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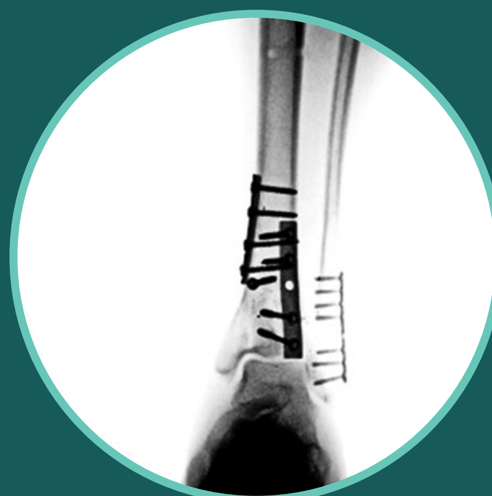

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Role of reading a scientific article in modern education of ankle and foot surgery: a strategy for adherence

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Prioritizing the training of ankle and foot residents and fellows is strategic for the future of our specialty.

The scenery of medical education is changing rapidly, and adapting to new educational methods is critical for the modern ankle and foot surgeon to ensure an effective, productive, and inspiring learning environment for new specialists.

Modern strategies to achieve these goals involve developing educators' and students' skills.

Educators benefit from the commitment to up-to-date content and innovation in the lectures and discussions; it is important to define learning expectations clearly and monitor progress in gaining clinical knowledge and surgical skills. Therefore, it is necessary to divide this process into stages; throughout the learning process, the student should receive objective assessment and feedback to establish a close relationship with the educator.

In this context, the power of scientific evidence and reading scientific journals are important for learning.

No one is born a good reader of medical literature; this skill improves with practice and can be taught and learned. However, some educators can help new specialists and residents gain regularity and productivity from critical reading.

Initial screening can be done by identifying a few reliable and accessible sources, such as one general interest orthopedic journal and two subspecialty journals, as they provide enough content to consume before the next issue is released.

The initial evaluation of articles begins with a close reading of the article titles. Then, for those papers that seem worthwhile, the next step is to devote attention to the objective, method, and conclusion sections and ask, "Assuming this information is validated, would it matter to my practice?"

In the third step, to decide to read the entire article in depth, the articles' key question or its main objective should be answered, which will define whether the chosen methodology is valid in answering it.

In methodology, two central factors must be considered: validity and bias.

Validity has two aspects: internal validity, which determines methodological accuracy and represents impartial measures between exposure/intervention and functional/clinical outcome, whose threats are the different biases; and external validity, which allows the generalization of findings to the general population and is related to the study participants are representative of the target population.

Critical components of modern teaching for ankle and foot surgery residents and fellows include goal setting, educator-student collaboration, science-based knowledge gain, team, feedback, and use of technology.

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Original Article

Does the posterior approach offer advantages in short-term in trimalleolar ankle fractures?

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Abstract

Objective: The aim of this study was to compare the early (nine months after surgery) synthesis of the posterior malleolus by direct posterior (P) approach versus the percutaneous anteroposterior (AP) screw in trimalleolar ankle fractures to analyze the early clinical status of the patient (eight months) by studying the American Orthopedic Foot And Ankle Society (AOFAS) scale to compare postsurgical clinical recovery between both approaches, the rate of hospital days in both groups, the quality of joint reduction by computed tomography (CT) study and the rate of most frequent complications (fibular tendinopathy and surgical wound).

Methods: A retrospective comparative study was performed between 2016-2020, including 94 patients with trimalleolar ankle fracture type 44-A/B/C (27 percutaneous AP surgical treatment and 67 P approach). Both groups were compared by analyzing demographic variables, clinical-functional status, radiological variables, and complications. Statistical analysis was performed using SPSS-20, with a p-value of 0.05 as significance.

Results: Demographically, both groups were comparable, not finding significant differences between them. An increase in the days of admission before surgery was observed in the P approach with a mean of 4 (p=0.001). No significant clinical differences were found in the AOFAS scale, with a mean of 85 in both groups. Regarding the radiological result, a better reduction was observed with P approach (good=57, fair=9, poor=0) compared to the AP approach (good=10, fair=7, poor=9) (p=0.001). As for the complications, no significant differences were observed for the surgical wound. However, a higher need for fibular plate removal could be observed with P approach (n=17) (p=0.046).

Conclusions: Clinically, both groups observed no significant differences through the AOFAS scale. The posterolateral approach has a higher rate of hospital days before surgery. Radiologically, a better joint reduction is achieved by a direct approach to the posterior fragment.

Level of Evidence III; Retrospective Comparative Study.

Keywords: Ankle fractures; Fracture fixation, internal; Fracture reduction.

Introduction

Ankle fractures are very common injuries and currently represent around 10% of total fractures in an adult. Its incidence has grown due to the increase in the population's life expectancy, a higher rate of obesity, and other factors such as the increase in sports practice. A recent study reported an incidence as high as 168.7/100,000 person-years with a mean age of 41 years and slightly more frequent in men than women (53% vs. 47%), following a bimodal distribution with peaks in younger men and older women[1-4].

Despite advances in knowledge of posterior malleolus fractures, they remain a controversial issue among surgeons due to the lack of consensus on the most appropriate treatment, which raises questions regarding the type of approach, reduction, and fracture fixation[5,6]. Without specific guidelines, until now, synthesis by internal fixation depended fundamentally on the fragment size and the percentage of the joint affected, considering the involvement of more than 25% of the joint surface as sufficient to perform internal fixation[7]. However, most recent studies conclude that the posterior

Study performed at the Servicio de Cirugía Ortopédica y Traumatología del Hospital Universitario Marqués de Valdecilla, Santander, Cantábria, Spain.
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complex, which includes the posterior syndesmosis and the posterior malleolus fracture, is the structure that provides the greatest stability to the ankle (42%). Hence, its anatomical reduction is essential regardless of fragment size[8].

Surgical treatment of displaced posterior malleolar fractures includes two main techniques: indirect reduction and anteroposterior (AP) fixation or direct reduction and posteroanterior (PA) fixation.

The aim of this study is to compare the early (nine months after surgery) synthesis of the posterior malleolus by direct posterior (P) approach versus the percutaneous AP screw in trimalleolar ankle fractures to analyze the early clinical status of the patient (eight months) by studying the American Orthopedic Foot And Ankle Society (AOFAS) scale to compare postsurgical clinical recovery between both approaches, the rate of hospital days in both groups, the quality of joint reduction by computed tomography (CT) study and the rate of most frequent complications (fibular tendinopathy and surgical wound).

Methods

This work has been approved by the Clinical Research Ethics Committee of Cantabria CEIC (IDIVAL). Code 2015.006. All patients signed the informed consent form to report individual cases or case series.

A retrospective comparative study was performed including 173 patients with trimalleolar ankle fractures type 44-A/B/C were studied according to the AO classification. The inclusion criteria were: trimalleolar ankle fractures (AO.44-A3, AO.44-B3, AO.44-C1, and AO.44-C2), whose synthesis of the posterior malleolus was performed by indirect reduction AP fixation with traction or direct reduction screws and PA fixation and who presented a minimum follow-up of nine months. Patients who did not complete the follow-up or did not respond to the AOFAS test at the end of the study were excluded. In addition, patients younger than 16 or those treated with posteromedial approaches were also excluded. The final study included 94 patients, 27 received surgical treatment by percutaneous AP approach (Group 1) and synthesis with 3.5 short cancellous bone screws with washer (Figures 1 and 2). The remaining 67 received surgical treatment by P approach (Group 2) with direct reduction with interfragmentary compression screws or non-slip compression plate (Figures 3 and 4). For this step, the size of the posterior fragment was not considered, and the patients in group 1 were treated between 2015-2017, and group 2 between 2018-2020. The reason why an evolutionary cutoff was set at nine months to make both groups comparable.

All fractures were evaluated with radiographs with two projections and/or CT, in cases in which the posterior fragment was multifragmentary or larger, to perform correct preoperative planning, evaluating the fragment size and location, and with radiographs (at one month, six, and nine months and CT from nine months in the postoperative study (except in two patients one in each group), so we were able to address

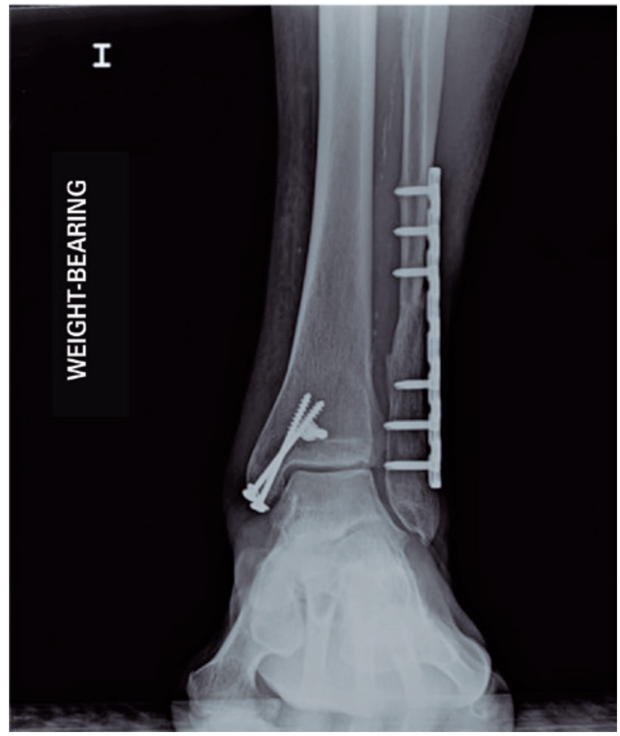

Figure 1. Ankle anteroposterior radiograph with trimalleolar fracture and synthesis by percutaneous anteroposterior approach.

Figure 2. Ankle lateral radiograph with trimalleolar fracture and synthesis by percutaneous anteroposterior approach.

and study the exact size of the fracture as well as the number of fragments, the percentage of joint involvement and the quality of reduction (Figures 5, 6 and 7). All procedures were performed by experienced surgeons in ankle surgery with the assistance of surgical residents. Antibiotic and antithrombotic prophylaxis was performed according to hospital protocol. Patients in group 1 (percutaneous AP reduction) were placed in decubitus and with ischemia. A lateral approach was performed for the fibula fracture. After reduction and fixation with interfragmentary screws, one third tubular plate or reconstruction plate synthesis of the posterior malleolus was performed with a 3.5 cortical or short cancellous bone in ankle dorsiflexion to allow the best indirect reduction of the posterior fragment and scopic control. Patients in group 2 (P approach) were placed in the prone position, also with ischemia. A posterolateral approach was performed through an incision where the fracture of the posterior malleolus was

Figure 3. Ankle anteroposterior radiograph with trimalleolar fracture and synthesis by posterior approach.

Figure 5. Ankle CT image (sagittal section) showing a good reduction.

Figure 4. Ankle lateral radiograph with trimalleolar fracture and synthesis by posterior approach.

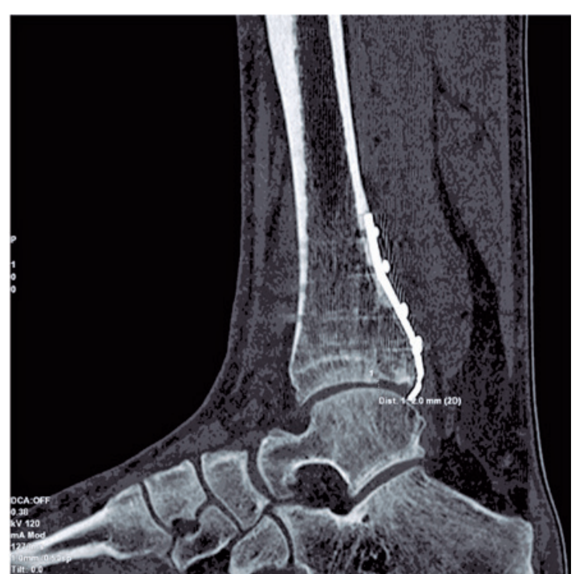

Figure 6. Ankle CT image (sagittal section) showing a regular reduction.

synthesized with short cancellous 3.5 mm screws or locking compression non-slip plate depending on the size of the fragment and the synthesis of the fibular malleolus with interfragmentary screws and small-fragment locking compression plate. The medial malleolus was synthesized with 3.5 short cancellous screws or plate depending on the size and fracture line utilizing a medial approach in the prone position or placing the patient in the supine position in case of more complex fractures. Reduction and intraoperative implant position were evaluated with C-arm fluoroscopy. After surgery, the patient was immobilized with a post-orthopedic plaster splint for about three weeks, and then active and passive mobilization was started. Progressive loading was allowed at six weeks assisted with crutches (both groups followed the same postoperative protocol, regardless of the posterior fragment size). Postoperative radiography was performed at 24 hours (AP and lateral) and later at one, three, six, and 12 months. Finally, a postoperative CT was performed on all patients between nine and 12 months after surgery to evaluate the quality of joint reduction. None of the patients had any loss of reduction that would have caused the final results to be biased.

The following demographic data were evaluated: age, sex, tobacco and alcohol use, diabetes mellitus (DM), arterial hypertension and body mass index (BMI), clinical data (placement of external fixator before definitive reduction by the poor condition of the soft tissues), hospitalization days before and after surgery, time of immobilization and discharge, clinical study with AOFAS scale, radiological data (type of fracture (AO/Haraguchi classification and percentage of posterior fragment preoperative joint on CT)), bimalleolar angle and the tibio-talar angle (TILT) in postsurgical load (six months), quality of postsurgical joint reduction utilizing CT and complications.

The reduction quality was evaluated by postoperative CT scan for residual displacement of the posterior fragment, joint step, and/or joint surface gap. Reduction was considered good (<1mm), regular (1-2mm), and poor (>2mm), as proposed by Ketz and Sanders[9]. The postoperative functional result was studied at a mean time of eight months and was evaluated using the AOFAS scale.

