points), jumping (5 points), squatting (5 points), support (10 points), and work/activity level (20 points). The total sum of scores across all items can then be classified as poor (0 to 30); reasonable (31 to 60); good (61 to 90) and excellent (91 to 100)[12]. This instrument has been validated based on a Linear Analog Scale ($p<0.01$), range of motion in dorsal extension ($p<0.05$), presence of osteoarthritis grade II-IV ($p<0.001$), and presence of dislocations on radiographs ($p<0.05$) after ankle fractures[1].

The OMAS was translated and adapted through the following 5-stage process, as proposed by Guillemin, Bombardier, and Beaton[15]: initial translation (2 bilingual Brazilians); synthesis of translations; back translation (2 bilingual Brazilians not involved in the first part of the study); consensus version and assessment (technical committee); and testing phase.

In the first stage, the OMAS was translated to Brazilian Portuguese by 2 bilingual Brazilian translators who produced versions T1 and T2 of the instrument. Neither individual was familiar with the content of the questionnaire. In the second stage, a committee formed by the authors of this study analyzed the two translations and combined them into a single version referred to as T1-2. In the third stage, version T1-2 was sent to two additional translators, who were also Brazilian and proficient in English, for back-translation. The resulting versions of the questionnaire were named BT1 and BT2. The translators were unfamiliar with the original questionnaire. The comparison of the back translation to the original scale allowed us to identify any grammatical inconsistencies or translation errors in the instrument. In stage four, the committee met once again to discuss the back translations and consolidate them into a single version of the questionnaire. We also evaluated semantic and conceptual equivalence, word meanings, colloquialisms, and the similarity of daily activities across countries. This process resulted in the final version of the questionnaire, referred to as BT12. This instrument was then administered to a pilot sample of 50 patients to verify the comprehensibility and acceptability of questions and answers. Any difficulties in the comprehension or interpretation of the questionnaire were noted for subsequent adjustment. Once these issues were addressed, the questionnaire was administered to 40 patients who had ankle fractures between 2018 and 2019.

Reliability (Test-retest reproducibility)

Test-retest reliability is the ability of an instrument to deliver the same results when administered more than once to the same participant.

Intra-rater reliability is evaluated by readministering a questionnaire within 7 days of an initial assessment[6,16]. Patients were asked to perform their daily activities as usual between the two evaluations. The coefficient of Intra-Class Correlation (ICC) type 2,1 was used to determine the reproducibility of the OMAS." These values were classified as follows: 1- Low reproducibility for values below 0.40; 2 - Good reproducibility for values between 0.40 and 0.75; 3- Excellent reproducibility for values greater than 0.75[14].

We also calculated the standard error of measurement (SEM) and minimal detectable change (MDC). The SEM and MDC were calculated as follows: $SEM = s\sqrt{1 - ICC}$ (where s is the standard deviation at baseline)[14] and $MDC = 1.96 \times \sqrt{2} \times SEM$, respectively[14,17]. The SEM reflects the precision of the instrument and the MDC is the smallest difference in scores that could be interpreted as a "real" change beyond measurement error, with $p<0.05$.

Validity

Construct validity is the extent to which an instrument is able to measure an abstract concept. In this study, the ability of the OMAS-BrP to evaluate functional disability was assessed based on its Pearson correlation with the SF-12 and FFI questionnaires.

The SF-12 was developed and validated as a shorter and faster version of the 36-item Short-Form Health Survey (SF-36) [18]. It evaluates health-related quality of life and was translated to Brazilian Portuguese in 1999[15] and validated in 2004[10]. It is a brief and understandable questionnaire used to monitor health outcomes in general and specific populations[10]. The questionnaire yields a physical (PCS) and a mental component score (MCS) based on an algorithm developed specifically for the SF-12[11].

The FFI is a 23-item instrument developed in the English language in 1991[19] to evaluate the functional impact of foot and ankle disorders in terms of pain, disability, and activity restrictions. It was translated and adapted to Brazilian Portuguese in 2015[9] and validated for use in the local population in 2016[6]. It has excellent ICC values[19].

Construct validity was evaluated using the Pearson correlation coefficient and a 95% confidence interval determined by bootstrapping. The Pearson correlation coefficient was interpreted as follows: values of 0.00 to 0.25 indicate little to no correlation; values of 0.25 to 0.50 indicate a weak correlation; values of 0.50 to 0.75 suggest a moderate correlation, while values of 0.75 or more indicate a strong correlation[14].

Sample characteristics were summarized using mean (range) for age, median (interquartile range) for time since surgery, and frequency for gender and side of injury. The mean and standard deviation, as well as the median and interquartile range, were also calculated for OMAS-BrP scores. A sample of 35 patients was required to detect an ICC of 0.85 that was significantly greater than 0.60 at a 5% significance level with a power of 80%. This was calculated using the calculateIccSampleSize function in the ICC.Sample.Size package of the R software. Based on an expected ICC of 0.85, two measurements were obtained for each of 40 patients on two separate days, with the minimum acceptable ICC of 0.7, indicating moderate reliability. Paired Wilcoxon tests were used to compare test and retest scores. Independent t-tests and chi-square tests were used to compare age, sex, and OMAS variables between groups. IBM SPSS (IBM Corporation, Somers, NY) version 18.0 was used for all statistical analyses.

Results

Sample characteristics

The questionnaires were administered to 40 patients who had received surgical treatment for ankle fractures. Half of participants were male (n=20). The mean age of patients was 50.2 years, and at least 50% were 51 years or younger. Participants were followed for a mean of 2 years, and 52.5% had fractures of the right ankle. The most prevalent fractures in the sample were supination-external rotation stage 4 (SER-4) fractures, as categorized by Lauge-Hansen[20] (Table 1).

The OMAS-BrP had a mean value of approximately 83 and there were no significant differences between the first and second assessments (p=0.149). Mean scores on the SF-12 and FFI were 50.5 and 7, respectively (Table 2).

A better classification on the OMAS-BrP was associated with higher scores on the SF-12, and differences between OMAS-BrP score groups were only observed on the PCS. The FFI also differed significantly between groups, with higher categories of the OMAS-BrP displaying lower FFI values. Age was not associated with scores on the OMAS-BrP, as mean age did not significantly differ between score levels (Table 3).

Table 1. Description of the variables gender, side and type of fracture, time, and age

Gender	
Male	50% (n=20)
Female	50% (n=20)
Side	
Right	52.5% (n=21)
Left	47.5% (n=19)
Type of fracture	
PABD-2	5.0% (n=2)
PABD-3	5.0% (n=2)
PER-4	5.0% (n=2)
SAD-1	2.5% (n=1)
SER-2	27.5% (n=11)
SER-3	15% (n=6)
SER-4	40% (n=16)
Mean duration of follow-up (months)	23.9 ± 9.0 (SD)
Mean age (years)	50.2 ± 13.9 (SD)

ABD: pronation-abduction; PER: pronation-external rotation; SAD: supination-adduction; SER: supination-external rotation; SD: standard deviation.

Table 2. Description of scores on the OMAS-BrP, SF-12, and FFI

Variables	N	Mean ± SD
OMAS-BrP Questionnaire 1	40	83.1 ± 18.0
OMAS-BrP Questionnaire 2	40	83.5 ± 17.7
SF-12 PCS	40	50.5 ± 7.7
SF-12 MCS	40	50.7 ± 6.3
FFI	40	7.0 ± 11.8

SD: standard deviation; OMAS-BrP: Brazilian Portuguese version of the Olerud-Molander Ankle Score; SF-12: Short-Form 12, PCS: physical component score; MCS: mental component score; FFI: Foot Function Index.

Table 3. Description of SF-12 and FFI scores, and age between categories of the OMAS-BrP

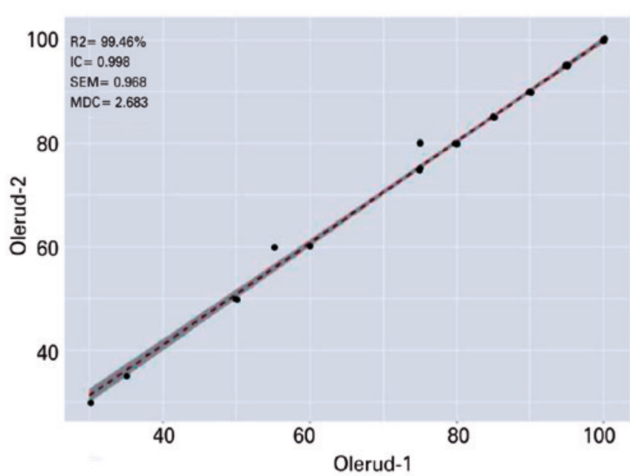
Variables	OMAS-BrP	N	Mean	SE	p-value[1]
SF-12 PCS	Excellent	17	54.5	0.5	0.004
	Good	17	51.1	1.5	
	Reasonable	5	35.6	3.3	
	Poor	1	46.00		
SF-12 MCS	Excellent	17	57.1	1.1	0.074
	Good	17	54.2	1.7	
	Reasonable	5	49.5	3.3	
	Poor	1	55.9	-	
FFI	Excellent	17	1.0	0.3	0.000
	Good	17	4.8	1.2	
	Reasonable	5	29.3	7.3	
	Poor	1	33.3	-	
Age	Excellent	17	50.1	4.00	0.448
	Good	17	48.1	2.6	
	Reasonable	5	53.2	5.9	
	Poor	1	72.0	-	

SE: standard error; OMAS-BrP: Brazilian Portuguese version of the Olerud-Molander Ankle Score; SF-12: Short-Form 12; PCS: physical component score; MCS: mental component score; FFI: Foot Function Index; [1]Kruskal-Wallis test.

Reliability and Reproducibility

A strong correlation was observed between scores on both applications of the OMAS-BrP. The ICC (2, K) was 0.99 (0.997-0.999) which indicates excellent reproducibility. We also calculated SEM and MDC values. The SEM contributes to the assessment of the reliability of the sample mean, with lower SEM values indicating greater precision. The SEM of the OMAS-BrP in this study was 0.95, which indicates adequate precision. The MDC refers to the minimum difference between test and retest scores that would indicate a significant difference at a 95% confidence level[21]. The MDC in this study was approximately 2.68, showing that a small difference between two test scores would be sufficient to indicate real change, which is a highly positive finding (Figure 1).

Wilcoxon's test did not reveal statistically significant differences between test and retest scores (p-value=0.149) (Table 4).



*IC: intraclass correlation coefficient; SEM: Standard error of measurement; MDC: Minimal detectable change.

Figure 1. Test-retest reliability of the OMAS-BrP.

Table 4. Wilcoxon's test for test-retest comparisons

	N	Mean	SD	p-value[1]
OMAS-BrP Questionnaire 1	40	83.1	18.0	0.149
OMAS-BrP Questionnaire 2	40	83.5	17.7	

OMAS-BrP: Brazilian Portuguese Version of the Olerud-Molander Ankle Score; SD: standard deviation; [1]Wilcoxon's test.

Table 5. Correlation between the OMAS-BrP and the FFI, SF-12 PCS, and SF-12 MCS

OMAS-BrP	FFI	SF-12 PCS	SF-12 MCS
r	-0.84	0.68	0.38
p	0.001	0.001	0.014

OMAS-BrP: Brazilian Portuguese version of the Olerud-Molander Ankle Score; SF-12: Short-Form 12; PCS: physical component score; MCS: mental component score; FFI: Foot Function Index.

Validity

Construct validity was analyzed using Pearson correlation coefficients. The OMAS-BrP had an excellent correlation with the FFI (r=-0.84 and p<0.001) and a moderate correlation with the SF-12 PCS (r=0.68 and p<0.001). These questionnaires evaluate physical function and the OMAS-BrP was strongly related to both. At the same time, the instrument had a low correlation with the SF-12 MCS, which evaluates mental health (r=0.38, p=0.014) (Table 5).

Discussion

The present study found that the OMAS-BrP had a strong correlation with both the FFI and SF-12 PCS (r=0.84, p<0.001; r=0.68, p<0.001, respectively), demonstrating its applicability to the assessment of functional capacity after treatment for ankle fractures. Furthermore, the instrument showed high reproducibility (ICC=0.99) with a strong correlation between the scores obtained in two administrations of the test to the same sample.

For several years, the OMAS has been used by researchers to assess the results of treatment for ankle fractures[11,12]. Its questions are easy to understand and its items are related to everyday activities[11]. Joint stiffness is an important factor to be considered after surgical or conservative treatment for ankle fractures. Pain when walking on different surfaces is a major cause of functional disability in patients with ankle fractures. These items are directly addressed in the OMAS[11]. During the adaptation of the OMAS to Brazilian Portuguese, the questions in the instrument were not significantly changed. Patients were able to understand all items and functional activities listed.

The test-retest reproducibility of an instrument refers to its ability to yield similar results when administered more than once to the same participant, thereby demonstrating consistency over time. It is one of the main indicators of instrument quality, as it reflects the instrument's stability, consistency, and precision. Internal consistency indicates that all items in an instrument measure the same construct. This is a crucial psychometric property since it demonstrates that the instrument is consistently assessing the same characteristic[22]. The internal consistency of the OMAS-BrP was high, with values similar to those reported for the Turkish and Swedish adaptations of the instrument (0.84 and 0.76, respectively). The test-retest reproducibility of the OMAS-BrP was excellent (ICC=0.99), with values similar to those obtained in the Turkish and Swedish validation studies (ICC=0.98 and 0.94, respectively)[11,13]. The MDC in this study was 2.68, showing that real changes in the underlying construct will be demonstrated by differences of at least this magnitude between administrations of the OMAS-BrP. This value is much lower than that found in the Turkish and Swedish versions of the instrument (12,00 and 9,10 respectively)[11,13].

The validity of the OMAS-BrP was evaluated based on its relation to the FFI and SF-12 (MCS and PCS scores). The correlation coefficient between the OMAS-BrP and the FFI was graded as excellent (r=0.84 and p<0.001). The FFI is one of the four most frequently used instruments for the functional assessment of the foot and ankle, and its reliability is extremely high. It has been translated and validated in Brazilian Portuguese, with excellent intra- and inter-rater reliability (ICC=0.99-0.97) and a high ICC[6]. These findings served as the basis for our selection of the FFI as a comparative measure in the present study.

The correlation between the OMAS-BrP and the SF-12-PCS, which measures the physical component of the questionnaire, was moderate (r=0.68 and p<0.001), and similar to the corresponding value in the Turkish validation study (r=0.72 and p<0.001)[11]. With regard to the SF-12 MCS, which evaluates aspects of mental health, the correlation was weak (r= 0.38 and p=0.014).

The Turkish study used the SF-12 and the Foot and Ankle Ability Measure (FAAM)[11] to validate the OMAS, while the Swedish study used the Foot and Ankle Outcome Score (FAOS)[13].

The present study was the first to perform the translation and cross-cultural adaptation of the OMAS to Brazilian Portuguese. The resulting instrument had excellent reproducibility and validity and was tested in an adequate sample. Its performance was also compared to that of the FFI, a PRO measure with excellent reliability and ICC values.

This study had some limitations. First, the OMAS-BrP was only administered to patients who received surgical treatment for ankle fractures. The fact that only two cross-cultural adaptations of the OMAS have been performed to date (Turkish and Swedish)[11,13] limits our ability to compare findings with similar studies in the literature.

In future studies, the questionnaire could be used in patients who received non-surgical treatment. As new versions of the OMAS are published and validated in other languages, a more comprehensive comparison of their similarities and differences can be performed.

Conclusion

The OMAS-BrP is a valid and reliable questionnaire, with psychometric parameters that are similar to those of its original version and other cross-cultural adaptations. It is easy to administer and interpret and takes minutes to be read and answered. Therefore, the OMAS-BrP is a useful PRO measure to evaluate the outcome of ankle fractures in Brazilian Portuguese speakers.

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Case Report

Anterograde fixation of inverted oblique medial malleolus fractures: case report

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Abstract

Fractures of the medial malleolus are common, with avulsion being the main trauma mechanism. In simple transverse fractures, retrograde fixation with interfragmentary screws is the most common means of achieving anatomical reduction and absolute stability. However, greater attention must be paid in cases of inverted oblique fractures, which make traditional fixation difficult. We report a case in which anatomical reduction and stabilization were achieved using a reduction clamp and two headless compression screws placed anteriorly, resulting in a mechanically stable, safe and effective repair.

Level of Evidence V, Therapeutic Studies; Expert Opinion.

Keywords: Ankle Injuries/surgery; Bone screws; Fracture fixation, internal/methods; Range of motion, articular; Treatment outcome.

Introduction

Different mechanisms of trauma to the ankle result in different fracture patterns and associated ligament injuries[1-2]. The precise identification of these injuries, as well as defining the direction of the fracture line, is essential for the best surgical planning and treatment.

In joint fractures, interfragmentary compression is more effective when the forces act perpendicular to the fracture line, otherwise shear forces and fracture deviation can occur[1]. In these small deviations, incongruence in the tibiotalar joint and joint instability can result in residual pain and joint degeneration[3].

The fracture classification system allows us to identify possible mechanisms of injury and determine which surgical technique is necessary[2]. In an assessment of Herscovici's classification[5] for fractures of the medial malleolus, Aitken et al.[4] observed greater disagreement in interpretation between types B and C due to the obliquity of the fracture line, and there was no subtype for inverted oblique type B fractures, which, in our understanding, require a different approach from conventional type B treatment (Figure 1).

In the medial malleolus, variation in the direction of the fracture line is responsible for different bone injury presentations, as well as the involvement of the deltoid ligament, especially its deep portion[6].

Several techniques have been described for the internal fixation of medial malleolus fractures, the most common being osteosynthesis with two partial thread screws for interfragmentary compression and the tension band technique. The latter is more indicated in cases of fragmentation, poor bone quality or small avulsed fragments[7].

In supracollicular avulsion fractures of the medial malleolus, the tension band technique has greater biomechanical resistance to pullout and can be used in all cases[7]. However, these conventional fixation methods present several complications, mainly related to irritation to soft tissue and the deltoid ligament, which in some cases requires removal of the osteosynthesis material[8].

The use of headless double compression screws for medial malleolus fractures has proven efficient and seems to be related to a shorter consolidation time and less soft tissue irritation[9-10]. In addition, the anterograde approach allows bicortical fixation, which provides greater resistance and less aggression to the deltoid ligament[8-10].

Study performed at the Casa de Saúde São José, Rio de Janeiro, RJ, Brazil.

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The purpose of this case report is to draw attention to medial malleolus fractures with an inverted oblique pattern in the anteroposterior view and the use of an anterograde approach with headless double compression screws to achieve osteosynthesis.

Case report

This study was approved by the Institutional Review Board under the protocol number: CSJ000-688-21 and the patient provided written informed consent.

This 21-year-old female patient suffered torsional trauma in the right ankle and was referred to the emergency department. Physical examination revealed deformity of the right ankle, severe pain, functional limitation, excoriation and edema (+++/4+). Radiographs and computed tomography showed a trimalleolar fracture-dislocation (Figures 2 and 3). As comorbidities, the patient was obese and glucose intolerant, and was using an oral hypoglycemic agent.

The patient was immediately taken to the operating room and underwent surgery for fracture dislocation reduction and definitive osteosynthesis, since the condition of the soft tissue was good. We will describe the fixation of the medial malleolus fracture, classified as a Herscovici type B with an inverted oblique profile, which was directly reduced with a reduction clamp and fixed with two 3.0mm No. 16 long-thread headless compression screws, which were inserted anterograde, as detailed below.

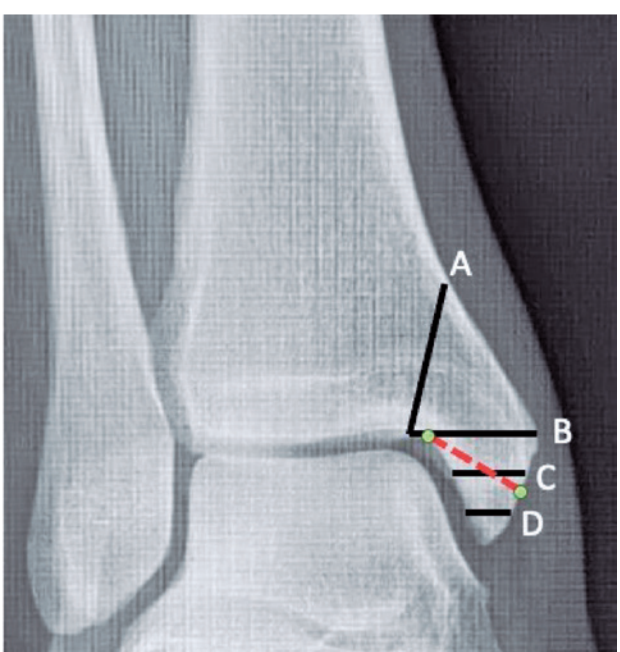

Figure 1. Medial malleolus fracture lines classified by Herscovici (types A, B, C and D); the red dotted line illustrates the patient's inverted oblique fracture (subtype not classified).

Surgical technique

The patient was placed in the supine position on a radiolucent table under spinal anesthesia and peripheral nerve block. The pneumatic cuff was positioned in the proximal third of the right thigh and we followed the usual steps for asepsis and placement of the surgical fields.

The reduction and fixation of the fibular fracture was performed according to AO foundation guidelines regarding anatomical fracture reduction, fixation with interfragmentary screws, and the use of a neutralization plate.

After osteosynthesis of the fibular fracture, a large opening was observed in the joint clamp, which hindered reduction of the medial malleolus due to the integrity of the deltoid ligament. Thus, it was necessary to reduce and stabilize the syndesmosis with two screws.

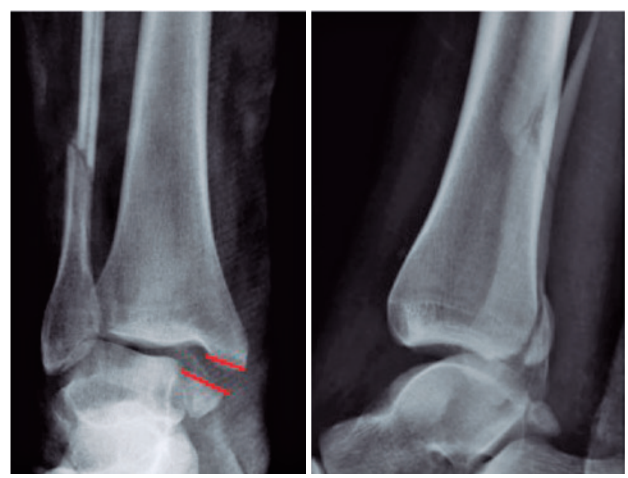

Figure 2. AP and ankle profile radiographs showing the trimalleolar dislocation fracture. The red lines show the inverted oblique fracture pattern in the medial malleolus.

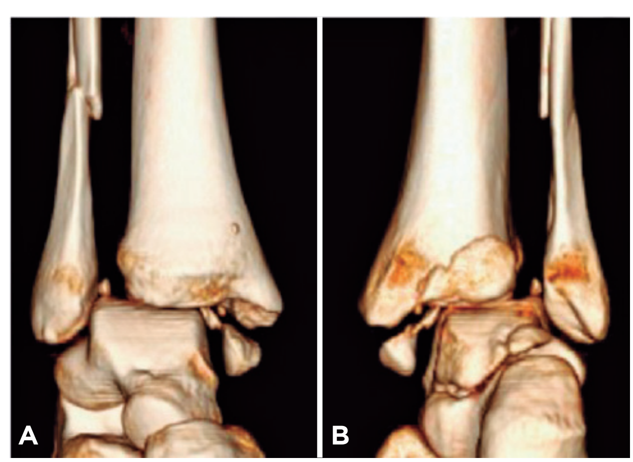

Figure 3. 3D tomographic reconstruction. (A) Trimalleolar fracture in the anteroposterior view. (B) Posteroanterior view. In the medial malleolus, the entire anterior colliculus is fractured, including a small fragment of the posterior colliculus.

A medial incision of approximately 3-4cm was made using the anteromedial cortex of the distal tibia as a reference and curving distally and posteriorly, preserving the saphenous vein and nerve. An anterior colliculus fragment and a small posterior colliculus fragment were identified, with the intact deltoid ligament attached to the fracture fragment. The fracture was reduced using a Backhaus clamp placed perpendicular to the fracture line (Figure 4).

Two guidewires were then introduced from the proximal to the distal end, perpendicular to the fracture line and with a good angle of attack, since this technique allows greater freedom of inclination than a distal-to-proximal placement. After measurement, two cannulated 3.0mm No. 16 long-thread headless compression screws were inserted anterograde, resulting in perfect interfragmentary compression between the fracture fragments (Figure 5). Through fluoroscopy we confirmed the correct placement of the guidewires and screws, which prevented them from becoming intra-articular.

After osteosynthesis of the medial malleolus, intraoperative stress radiographs showed no instability and that the ankle anatomy was restored.

At the end of the procedure, the pneumatic cuff was opened and the blood perfusion was checked. The skin was sutured after revision of hemostasis. The patient was initially immobilized with a plaster cast and then a short ankle orthosis at discharge.

Figure 4. Intraoperative fluoroscopy image showing anatomical reduction of the medial malleolus fracture with Backhaus forceps, whose upper end was introduced through the medial cortex after drilling with a 1.5mm bit.

Discussion

To classify the medial malleolus fracture, we observed the size of the fragment, relating it to the height of the horizontal line of the fracture (Herscovici types A, B and C) and the vertical direction (shear - Herscovici type D)[5].

Pancovich and Shivran identified 6 main medial malleolus injury patterns[6], which facilitates selection of the osteosynthesis type (all retrograde) for each fracture pattern.

We have observed that fractures involving the entire anterior colliculus and a small fragment of the posterior colliculus may be associated with an inverted oblique pattern.

The Herscovici classification differentiates four main fracture patterns and helps determine the treatment. However, as found by Aitken in 2016, there is a high prevalence of disagreement between types B and C due to the obliquity of the fracture, which we believe is essential for selecting the surgical technique[4,5].

Fractures in which the medial cortex fracture pattern is compatible with Herscovici type B and the joint face fracture pattern is compatible with Herscovici type C can be characterized as an inverted oblique pattern, a subtype not considered in this classification system.