Statistical analysis was performed using the SPSS-20 program. For the quantitative variables, the U-Whitney was used, and for the qualitative variables, a Chi-square was performed. Statistical significance was considered a $p<0.05$.

Results

The study was performed including 94 patients after applying the exclusion criteria: 79 women (group 1 = 23 and group 2 = 56) and 14 men (group 1 = 4 and group 2 = 10), all patients completed the follow-up exams. Table 1 shows no differences between the groups regarding the demographic variables, only statistically significant differences were found in the BMI value, where group 1 had a mean of 28 (17-40) while group 2 was 25 (19-38) (p=0.028).

Referring to the clinical variables, no significant differences were found with respect to the AOFAS scale and approach route (Figure 8). However statistically significant differences

Table 1. Result of demographic variables

	Posterolateral approach n= 66	Anteroposterior screw n= 27	p-value
Sex	Male=10/Female=56	Male=4/Female=23	0.967
Age	M= 53.6 (17-85)	M= 60 (16-86)	0.123
Alcohol	7	5	0.302
MD	3	3	0.162
BMI	M_e=25	M_e=28	0.028
Tobacco	15	4	0.547
High energy	6	1	0.441

MD: Mellitus diabetes; BMI: Body Mass Index; Me: Mean value; n: number

Figure 7. Ankle CT image (sagittal section) showing a bad reduction.

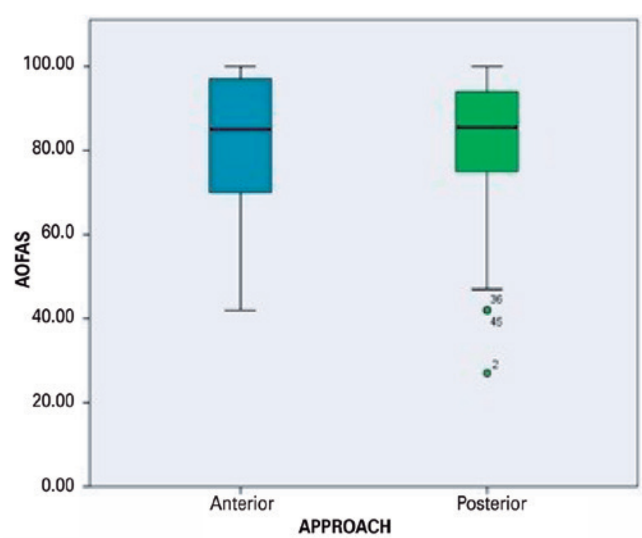

Figure 8. Comparative graph of the AOFAS scale and approach.

were found in external fixator use before definitive reduction, which was more frequent in group 2 with 24 patients compared to group 1 where no patient received prior treatment with this device (p<0.001). Furthermore, in the days until surgery, group 1 had a mean of 1.44 days compared to group 2 with 5.7 days (Figure 9). These results may be because in cases where a P approach is performed, there is a tendency to a more complex surgical programming and, therefore, a greater use of an external fixator until surgery since a more refined surgical technique is required. In contrast, in cases of AP approach, it is a simpler and more well-known technique, so on many occasions, the surgery was performed by the medical on-call team (Table 2).

The analysis of the radiographic variables of the patients submitted to preoperative CT (group 1 = 14 and group 2 = 52) can be seen in table 3. Only statistically significant differences were observed with p<0.001 regarding the quality of joint reduction, achieving a good quality of joint reduction of 86.36% (n=41) in group 2 and 38.46% (n=11) in group 1, a regular reduction quality of 13.63% (n=9) in group 2 and 26.92% (n=7) in group 1 and a poor quality of reduction of 0% in group 2 and 33,33% (n=9) in group 1 (Figure 10 and Table 3).

The overall complication rate was 24.47% (n=23) between both groups, including those derived from the surgical wound, complex regional pain syndrome, peroneal irritation or Achilles tendinopathy, and delayed union. There were no differences in the number of consolidation delays nor in the rate of surgical wound complications (infections, dehiscence, or need for plastic coverage). However, both groups had significant differences, with a p=0.046 regarding peroneal tendinopa-

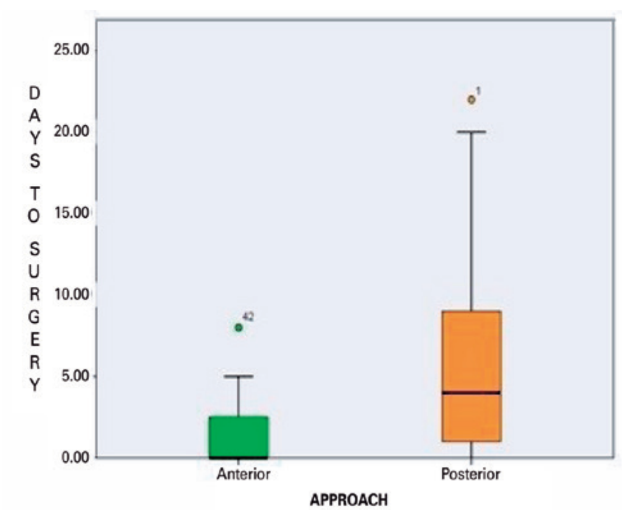

Figure 9. Comparative graph of days until surgery according to approach.

Table 2. Result of clinical variables

	Posterolateral approach n=66	Anteroposterior screw n=27	p-value
Hospitalization	Me= 4 (0-22)	Me=0 (1-8)	0.001
Pre-surgery (d)	Me= 4 (1-19)	Me= 4 (1-6)	0.031
Post-surgery admission (d)	24	0	0.001
External Fixator	Me= 85 (27-100)	Me= 85 (42-100)	0.757
AOFAS scale	48	7	0.001
Preoperative CT	3,43	3,8	0.278
Immobilization (w)	6,4	6,14	0.905
Discharge (w)	56	18	0.048
Dislocation	32	12	0.723

d: days; w: weeks; n: number; Me: median value; CT: computed tomography; AOFAS: American Orthopaedic Foot and Ankle Society

Table 3. Result of the radiographic variables

	Posterolateral approach n= 66	Anteroposterior screw n= 27	p-value
Joint (%)	27.75	23.3	0.187
I	41	11	0.862
Haraguchi II	10	3	
III	1	0	
Talar Tilt	Me=0.73	Me=0.73	0.679
Bimalleolar angle	12.87	12.91	0.765
Joint reduction			
Good	57	10	0.001
Regular	9	7	
Poor	0	9	
Anteroposterior fragment size	16.6	12.3	0.024
Transverse fragment size	24.2	26.4	0.907

n: number; Me: Mean value

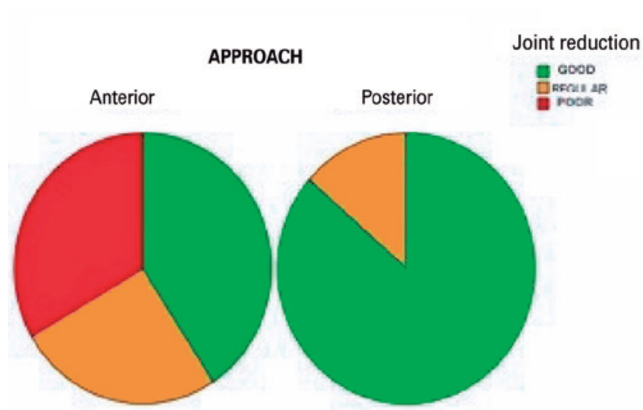

Figure 10. Quality of joint reduction measured on CT according to approach.

thy (group 1 = 2 and group 2 = 17). In addition, all patients from both groups required surgical revision and removal of the fibular plate placed posteriorly on the fibular malleolus (Figure 11 and Table 4).

A cross-sectional analysis was performed analyzing the complication rate of both groups for age, DM, use of external fixator, and value of the AOFAS scale. No statistically significant differences were observed except for the lower values of the AOFAS scale found in those patients who presented complications (77 vs. 84) (p=0.024) (Table 5).

Discussion

Surgical treatment of displaced ankle fractures includes anatomic reduction and stable fixation that allows early functional rehabilitation[5,10-16]. However, the optimal treatment of the posterior fragment in trimalleolar fractures is still a topic of discussion regarding the diagnostic method, type of treatment, and approach. Despite the number of different published studies, some concepts, such as the choice between indirect reduction and AP fixation and direct reduction and P fixation, remain controversial[5,17-19].

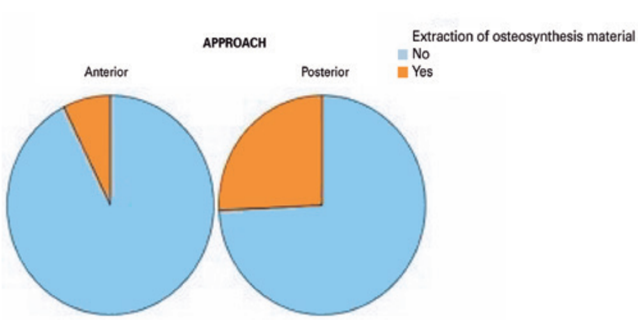

Figure 11. Comparative graph of the need for revision according to approach.

Table 4. Result of complications rate

Complications	Posterolateral approach n=66	Anteroposterior screw n=27
Surgical wound	18 (27.2%)	5 (18.5%)
Peroneal tendinopathy	17	2

n: number

Table 5. Result of complications

	Complications		p-value
	Yes	No	
Age	M_e=59	M_e=54	0.183
MD	6	21	0.162
AOFAS scale	77	84	0.024
External Fixator	33.3	21.7	0.257

n: number; M_e: Mean value; MD: Mellitus diabetes; AOFAS: American Orthopaedic Foot and Ankle Society.

The ankle stability after a fracture is a fundamental factor that must be considered before choosing the treatment for this pathology since it determines the clinical and functional outcomes and future complications. Studies such as Bartoníček et al.[20] show that the syndesmosis together with the posterior malleolus are structures with an important weight when it comes to maintaining ankle stability. Hence, they conclude that their surgical treatment is essential, regardless of the fracture size[8,20-22].

Ankle fractures include fractures of the posterior malleolus or Volkmann's malleolus, which is observed in up to 46% of AO/ASIF type B and C fractures[5,23]. However, recent studies have shown that nondisplaced posterior malleolus fractures may be missed or underdiagnosed in many patients, leading to iatrogenic displacement during surgery and permanent ankle damage[24-27]. Furthermore, in the last ten years, published studies using additional CT and MRI examinations have shown that the incidence of posterior malleolus fractures associated with other tibial fractures increases considerably and are highly under-diagnosed if studied using plain radiographs. Therefore, authors such as Boraiah et al.[28] recommend additional ankle CT for patients with distal tibial fractures for proper diagnosis and treatment[28-30]. Finally, Bartoníček et al.[20] recently concluded that appropriate diagnosis, classification, and treatment require preoperative CT scan, preferably with three-dimensional reconstructions. This is because today, the three-dimensional contour of the fragments, the involvement of the notch, the presence of joint impaction, and intercalated fragments interposed in the fracture line seem to have greater therapeutic relevance than the fragment size and the extension of the fractured articular surface[8,20,24,31]. Our study observed that most patients who do not present preoperative CT are treated by the AP approach (Group 1), which agrees with the patients in the first years of the study. This may be because preoperative CT scans were not performed in simple trimalleolar ankle fractures before the publication of these studies. Within the surgical techniques to treat posterior malleolus fractures, indirect reduction and AP fixation with lag screws was the first technique to be applied. Although it tends to be displaced by the direct reduction technique today, it is still used in many centers. In this case, reduction is achieved percutaneously, and fixation is performed with 3.5 mm partially threaded cancellous bone lag screws. However, despite being a simple technique that has provided good results during its use, it has several questions, such as the quality of indirect reduction and the quality of interfragmentary compression with AP fixation if the threaded portion of the screw does not penetrate the smaller fragments completely[5,17]. Direct reduction allows for direct reduction using a posterolateral, posteromedial, or modified posteromedial approach, disimpaction of the smaller osteochondral fragments, and definitive fixation with screws or non-slip compression plate. Nowadays, different authors publish favorable functional results using this technique[5,17,31]. Most studies suggest using a single wide posterolateral incision that allows fixation of the posterior fragment of the tibial malleolus and the fibula fracture. However, other authors propose several separate incisions for the approach to malleolar fractures; therefore, they propose to analyze the fracture line to decide the type of approach[5].

Thus, after confirming that the success of surgery depends largely on the posterior malleolus fixation, we present this study comparing two groups of patients with posterior malleolus fracture treated with different techniques, indirect reduction, and AP fixation and direct reduction through posterolateral approach and AP fixation. There was no difference in complications rate between these two groups within a minimum nine months period; however, this period is insufficient to assess complications such as the presence of osteoarthritis, although some studies demontrated that an intra-articular step of 2mm after reduction is an independent risk factor for a worse clinical outcome and the development of posttraumatic osteoarthritis regardless of the fragment size[9,20,22,32,33]. Furthermore, this period is insufficient to evaluate the possible osteoarthritis that could affect this joint in cases the joint reduction presents a step greater than 2mm. This fact could, in theory, change the AOFAS score in the long-term. Direct reduction of the posterior fragment using a posterolateral approach and direct fixation of the fragment is associated with advantages: it provides a technically more stable anatomical reduction under direct visual control and interfragmentary compression than indirect reduction and percutaneous AP fixation, which could be less stable if the threaded portion of the screw does not fully accommodate within small or medium fragments. In addition, direct reduction allows the osteochondral fragments to be addressed, which is very difficult, if not impossible, to achieve with indirect reduction. Moreover, the posterolateral approach allows the reduction and fixation of the fibula utilizing a posterior non-slip plate (with a higher rate of peroneal tendinopathy 25.37% vs. 7.4%) or by reduction and placement of an interfragmentary screw and a neutralization plate, performing it in front of the peroneal tendons, allowing visualization and work from the lateral aspect of the fibula[5]. Despite these advantages, indirect reduction and percutaneous AP fixation are still widely used, mainly due to the lack of studies showing that anatomical reduction has better clinical results in the short to medium term[34].