In this fracture "subtype", it is difficult to obtain perpendicularity during compression with any conventional retrograde technique. Anterograde fixation with cannulated headless screws is a more mechanically stable alternative that involves less consolidation time, less pain due to the

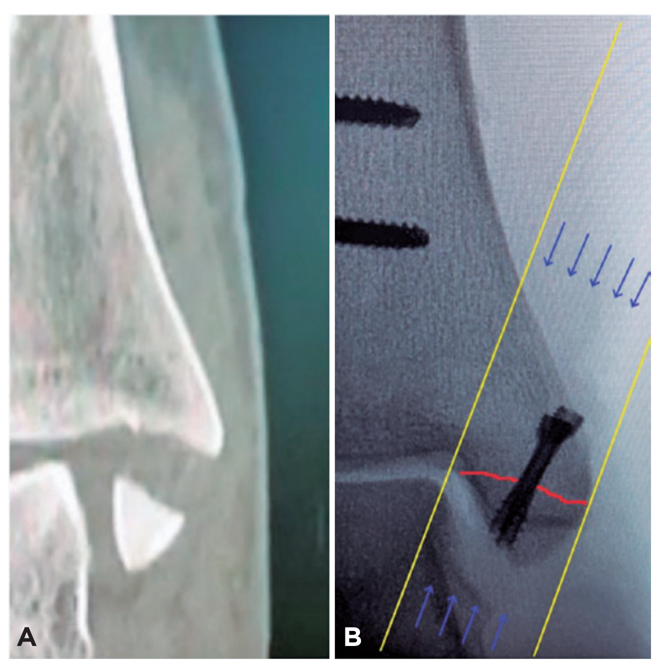

Figure 5. (A) Coronal CT section showing the inverted oblique fracture line; (B) AP radiograph of intraoperative control showing screws inserted in the perpendicular "corridor" to the fracture line.

implants (reducing the need for removal), an easier surgical approach, and less damage to the medial ligament complex (Figure 6).

Conclusion

Inverted oblique type B Herscovici fractures hinder conventional retrograde osteosynthesis and are a challenge due to difficulties in intraoperative reduction and fixation. The surgeon must prepare for these fractures with good planning and a collection of images that enable identification of this unusual pattern. Reduction and provisional stabilization that applies the correct compression force in the correct direction is fundamental for success. The anterograde approach allows the compression screw to be inserted perpendicular to the fracture line, which is adequate for interfragmentary compression and absolute stability.

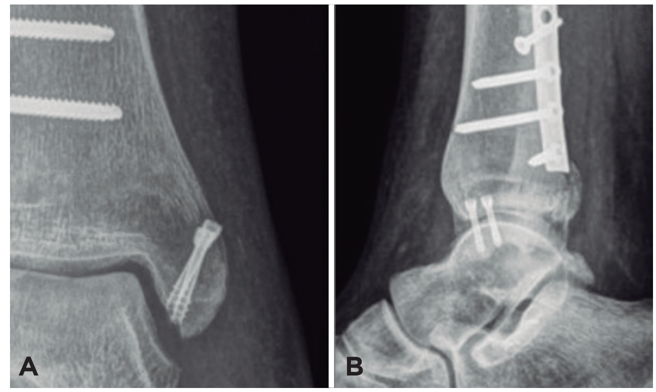

Figure 6. (A) AP radiograph showing the consolidated medial malleolus 4 weeks after surgery. (B) Ankle profile 30 days after surgery.

Authors' contributions: Each author contributed individually and significantly to the development of this article: SMC *(https://orcid.org/0000 0001 6416 5865) performed the surgeries; TLL *(https://orcid.org/0000-0002-5242-4548) Participated in the review process; ABP *(https://orcid.org/0000-0001-9785-1642) performed the surgeries; BJS *(https://orcid.org/0000-0001-5817-2743) participated in the review process; JSF *(https://orcid.org/0000-0002-4964-0979) conceived and planned the activities that led to the study; RCB *(https://orcid.org/0000-0003-3199-4055) participated in the review process. All authors read and approved the final manuscript. * ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Surgical treatment of cleft foot in an adult patient: case report

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Abstract

Cleft foot is a rare congenital malformation characterized by a central conical defect extending from the periphery of the foot towards the tarsus, affecting one or more central rays. Surgical intervention should be attempted at a very early age to prevent further pathological adaptations. The authors present the case of an adult woman admitted with painful callosities on the feet and difficulty selecting shoes. She was diagnosed with cleft foot and submitted to surgical treatment. The postoperative period was uneventful and the patient was very satisfied with the results of the surgery. This is only the second reported case of surgical management of cleft foot in an adult patient, and the first to describe the use of internal fixation.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Foot deformities, congenital; Syndactyly/surgery; Female; Adult.

Introduction

Cleft foot or ectrodactyly is a rare congenital malformation with an incidence of approximately 1 in 90,000 live births. It is also known as a lobster claw or congenital split foot and is characterized by a spectrum of foot abnormalities[1,2]. Cleft foot is usually inherited as an autosomal dominant trait with reduced penetrance. It may be isolated or occur as part of a syndrome. It usually presents bilaterally and is often combined with cleft hands[1,3]. Other anomalies associated with cleft foot include cleft lip and palate, syndactyly, scoliosis, imperforate anus, cataract, and deafness[2].

The main characteristic of the cleft foot is a central conical defect running from the periphery toward the tarsus, resulting in the absence of one or more central rays. The malformation may range from a mere deepening of the interdigital commissure to a lobster-claw or monodactyl foot[4,5]. Blauth and Borisch classified these defects into six major types:

1. Five normal metatarsal bones with partial or complete aplasia of toes 2-5.
2. Five metatarsals with partial hypoplasia or synostosis.
3. Only 4 metatarsals with the second or third always missing.
4. Only 3 metatarsals with the second and third, or third and fourth, always missing.
5. Lobster-claw foot with absence of the second, third, and fourth rays.
6. Monodactyl foot with only the fifth metatarsal and toe.

Surgical intervention should ideally be attempted at a very early age to reduce the likelihood of further pathological adaptations to compensate for the effects of the malformation. Delaying surgical intervention could result in the continued progression of the deformity. The objectives of cleft foot surgery: closing the cleft to the greatest possible extent, maintaining symmetrical feet, and preserving the position of the border rays to prevent collapse and valgus deformities of the toes. In this study, the authors describe the surgical correction of congenital cleft foot in an adult patient[6-8].

Case report

This study was approved by an Institutional Review Board.

A 44-year old woman was admitted to the hospital with complaints of painful callosities on the feet and difficulty wearing shoes. Both issues had been progressively worsening over time. A clinical interview revealed that her sister and nephew had similar developmental anomalies of the hands and feet. No other members of the family reported a similar issue.

Study performed at the Hospital Dr. Francisco Zagalo, Ovar, Portugal.

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The patient's feet were widely spread with only two rays present (deep cleft with an absence of central foot rays) (Figure 1). Calluses were present on the bunion and bunionette but not on the plantar aspect of the foot. Ankle range of motion was normal.

Her American Orthopedic Foot and Ankle Society (AOFAS) score was 72 out of a possible 100. Anteroposterior and lateral standing X-rays revealed the presence of only two rays in each foot (type V according to the Blauth W. and Borisch N.C. classification) (Figure 3). There was no axial deviation of the ankle.

Figure 1. Photo and AP X-ray of the patient's feet.

Figure 2. Medial and lateral approaches for the modified Lapidus procedure, basal fifth metatarsal osteotomy, and removal of the hypoplastic fourth metatarsal.

Surgical correction was first performed on the foot that caused the most inconvenience to the patient. In the first stage, two different procedures were performed on the right foot. A tourniquet was applied with the patient in a supine position, and a 5cm medial incision was made over the first tarsometatarsal joint. After careful dissection and protection of the extensor tendons, closing base lateral wedge osteotomy was performed on the first metatarsal, which was fixed to the first cuneiform bone using a plate and screws in a modification of the Lapidus procedure. A 10cm lateral incision was then made, and after protecting the extensor tendons, the authors performed an en bloc excision of the fourth metatarsal using a periosteotome, followed by a medial wedge osteotomy of the fifth metatarsal, and fixation with plate and screws. The access openings were closed with absorbable multifilament sutures for subcutaneous closure and nonabsorbable monofilament suture for skin closure. The patient was asked to wear Barouk shoes and allowed to bear weight as tolerated.

The postoperative period was uneventful with no skin-related complications. Alternate sutures were removed on the 15th postoperative day. After 6 postoperative months, the patient was very satisfied with the results of the surgery. She reported increased quality of life and was now able to wear a regular shoe on her right foot (Figure 3 and 4). The patient also expressed interest in undergoing surgery on the other foot.

Discussion

Cleft foot is a rare congenital anomaly characterized by foot splitting of varying severity[1,2,4]. The condition does not affect the rearfoot, which is why the intervention described in the present study was limited to the forefoot. The anomaly is usually bilateral and often co-occurs with the splitting of the hands[1,3].

There is no consensus on the surgical management of cleft foot deformity. Due to the rarity of this pathology, few publications have discussed its surgical treatment; moreover, all but one of the articles published on the topic concern the treatment of children[6-10].

Figure 3. Photo and X-ray of patient's right foot at 6 postoperative months.

Figure 4. Postoperative comparison of shoes on both feet of the patient.

Many authors recommend that children do not undergo surgery if their feet provide adequate support and they can wear normal shoes. Others support the applicability of surgical interventions for cleft foot deformity and suggest that they be carried out before the patient reaches 1 year of age[6,7]. The aim of treatment in patients with this congenital anomaly is to improve foot function and esthetics [8].

Cleft closure is a standard operative procedure for the treatment of cleft foot. It is useful in patients with at most one central ray deficiency, who tend to have a narrow forefoot and overlapping toes. However, in patients with two or three central ray deficiencies, there is no tissue in the central region of the forefoot. In these cases, the simple closure of the cleft cannot correct the defects and maintain the width of the forefoot, and a valgus deformity of the residual toes is likely to occur[10].

Leonchuk et al, are responsible for the only description of surgical treatment of cleft foot in an adult. The authors described the case of a 31-year-old patient treated with the Ilizarov technique with minimum fixation due to concerns regarding soft tissue defects of the central rays and central wound healing[10]. Despite the lack of previous reports on the use of this particular management strategy, the authors suggested the use of internal fixation and the patient agreed.

Conclusion

Cleft foot is a rare condition that is typically familial and co-occurs with cleft hand. The main aim of surgery in these cases is to improve the cosmetic appearance of the foot and allow for the use of normal shoes. While surgical interventions for cleft foot are usually performed in children, surgical treatment using internal fixation is an option for adults with this deformity.

Authors' contributions: Each author contributed individually and significantly to the development of this article: FSM *(https://orcid.org/0000-0002-1555-7181) bibliographic review, conceived and planned the activities that led to the study, clinical examination, performed the surgeries; JMB *(https://orcid.org/0000-0003-2649-9762) participated in the review process; AM *(https://orcid.org/0000-0002-9657-2710) performed the surgeries. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Achilles tendon detachment after local infiltration of corticosteroids: a case report

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Abstract

Complete disinsertion of the Achilles tendon is relatively rare but is an injury of considerable clinical significance. A 50-year-old non-smoking man presented with complete disinsertion of the Achilles tendon due to an indirect low-energy trauma shortly after administration of local corticosteroid injections (LCI) for treatment of deep retrocalcaneal bursitis. Imaging studies showed complete disinsertion of the Achilles tendon as well as severe Haglund syndrome and retrocalcaneal bursitis. The tendon was repaired, and the Haglund deformity and retrocalcaneal bursa were then resected. Although Achilles tendon rupture is a frequent complication after LCI, to date, no cases of disinsertion have been published. Surgeons must be aware of this issue, especially in patients with previous insertional calcific Achilles tendinosis and Haglund syndrome.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Achilles tendon/injuries; Rupture; Injections, intralesional; Bursitis/surgery; Calcaneus.

Introduction

Complete disinsertion of the Achilles tendon is relatively rare but is an injury of considerable clinical significance. A common cause of non-traumatic, non-insertional tendon rupture is local corticosteroid infiltration (LCI)[1]. LCI may start a degenerative process resulting in partial and, subsequently, complete rupture of the tendon due to a direct toxic effect. This is produced by inhibition of the production of extracellular matrix collagen and poor local vascularization[2].

This case report describes a patient who presented with the rare complication of complete disinsertion of the Achilles tendon shortly after administration of LCI during treatment of retrocalcaneal bursitis (RB). Although Achilles tendon rupture is a frequent complication after LCI, no cases of disinsertion have been published to date. Surgeons must be aware of this issue, especially in patients with previous insertional calcific Achilles tendinosis (ICAT)[3] and Haglund syndrome.

Case report

This report was approved by our institutional Human Research Ethics Committee, and the patient provided written informed consent for publication.

A 50-year-old healthy, non-smoking male presented following indirect low-energy trauma (forced dorsiflexion) to the Achilles region caused by a bicycle accident. The patient was overweight (BMI 30.47m^2; height 1.90m, weight 110kg) and engaged in occasional recreational physical activity. No history of quinolone intake was found in his medical record. He had a history of two infiltrations with corticosteroids (6 and 11 months before the beginning of symptoms) for retrocalcaneal bursitis with satisfactory initial results. The patient also presented clinical and radiological signs of ICAT[3], showing no pain at the Haglund deformity or the posterior calcification.