Indeed, more and more authors favor the posterior approach and reduction, presenting better clinical and functional results[7,33,35].

Despite this, in our study, it was not possible to demonstrate better functional results during the follow-up period through the clinical-functional assessment of the AOFAS scale between both groups. This may be because a longer follow-up period is required for complications such as posttraumatic osteoarthritis to appear, causing clinical and functional differences between both groups.

There is a great variety of opinions regarding the timing of the use of trans-syndesmal screws after fixation of the posterior malleolus; however, in case of performing a correct synthesis of the posterior malleolus, utilizing an AP screw or posterior plate that presents good stability to allow correct joint dynamics restoration, it would not be necessary to add the suprasyndesmal screw, although it would be important to keep in mind the patient's BMI[8,36,37].

According to the literature, the most frequent complications of the posterolateral approach are that it increases the risk of peroneal tendinopathy and sural nerve injury[38]. Our study presents a statistical significance of tendinopathies in group 2 ($p=0.046$).

The quality of the reduction was significantly better in group 2 (posterior direct approach) compared to group 1 (percutaneous AP reduction) ($p<0.001$), achieving a good joint reduction of 86.36% (n=41) in group 2 and 38.46% (n=11) in group 1. Shi et al.[39] reported an excellent reduction of 53.1% treated with direct reduction and 30.8% in those treated with indirect reduction. Huber et al.[40] concluded that in 83% of patients, the anatomical reduction was achieved by direct reduction, while only 27% was achieved by indirect reduction[3,12,27]. Further investigation of the specific type of reduction and internal fixation with long-term results is required.

Study limitations

This study was performed to compare the early results (mainly the quality of joint reduction and the clinical differences between both approaches) after nine months of follow-up, sufficient time to consider the consolidation of the fracture and thus avoid secondary displacement of the fragments. Therefore, one of the study's fundamental limitations is that the nine-month follow-up period is insufficient to evaluate the possible osteoarthritis that could affect the ankle joint due to poor joint unity. This fact could modify the AOFAS scale in a later evaluation.

Conclusions

- No significant differences were observed utilizing the AOFAS scale in both groups at eight months of follow-up. Although this time is insufficient to evaluate the clinical status of the patient in those cases in which joint arthrosis develops, especially in those patients with insufficient joint reduction (joint step >2mm), it is very useful to show that despite that the anteroposterior approach is less aggressive, since it is a percutaneous technique, the short-term clinical status does not vary between both approaches.
- There is a higher rate of days of admission before surgery with the posterolateral approach.
- A direct approach to the posterior fragment achieves a better joint reduction.
- There is a higher rate of fibular tendinopathies in the posterolateral approach when the posterior fibular plate is placed.
- No differences were observed in surgical wound complications in both groups.

Author's contributions: Each author contributed individually and significantly to the development of this article: MHF *(https://orcid.org/0000-0002-4642-404X) Conceived and planned the activities that led to the study, wrote the article, participated in the reviewing process, approved the final version; GGJ *(https://orcid.org/0000-0002-2289-387X) Interpreted the results of the study, participated in the reviewing process; PMZ* (https://orcid.org/0000-0002-5415-1723) Conceived and planned the activities that led to the study, wrote the article, participated in the reviewing process, approved the final version; ELB *(https://orcid.org/0000-0003-2319-9641) Participated in the reviewing process, approved the final version; GMS *(https://orcid.org/0000-0003-3161-0752) Participated in the reviewing process, approved the final version; EGA* (https://orcid.org/0001-7354-1260) Conceived and planned the activities that led to the study, wrote the article, participated in the reviewing process, approved the final version; JHE *(https://orcid.org/0000-0002-5258-1615) Participated in the reviewing process, approved the final versión; MIPN *(https://orcid.org/0000-0001-6423-260X) Participated in the reviewing 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

AOFAS and Karlsson-Peterson scales in evaluating patients treated with modified Broström-Gould and suture tape augmentation for ankle instability: a performance analysis

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Abstract

Objective: The objective of this study was to evaluate the performance of the American Orthopedic Foot and Ankle Society (AOFAS) and Karlsson-Peterson scales in patients with lateral ankle instability treated with modified Bröstrom-Gould (MBG) plasty and suture tape augmentation.

Methods: This retrospective, bicentric, cohort study involved consecutive patients with lateral ankle instability treated with MBG plasty and suture tape augmentation. The Visual Analog Scale (VAS), AOFAS scale, and Karlsson-Peterson scale were used in pre-/postoperative assessments.

Results: Fifty-five patients who underwent MBG plasty and suture tape augmentation were included. Mean preoperative and postoperative VAS scores were 7.1 ± 1.4 and 1.3 ± 1.6 ($p<0.001$), respectively. Mean AOFAS scores were 61.3 ± 21.1 and 95.4 ± 8.4, respectively ($p<0.001$). Mean Karlsson-Peterson scale scores were 46.8 ± v14.3 and 95.2 ± v7.9 ($p<0.001$), respectively.

Conclusions: The Karlsson-Peterson scale showed a better performance than the AOFAS scale in the clinical and functional evaluation of patients with ankle instability treated with MBG plasty and suture tape augmentation.

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

Keywords: Ankle joint; Joint instability; Lateral ligament, ankle; Orthopedic procedures.

Introduction

The combination of suture tape augmentation and modified Broström-Gould (MBG) procedure has been found to be effective in the treatment of lateral ankle instability. This therapeutic alternative appears to be better at increasing mechanical stability of the ankle than MBG alone[1-4]. By increasing the strength and stiffness of the ankle, it can be protected from injury-causing inversion and forced flexion. In a study involving five freshly-frozen cadaveric specimens, the biomechanics of the ankle and foot were compared using native and sectioned anterior talofibular ligaments to simulate instability, which were later reconstructed with a suture tape that reestablished the physiological ranges of motion of the ankle and, partially, the dynamic alignment of the foot; the ligament was found to be protected from elongation during the healing process[5]. Previous studies have shown that seve-

Study performed at the Medyarthros Foot and Ankle Clinic, Center for Sports Medicine and Arthroscopy, Jalisco, Mexico.

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ral years after a Broström procedure, the performance of the ankle is decreased by elongation of the repaired ligament[6], and this can be avoided with suture tape augmentation. Recently, excellent clinical and functional results were demonstrated using the combined procedure, which provides protection against inversion and forced flexion recurrence and reduces the revision surgery risk[4].

In a systematic review of scales used to assess the surgical management of chronic ankle instability in 104 studies[7], 66% and 43% of studies used the ankle and hindfoot American Orthopedic Foot and Ankle Society (AOFAS) scale[8] and the Karlsson-Peterson scale[9], respectively.

The accuracy of the AOFAS scale has not been validated and may show questionable statistical behavior in patients with lateral ankle instability because it uses a mixed system that combines medical evaluation and patient responses[10,11].

Subjective patient-reported ankle instability is the most important diagnostic criterion. Recently, the term "patient-reported outcome measurements" (PROMs) is being used to refer to subjective data presented by the patient and has become the most important tool in patient assessment, surpassing objective evaluation in physical examination[11]. In this context, the Karlsson-Peterson scale has demonstrated a statistically significant correlation between the subjective and objective parameters of ankle stability and function[9] that are used in studies to evaluate the clinical outcomes of patients with ankle instability treated with surgery. The objective of this study was to compare the performance of the AOFAS and Karlsson-Peterson scales in patients with lateral ankle instability treated with MBG plasty and suture tape augmentation.

Methods

A retrospective, bicentric, cohort study was conducted with consecutive patients with lateral ankle instability treated with MBG plasty and suture tape augmentation. The protocol was approved by our Institutional Review Board. The inclusion criterion was subjective patient-reported ankle instability. The diagnosis of lateral ankle instability was confirmed by anterior drawer test and magnetic resonance imaging (MRI). Exclusion criteria were as follows: osteochondral injury, history of ankle surgery or revision surgery, refusal to participate, and patients who could not be reached.

Data were obtained from clinical records and through telephone surveys. Variables of the study were sex, age, affected side, postoperative follow-up time, brand of anchors used in each center, immobilization duration, and rehabilitation time. Postoperative complications and patients with recurrence of ankle inversion and forced flexion mechanism were recorded.

Scales

Data on the clinical and functional variables were recorded using the Visual Analog Scale (VAS), AOFAS scale, and Karlsson-Peterson scale. Scores obtained on the Karlsson-Peterson scale were classified as excellent (95 points), good (80-94 points), fair (50-79 points), and poor (<50 points)[9,12].

Postoperative Care

A posterior cast was used without weight-bearing for two weeks, after which the stitches were removed. A CAM-Walker boot was placed for one week with progressive weight-bearing at tolerance and use of crutches. At week four, the boot was removed and accelerated rehabilitation was initiated with emphasis on proprioception, strength, and range of motion[13]. At week six, jogging was prescribed. At week eight, patient was allowed to return to daily activities.

Statistical Analysis

Data were recorded in Excel® (Microsoft Corporation, Redmond, Washington, USA) being presented as frequency, percentage, mean, and standard deviation. Scales were analyzed using the student's t-test; $p \leq 0.05$ was considered significant. STATA v15.0 software (Stata Corp LLC, Texas, USA) was used.

Results

Fifty-five patients with lateral ankle instability treated with MBG plasty and suture tape augmentation were included (Table 1); mean age was 32.3 ± 10.6 years. Diagnoses were confirmed by MRI; in addition, 25 (45.5%) patients underwent ankle arthroscopy. All patients reported a subjective sensation of instability and presented positive evidence on anterior drawer test. Arthrex anchors (Arthrex, Inc., Naples, Florida, USA) were used in 41 (74.5%) MBG procedures, and Smith and Nephew anchors (Smith & Nephew, Inc., Massachusetts, USA) in 14 (25.5%) MBG procedures.

The mean duration of postoperative immobilization was 2.7 ± 1.4 weeks. In mean, early rehabilitation was started at 10.2 ± 7.6 weeks; mean time taken to return to daily activity after surgery was 22.5 ± 11.7 weeks. A patient with depressive di-

Table 1. Description of 55 patients with lateral ankle instability treated with MBG plasty and suture tape augmentation

Description	n=55
Age (years)[a]	32.3 ± 10.6 (16–58)
Sex (male/female)	22 (40%)/33 (60%)
Affected side (left/right)	28 (50.9%)/27 (49.1%)
Postoperative follow-up (months)[a]	22.4 ± 13.6 (6–55)
Arthrex anchors – MBG	41 (74.5%)
Smith and Nephew anchors – MBG	14 (25.5%)
Postop immobilization duration (weeks)[a]	2.7 ± 1.4 (1-8)
Rehabilitation time (weeks)[a]	10.2 ± 7.6 (2-24)
Time of return to activity[b] (weeks)[a]	22.5 ± 11.7 (3-48)
Ankle inversion mechanism recurrence (yes)	8 (14.5%)

Modified Bröstrom-Gould (MBG).
[a] Data are presented as mean, with the standard deviation and range in parentheses.
[b] A patient who presented complex regional pain syndrome was not included.

sorder presented with complex regional pain syndrome as a complication of the surgical procedure; her rehabilitation adherence was intermittent and, at the 64-week follow-up after surgery, she still had not returned to her daily activities.

In eight (14.5%) of 55 patients, there was ankle inversion recurrence; initial treatment was symptomatic, with rest, application of cold compresses, bandaging, and pelvic limb elevation. After seven days, rehabilitation was continued until complete recovery.

In table 2, the scores on the VAS, AOFAS, and Karlsson-Peterson scales are presented. The mean preoperative and postoperative VAS scores were 7.1 ± 1.4 and 1.3 ± 1.6 (p<0.001), respectively. The mean preoperative and postoperative AOFAS scores were 61.3 ± 21.1 and 95.4 ± 8.4 (p<0.001), respectively. On the Karlsson-Peterson scale, the mean preoperative and postoperative scores were 46.8 ± 14.3 and 95.2 ± 7.9 (p<0.001), respectively.

The contrast between mean preoperative scores on the AOFAS and Karlsson-Peterson scales (61.3 ± 21.1 vs. 46.8 ± 14.3) (p<0.001) may be due to the differences in the parameters of these scales.

Figure 1 shows the preoperative and postoperative scores on the AOFAS scale by category. In panel A, which presents the preoperative evaluation, patients showed high scores in the categories of pain and limitation of physical activity. Regarding the perception of ankle stability, only 28 (51%) patients showed instability. In panel B, there was an overall improvement in all parameters; improvement was significant in the categories of pain, limitation, and use of support, with an increase in maximum walking distance on different surfaces (p<0.05). Likewise, 27 (96%) out of 28 patients with preoperative perception of instability reported stability in the postoperative evaluation.

The patient evaluation results using the Karlsson-Peterson scale are shown in figure 2. In panel A, which presents the preoperative evaluation, 42 (76%) patients reported pain while walking, and eight (14.5%) patients reported severe, constant pain. On the other hand, all patients (n=55, 100%) reported instability, and in 46 (84%) patients, it was manifested when walking. In addition, 63.6% (n=35) of patients reported no problem climbing stairs and 76.4% (n=42) of patients reported difficulty in running. In panel B, which presents the postoperative evaluation, improvement was observed in all categories; 39 (70.9%) patients showed remission of pain, while 14 (25.5%) patients experienced it only during physical activity. It should be noted that in all (n=54, 98%) except one patient, the perception of ankle instability had disappeared (p<0.001).