Study performed at the Fundacion Favaloro and Hospital Universitario, Ciudad Autonoma de Buenos Aires, Argentina.

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Upon arrival in the emergency room, the patient was initially immobilized with a walking boot in a neutral position. Physical examination showed mild ecchymosis at the calcaneus associated with a palpable gap of approximately 30mm. The Thompson and heel-rise tests were positive. X-rays and an MRI showed complete disinsertion of the Achilles tendon, as well as severe Haglund syndrome and retrocalcaneal bursitis.

Surgical repair was done under general anesthesia. The surgical technique consisted of a posterior midline approach 8cm long with protection of the sural nerve. The tendon was repaired with the Arthrex Achilles SpeedBridge™ Implant System (Arthrex Inc, Florida, United States). Complete detachment of its calcaneus insertion was observed (Figure 1). The Haglund deformity and retrocalcaneal bursa were then resected (Figure 2). The SpeedBridge System was placed in an hourglass shape as described in the original procedure (Figure 3), and the wound was sutured closed.

Postoperatively, the patient was immobilized with a plaster boot in an equinus position at 20 degrees for 2 weeks until wound closure and removal of sutures. He was then allowed to weight-bear with a walker boot for another 2 weeks in 10 degrees of equinus and, finally, for another 2 weeks in a neutral position.

The patient was evaluated with the American Orthopedic Foot and Ankle Society Score (AOFAS), a visual analog scale (VAS) of pain, and the Foot and Ankle Ability Measures (FAAM) subscale for activities of daily living (ADL) and sports at final follow-up (12 months). Clinical and functional evaluation was also performed with the Achilles Tendon total Rupture Score (ATRS), and the total length of the surgically operated Achilles tendon was compared with the contralateral tendon.

At 12-month follow-up, the results were as follows: AOFAS, 85 points; VAS, 2; FAAM ADL, 55; FAAM Sports, 72.3. Although the ATRS score was designed for complete rupture rather than disinsertion of the Achilles tendon, we implemented it in this case and obtained a score of 85 at 12 months postoperatively. MRI measurement showed a length of 205mm in the healthy tendon and 200mm in the operated tendon with a negative formula. We assume that this outcome is due to the distal resection needed for reinsertion, not to a preexisting anatomical variant or congenital shortening.

Discussion

Complete disinsertion of the Achilles tendon without a traumatic mechanism of injury is rare[1].

Most corticosteroids currently used in orthopedic practice are synthetic analogs of endogenous human hormones. They are widely used for their anti-inflammatory and analgesic activity, but must be used judiciously. Adverse effects include osteopenia and immunosuppression, post-injection dermatitis, facial erythema, tendon and ligament rupture, pigmentation changes, and fatty atrophy, which can be severe in some cases. Animal studies report that tendon infiltration with corticosteroids causes changes in microvascularization, areas of collagen necrosis, and decreased tensile strength, ultimately leading to tendon rupture[2].

LCI has proven to be a safe and effective option for treating a variety of foot and ankle conditions, and reduces the need for surgery (only 12% for RB)[4]. Infiltration of the Achilles tendon is rarely performed nowadays, as they are associated with non-insertional injuries. However, in cases of retrocalcaneal bursitis, it is still considered a valid treatment and is widely performed[5]. In 2011, Johnson et al. published a study on complications from corticosteroid injection in foot and ankle pathologies. They included the experience of 969 surgeons and more than 50% infiltrations of retrocalcaneal bursitis, reporting no cases of rupture or detachment of the Achilles tendon.

Some authors report that an accurate ultrasound (US)-guided LCI of the retrocalcaneal bursa guarantees an effective and safe technique and prevents secondary complications[6,7]. In the case we presented, we believe that an

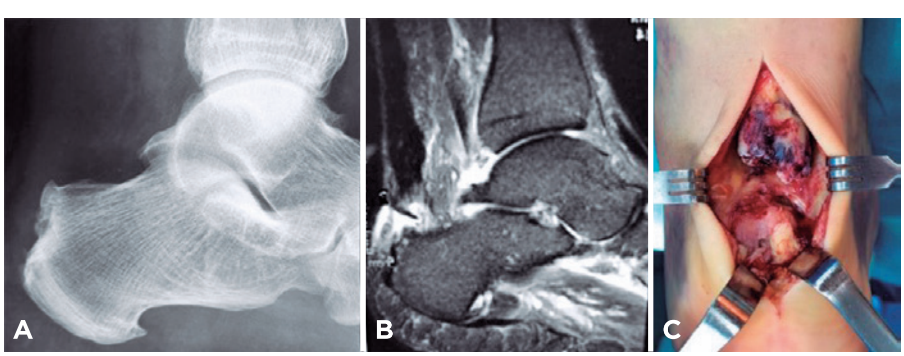

Figure 1. (A) X-ray showing Haglund exostosis and irregularity in the insertion area. (B) T2-weighted MRI, sagittal view, showing complete detachment of Achilles insertion. (C) Clinical view.

incorrect LCI technique (LCI outside the retrocalcaneal bursa) was the cause of the injury. Although LCI is still a valid treatment for retrocalcaneal bursitis, in our opinion and based on published studies, this must be performed under US guidance. Haglund syndrome can be treated by LCI without the use of ultrasound, but our patient did not have a trigger point over his Haglund deformity.

Recently, some authors found connections between the retrocalcaneal bursa and the anterior fibers of the Achilles tendon, which should be considered a weak zone when performing infiltrations[8,9]. Although LCI may help to relieve symptoms of RB, it may also increase the risk of Achilles tendon rupture. According to Turmo-Garuz et al., this risk-benefit ratio has to be considered when LCI is to be performed on professional and high-level athletes. These authors found gastrocnemius and soleus muscle lesions in three patients[9]. We think that our patient had been injected in the retrocalcaneal space but outside the bursa, and this may have weakened the Achilles insertion.

The SpeedBridge technique allows the use of an "hourglass suture procedure" beyond the distal end of the tendon, without knots and with a greater compression area for the Achilles tendon in the calcaneus. According to some authors, this procedure improves insertional strength and can allow early return to sports activities[10]. In a recent study by Rigby et al.[10], 42 of 43 patients operated with the SpeedBridge technique recovered 100% of their activities of daily living and physical capacity.

Conclusion

To date, there are no published cases of complete disinsertion of the Achilles tendon as a complication of LCI. Corticosteroid treatment must be administered correctly and accurately. We recommend the use of ultrasound guidance for LCI to allow correct localization of the retrocalcaneal bursa, which is essential to achieving good results and safe infiltration, avoiding damage to the Achilles tendon. Finally, surgeons must be aware that LCI may lead to Achilles tendon rupture (even if correctly done under US guidance) and even tendon disinsertion (if infiltrated incorrectly outside the bursa).

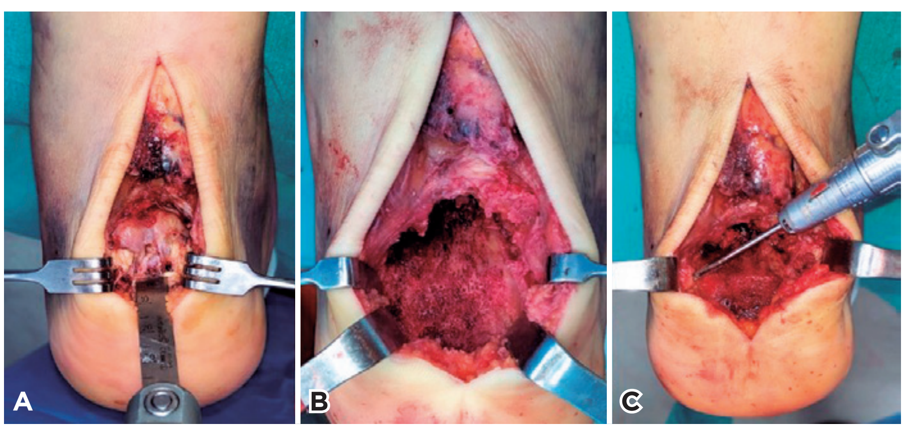

Figure 2. (A) Resection on Haglund's deformity with sagittal saw. (B) Complete resection. (C) Remodeling of calcaneus posterior tuberosity with 3.1 wedge burr.

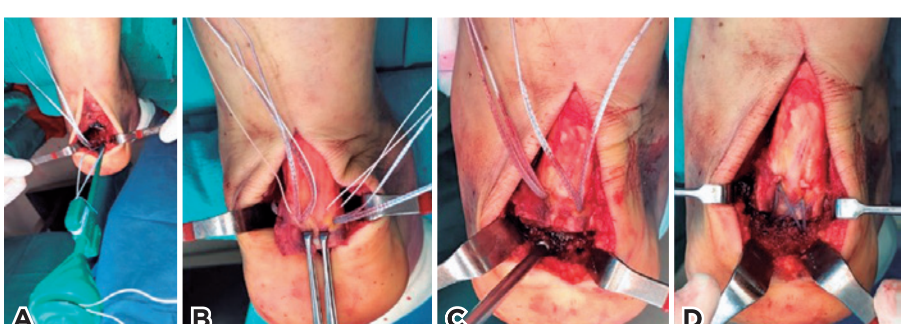

Figure 3. (A) Insertion of first 4.75 SwiveLock® anchor for the SpeedBridge™ System technique. (©Arthrex, Inc.) (B-D). Threading of Achilles tendon until final reinsertion.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JJDV *(https://orcid.org/0000-0001-5263-7626) conceived and planned the activities that led to the study, performed the surgery; EDD *(https://orcid.org/0000-0001-5684-3902) data collection, bibliographic review; JPB *(: https://orcid.org/0000-0003-0910-4140) interpreted the results of the study; MEG *(https://orcid.org/0000-0002-5953-9380) interpreted the results of the study, participated in the review process; LNC *(https://orcid.org/0000-0003-4981-6169) clinical examination, survey of the medical records, bibliographic review. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Special Article

New classification of osteochondral lesions of the talus in adults

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Abstract

Osteochondral lesions (OCL) of the ankle in adults are frequent lesions that mainly affect the cartilage and the subchondral bone, are relatively common, and have varied etiologies. However, in 50% of patients, these lesions may occur concomitantly with chronic instability of the ankle associated with lower limb deformities, acute sprains of the ankle, or fractures. We propose a classification into four types of lesions (traumatic, non-traumatic, with lateral instability of the ankle, and with mechanical axis defects), focusing not only on the diagnosis and treatment of OCL but also on associated injuries, such as instability and/or supramalleolar and hindfoot deformities.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Osteochondritis/classification; Osteochondritis/diagnosis; Ankle joint/surgery; Ankle injuries/diagnosis.

Introduction

Osteochondral lesions (OCLs) of the ankle in adults are frequent lesions that mainly affect the cartilage and the subchondral bone, with an incidence ranging from 0.09% to 4%[1]. There is still controversy about the etiology and pathogenesis of OCLs. Several terminologies have been used to classify these lesions: OC defects, transchondral fractures, osteochondritis dissecans, and intra-articular fractures[2,3]. The expression osteochondral lesion covers a wide range of diseases, including bone edema with or without subchondral contusion, OC fracture, osteochondritis dissecans, and osteoarthritis resulting from a long-term disease. Subchondral bone compromise may manifest as bone marrow edema, fractures, sclerosis, and/or formation of cysts. Ankle OCLs are relatively common lesions with many etiologies, but in 50% of patients they may occur concomitantly with chronic instability of the ankle, lower limb deformities, acute sprains of the ankle, or fractures.

We propose a classification into four types of lesions (traumatic, non-traumatic, with lateral instability of the ankle, and with mechanical axis defects), focusing not only on diagnosis and treatment of OCL, but also on associated injuries, such as instability and/or supramalleolar and hindfoot deformities.

Discussion

In the current literature, different hypotheses have been proposed for the origin of OCLs. These hypotheses, which include vascular diseases, hormone factors, endocrine disorders, ossification defects, genetic and embolic phenomena, could explain the onset of these disorders and, in some cases, the bilateral presentation of the lesions. The classification and understanding of these lesions have been developing in a gradual and staggered manner[4]. The emergence of computed tomography and magnetic resonance imaging (MRI) has changed the perspective on the correct classification and treatment of these lesions. Advances in these technologies and devices in the last 10 years, as well as new high-definition MRI techniques, have provided great detail on pathological anatomy and have allowed us to incorporate a new approach on these lesions.

The diagnostic strategies for suspected cartilage injuries of the ankle remain a subject of frequent debate worldwide. Up to date, there is no consensus in the literature with regard to optimal images and tests to request in patients with suspected ankle cartilage injury, as well as with regard to specific imaging protocols that should be used. Furthermore, no study has examined the relationship between the results of preoperative imaging scans and operative findings[5].

Study performed at the Centro Artroscopico Jorge Batista, CABA, Buenos Aires, Argentina.