In the preoperative evaluation using the AOFAS scale, only 28 patients reported instability perception (Figure 1A). In contrast, with the Karlsson-Peterson scale, 55 patients reported instability in at least one parameter (Figure 2A): two patients reported persistent and severe symptoms that required the use of support, thirteen and 33 patients perceived instability when walking on regular surfaces and irregular surfaces, respectively; and two and five patients perceived instability only during physical activity in the last 1–2 months and 12–24 months, respectively. On the other hand, 47 (85.5%) patients reported good alignment (score 10) on the AOFAS scale; the contrast between the mean preoperative assessment scores using the AOFAS and Karlsson-Peterson scales (61.3 ± 21.1 vs. 46.8 ± 14.3) (p<0.001) may be due to the fact that the parameter of alignment is represented on the AOFAS scale but not on the Karlsson-Peterson scale.

Table 3 shows the postoperative evaluation scores on the AOFAS scale by category: 41 (74.5%) of 55 patients reported excellent clinical and functional outcomes; 10 (18.2%) patients reported good outcomes; and only two (3.6%) patients reported fair outcomes. These results are comparable to those reported using the Karlsson-Peterson scale, where excellent clinical and functional outcomes were reported by 41 (74.5%) patients and good outcomes, by 12 (21.8%) patients; only two (3.6%) patients reported fair results and none reported poor outcomes (Table 4).

Postoperative complications included pain in five patients (9.1%), joint stiffness in three (5.5%) patients, and hematoma in one (1.8%) patient, which needed to be drained; superficial wound infection was seen in one (1.8%) patient, being successfully treated with oral antibiotics for seven days and resulting in complete remission. One patient (1.8%) developed complex regional pain syndrome.

Table 2. Results of the VAS, AOFAS, and Karlsson-Peterson scales in 55 patients with lateral ankle instability treated by MBG plasty and suture tape augmentation

Scale	Preoperative Evaluation[a]	Postoperative Evaluation[a]	p-value
VAS	7.1 ± 1.4	1.3 ± 1.6	<0.001
AOFAS	61.3 ± 21.1	95.4 ± 8.4	<0.001
Karlsson-Peterson	46.8 ± 14.3	95.2 ± 7.9	<0.001

Visual Analog Scale (VAS), American Orthopaedic Foot & Ankle Society (AOFAS), modified Bröstrom-Gould (MBG).
[a] Data are presented as mean, with standard deviation.

Discussion

The Karlsson-Peterson scale showed optimal performance in evaluating the clinical and functional outcomes of MBG plasty and suture tape augmentation in patients with ankle instability. Regarding preoperative evaluation, this scale offers a high precision, as it includes six different parameters based on subjective patient-reported instability, thus allowing the magnitude of instability to be defined and the clinical and functional outcomes of the treatment to be evaluated. The AOFAS scale overestimates the clinical and functional parameters of ankle instability by assigning a high score in the pretreatment assessment.

The AOFAS scale is the most frequently used scale in clinical studies, although its validity and reliability in assessing ankle instability has not been determined[7]; critical weaknesses are the little emphasis placed on instability and the high scores for pain, function, and alignment, resulting in unclear results. It is possible to obtain a high score (greater than 90) in the absence of pain and with a normal range of motion, even when the patient has ankle instability[7]. In a meta-analysis of 88 studies, mechanical laxity and ligamentous insufficiency were found to be related to the subjective feeling of instability, and this was sufficient to determine surgical treatment in 16 of the analyzed articles[7]. Spennacchio et al.[7] proposed that the subjective patient perception is critical in determining the severity of ankle instability and treatment outcomes. Furthermore, AOFAS expressed its opinion on this matter, pointing out that it is not advisable to use the AOFAS scale for clinical and functional assessment of ankle instability[14]. Recent studies have shown lower pretreatment scores on the Karlsson-Peterson scale than on the AOFAS scale[15,16]. Our results are comparable with those reported by Yeo et al.[17]: they examined 48 patients with ankle instability and, in the preoperative evaluation, they found mean scores of 68.7 ± 2.1 on the AOFAS scale and 46.8 ± 2.4 on the Karlsson-Peterson scale. Likewise, in a study involving 24 athletes, in the pretreatment evaluation using the Karlsson-Peterson scale, a mean score of 43.5 (range, 32 to 55) was obtained[18], which is similar to that found in the current study. Self-report of ankle instability is considered enough to determine the need for surgical management, as observed in 16 articles analyzed in a meta-analysis[7]. The discrepancy between the scores obtained on the AOFAS and Karlsson-Peterson scales in the pretreatment assessment of ankle instability is related to the fact that the latter scale includes the most important criterion of self-reported perception of instability[7].

The Karlsson-Peterson scale shows better performance in assessing ankle instability than the AOFAS scale, which overestimates the pretreatment severity score; the former uses a combination of patient responses and physical examination[11]. The main differences between the scales, which impact the total score in the pretreatment assessment of ankle instability, are as follows: the AOFAS scale underestimates ankle instability by assigning it a maximum of eight points; in contrast, the Karlsson-Peterson scale assigns it up to 25 points. Regarding pain, the former assigns it up to 40 points, and the latter, 20 points; in addition, the AOFAS scale assigns the alignment parameter, which is absent in Karlsson-Peterson scale, a maximum of 10 points. Our study is the first in the

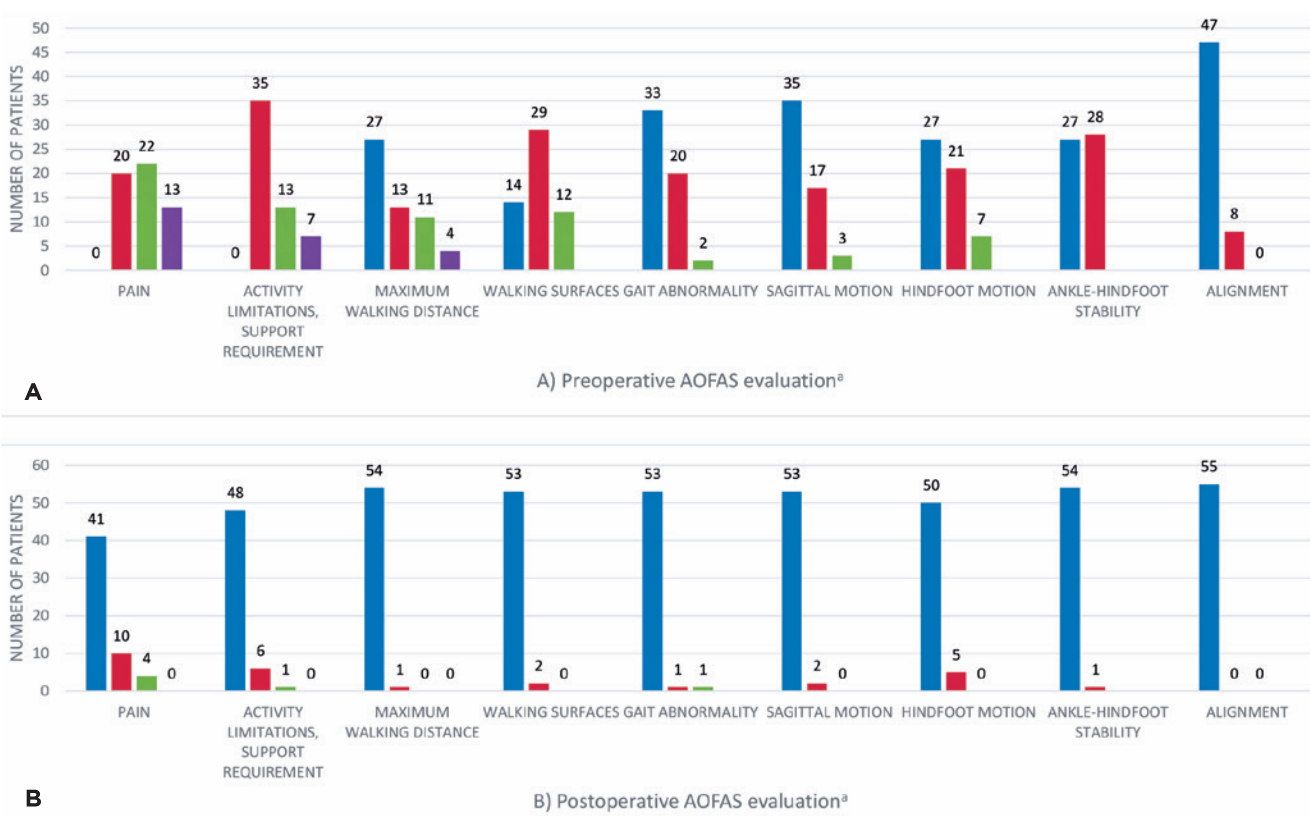

Figure 1. Preoperative (A) and postoperative (B) scores on the AOFAS scale by category in 55 patients with lateral ankle instability treated with MBG plasty and suture tape augmentation. Overall improvement in all parameters is observed; it was significant in the categories of pain and activity limitations, with an increase in maximum walking distance and in walking on different surfaces ($p<0.05$).
*Each category relates to the parameters defined on the AOFAS hindfoot scale[13].

literature to compare categories and their impact on the total scores of the AOFAS and Karlsson-Peterson scales when used in the clinical and functional assessment of patients with ankle instability.

Currently, the use of PROMs that include patient-reported outcomes in clinical and functional assessment is gaining popularity[(11,14)]. The main features of PROMs are the consistent findings and good performance in clinical studies; AOFAS recommends the use of PROMs to assess clinical and functional conditions and treatment outcomes[(14)]. The AOFAS scale uses a combination of medical evaluation and patient response and is therefore not considered a PROM-based scale[(11)]; in contrast, there is evidence that the Karlsson-Peterson scale can be considered a PROM-based scale[(15-19)]. Likewise, the Foot and Ankle Ability Measure (FAAM) and Foot and Ankle Outcome Score (FAOS) scales recommended for foot and ankle are also considered PROM-based scales[(11,20)] and have been used to evaluate MBG plasty and suture tape augmentation outcomes[(1,2,21,22)]. Furthermore, in a systematic review, the Karlsson-Peterson, FAAM, and FAOS scales were preferred for evaluating outcomes of surgical treatment of ankle instability[(7)]. Recently, automatized question banks have been designed for a computer application known as the Patient Reported Outcomes Measurement Information System (PROMIS) (National Institutes of Health (NIH))[(14)]. It is a standardized system used to assess patient-reported clinical and functional outcomes according to patient responses and integrates objective function and subjective satisfaction information, including function and activities of daily living[(11)].

The results of MBG plasty with suture tape augmentation are superior to those of standard techniques[(3,4,21,23)]. Suture tape provides an increased mechanical stability to the ankle that helps prevent recurrence of injury to the lateral ligaments and underlying structures, improves functional stability, and optimizes active rehabilitation[(21)]. Suture tape augmentation has a positive impact on the patient's self-perception of ankle stability[(3)]. In our study, 55 patients with ankle instability who underwent MBG plasty and suture tape augmentation were examined; the mean outcome scores at the 22-month follow-up were 95.4 ± 8.4 and 95.2 ± 7.9 on the AOFAS and Karlsson-

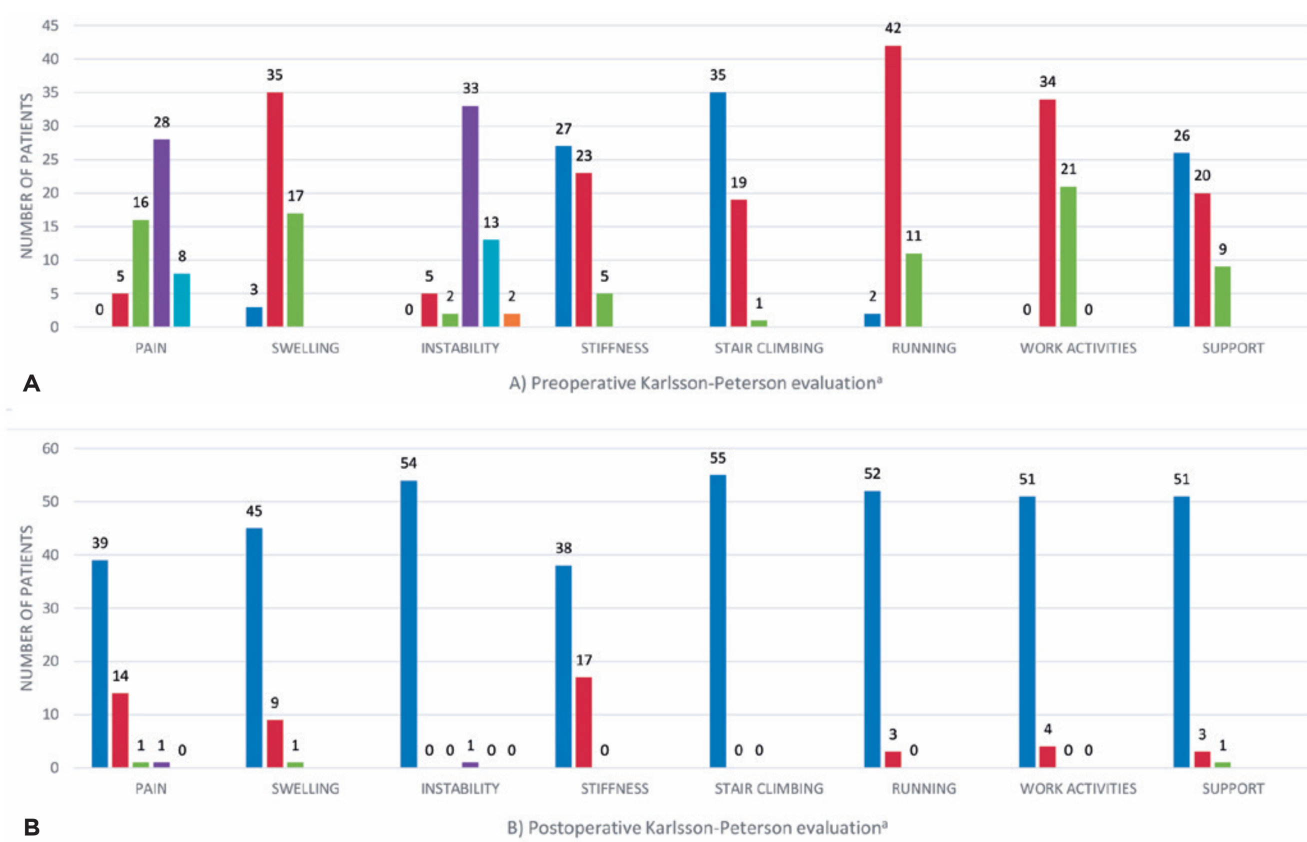

Figure 2. Preoperative (A) and postoperative (B) scores on the Karlsson-Peterson scale by category in 55 patients with lateral ankle instability treated with MBG plasty and suture tape augmentation. In all patients, except for one (n=54, 98%), the perception of ankle instability disappeared (p<0.001).

*Each category relates to the parameters defined on the Karlsson-Peterson scale[(12)].

Table 3. Results of the AOFAS scale by category in 55 patients with lateral ankle instability treated with MBG plasty and suture tape augmentation

Score: category	n=55 (%)
91-100: excellent	41 (74.5%)
81-90: good	10 (18.2%)
71-80: fair	2 (3.6%)
61-70: poor	2[a] (3.6%)

American Orthopaedic Foot & Ankle Society (AOFAS), modified Bröstrom-Gould (MBG).
[a] A patient presented with a score of 60.

Table 4. Karlsson-Peterson scale results by category in 55 patients with lateral ankle instability treated with MBG plasty and suture tape augmentation

Score: category[a]	n=55 (%)
95-100: excellent	41 (74.5%)
80-94: good	12 (21.8%)
50-79: fair	2 (3.6%)
<50: poor	0 (0%)

[a] Sefton Classification.

Peterson scales, respectively. Yeo et al.[17] examined 48 patients divided into two groups who underwent MBG plasty in open or arthroscopic procedure; the clinical and functional outcomes on the AOFAS and Karlsson-Peterson scales at the 12-month follow-up were evaluated. In the open MBG group (n=23), mean scores of 89.2 ± 2.3 and 73.5 ± 2.8, respectively, were reported. We consider that the superior results achieved in our study are related to the benefit offered by the suture tape augmentation, which led to a positive impact on self-reported stability, resulting in high scores (95.4 ± 8.4 and 95.2 ± 7.9, respectively). Similarity between clinical and functional scores on the AOFAS and Karlsson-Peterson scales can be explained by the fact that ankle instability and pain were already resolved with surgical procedure, which had a positive impact on the patients' perception. On the other hand, in a meta-analysis including three studies with 92 patients who underwent open MBG plasty, the mean score was 90.9 on the Karlsson-Peterson scale[24]; in contrast, we obtained an mean postoperative score of 95.2 ± 7.9. The difference between the scores obtained can be attributed to the benefit of using suture tape augmentation with MBG plasty.

This study has several strengths, such as the large number of patients included and assessment of ankle instability using the Karlsson-Peterson scale, which identifies and categorizes the self-reported ankle instability using PROMs, thus increasing the external validity of data reported in this study. On the other hand, limitations of the study are related to its retrospective design and to the short-term follow-up of the clinical and functional results of surgical management of ankle instability with MBG plasty and suture tape augmentation.

Conclusions

In our study, the Karlsson-Peterson scale showed a better performance than the AOFAS scale in the clinical and functional assessment of patients with ankle instability treated with MBG plasty and suture tape augmentation, which made our study valuable for using this scale in our regular practice. The Karlsson-Peterson scale is a specific, reproducible, and reliable tool that records subjective patient report of clinical and functional features of ankle instability; in contrast, the AOFAS scale overestimates clinical and functional outcomes prior to treatment and underestimates improvement after surgical management. Further clinical studies are needed to validate the performance of the Karlsson-Peterson scale as a PROM-based scale. Modified Bröstrom-Gould plasty with suture tape augmentation is a beneficial procedure that can be adopted in surgical centers for the management of ankle instability.

Author's contributions: Each author contributed individually and significantly to the development of this article: HBTO *(https://orcid.org/0000-0001-6813-4177) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection and approved the final version; ACKM *(https://orcid.org/0000-0003-2457-9654) Performed the surgeries, data collection and approved the final version; ACA *(https://orcid.org/0000-0002-6129-954X) Performed the surgeries, data collection and approved the final version; VJRG *(https://orcid.org/0000-0002-7384-7080) participated in the review process and approved the final version; ROO *(https://orcid.org/0000-0003-3861-2355) Conceived and planned the activities that led to the study, performed the surgeries, data collection and approved the final version; DAZO *(https://orcid.org/0000-0001-9680-6831) Interpreted the results of the study, participated in the review process and approved the final version; LAGC *(https://orcid.org/0000-0002-0812-2497) Conceived and planned the activities that led to the study, performed the surgeries, data collection and 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

Peroneal nerve injuries during anterior ankle arthroscopy

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Abstract

Objective: Ankle arthroscopic surgery is considered a safe procedure with minimal risk of peripheral nerve injury. The primary objective of this study was to determine the incidence of peripheral nerve injuries during anterior ankle arthroscopy. The secondary objective was to evaluate the most frequent types and the clinical relevance of deep peroneal nerve injuries.

Methods: Patients who underwent anterior ankle arthroscopy at our institution from 2000 to 2020 were retrospectively analyzed. Those present neurological symptoms after surgery were evaluated with clinical examination and ankle ultrasonography looking for nerve injuries.

Results: Three hundred and thirty-four patients were included in the present study. There were 26 iatrogenic neurological complications (7.78%). The superficial peroneal nerve was injured in 16 cases (4.79%) and the deep peroneal nerve, in 10 cases (2.99%). Among the injuries of the deep peroneal nerve, 1.5% of cases had nerve entrapment in postoperative tissue adhesions, 0.9% presented neuromas, and 0.6% had axonotmesis. Complications were classified using the Modified Clavien-Dindo-Sink Complication Classification System: 2.1% of complications were grade I, while 0.9% were grade II.

Conclusion: Nerve injury is the most common complication related to anterior ankle arthroscopy. The deep peroneal nerve is rarely damaged during this procedure. We found that most deep peroneal nerve injuries are not clinically relevant and do not have a big impact on patient evolution during the postoperative period.

Level of Evidence II; Retrospective Study; Prognostic Studies.

Keywords: Ankle; Arthroscopy; Deep peroneal neuropathies; Peroneal nerve; Postoperative complications.

Introduction

Ankle arthroscopic surgery has been well accepted worldwide and has become an important part of orthopedic surgery. It is considered a safe procedure, with minimal risk of peripheral nerve injury. The use of arthroscopy has reduced patient hospital stay, overall costs of surgery, and the time required for patients to return to sports, work, and daily life activities. However, during this procedure, arthroscopic instruments and portals are in close proximity to neurovascular structures, thus, there is a potential risk of nerve injury[1-4].

Nerve injury is the most common complication related to anterior ankle arthroscopic procedures[1-3,5]. Such procedures are usually performed through two classic portals: the anteromedial (AM) portal and the anterolateral (AL) portal. The superficial peroneal nerve (SPN) is one of the most frequently injured structures during ankle arthroscopy, specifi-

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cally occurring when the AL portal is performed[5,6]. On the other hand, the deep peroneal nerve (DPN) is rarely injured during ankle arthroscopy.

The primary objective of this study is to determine the incidence of peripheral nerve injuries during anterior ankle arthroscopy. The secondary objective is to evaluate the most frequent types and the clinical relevance of DPN injuries.

Anatomical review

At the level of the ankle, the anterior neurovascular bundle is located just anterior to the joint capsule, being composed by the DPN and the anterior tibial artery (ATA) or dorsalis pedis artery and veins[7] (Figure 1).

The DPN and SPN are the terminal branches of the common peroneal nerve, which divides around the proximal fibula. At the ankle, the DPN runs deep to the inferior extensor retinaculum, between the tibialis anterior and the extensor hallucis longus (EHL) tendons, just anterior to the ankle joint capsule. In its turn the SPN reaches the lower third of the leg, pierces the deep crural fascia, and divides into two terminal branches: the medial and intermediate dorsal cutaneous nerves. These nerves enter the foot to innervate the majority of its dorsal surface.

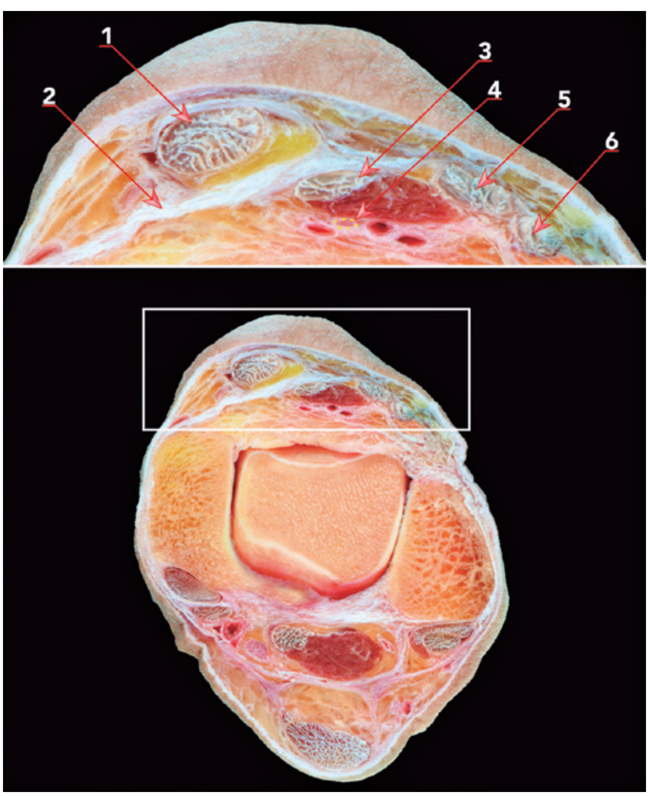

Figure 1. Transversal cross-section of a specimen showing the anatomy of anterior ankle structures: 1. Anterior tibialis tendon; 2. Oblique superomedial band of the inferior extensor retinaculum; 3. Extensor hallucis longus; 4. Deep peroneal nerve; 5. Extensor digitorum longus tendons; and 6. Peroneus tertius tendon.

Nerve injury diagnosis

The diagnosis of nerve injury is based on symptoms referred by the patient, physical examination, and diagnostic imaging, among which ultrasonography plays an important role.

Symptoms manifested by patients with neurological injury after ankle arthroscopy include pain, hypoesthesia, or anesthesia on the dorsum of the foot.

The degree of nerve injury is classified as neuropraxia, axonotmesis, or neurotmesis with or without intra-fascicular fibrosis, and with or without change in nerve diameter.

High-resolution ultrasonography is an excellent imaging method to explore normal anatomy and disorders of peripheral nerves[8]. Recent improvements on transducer quality allow the examination of large- and medium-sized nerves, but can also be used to explore small peripheral nerves, especially when they are superficially located[9,10].

Methods

Patients who underwent anterior ankle arthroscopy at our institution from 2000 to 2020 were retrospectively analyzed. All procedures were performed by the senior author (JPB) using two arthroscopic portals: the AL portal and the AM portal.

Inclusion criteria: All patients who underwent anterior ankle arthroscopy at our institution between 2000 and 2020, answered our telephone call, and could be evaluated by physical examination in order to find nerve damage signs.

Exclusion criteria: Patients who could not be evaluated by physical examination to identify signs of neurological damage.

The arthroscopic surgeries analyzed in this study included: synovectomy, excision of osteophytes, debridement of the lateral gutter, removal of loose bodies, removal of painful ossicles, excision or drilling of osteochondral lesions of the talus, and repair of the anterior talofibular ligament. These procedures were performed to treat patients with a number of primary diagnoses, including synovitis, osteophytes, soft tissue and bone impingement, loose bodies, painful ossicles, osteochondral lesions of the talus, and lateral ankle instability.

Neurological complication was defined as any problem involving a peripheral nerve of the ankle with any of the following symptoms: diffuse pain in the anterior region of the ankle and foot, postoperative paresthesia, hypoesthesia, hyperesthesia, or anesthesia. Only patients who presented any of these neurological symptoms upon interrogation and clinical examination were evaluated by ankle ultrasonography.

Ultrasonographic evaluation

Ultrasonographic evaluations were performed by a musculoskeletal radiologist experienced in nerve evaluation using a Philips ultrasound equipment with a 418 Mhz multi-frequency, linear transducer.

The anterior aspect of the ankle was examined and the structures at risk during ankle arthroscopy were assessed.

The EHL and extensor digitorum longus (EDL) tendons, ATA, DPN, and medial branch of SPN were examined with particular attention.

Color Doppler imaging was used in all examinations to identify vessels and investigate blood flow. The ATA was examined to rule out the presence of pseudoaneurysm[1,4,11-13], looking for integrity and intact blood flow.

The DPN was identified. Integrity and continuity, areas of focal thickening and thinning, and alterations in its arrangement with signs of displacement or retraction related or not to areas of perineural or intraneural fibrosis were assessed.

The SPN was identified at the point where it pierces the crural fascia, proximal to the ankle joint. The medial and intermediate dorsal cutaneous branches were identified and studied looking for the presence of neuroma.

Complication classification system

The different types of nerve injuries were analyzed and classified according to the Modified Clavien-Dindo-Sink Complication Classification System. This system consists of five grades of complications based on their severity and considering the therapy required to treat such complications.