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The first description of the topic was made in 1959 by Bernd and Harty[6], who identified and described several determining concepts, such as trauma as the primary cause of all OC "fractures", and based their classification on radiological manifestation of the injury. For many years and after this publication, traumatic etiology was commonly accepted as the predominant causal agent and has been widely used to choose the best therapeutic option between conservative or surgical treatment. The main advantage of this classification is its generalized use and its simplicity. Although conventional radiography (CR) is still the diagnostic modality initially used to evaluate the ankle, Hepple showed that from 30 to 43% of OCLs of the talus diagnosed on MRI were invisible on CR. However, Lusse and O'Loughlin reported that, in a prospective study with 92 patients, 50% of OCLs were not identified on simple X-rays[4,7].

In 1989, Anderson showed that the four-stage classification did not predict the formation of subchondral cysts during the pathogenesis of OCLs, and stage 2b was subsequently added to take this matter into account. With the use of axial computed tomography (ACT) and MRI, these cysts are more frequently observed. Histological studies suggest that such cysts develop in areas of post-traumatic bone necrosis containing fibrin, vascular granulation tissue, and often segments of articular cartilage[8-10].

In 1990, Ferkel and Sgaglkione designed a staging system that assesses OCLs by ACT, based on the original classification by Berndt and Harty[11,12]. The authors introduced stage I, which described a cystic lesion within the talar dome with intact roof in all views; stage IIA was described as a cystic lesion that communicates with the talar dome surface; and stage IIB as a lesion of the open articular surface with overlying non-displaced fragments. Stages III and IV were similar to those described in the classification by Bernd and Harty[11]. MRI can evaluate location and size of the injury in three planes, subchondral bone marrow edema, formation of subchondral cysts and/or sclerosis, status of the overlying cartilage, and depression in the contour of the articular bone plate.

Taranow et al.[13] used MRI to describe the condition of both the cartilage and the subchondral bone using the classical four-stage classification for the bone component, while describing that the cartilage was viable and intact (grade A) or non-viable (grade B). Mintz et al.[14] established a correlation between MRI and arthroscopic findings. Anderson classification[15], presented in 1989, is another modification of the initial staging system based on conventional radiological assessment by Berndt and Harty. Stage 1 lesions result from bone marrow contusion. MRI is the most sensitive method to represent this stage, with no correlation sign on CR or on ACT with intra-articular contrast injection. Stage 2 refers to partial detachment of OCL, with formation of subchondral cyst or fissure that incompletely separates the lesion from the talar dome. In stage 3, it is possible to observe a completely separated non-displaced fragment on MRI, with adjacent bone marrow edema. Stage 4 consists of a displaced fragment, often accompanied by surrounding bone marrow edema.

The use of MRI should be evaluated in a clinical context, and in all cases ACT or cone beam CT (CBCT) are recommended to assess the size and extent of the lesion. Some authors, including us, believe that MRI may overdiagnose or overestimate the depth of OCLs and advise caution in using these classification systems[16,17]. The use of MRI should be reserved only to evaluate the subchondral bone[18]. Arthrographic techniques are often used in an OCL is detected on MRI and in those cases when arthroscopic treatment is considered. Similar to the Outerbridge classification (widely used in the staging of knee cartilage lesions), a modified staging system may be used to assess the extent of cartilage defects with correlation with knee arthroscopy[19].

In a great number of patients, cartilage lesions may be isolated. In the last years, a new technique (CBCT) has been used for the first time in the preoperative assessment of dental implants, but its use has been recently expanded to musculoskeletal injuries. This technique combines high spatial resolution, a relatively low radiation dose, and low cost equipment, and is useful in the assessment of trauma of small bones and joints, particularly when there is clinical suspicion of fracture despite negative findings on simple radiographies[20]. CBCT after intra-articular injection of iodine contrast (CBCT arthrography) may provide exquisite details of the articular cartilage using very thin slices and multiplanar reformatting. In patients with suspected isolated chondral lesion, the trabecular architecture of the subchondral bone is much better visualized on CBCT than on CR or MRI. In this sense, CBCT-arthrography (CBCT-A) may be a very promising technique that could be used in specific situations.

Complementary classification systems have emerged using intra-operative findings, with the development of new arthroscopic devices. Pritsch et al.[21] classified OCLs of the talus according to the quality of cartilage, as it can be observed on arthroscopic visualization. The disadvantage of an arthroscopic classification system is the fact that it is centered on the cartilage injury and it does not consider the underlying bone component of the lesion.

A myriad of additional classification systems have been proposed, on the basis of computed tomography, MRI, arthroscopic findings, and an anatomical grid, which was introduced by Elias et al.[17] in 2007 with the purpose of allowing for a better treatment planning. These authors assess the actual incidence of OCLs in talus dome by location and by morphological characteristics through MRI. The articular surface of the talar dome was divided using a grid with three columns and three rows, resulting in a configuration with nine equal zones in the axial axis. The nine equal areas were assigned numerical identifiers from 1 to 9, beginning with the most anterior and medial region and advancing laterally and then posteriorly[17].

Other authors indicate treatment based on OCL size, symptoms, age, level de activity, and limb alignment[18,22].

The aim of surgical treatment is to create an optimal biological environment to repair the subchondral bone and allow for the generation of a chondral surface[4]. Different treatment options have also been proposed, including conservative and surgical treatment, based on location, size and extent of subchondral bone injury. Surgical treatment may be arthroscopic or open surgery that includes bone marrow stimulation (BMS), with debridement, curettage, and microfractures. Replacement and fixation of fragments, autologous transplantation, or allograft, and cultivation of chondrocytes are also indicated[4,22]. A minimally invasive (arthroscopic) approach to treat these lesions also brings some advantages[23,24].

Most authors reported that more than 50% of patients with OCL have an acute ligament injury, an associated fracture, or history of chronic ankle instability. Basement on our review and our experience on management and treatment of OCLs of the talus, we have introduced a reviewed classification, based on CR and specific radiographies with assessment of alignment of distal extremities, computed tomography, MRI, arthroscopic findings, and history of ankle instability (Table 1).

The focus of this new classification is based on determining associated instabilities and/or ankle and hindfoot deformities. It also refers to OCL size and depth. All these parameters allow us to define the appropriate treatment of each lesion and may predict its prognosis in an increasingly manner according to the type. The first distinction on which we based the new classification was between patients with or without associated trauma. Traumatic lesions (stage 1) were classified into two groups: stage 1A in cases of previous trauma with isolated compromise of the talar cartilage (flap); and stage 1B in those with previous history of cartilage and subchondral bone trauma. Non traumatic lesions (Stage 2) were also divided into two types: stage 2A, in which an intact subchondral cyst can be visualized (Figure 1); and stage 2B, with open cyst in the talotibial joint (progression of stage 2A) (Figure 2). Stage 1B and 2B are subdivide in: .1: lesion <10mm diameter <5mm deep and .2: lesion >10mm diameter >5mm deep. Stage 3 refers to the above mentioned subtypes when associated with lateral ankle instability. Stage 4 includes any of the previous OCL stages when associated with varus or vagus misalignment of the hindfoot and/or talotibial joint and is divided into stage 4A, which encompasses calcaneus varus or valgus; and stage 4B, which encompasses varus or valgus deformities, mechanical axis deviation of the talotibial joint.

Table 1. Chart of the new classification of osteochondral lesions of the talus in adults

	Osteochondral lesions of the talus in adults J. Batista, G. Joannas, L. Casola, L. Logioco, G. Arrondo
1A	*Traumatic lesion* with isolated cartilage injury (flap) Tx: arthroscopy, curettage, and microfractures.
1B	*Traumatic lesion* (cartilage and subchondral bone injury)
1B.1	Lesion <10mm in diameter and <5mm of depth (superficial lesion) Tx: arthroscopy, curettage, and microfractures.
1B.2	Lesion >10mm in diameter and >5mm in depth Tx: fragment fixation with osteosynthesis, open surgery, osteochondral graft, or mosaicoplasty.
2A	*Non-traumatic* isolated bone injury, subchondral cyst. Tx: retrograde drilling.
2B	*Non-traumatic* open subchondral bone cyst with articular connection (progression of type 2A).
2B.1	Lesion measuring <10mm in diameter and <5mm in depth (superficial lesion). Tx: arthroscopy, curettage, and microfractures.
2B.2	Lesion measuring >10mm in diameter and >5mm in depth. Tx: open surgery, osteochondral graft, or mosaicoplasty.
3	*Type 1 or 2 lesions associated with lateral instability of the ankle* Tx: ligament repair.
4	*With limb deformities*
4A	*Types 1 or 2 lesions with hindfoot deformity* = varus or valgus calcaneus Tx: varus or valgus calcaneal osteotomy.
4B	*Type 1 or 2 lesion with supramalleolar deformity of distal tibia* (varus or valgus) Tx: varus or valgus supramalleolar osteotomy.

Tx: treatment.

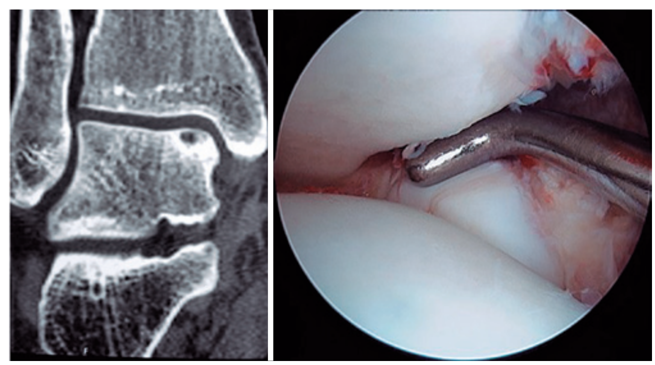

Figure 1. Intact subchondral cyst, computed tomography scan on the left. Arthroscopic image showing no evidence of communication between the cyst and the articular cavity.

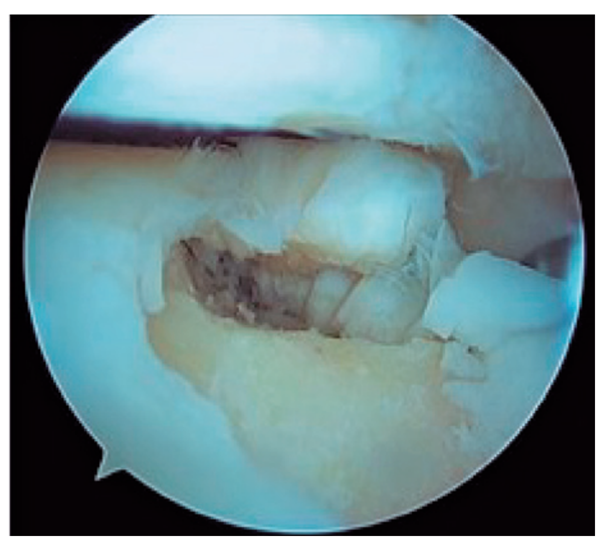

Figure 2. Arthroscopic view showing communication between the subchondral cyst and the articular cavity. It is the progression of type 2A in which cartilage collapse occurs within the bone defect.

Type 1A: traumatic (chondral flap with intact subchondral bone). We suggest arthroscopic treatment with flap resection, with subsequent curettage, debridement, and microfractures (Figure 3).

Type 1B: traumatic lesions that affect the cartilage and the subchondral bone.

1B.1: lesion <10mm of diameter and <5mm of depth (superficial lesion). We suggest arthroscopic treatment with curettage of the lesion, debridement, and microfractures.

1B.2: >10mm of diameter and lesion >5mm of depth. We suggest arthroscopic fixation of the fragment or open surgery with OC transplantation or mosaicoplasty.

Type 2A: non-traumatic bone injury due to intact subchondral cyst. We suggest retrograde perforations with previous arthroscopic evaluation of the lesion to confirm that talar cartilage is intact.

Type 2B: non-traumatic lesion and visualization of an open subchondral bone cyst with articular connection (progression of type 2A).

2B.1: lesion measuring <10mm in diameter and <5mm in depth (superficial). We suggest arthroscopic treatment with curettage of the lesion, debridement, and microfractures.

2B.2: lesion measuring >10mm in diameter and >5mm in depth. We suggest open surgery with OC graft or mosaicoplasty.

Type 3: type 1 or 2 OCLs associated with lateral instability of the ankle.

In both subtypes, the associated ligament injury should be treated by ligament repair, augmentation, or reconstruction, depending on the degree of lateral instability (Figure 4).

Type 4: type 1 or 2 OCLs associated with hindfoot deformity (varus or valgus) and/or talotibial deformity (supramalleolar).

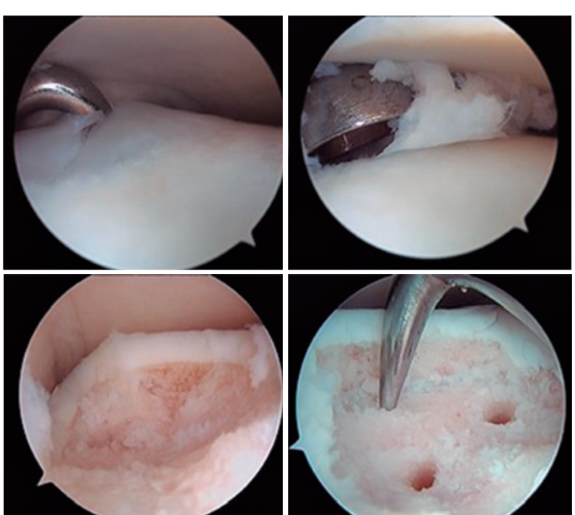

Figure 3. Arthroscopic treatment of type 1A: curettage, debridement, and microfractures.

4A: when the deformity occurs exclusively on the hindfoot, we treat the OCL according to the above mentioned subtypes and indicate varus or valgus calcaneal osteotomy, according to the deformity (Figure 5).

4B: when the deformity is on the talotibial joint, we indicate treating the OCL according to its type and subtype and then performing a varus or valgus supramalleolar osteotomy, according to the deviation of loading axis (Figure 6).

It is worth mentioning that this treatment for type 4 lesions is recommended only when the cartilage is at least 50% intact in asymmetric ankle arthrosis. When cartilage compromise is greater than 50%, indication changes to total ankle replacement or talotibial arthrodesis.

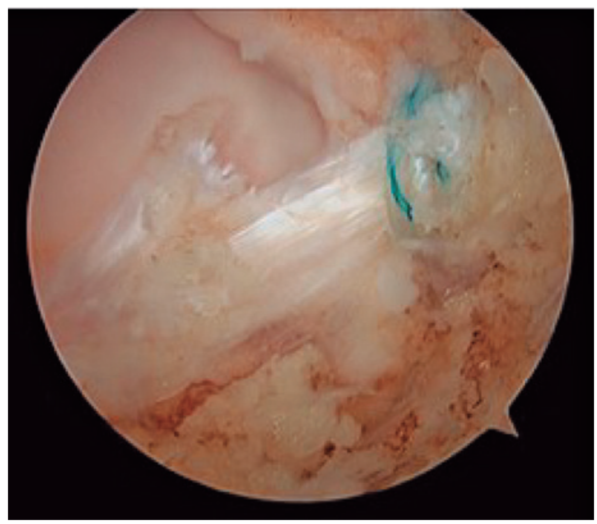

Figure 4. Arthroscopic repair of the anterior talofibular ligament.

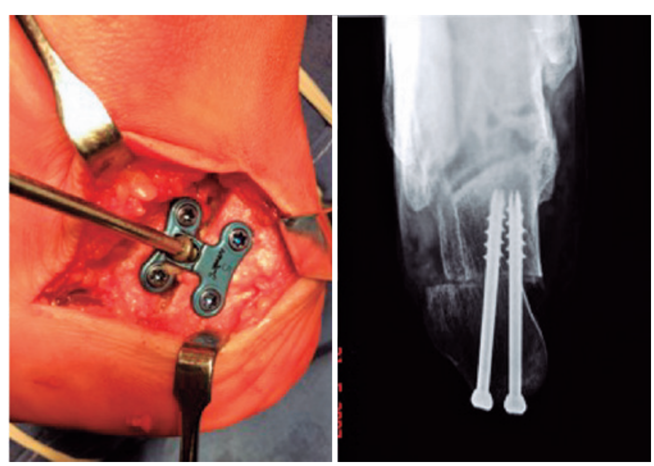

Figure 5. Valgus calcaneal osteotomy fixed with a staggered plate to the left and with two partially-threaded cannulated screws compressing the osteotomy to the right.

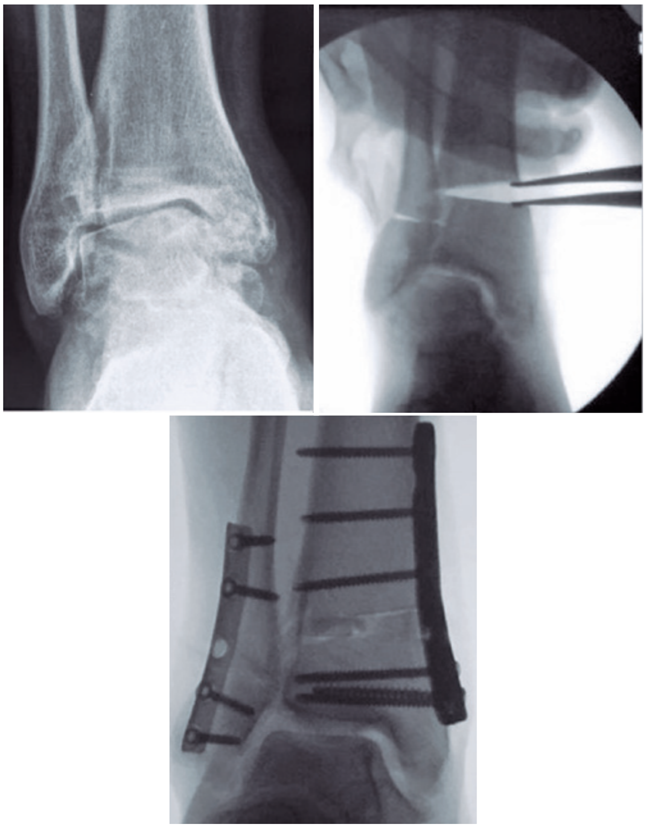

Figure 6. Varus deformity treated with supramalleolar opening wedge osteotomy.

With regard to postoperative rehabilitation, it is indicated to start self-assisted early passive mobilization as soon as pain and edema allow so. Partial support is initiated after from 2-4 weeks in lesions smaller than 10mm, and after 6 weeks in those larger than 10mm or if the lesion is located anteriorly. In patients subjected to concomitant procedures, such as supramalleolar or calcaneal osteotomy and/or ligament repair, support is initiated after 6 weeks. Recreational activities are limited for 3-6 months, and competitive activities for 6-12 months.

In the case of concomitant procedures, such as supramalleolar or calcaneal osteotomy and/or ligament repair, patients are immobilized for 3 weeks with orthopedic walker boots or plaster cast, without load, then partial support with assistive walkers for 3 weeks, and beginning of complete support after 6 weeks. Recreational activities are limited for 3-6 months, and competitive activities for 6-12 months.

Conclusion

The classification presented here allows us to provide a guide for the treatment of OCLs, according to their morphology, extension, and depth, along with their association with ankle instabilities and disorders in loading axes, which enables for the physician to indicate a specific treatment for each type and subtype of this multifactorial disease.

Yet, we still need to assess the reproducibility of our classification in the treatment of OCLs, with the conduction of a future prospective study.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JB *(https://orcid.org/0000-0003-0910-4140) conceived and planned the activities that led to the study, performed the surgeries, bibliographic review and clinical examination; GA *(https://orcid.org/0000-0003-4767-5489) performed the surgeries, clinical examination and participated in the review process; GJ *(https://orcid.org/0000-0001-9998-190X) formed the surgeries, formatting of the article; LC *(https://orcid.org/0000-0003-1187-0864) participated in the review process, data collection, performed the surgeries; LL *(https://orcid.org/0000-0001-9094-7609) performed the surgeries and formatting of the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Special Article

Charcot arthropathy of the foot and ankle: an update

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Abstract

Objective: To critically evaluate the current literature on the etiopathogenesis of Charcot neuroarthropathy, its diagnostic methods and therapeutic management.

Methods: We searched for studies that related Charcot arthropathy with a location in the foot and ankle in the PUBMED and MEDLINE databases.

Results: A total of 52 studies were used for this analysis.

Conclusion: Charcot neuroarthropathy is a serious disease with significant potential to impact patient quality of life. Although its pathogenesis still raises much controversy, neuropathy seems to have a central role, leading to a trauma, injury, and inflammation cycle.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Charcot; Neuroarthropathy; Diabetes mellitus; Ankle; Foot Diseases.

Introduction

Charcot neuroarthropathy (CN) is a rare but serious complication of peripheral neuropathy and is also known as Charcot osteo-neuroarthropathy[1]. It is a disabling osteoarticular pathology that causes weakening of the musculoskeletal system, progressing to fracture and destruction of the joint under stress. The foot and ankle are the most often affected segments[2]. However, there are reports of the involvement of several body segments, such as the knees, spine, shoulders, hips, and wrists[3].

Several neurological conditions, many of which are affected by sensitive neuropathy, are associated with CN, such as tertiary syphilis, meningomyelocele, syringomyelia, poliomyelitis, Charcot-Marie-Tooth disease, alcoholic peripheral neuropathy, and Hansen's disease. Currently, diabetes mellitus (DM) has become the most common etiology of CN[1,3-5].

In 1968, Jean-Martin Charcot described osteoarticular changes in patients with tabes dorsalis. Despite the pathology having his name, he recognized he was not the first to describe such changes[5]. JK Mitchel, in 1831, and William Musgrave, although with controversy, had already described cases of osteoarticular destruction associated with neurological dysfunction[1,5]. However, only in 1936 did Jordan[6] publish the first work associating CN with DM[7,8].

Despite the high worldwide prevalence of DM, CN is underdiagnosed; this is due, in part, to the difficulty and delay in diagnosis, resulting from the lack of clinical and radiological criteria, especially considering an initial approach by non-specialists[1,7,9,10]. The annual incidence is estimated to vary from 0.1% to 29% and the prevalence, between 0.08% to 13%[2,9]. CN usually appears asymmetrically in the fifth or sixth decades of life, usually 10 years after DM onset[11]. The proportion of men and women with CN is similar, with some studies showing greater involvement in male patients[9,11].

CN is considered a risk factor for lower limb amputation in diabetic patients, reaching rates of up to 67%[2]. When associated with ulcers, this prevalence increases considerably, as does mortality, with almost half of these patients undergoing at least one foot surgery[7,12].

As well as other chronic changes that are part of the DM, CN is also a complication of its progression, being one of the concerns of the diabetic foot syndrome. Therefore, these comorbidities should always be carefully screened by a multidisciplinary team, as their early detection and management are essential[11,13].

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

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Methods

Through a research of the PUBMED and MEDLINE platforms, studies published between 1936 and 2021 were retrieved. Descriptors used in the research were "Charcot neuroarthropathy" and "ankle and foot", as described in table 1. Case-control, cohort, and experimental studies, as well as case reports, systematic reviews, and meta-analyses were included.

All studies relating Charcot arthropathy to a location in the foot and ankle were included. Studies unrelated to the involvement of the pathology in this region were excluded. The analyzed results included epidemiology data, pathophysiology, classification, diagnostic tests, conservative and surgical treatments, and complications; these were retrieved from 52 studies, classified as shown in table 2.

Pathophysiology

The exact mechanism of CN is not yet established[14]. Nevertheless, this understanding is evolving rapidly. Several theories have been postulated and it is currently accepted that the pathophysiology is multifactorial and theories that were previously antagonistic now complement each other[3].

Neurovascular theory

This French theory, supported by Charcot and Mitchel[3,5,15], considers that a vascular reflex secondary to an autonomous neurological dysregulation (sympathectomy) would increase bone blood flow (arteriovenous shunts) and arterial perfusion, causing greater bone resorption (osteopenia) due to osteoclastic activity and resulting in destructive changes and pathological fractures and dislocations[2,15].

Table 1. Keywords used for researching the PUBMED and MEDLINE databases.

Main keywords used in our literature search on the PUBMED and MEDLINE databases			
Neuropathy	Charcot	Ankle	Foot
Subtitles used for research in Literature search on PUBMED and MEDLINE			
Imaging exams	Pathophysiology	Diagnosis	Diabetic Foot
Diabetic neuropathy/complications	Diabetic neuropathy/treatment	Quality of life	Bone metabolism
Surgeries	Treatment	Diabetes	Therapies under study

Table 2. Types of studies and numbers of cases retrieved from the databases.

Review/Meta-analysis	24
Case series	5 (Total cases: 131)
Cohort	9 (Total cases: 10 491)
Case control	5 (Total cases: 345)
Case reports	2 (Total cases: 4)
Guidelines	1
Technique/Biomechanics	4
Randomized clinical trial	2 (Total cases: 60)
Total selected studies	52

Neurotraumatic theory

The German theory, proposed by Volkman and Virchow, suggests that repetitive mechanical microtrauma or even acute trauma of insensitive joints causes progressive bone destruction, with joint deformity and incongruity[2,3,15].

Inflammatory theory

Current evidence directly linking osteopenia to diabetic neuropathy vary[15]. However, it has been shown that bone mineral density is diminished in the acute phase of foot involvement by CN, and this fragility can predispose to fracture-dislocations[15-17].

The receptor activator of nuclear factor-kB (RANK) is located on the surface of osteoclast progenitor cells and regulates their differentiation. The RANK ligand (RANK-L) is a molecule produced by osteoblasts and bone marrow stromal cells that binds to its specific RANK receptor. This ligation promotes osteoclast differentiation, activation, and survival (osteoclastogenesis), as well as bone resorption. On the other hand, osteoprotegerin (OPG) is a cytokine produced by activated osteoblasts that antagonizes the binding of RANK-L to RANK in the osteoclast membrane, limiting excess osteoclastogenesis and osteolysis. Therefore, regulation of the RANKL/OPG ratio is one of the mechanisms of bone metabolism control, with an impact on bone density[14,18,19] (Figure 1).

Jeffcoate et al.[20] suggested that the RANK/RANKL/OPG signaling pathway, responsible for balancing bone metabolism, has implications in the development of an acute CN event. They considered, along with other authors[21,22], that in this phase of CN there is an accentuated inflammatory response to trauma, increasing the expression of pro-inflammatory cytokines such as TNF-α, IL-6, and IL-1β and the number and local function of osteoclasts, activated by RANK-L and with insufficient OPG to neutralize them; this potentializes local inflammation, resorption, bone fragility, and bone destruction[3,8,15,18-20]. Jansen et al.[23] showed this increase in the acute phase of NC, but not in the chronic phase; it may even be a potential marker of Charcot activity[15].