Results

A total of 526 patients who underwent ankle arthroscopy at our institution from 2000 to 2020 were identified, but only 334 patients answered our telephone call and could be examined and being were finally included in the present study.

The mean age of patients was 32 years old (range 15-59 years old, median 31 years old). Two hundred and fourteen patients (64.07%) were male, and 120 patients (35.93%) were female. The right ankle was operated in 131 cases (39.22%) and the left ankle in 203 cases (60.78 %) (Table 1).

Of the 334 patients evaluated, 26 (7.78%) had neurological symptoms manifested during interrogation and physical examination, and thus underwent ultrasonographic evaluation.

Ultrasonography confirmed the integrity of ATA in all patients who underwent ultrasonographic evaluation (Figure 2). However, the 26 patients with neurological symptoms demonstrated ultrasonographic signs of nerve damage. Of these 26 complications, 16 cases (4.79%) affected the SPN, and 10 cases (2.99%) affected the DPN.

Among the 10 patients with DPN injuries, five cases (1.5%) had an entrapment of the nerve in postoperative tissue adhesions of the capsule joint; three patients (0.9%) presented neuromas, two neuromas-in-continuity and one terminal neuroma (neurotmesis); and two patients (0.6%) had axonotmesis (Table 2).

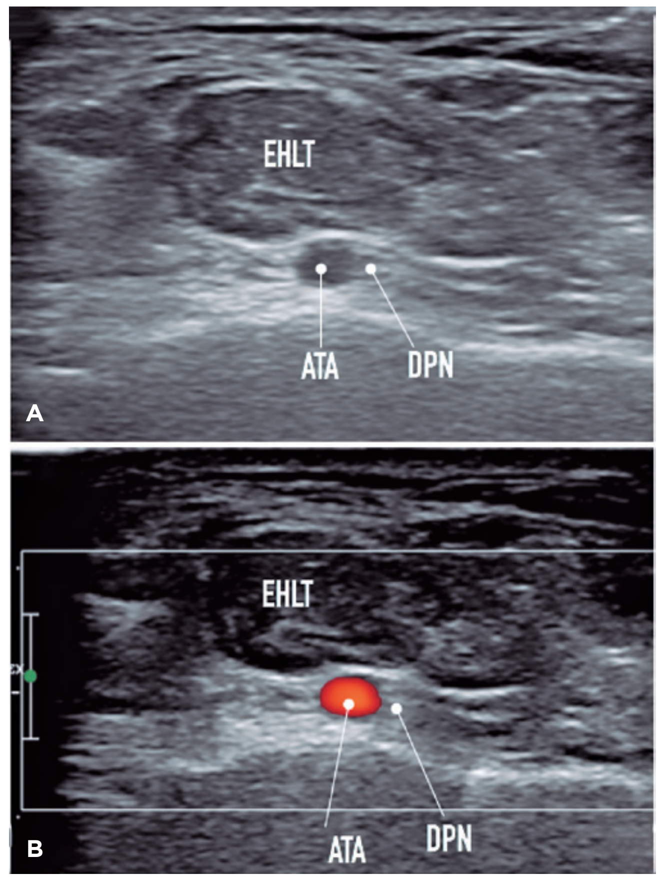

Figure 2. The images show the relationship of the deep peroneal nerve (DPN) with the anterior tibial artery (ATA), deep to the extensor hallucis longus tendon (EHLT). A) B-mode image with the anatomical relationship of vasculonervous structures. B) Color Doppler technique allows differentiation of the vascular structure from the adjacent nerve.

Table 1. Demographic data

Mean age	32 (15-59)
Gender	
Male	214 (64.07%)
Female	120 (35.93%)
Side	
Right	131 (39.22%)
Left	203 (60.78%)

Table 2. Nerve injury due to anterior ankle arthroscopy

	N
Superficial peroneal nerve injury	16
Deep peroneal nerve injury:	10
- Nerve entrapment in scar tissue	5
- Neuroma	3
- Axonotmesis	2
Total	26

No cases of neurological injury due to compartment syndrome or tourniquet compression were observed (Figures 3, 4, 5, and 6).

The abovementioned complications were classified based on the Modified Clavien-Dindo-Sink Complication Classification System[14].

We considered the cases of entrapment of the nerve in postoperative tissue adhesions and neuromas-in-continuity as grade I complications (complications that do not result in a deviation from routine follow-up in the postoperative period, have minimal clinical relevance, and require minimal treatment, such as analgesics and physical therapy, or no treatment at all). This kind of complication had an incidence of 2.1% in the present study.

Cases of terminal neuroma (neurotmesis) and axonotmesis were considered as grade II complications (complications that result in a deviation from the normal postoperative course, including unplanned clinic/office visits, and require outpatient treatment, either pharmacological or for close monitoring). Grade II complications had an incidence of 0.9% in this study.

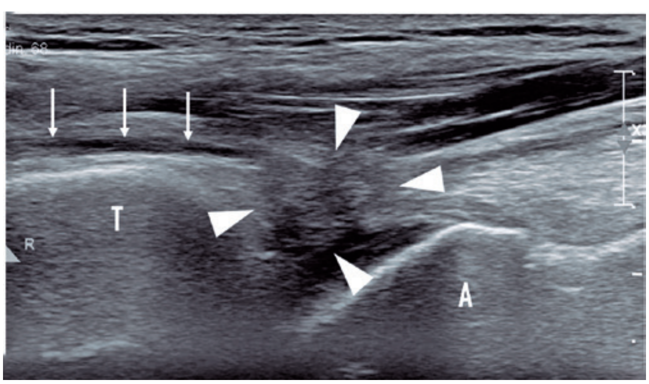

Figure 3. Ultrasonography showing an entrapment of the deep peroneal nerve within postoperative tissue adhesions of the capsule joint. White arrows mark the course of the deep peroneal nerve in longitudinal plane. White arrowheads show the margins of the area of periarticular fibrosis that entraps the nerve in its course.

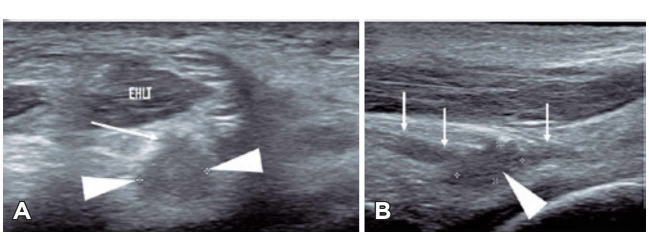

Figure 4. Ultrasonography showing a neuroma-in-continuity. A) Axial plane. B) Longitudinal plane. Short white arrows show the path of the deep peroneal nerve in longitudinal plane, proximal and distal to a neuroma in lateral continuity (arrowheads) adjacent to the nerve visualized in axial plane (long white arrow).

Considering that all complications were grade I or II, they were not serious complications and did not have clinical relevance for patient recovery.

Discussion

There are different causes of DPN injury, such as due to direct trauma or repetitive microtrauma, as happens in soccer players, where DPN injury is related to frequent trauma to the dorsum of the ankle and foot during the kicking action. Other causes are recurrent ankle sprains or bony impingement, with prominent osteophytes near the DPN (or its branches), in which the nerve may be stretched.

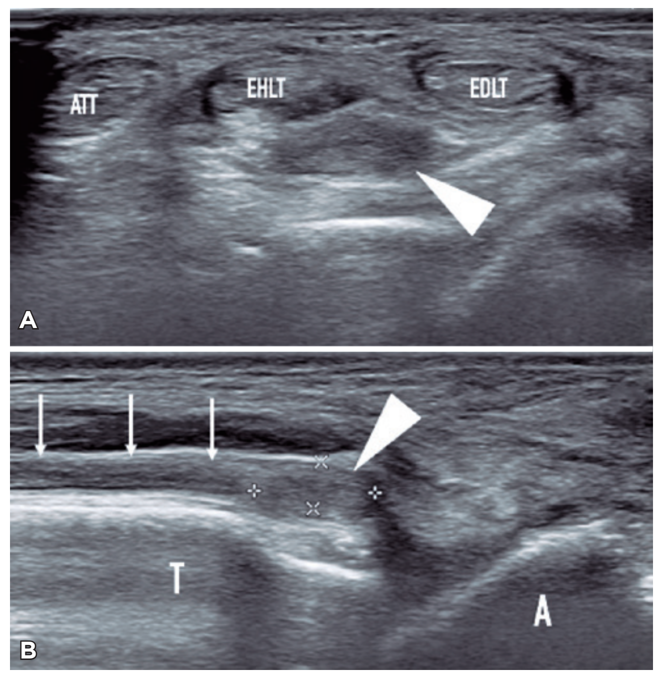

Figure 5. Ultrasonography showing a terminal neuroma. A) Axial plane. B) Longitudinal plane. White arrows mark the course of the deep peroneal nerve. Arrowheads mark the terminal neuroma.

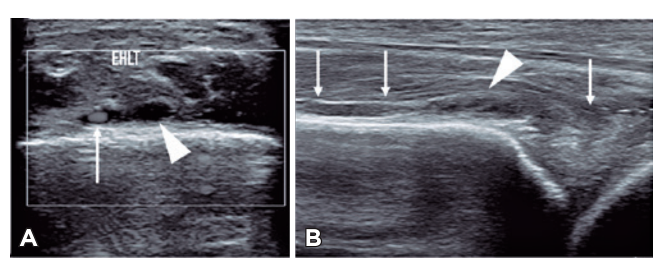

Figure 6. Ultrasonography showing a case of axonotmesis. A) Color Doppler axial plane. B) Color Doppler longitudinal plane. In axial plane, heterogeneous thrust of the deep peroneal nerve is observed in its course (arrowhead) adjacent to the anterior tibial artery (long white arrow), which can be recognized in the course of the nerve (white arrows).

However, one of the most important causes of DPN disorders is iatrogenic nerve damage during or after arthroscopic surgery, in which the nerve may be directly damaged by the shaver or entrapped in scar tissue. In these patients, nerve injury may be caused by the pressure exerted by surgical instruments, nerve stretching, or nerve section while using the shaver. Furthermore, an entrapment of the nerve caused by postoperative fibrosis might produce similar symptoms.

Nerve injury is the most common complication related to anterior ankle arthroscopy. Superficial peroneal nerve is one of the most frequently injured structures during ankle arthroscopy more specifically, during anterolateral portal placementand several articles about this complication have been published(1-5). However, only a few studies have been focused on DPN injury after ankle arthroscopy(2,3,5).

The primary objective of this study was to determine the incidence of neurological injuries during anterior ankle arthroscopy. We found an incidence of neurological complications of 7.78%. Although this is a high complication rate, most of these cases were not clinically relevant (grade I or II in the Modified Clavien-Dindo-Sink Complication Classification System)(14). The SPN was injured in 4.79% of cases and the DPN was affected in 2.99% of cases. The secondary objective of this study was to evaluate the most frequent DPN injury types. Among patients who presented DPN injuries, 1.5% had an entrapment of the nerve in postoperative tissue adhesions of the capsular joint, 0.9% presented neuromas, and 0.6% had axonotmesis.

There are different factors that predispose to injuries of the DPN during arthroscopic procedures. The main risk factor is the overuse of the shaver against the joint capsule: as the DPN is located just anterior to the joint capsule, excessive shaver use against the capsule may cause direct nerve damage.

Most surgeons recommend working in ankle dorsiflexion, which increases the working area during arthroscopic surgery, allowing the use of larger diameter arthroscopes and wider arthroscopic instruments. In addition, working in ankle dorsiflexion reduces the tension on anterior neurovascular structures, thus reducing the complication rate associated with anterior ankle arthroscopy(3) while allowing the performance of advanced arthroscopic techniques(15). Another advantage of this maneuver is that, during ankle dorsiflexion, the articular cartilage of the talus is protected against iatrogenic damage(16).

Preventing neurological complications are crucial, because these are directly related to the arthroscopic technique employed. Extensive knowledge of the ankle arthroscopic anatomy, surgeon training, and experience in this field are essential variables that can play an important role in preventing this undesirable complication.

Conclusions

Nerve injury is the most common complication related to anterior ankle arthroscopy.

We found an overall incidence of neurological complications of 7.78%. Although this is a high complication rate, most of these were not clinically relevant (grade I or II in the Modified Clavien-Dindo-Sink Complication Classification System).

Preventing this kind of neurological complication is crucial because they are directly related to the arthroscopic technique employed.

Further studies with a multicenter approach might be useful to determine the actual incidence of DPN injuries during ankle arthroscopy.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JPB *(https://orcid.org/0000-0003-0910-4140) Conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, interpreted the results of the study, approved the final version; GMA *(https://orcid.org/0000-0003-4767-5489) Data collection and approved the final version; GMJ *(https://orcid.org/0000-0001-9998-190X) Participated in the review process, formatting of the article, approved the final version; LVC *(https://orcid.org/0000-0002-0202-9603) Data collection, bibliographic review; RB *(https://orcid.org/0000-0001-5940-7540) Clinical examination, bibliographic review; LC *(https://orcid.org/0000-0003-1187-0864) Data collection and approved the final version; MDP *(https://orcid.org/0000-0001-6043-698X) Interpreted the results of the study, bibliographic review , participated in the review process and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Postoperative outcomes of oblique osteotomy and capsuloplasty for the treatment of bunionette in the fifth metatarsal neck

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Abstract

Objective: Present the outcomes of oblique osteotomy and capsuloplasty based on the pre-/postoperative American Orthopaedic Foot & Ankle Society (AOFAS) scores and demonstrate the possibility of correcting all four types of bunionette through a single technique.

Methods: Descriptive observational study performed through medical records assessment based on the pre-/postoperative AOFAS scores.

Results: Fifty-three feet were operated on, 28 on the right side and 25 on the left, predominantly female (n=34) and one male. The mean age was 44.8 years (range 19-77). The improvement in the AOFAS score occurred in all patients, the preoperative mean was 53.7 (44-57), and the postoperative mean was 77.4 (65-80). The distal oblique osteotomy of the fifth metatarsal associated with capsuloplasty was used.

Conclusion: The technique used in our study presents a significant improvement in all cases, corroborating with the outcomes in the literature.

Level of Evidence IV; Descriptive Observational Study.

Keywords: Osteotomy; Metatarsal bones; Bunion; Postoperative.

Introduction

The bunionette of the fifth metatarsal is defined as a painful prominence of the fifth metatarsal head secondary to a valgus deformity of the fifth ray and medial displacement of the fifth toe[(1)].

The multifactorial etiology includes anatomical and biomechanical variations, enlargement of the metatarsal head, lateral deviation in the metadiaphyseal transition, and increased intermetatarsal angle. Most commonly, the deformity results from an increased 4-5 intermetatarsal angle and varus of the metatarsophalangeal joint[(2)].

The pathology occurs more frequently in adolescents and adults. Its prevalence is 13.8%, with a mean age of 45 years[(3)], and affects 3-6 times more women than men[(4)].

According to Lui et al.[(2)], the patient can present dorsolateral, lateral and/or plantar pain. Symptoms are mechanically induced by using narrow shoes and are often associated with diffuse callosity and chronic irritation of the bursae. The diagnosis is based on clinical and radiographic findings.

As described by Coughlin et al.[(5)], the bunionette can be classified into three subtypes: enlargement of the metatarsal head (type 1), lateral deviation in the metadiaphyseal transi-

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tion (type 2), and increased 4-5 intermetatarsal angle (type 3). Fallat et al.[6] described type 4, a combination of these abnormalities.

Non-surgical treatment aims to relieve symptoms. The treatment involves footwear changes, or use of insoles and/or orthoses, presenting satisfactory results in mild cases[7]. Surgical treatment can be considered in patients with refractory symptoms[8].

Surgical techniques include lateral condylectomy, metaphyseal osteotomy (distal or proximal), and fifth metatarsal open or percutaneous diaphyseal osteotomy[9]. The proximal metaphyseal osteotomy is suitable for types 3 and 4, while the distal is used for types 2 and 3. Diaphyseal osteotomy is recommended if more corrections are needed than would be achieved with a distal osteotomy.

The outcomes of surgical treatment with osteotomy are satisfactory, with low complication rates[10].

This descriptive observational study was conducted to evaluate patients submitted to oblique osteotomy and capsuloplasty, a technique used to correct all four types of deformity and supination-adduction deformity of the fifth toe (present in 20% of our cases) and compare our results with the literature. This study is relevant because of the high prevalence of this pathology in orthopedic practice. Therefore, it can generate valuable information in applying a reproducible technique with excellent results and very low complication rates.

Methods

This study was approved by the Institutional Ethics Committee. A descriptive, observational study including thirty-five medical records of patients submitted to surgical treatment between January 2010 and January 2021 from a reference public orthopedic service, according to the inclusion/exclusion criteria.

The inclusion criteria were patients aged 18 years or older, diagnosed with bunionette of the fifth metatarsal and submitted to surgical treatment by the same surgeon, with oblique osteotomy and capsuloplasty, after non-surgical treatment for at least six months.

Exclusion criteria were patients' refusal to access the medical record, under 18 years, and patients cognitively unable to understand the terms of the informed consent form.

The surgical technique used was the same in all patients, regardless of the type of fifth metatarsal deformity. Patient in dorsal decubitus with a cushion under the ipsilateral gluteus, tourniquet at the thigh root, mean incision of 3cm in the transition of the dorsoplantar skin lateral to the fifth metatarsal, the opening of the capsule in line with the skin incision with careful detachment and wide exposure of the fifth metatarsal neck and base of the proximal phalanx of the fifth toe. As shown in Figure 1A-B a short oblique osteotomy was performed from distal lateral to proximal medial in the fifth metatarsal neck. The prominence of the proximal fragment was resected and regularized to leave no bone prominence. Then, one 2.0mm anchor was placed (Figure 2) on the fifth metatarsal head. Its threads were passed through the dorsal and plantar capsule, keeping the fifth metatarsal head in the medial position, simultaneously correcting the supination-adduction (Figure 3A-B) of the fifth toe when necessary. The closure was performed by layers, compressive dressing, and a robotfoot boot. On the postoperative, the patients were instructed to ambulate with partial load for short periods, and the stitches were removed after 21 days. The patients were asked to perform active and passive movement of the fifth toe in the same period, and the boot was removed six weeks after surgery. Then the use of wide and comfortable footwear was authorized. Around 90 days, the patients could use common, daily, and recreational shoes. Figure 4 shows the osteotomy consolidated.

Figure 1. A) Preoperative and B) Immediate postoperative.

Figure 2. Anchor fixation.

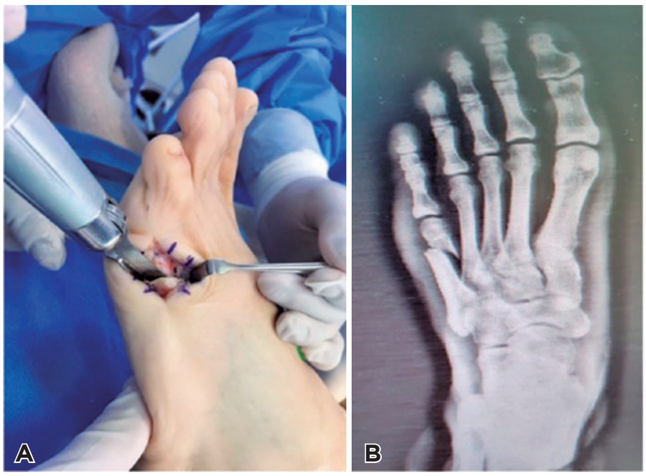

Figure 3. A) Osteotomy, intraoperative, and B) Postoperative radiographic image.

Figure 4. Postoperative radiographic image showing the osteotomy consolidated.

The study was based on medical records analysis, including epidemiological data and American Orthopaedic Foot & Ankle Society (AOFAS) score assessment on preoperative and between 90-120 days postoperative.

AOFAS is a standardized system to assess the treatment outcomes of patients with foot and ankle conditions to conduct the patients' pre-/postoperative analyses. This score was completed in all pre-/postoperative consultations in patients indicated for surgical treatment.

The following data were compiled from medical records, gender, age, comorbidities, laterality, practice of physical activity, supination-adduction deformity, complications, pre-/postoperative AOFAS scores, and year of surgery.

The data were compiled on Microsoft Excel® (Microsoft Corporation, Redmond, Washington, USA). Descriptive statistics were used to determine the normal distribution and compare the means of AOFAS scores. The Shapiro-Wilk test was performed to verify normal distribution. The paired Student's *t*-test was used to compare the means of pre-/postoperative AOFAS scores. The Mann-Whitney U test would be applied in case of nonparametric distribution. A significance level of $p<0.05$ (alpha=0.05) was applied.

The study was explained to the patients via contact by the researcher, and then the informed consent form was signed.

Results

The study was based on medical records analysis, including epidemiological data and AOFAS score assessment on preoperative and between 90-120 days postoperative. All medical records contained the data and met the necessary criteria. There was no exclusion in the study.

Table 1 shows the epidemiological data. A total of 53 feet were included from 35 patients, 34 (97.1%) female, and one (2.8%) male. The mean age was 44.8 years, ranging from 19 to 77 years. In the laterality, 28 patients (52.8%) were affected on the right side and 25 (47.2%) on the left side.

In our sample, 12 patients practiced physical activity. Among the activities, the most common was running. Only two patients had comorbidity among the 35 patients. Supination-adduction deformity of the fifth toe was found in 20% of cases (n=7). Regarding complications, four dehiscences (7.5%) were treated with serial dressing and three pseudarthroses (5.6%) without surgical intervention.

Table 2 shows the improvement in the AOFAS scale in all patients, the preoperative mean was 53.7 (44-57), and the postoperative mean was 77.4 (65-80). There was a nonparametric distribution between the groups of scores, and the Mann-Whitney U test was used, which showed a significant difference between the pre-/postoperative groups. ($U=0$, $p<0.00001$ ($\alpha=0.05$).

Table 1. Epidemiological data of the patients analyzed

Name	Sex	Age	Side	Activity	Comorbidities	Supination-adduction	Complications	Preop AOFAS	Postop AOFAS	Year of surgery
1	Female	76	Right	Inactive	No	No	No	52	72	2010
2	Female	77	Left	Inactive	No	No	No	52	72	2010
3	Female	26	Bilateral	Inactive	No	No	No	57	80	2010
4	Female	33	Bilateral	Run	No	No	No	57	80	2011
5	Female	56	Right	Inactive	No	Yes	No	57	80	2011
6	Female	25	Bilateral	Run	No	No	Dehiscence	57	80	2011
7	Female	23	Bilateral	Inactive	No	Yes	No	57	80	2011
8	Female	60	Bilateral	Inactive	No	No	No	52	80	2012
9	Female	69	Right	Inactive	No	No	No	52	80	2012
10	Female	35	Bilateral	Tenis	No	No	No	57	80	2012
11	Female	27	Bilateral	Inactive	No	No	Dehiscence (left)	57	80	2013
12	Female	55	Right	Inactive	No	Yes	Pseudoarthrosis	44	62	2013
13	Female	57	Right	Inactive	No	No	No	57	80	2013
14	Female	31	Bilateral	Volleyball	No	No	No	57	80	2013
15	Female	53	Left	Walking	No	No	Pseudoarthrosis	52	70	2014
16	Female	49	Left	Walking	No	No	No	52	80	2014
17	Female	47	Left	Inactive	Obesity	Yes	No	57	80	2014
18	Female	30	Bilateral	Inactive	No	No	No	57	80	2014
19	Female	42	Right	Run	No	No	No	57	80	2015
20	Female	54	Bilateral	Inactive	No	Yes	Dehiscence	52	80	2016
21	Female	57	Left	Inactive	Rheumatoid arthritis	No	No	57	80	2016
22	Female	37	Right	Inactive	No	Yes	No	57	80	2016
23	Female	42	Bilateral	Fighting	No	No	No	57	80	2016
24	Female	42	Right	Inactive	No	No	No	57	80	2016
25	Female	27	Bilateral	Cross-fit	No	No	Pseudoarthrosis	44	65	2017
26	Female	27	Bilateral	Run	No	No	No	57	80	2018
27	Female	38	Left	Run	No	No	No	57	80	2018
28	Female	19	Bilateral	Soccer	No	No	No	57	80	2019
29	Female	55	Bilateral	Run	No	No	No	57	80	2019
30	Female	60	Left	Inactive	No	Yes	No	44	75	2019
31	Female	35	Right	Inactive	No	No	No	57	80	2019
32	Female	46	Bilateral	Inactive	No	No	No	44	75	2019
33	Female	63	Right	Inactive	No	No	No	44	75	2020
34	Female	39	Bilateral	Inactive	No	No	No	57	80	2020
35	Male	59	Bilateral	Inactive	No	No	Dehiscence	44	65	2021

AOFAS: American Orthopedic Foot and Ankle Society.
Source: Authors

Table 2. Comparison between pre-/postoperative AOFAS scores

	Preoperative AOFAS	Postoperative AOFAS
Mean	53.77	77.45
Median	57	80
Standard deviation	4.92	5

AOFAS: American Orthopedic Foot and Ankle Society.
Source: Authors

Discussion

The chosen surgical technique in this study, the use of the 2.0mm anchor in the fifth metatarsal head, allowed a better rotation control of the head and gave the possibility to control how much medial deviation was necessary to correct each deformity. The stitch passed with the anchor wire through the capsule is made in a U-shaped dorsal and plantar position in a way where the stitches help to control with good precision how much it is necessary to correct the rotation of the fifth toe and also how much of medial deviation of the metatarsal head to give a fine tune to the correction.

The bunionette of the fifth metatarsal is a common pathology in a foot and ankle outpatient clinic with varied clinical conditions and may present from mild to disabling symptoms.

Our study showed that the highest prevalence of this pathology in mature adults (mean age: 44.8 years) were female (97.14%). When compared to the current literature, our results were compatible with Mazoteras-Pardo et al.[3] with a mean age of 45 years and the Laffenêtre et al.[4] with an involvement 3-6 times more in women than men.

The aim of Tonogai et al. study[9] was to evaluate the vascularization of the fifth metatarsal through barium injection and tomographic evaluation, and they concluded that the nutrient artery penetrates the fifth metatarsal in the medial position around the junction of the middle and proximal thirds with distal direction. Thus, the direction and location of the nutrient artery of the fifth metatarsal are important when performing an osteotomy because a proximal osteotomy can interrupt blood flow in the artery, resulting in osteonecrosis or pseudarthrosis. The conclusion of this study explains the low rate of these complications in our studies, pseudarthrosis (5.6%) without long-term clinical repercussion and no osteonecrosis (0%).

Martijn et al.[10], in a meta-analysis including 28 studies aiming to define the best osteotomy for bunionette of the fifth metatarsal, concluded that the lowest number of complications occurred with distal osteotomies. This data is comparable to our findings, which demonstrated only four superficial wound dehiscences, controlled with serial dressings, and three pseudarthroses without surgical intervention. Therefore, distal osteotomy may be the treatment of choice due to its low complication rates and is an easy-to-reproduce technique. Furthermore, data from this study corroborate our outcomes, which demonstrated the improvement in the AOFAS scores in all patients (mean preoperative 53.7 and postoperative 77.4). It is important to highlight that in this meta-analysis, only two studies had a higher number of cases than ours.