These theories can be interpreted in a complementary fashion, and some authors consider 2 factors to be essential in the pathophysiology of NC: neuropathy and inflammation[2,20]. In summary, it is as if the exacerbated post-traumatic inflammatory response in a patient with CN increased RANK-L expression by increasing pro-inflammatory cytokines, resulting in clinical signs of inflammation and stimulating osteoclastogenesis and osteolysis. In individuals without a neuropathy, this process is limited by immobilization in response to the pain caused by local inflammation. However, when the sensation of pain is reduced due to a sensory neuropathy, there is no protective suppression, allowing the continuation of the mechanical injury and inflammatory process, which in turn leads to bone fragility and fractures. The result is the establishment of a vicious cycle of inflammation and structural damage to the foot[15,20] (Figure 2).

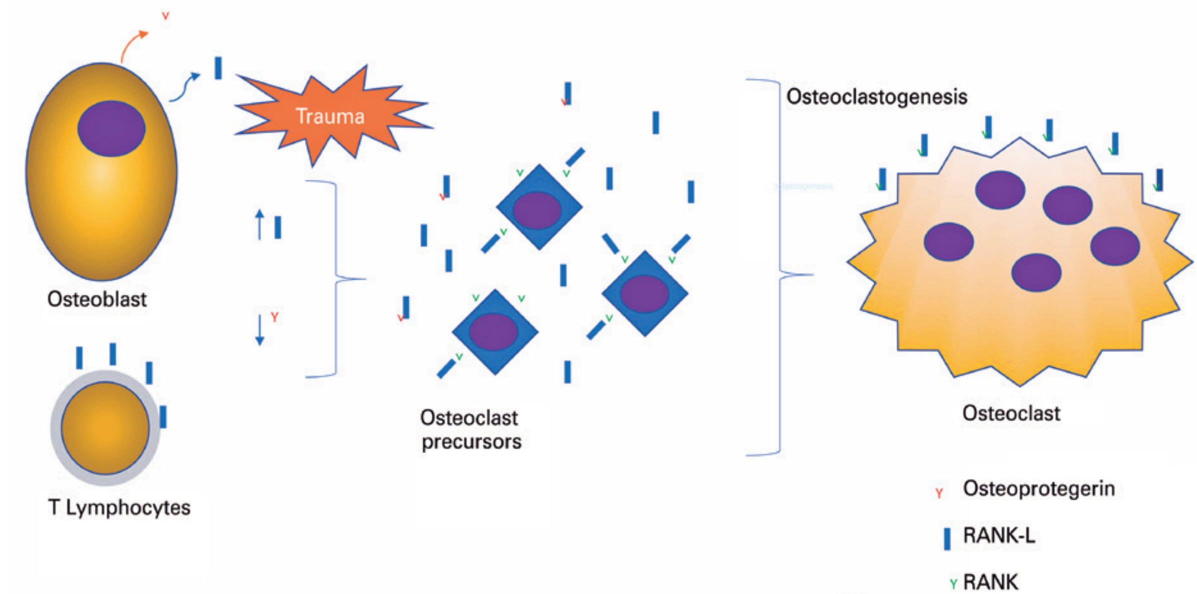

Figure 1. Schematic representation of the RANK/RANK-L/OPG signaling pathway in CN. Adapted from Molines et al.[27] and Ndip et al.[19]. RANK: receptor activator of nuclear factor-kB; L: ligand.

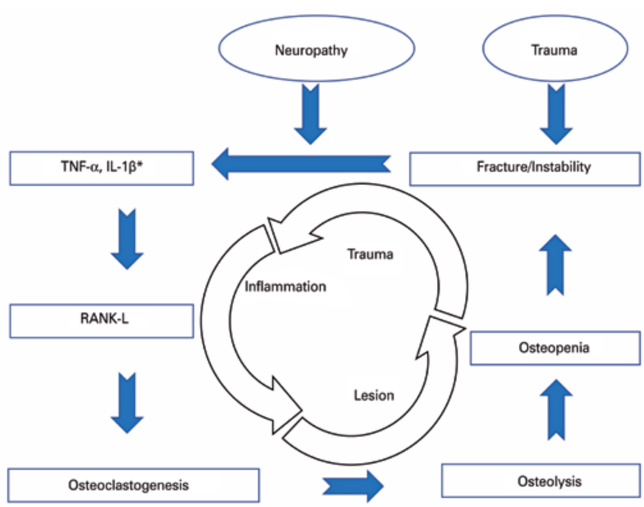

Figure 2. Schematic representation of the inflammatory theory in the development of the acute Charcot foot.
Adapted from Molines et al.[27] and Jeffcoates et al.[20].

The hyperglycemic state in diabetic patients has been shown to increase the levels of advanced glycation end products that when associated with inflammation, denature and weaken tendons and ligaments, further increasing instability and corroborating the vicious cycle[2].

Classification

One of the most well-known and used classifications is that of Eichenholtz, described in 1966 and modified in 1990[1,24,25]. CN staging, according to this classification, considers clinical and radiographic criteria, and describes the natural history of the disease in four stages. It has been used as an aid, although controversial, for deciding the best surgical moment[15] (Table 3).

The inflammatory process is evident in the initial stages (0 and 1), and some authors consider it as acute CN[2,15,26]. In these phases, the inflammatory process is exacerbated due to the loss of protective innervation and perpetuation of microtrauma, progressing to a vicious cycle of trauma – injury – inflammation. There is an increase in inflammatory cytokines and, consequently, in the osteoclastic activity that weakens the bone. Chronic CN is recognized when a reduction of inflammatory activity is observed and the patient presents changes in radiographic images due to the collapse or destruction of the joint (classically represented as a "rocker bottom deformity"[15,26]); it is described by Eichenholtz as stages 2 and 3.

In association with the abnormal mechanics of the foot, the formation of these bone deformities causes changes in areas of plantar pressure during gait, resulting in tissue damage and ulceration. The midfoot is a common area of collapse as it is subjected to substantial forces during the transfer of weight from the hindfoot to the forefoot[2,11]. This way, some authors classify CN in the foot and ankle according to the anatomical location of involvement. Brodsky and Rouse, in 1993[1], described one of these classifications and the prevalence of each

Table 3. Eichenholtz classification modified by Shibata et al.[24], Yu et al.[25], Botek et al.[15], and Dodd et al.[2].

Stage	Image	Physical examination
0 – Inflammatory	X-ray: - Normal findings MRI: - Signal change in bone marrow and subchondral bone (edema) Nuclear: - Positive scintigraphy PET-CT: - Positive	- Hyperemia and edema. - >2°C difference between members - Neuropathy
1 – Development	X-ray: - Osteopenia - Subchondral bone fragmentation - Fractures - Joint incongruity - Loose bodies	- Edema - Hyperemia - Local heat - Neuropathy
2 - Coalescence	X-Ray: - Bone formation at fracture sites - Resorption of bone fragments - Beginning of the fusion process of the affected joints MRI: - Reduction of bone edema Nuclear: - Reduced uptake	- Decreased signs of inflammation from previous phases
3 – Remodeling	X-ray: - Bone consolidation - Sclerosis - Arthritis - Bone deformities	- Great decrease or absence of phlogistic signs - Varied degrees of deformity and stability

type. The most affected site, the midfoot (with 60% prevalence), is classified as type 1. In type 2 it occurs in the hindfoot, the second most affected site. Type 3 is subdivided into 3A when it affects the tibiotalar joint and 3B when it affects the calcaneus tuberosity, which is the least frequently affected site.

Diagnosis

Identifying CN can be as challenging as its etiopathogenesis, resulting in high rates of late and even incorrect diagnoses that can lead to gross deformities, ulceration, and amputation of the foot[3,7]. CN should always be considered in a patient with diabetes who presents with edema, hyperemia, heat, and sometimes pain in the foot or ankle, depending on the degree of neuropathy[2,26].

Investigating the presence of inflammatory diseases, such as gout, and infection, such as cellulite and osteomyelitis, helps in the differential diagnosis[2,3]. These pathologies can even coexist, being extremely important a search for ulcers, secretion, and direct contact of the bone with the external environment[2,27].

Infrared dermal thermometry, when compared to the contralateral side, can present a difference of more than 2°C and be used with confidence[28,29]. The presence of neuropathy is one of the pillars for diagnosis, and the Semmes-Weinstein 10g monofilament and the 128 Hz tuning fork should be used; in general, proprioception and reflexes are reduced or absent[30]. If sensory neuropathy is absent, some authors question the diagnosis of NC[2].

Vascular conditions must be assessed; pulses are generally present and even increased, and some authors consider their absence to be a protective factor for CN[20]. Determining the time of onset of signs and symptoms is important, as the inflammatory phase can last for up to 18 weeks[31].

The similarity with the onset of several pathologies that have different treatments makes laboratory investigations a routine. However, we must consider that even though they assist with many diagnoses, these tests can be negative in patients with DM, even in the presence of infection. An association between CN and infection exists and should be considered[27].

So far, there is no imaging technique that is specific and sensitive enough to detect CN, especially in the acute phase (stage 0). Radiography, a cheap and widely available examination, cannot distinguish it from other differential diagnoses, being not enough sensitive and specific. Even so, it should be the first examination to be requested with front, lateral, and oblique views of the feet and front, lateral, and mortise of the ankle, preferably in a weight-bearing modality. Radiographic images provide important information on anatomy and bone alignment, and one should always look for signs of fractures, dislocations, consolidations, and eventual radiological signs of osteomyelitis. However, our findings usually follows what was described by Eichenholtz[11,32].

Magnetic resonance imaging (MRI) is particularly useful in the early stages of NC, detecting subtle changes in face of a normal radiograph, and is considered the imaging exam of choice at this stage as it has good diagnostic accuracy[15,25,27].

When there is a suspicion of infection associated with CN, we can resort to nuclear imaging studies, seeking early diagnosis and treatment guidance. Scintigraphy with marked leukocytes (Indium-111) has excellent diagnostic capabilities for musculoskeletal infection; however, these scintigraphic methods have poor spatial resolution and lack anatomical details[27,33].

Positron emission tomography (PET-CT) with fluorodeoxyglucose, which measures the increase in the intracellular glucose metabolism, has shown promise in diagnosing NC, particularly with regard to its negative predictive value[2]. It offers excellent sensitivity and specificity for the diagnosis of osteomyelitis in the diabetic foot and is able to distinguish CN from osteomyelitis better than MRI with the advantage of having less image artifacts in the presence of synthesis material[2,15].

Despite the good specificity and sensitivity of PET-CT, its use is still limited when compared to MRI and leukocyte scintigraphy. MRI has a slightly lower sensitivity and specificity than PET-CT and an excellent spatial resolution, identifying the extent of the involved area and assisting in surgical planning[27,34].

Regardless of the diagnostic method, the most important aspect is the recognition of the pathology, mainly by the non-specialist, by performing a good anamnesis and physical examination. Therefore, in the presence of a patient with a hot and swollen limb associated with sensory neuropathy, the diagnosis of CN should be considered.

Treatment

The treatment is eminently multidisciplinary, with medical, nursing, and physiotherapy professionals working to control comorbidities and promote dressing changes and rehabilitation[31,32,35].

Orthopedic goal of CN treatment is to obtain and maintain a stable, plantigrade foot with satisfactory alignment, allowing weight-bearing, use of shoes or orthoses, performing of daily activities, and avoiding ulcerations and amputations[15,32,36,37].

In general, treatment is based on the evolutionary stage of the disease, and early diagnosis and interventions are essential to prevent progression to deformities that require more complex and costly treatments.

Conservative treatment

Treatment in the early or inflammatory stages (0, 1, and 2) consists of immobilization, protection, and offloading, leading to a reduction in the inflammatory stimulus and better pain control while preventing the progression of deformities[38,39].

The main measures in this phase consist of removing or reducing the load with full contact plaster casts or removable orthoses[2,15,40,41]. This type of treatment with load protection can be extended from months to more than a year, which decreases patient compliance, especially considering those who are not allowed to weight-bearing[39,41]. Some authors have demonstrated that full load release with these devices is safe and also effective in preventing progression of the deformity and reducing acute symptoms[40,41].

Treatment is continued until there are signs of bone consolidation (which can take much longer than in patients without diabetes) and reduced inflammation. Objective parameters include a temperature difference of less than 2ºC between limbs and a reduction of hyperemia[2,29,31,39], but there is scarce evidence in the literature to support their use[3]. PET/CT seems to offer a more objective assessment to quantify the inflammatory process, showing its persistence for a much longer time even after its clinical resolution, which could lead to early withdrawal of immobilization and recurrence[2,15].

Drug therapies are focused on anti-osteoporotic drugs, mainly bisphosphonates, and appear to have benefits even though studies present little evidence[3,32]. Calcitonin has also been tested in association with calcium supplementation for its regulatory effect on bone turnover[15]. Other studies have demonstrated benefits of anti-RANK-L and teriparatide antibodies[15]. Despite satisfactory results, there is a lack of better evidence in the literature regarding their benefits in faster the healing process and to provide satisfactory clinical results[3,15].

There is a considerable recurrence rate after treatment, which ranges from 7.1% to 33% in an average time of 27 months; obesity (body mass index [BMI] >30) and non-adherence are the main risk factors[39]. Saltzman also demonstrated that non-surgical treatment is associated with a prolonged immobilization time, with a 23% risk of immobilization for more than 18 months, an amputation rate of 2.7%, and a 49% risk of recurrent ulcerations[42].

Surgical treatment

Surgical treatment is classically reserved for later stages of the disease (stage 3), although some authors have proposed approaches in earlier stages[43]. Surgical indications include gross deformities that do not allow the use of orthoses, joint instabilities, recurrent ulcerations, infection, chronic pain, and some cases of acute fractures. The goal is to obtain a stable, plantigrade and functional foot that allows weight bearing[2,15,31,35,39].

Despite being well described in the literature, the considerable recurrence rate (7.1% to 33%[39]) associated with a prolonged restriction time imposed by the conservative treatment, while not always providing the desired results[37], has led to a trend towards an earlier surgical approach to stabilize these feet[15].

There are several types of surgical treatments, from soft tissue surgical procedures and simple exostectomy to complex internal fixations (plates, screws, intramedullary nails) and external fixators[37,39].

The treatment method is guided by the location of the disease, the degree of bone deformity, soft tissue conditions, presence of associated osteomyelitis, and surgeon's expertise. Challenges encountered by the surgeon include large bone defects, osteopenic bone, chronic deformities, fibrosis close to the neuro-vascular bundles, and less potential for healing[15,39].

Lowery et al.[43], in a review of more than 1000 cases of Charcot, observed that the most surgically approached location is midfoot, followed by the ankle. Exostectomy and arthrodesis have a Grade C recommendation; lengthening of the posterior chain has a grade B recommendation; and there is no conclusive evidence on the superiority of fixation techniques. Schneekloth et al.[12] found that the hindfoot was the most surgically approached site.

It is important to remember that patients with Charcot have diabetes in advanced stages associated with other comorbidities that may hinder their post-surgical rehabilitation, also influencing in the extension of the proposed surgery[2].

Rettedal et al.[44] proposed one of the currently available preoperative prognostic scores for predicting the outcome of Charcot reconstruction. It evaluates age, BMI, the presence of wounds or osteomyelitis, anatomical location, disease activity, and glycated hemoglobin levels, totalizing 10 points. Patients who scores more than 4 points would have higher chances of having a poor outcome, with reasonable sensitivity and statistical specificity.

Lengthening of the posterior chain

Shortening of the posterior chain, evidenced by an inability to dorsiflex the ankle beyond neutral or objectively less than 10° being clinically assessed with the Silfverskiold test, has a direct correlation with the increase in plantar pressure[35,43,45]. DM itself seems to act in the pathophysiology of this issue, with structural changes to the Achilles tendon that predispose to its shortening[45].

This increase in plantar pressure raises the risk of ulcers in patients with neuropathy[45]. Surgical lengthening of the posterior chain leads to a reduction of stress in the joints of the midfoot and forefoot, enhancing the healing of ulcers. This procedure is indicated in cases of recurrent ulcerations in the forefoot associated with equinus[15,37,39].

Lengthening is generally used as an adjunct treatment, associated with other procedures, and is performed by stretching one of the portions of the sural triceps. Several techniques have been described for this procedure, such as the release of fascia of the medial head of the gastrocnemius, total tenotomy of the calcaneus tendon, and percutaneous releases[45] (Figure 3).

Exostectomy

Exostectomy is a procedure for removing bone prominences that may be symptomatic, leading to recurrent ulcerations or problems with shoe adaptation; it is only performed on stable feet.[2,15,31].

It can be done indirectly, through accessory pathways and minimizing the risk of spreading the infection, or directly through the ulcer, with primary or delayed closure. Exostectomy can be associated with other procedures, such as Achilles tendon lengthening[15,35].

One of the possible complications of this procedure is the instability of the midfoot in aggressive resections[31]. It is contraindicated in case of peripheral arterial insufficiency, acute infection, unstable midfoot, and in the inflammatory stages of arthropathy[15] (Figure 4).

Arthrodesis

The main objective of arthrodesis is to restore, through surgery, the alignment and stabilization of the foot[31,35].

Dodd et al.[2], in a literature review, found mean fusion indices of 84% (50–100%). The mean non-union rate was 13.6% (0–38%). Amputations below the knee were observed in up to 5.8% of the cases. Wound complications and postoperative infections were commonly found. Shazadeh Safavi et al.[46] found consolidation rates of 91% and amputation rates of 6%.

This procedure involves the removal of non-viable or infected bone, correction of the deformity, and stabilization. Correction can be performed in 1 or more instances, depending on soft tissue injury, infection, and the degree of deformity[31].

Sammarco et al.[36], in an attempt to increase local stability and decrease the chance of failure regularly found in common fixations due to poor bone quality and poor local biology, defined the concept of superconstructs. These involve extending fusions beyond the injury area and including

Figure 3. Patient with a plantar ulcer under the head of the first metatarsal and signs of chronic osteomyelitis in the sesamoid. Surgical debridement of the ulcer was performed with resection of the sesamoid and lengthening of the posterior chain to reduce plantar pressure in the forefoot.

non-diseased joints to increase fixation; bone resection allowing the reduction of the deformity without tension in the soft parts; and using the strongest fixation that can be tolerated by the soft parts in a position that optimizes local mechanics. Examples of constructs that fit this concept include plantar plating, locked plating, and axial screw fixation[36] (Figure 5).

Plantar plates and axial screws

Plantar plates offer mechanical superiority because they are positioned on the tension side of the fusion and can be extended up to the metatarsals and into the cortical bone, allowing better fixation[36,43]. The use of locked plates can add even more rigidity and stability to this type of fixation[36,47].

Garchar et al.[48] described a series of cases in which 96% consolidation was achieved, and a return to walking was reached in around 12 weeks.

Axial screws involve fixation of the fusion with longer and larger caliber screws, in which the distal portion is intramedullary in the metatarsals; it can be performed in a minimally invasive, anterograde, or retrograde manner[15,36].

As advantages of this technique, the position of passage of the screws helps reduce the deformity, while pre-fixation with a cannulated guide wire allows the surgeon to check the position before final synthesis. Compression is achieved only by tightening the screw, and the intraosseous position reduces the risk of exposure[36].

Pope et al.[47], in a biomechanical comparison between plantar plates and axial screws, found no differences between rigidity and load until failure, with the plantar plate forming a more rigid construct in the first tarso-metatarsal joint. Simonik et al.[49] also found no statistical difference between the stiffness of the 2 constructs, although the axial screws supported more load until failure.

A major disadvantage of plantar plates is the extensive mobilization/dissection of soft tissues for fixation.

External fixation

External fixation provides a less invasive form of stabilization than internal syntheses, avoiding a direct approach to sites of intense contamination, with soft tissue injury or poor bone stock; it also allows gradual correction and can tolerate weight bearing[2,15,31,50]. It manages to correct the deformity, simultaneously providing stability and compression. External fixators can be used as primary stabilizers or even to increase the stability of another construct[50]. Their use is proposed even in cases of severe infection as an alternative to amputation[51].

External fixation can even be used in a 2-time procedure, where the first stage comprises the correction of the deformity performed with a computer-aided hexapod external fixator, allowing a more anatomical correction and without much pressure on soft parts; later, in the second procedure, stabilization is achieved with internal synthesis[37].

Amputation

With the improved perioperative management of patients with Charcot, along with better surgical techniques, wound management, and understanding of the disease pathophysiology, amputation numbers have decreased; it is currently

Figure 4. Patient with midfoot Charcot, rocker bottom deformity, and pre-ulcerative lesions on medial and plantar exostoses. The foot was stable upon clinical examination. Exostectomies of medial and plantar prominences were performed, leading to reduced pressure on soft tissues.

Figure 5. Patient with Charcot neuroarthropathy affecting the hindfoot. The treatment option was surgical correction of the deformity and stabilization with a panarthrodesis; fixation was done with an intramedullary nail and screws.

reserved as a salvage procedure when reconstruction is not possible or active infections pose a risk to the patient's life[31].

Indications for amputation would be refractory infections with multi-resistant bacteria and non-functional limbs that have already undergone several surgical approaches[32,35]. Studies show rates that can range from 5.8% to 8.9% of all cases[2,12].

Amputations are associated with higher energy expenditure, increased chances of contralateral amputation, and a worsening quality of life. More proximal amputations tend to have worse clinical results and poorer outcomes for the patient[52].

Conclusion

CN, commonly associated with DM, is a serious disease that can have great morbidity, impacting the patient's quality of life and ability to move. Despite research efforts, its complex pathophysiology is not yet fully understood, being related to neuropathy and resulting in a cycle of trauma – injury – inflammation. Its evolution seems to occur in phases, based on which treatment strategies are designed. In the early inflammatory stages, the focus is on the use of orthoses and devices that reduce stress on the region. The role of transmitters and inflammatory markers in pathogenesis and the potential use of medications or immunobiologicals that modulate this response are currently in vogue, leading to better results without surgical approaches. Surgical treatment is reserved for cases of complications and refractoriness to conservative treatment. Regardless of the method of choice, the objective is to obtain a stable plantigrade foot, without ulcerations or infections, that allows the patient to perform his or her daily activities.

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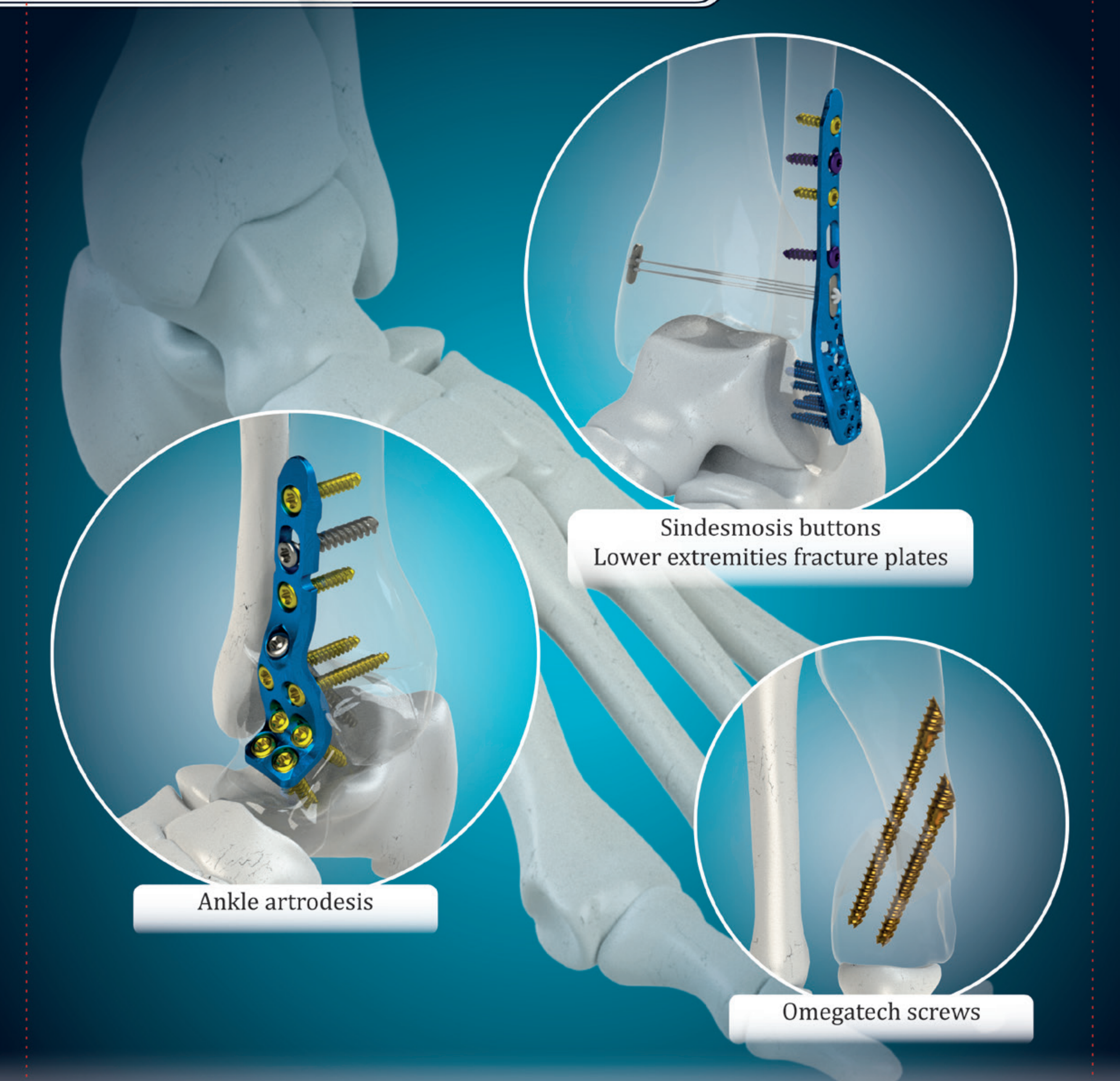

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