The study by Magnan et al.[11] evaluated the results of percutaneous subcapital osteotomy of the fifth metatarsal in 30 patients from 1996 to 2006, concluding that the percutaneous technique is safe and reliable and also offers the potential benefits of a minimally invasive procedure. Similar to the literature, our study showed low complication rates and significant improvement in postoperative AOFAS scores in all patients. Thus, comparing the results of the open and percutaneous techniques, it can be inferred that they present satisfactory results; however, to date, no relevant studies define superiority between these treatment options.

Our study had limitations, such as a higher statistical value with a larger sample; however, it can contribute to future meta-analyses. In the literature research, it was not found any study that referred to the deformity of the fifth toe (present in 20% of our cases); although the pre-/postoperative comparison between patients with supination-adduction deformity was not performed due to low statistical sampling, the preliminary findings suggest that the scores increase even within this group.

Ultimately, based on our outcomes, the distal oblique osteotomy technique and capsuloplasty for the surgical treatment of bunionette in the fifth metatarsal proved to be reliable, reproducible, and with low complication rates.

Conclusion

The surgical technique used in our study presents a significant improvement in the postoperative AOFAS scores in all patients with low complication rates.

Authors' contributions: Each author contributed individually and significantly to the development of this article: GDFJ *(https://orcid.org/0000-0003-2410-4691) Wrote the article, interpreted the results of the study; JMN *(https://orcid.org/0000-0002-0837-4037) Conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; CASA *(https://orcid.org/0000-0002-2533-5793) Wrote the article, participated in the review process; AMO *(https://orcid.org/0000-0003-2364-3183) Wrote the article, participated in the review process; DSL *(https://orcid.org/0000-0003-4401-5354) Wrote the article, participated in the review process; RSM *(https://orcid.org/0000-0002-7120-1649) Wrote the article, participated in the review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) .

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Original Article

Reproducibility of the point connection technique for measuring hallux valgus angles using a smartphone application

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Abstract

Objective: A) To evaluate the reliability of a new technique for the measurement of both intermetatarsal and hallux valgus angles. B) To evaluate whether this technique can be performed with the aid of a smartphone application.

Methods: Preoperative radiographs of 30 patients were evaluated by four observers, two experienced surgeons and two surgeons in training. They performed measurements of the intermetatarsal angle and hallux valgus angle using the classical method and using the new method, both employing a goniometer and a smartphone application. Analysis of agreement was done by quantifying the raw agreement and calculating the intraclass correlation coefficient (ICC).

Results: The hallux valgus angle presented excellent agreement (ICC>0.80) both using the traditional method and the point connection method, while the intermetatarsal angle presented a very good agreement (0.60<ICC≤0.80) in both methods.

Conclusion: The point connection technique showed good concordance rates when measured by smartphone applications, although it did not prove to be superior to the traditional one.

Level of Evidence II; Diagnostic Study; Development of Diagnostic Criteria.

Keywords: Hallux valgus; Radiography; Reproducibility of results; Smartphone.

Introduction

Hallux valgus (HV) is one of the most common chronic foot pain complaints in the practice of a foot and ankle specialist[1]. It is represented by a lateral deviation of the hallux towards the other toes and a medial deviation of the first metatarsal, evolving with pronation of the first metatarsal and metatarsophalangeal subluxation[2]. The severity of these deformities, associated with other factors, is determinant for the choice of treatment[3-5].

The gold standard for diagnosing HV is obtaining weight-bearing anteroposterior and lateral view radiographs of the foot. In the anteroposterior view, the hallux valgus angle (HVA), the intermetatarsal angle (IMA), and the position of the tibial sesamoid in relation to the anatomic diaphyseal axis of the first metatarsal are measured.

According to Coughlin's classification, a mild deformity is characterized by an HVA of less than 20°, an IMA of less than 11°, and a lateral subluxation of the sesamoid of up to 50%. A moderate deformity is defined by an HVA of 20º to 40°, an IMA of less than 16°, and a subluxation of 50–75%. Finally, a severe deformity is defined by an HVA greater than 40°, an IMA greater than 16°, and a lateral subluxation greater than 75%[2].

The HVA measurements have proven to be very important in assessing the severity of the disease, therefore, the standardization of methods with good inter- and intraobserver reproducibility becomes imperative. Parameters to be followed in measurements of HVAs were defined in a publication issued by the American Orthopaedic Foot and Ankle Society (AOFAS) in 2001. The IMA measurement uses the diaphyseal

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axes of the first and second metatarsals. To define the HVA, at first the axis of the first metatarsal is traced, followed by the axis of the proximal phalanx of the hallux, the angle formed between these two lines is then evaluated.

Although these parameters have become widespread and widely used by foot and ankle surgeons, some studies have shown that the reproducibility of these measurements when performed manually or by computerized programs may be low[(6-9)].

In 2016, Seo et al.[(10)] proposed a new way to measure HVAs. This technique is based on using a different reference point connection and showed good inter- and intraobserver reproducibility in IMA and HVA measurements.

Considering that printed radiographs are currently losing space to digital radiographs and that smartphone applications have become an alternative to speed up the measurement of angles in clinical practice, it is essential to also validate new measurement techniques in digital methods.

The objective of this study is to evaluate the reproducibility of this new technique for the measurement of IMA and HVA comparing it with the traditional technique. In addition, we aim to evaluate whether the described technique can be used both manually and in smartphone applications.

Methods

This study was approved by the Ethics and Research Committee of our institution and was conducted by our team of experts.

A retrospective observational study was conducted where 30 preoperative, weight-bearing anteroposterior radiographs of patients undergoing HV surgery at our institution between January 2018 and December 2019 were reviewed. The sample calculation was based on previous literature[(7,8,10)]. These radiographs were taken with the beam centered on the midfoot, with a 20° inclination from vertical in the sagittal plane and a focus-film distance of 100 cm[(11)]. Four observers, two experienced foot and ankle surgeons and two foot and ankle surgery residents, performed the IMA and HVA measurement using the traditional technique validated by AOFAS and the new point connection technique. These techniques were performed both manually, using a goniometer, and digitally, using the TraumaCadTM software system (TraumaCad, Petach-Tikva, Israel)[(12)]. This application is used in the surgical planning of several orthopedic pathologies and has easy-to-use tools for angle measurement (Figure 1).

The conventional method for measuring the IMA uses the diaphyseal axes of the first and second metatarsals, while the HVA measurement uses the axis of the proximal phalanx and the axis of the first metatarsal. To find the axis of the first metatarsal, one must connect a point equidistant from both cortices located 1–2 cm distal to the tarsometatarsal joint with another point located 1–2 cm proximal to the metatarsophalangeal joint. The same is done to find the second metatarsal axis, and the angle is measured between these two lines. The axis of the proximal phalanx is found by connecting the equidistant points of the cortices, located 0.5–1 cm proximal to the interphalangeal joint and 0.5–1 cm distal to the metatarsophalangeal joint[(11)].

The new method of connecting points is performed by marking a point on the most medial portion of the head of the first metatarsal connecting with a point positioned on the most medial, prominent, sclerotic portion of the base of the first metatarsal. A point is then marked on the most prominent and medial portion of the second metatarsal head and on the most medial and sclerotic portion of the base of the second metatarsal. The angle formed between these two lines is the IMA (Figure 2). The axis of the proximal phalanx, on the other hand, is found by drawing a straight line connecting the most medial and prominent point of the proximal phalanx at the interphalangeal joint with a more prominent and medial point at the head of the first metatarsal. The angle formed between this line and the axis of first metatarsal is the HVA[(10)] (Figure 3).

Figure 1. Image of the TraumaCad (TraumaCad, Petach-Tikva, Israel) application interface used to measure angles.

Figure 2. Point-connection measurement of the IMA using two lines as the longitudinal axis of the first metatarsal (A) and the longitudinal axis of the second metatarsal (B).

Figure 3. Point connection measurement of the HVA using two connecting lines as the longitudinal axis of the proximal phalanges (A) and longitudinal axis of the first metatarsal (B).

Statistical analysis

From the collected measurements, a database was built and analyzed using computational resources of the programs R version 3.6.3 (The R Foudation, Indianapolis, Indiana, USA) and SPSS, Statistical Package for the Social Science, version 22.0 (IBM Corp., Armonk, New York, USA) and using the application Microsoft Excel® 2015 (Microsoft Corporation, Redmond, Washington, USA).

For sample characterization and descriptive analysis of the behavior of variables, measurements obtained by the two methods were synthesized using boxplots, calculation of descriptive statistics (mean, median, standard deviation, coefficient of variation, and proportions of interest), simple frequency distributions, and cross tables. All analyses were done globally, by level of expertise of evaluators, and by evaluator individually.

The analysis of agreement between both paired measurements was done by quantifying the raw agreement (percentage of cases with variation D = difference between both measurements = 0) and by calculating the intraclass correlation coefficient (ICC). The ICC expresses the proportion of total variability that is due to inter-unit variability. When evaluating the agreement between two measurements, as is the case in this paper, ICC can be interpreted as a measure of agreement that finds the degree of distance of both measurements from the 45-degree straight line, where there should be perfect agreement, since both measurements should be equal. Since we are only interested in the two measurements under analysis, the one measured by the application and the one measured by the traditional method, ICC was calculated using the mixed-effects model ANOVA (two-way mixed model) and the study interest was 'consistency analysis,' as recommended by Shrout and Fleiss[13]. The ICC classification of agreement will be based on Weir's classification[14]:

$0.00 \leq ICC \leq 0.20$ = poor agreement;

$0.20 < ICC \leq 0.40$ = fair agreement;

$0.40 < ICC \leq 0.60$ = good agreement;

$0.60 < ICC \leq 0.80$ = very good agreement;

$0.80 < ICC \leq 1.00$ = excellent agreement.

The ICC was analyzed by the confidence interval at the 95% level and the significance of ICC was evaluated by the F test. The agreement found was considered significantly good when every value within the confidence interval of ICC at the 95% level was at least comparable to the 'good agreement' level, that is, when the lower limit of the agreement coefficient confidence interval at the 95% level was greater than 0.40.

The analysis of agreement between both measurements was done inter-rater and intra-rater. Additionally, in order to evaluate if the angle was independent of the rater's expertise, the agreement by rater level (resident or specialist) was analyzed. All analyses were performed at a 5% significance level, and details of the methodology can be obtained in Medronho et al.[15] and Weir[14].

Results

As shown in Table 1, when evaluating the HVA by the traditional method in global analysis, not discriminating the evaluator, the agreement between the HVA measured using a goniometer and the HVA measured using the application was significant and excellent (ICC=0.84).

When evaluators were discriminated by level of expertise, the HVA evaluated by the traditional method with a goniometer and using the application showed no statistically significant difference (p-value=0.654). However, there was a significant difference between the residents measurements of the HVA (p-value=0.013), as well as a lower ICC compared to that found in measurements by specialists.

By evaluating the HVA by the new method in a global analysis, not discriminating the evaluator, the agreement measured by ICC is excellent (ICC=0.84) and statistically significant.

When evaluators were discriminated by level of expertise, by measuring the HVA using the new method, there was no significant difference between the residents measurements (p-value=0.286), and significant ICC values referring to excellent or very good agreement were found. The specialists, on the other hand, showed a significant difference between their measurements using a goniometer and the application (p-value=0.003).

By evaluating the IMA using the traditional method not discriminating the evaluator, the agreement between the IMA measurement using a goniometer and the application was very good and statistically significant (ICC=0.60) (Table 2).

Considering only the specialists, no significant difference was found between the measurements of the IMA using the traditional method with a goniometer and with the application (p-value=0.722); besides, a very good agreement was found (ICC=0.71). However, when it comes to resident evaluators, a lower level of agreement was found, with an ICC lower than that found with the specialists (ICC=0.52).

Table 1. Concordance analysis for the HVA measurements using different instruments: goniometer and smartphone application

Method	Evaluator	Tool	Mean	Median	SD	VC	ICC	AC	p-value*
TM	Resident 1	GN	30.1	29.0	10.1	0.33	0.76	6.7%	**0.017**
		App	27.4	28.0	7.0	0.25	(0.52-0.88)		
	Resident 2	GN	27.9	28.0	7.4	0.27	0.79	10.0%	0.344
		App	27.1	26.0	6.5	0.24	(0.60-0.89)		
	Residents Global	GN	29.0	28.0	8.8	0.31	0.77	8.3%	**0.013**
		App	27.3	26.0	6.7	0.25	(0.63-0.86)		
	Specialist 1	GN	28.1	26.5	8.4	0.30	0.94	3.3%	0.051
		App	27.1	25.0	7.5	0.28	(0.87-0.97)		
	Specialist 2	GN	28.2	28.0	8.5	0.30	0.88	13.3%	0.417
		App	28.8	28.0	8.0	0.28	(0.77-0.94)		
	Specialists Global	GN	28.1	27.5	8.4	0.30	0.91	8.3%	0.654
		App	27.9	27.0	7.7	0.28	(0.85-0.95)		
	Global	GN	28.6	28.0	8.6	0.30	0.84	8.3%	**0.020**
		App	27.6	26.5	7.2	0.26	(0.77-0.88)		
PC	Resident 1	GN	35.6	34.0	8.4	0.24	0.87	6.7%	0.511
		App	36.1	35.0	7.8	0.22	(0.75-0.94)		
	Resident 2	GN	35.4	34.0	7.7	0.22	0.68	10.0%	0.405
		App	36.3	36.0	6.3	0.17	(0.44-0.84)		
	Residents Global	GN	35.5	34.0	8.0	0.23	0.79	8.3%	0.283
		App	36.2	35.5	7.1	0.20	(0.67-0.87)		
	Specialist 1	GN	36.6	35.5	7.5	0.21	0.97	16.7%	0.719
		App	36.5	35.0	7.9	0.22	(0.93-0.98)		
	Specialist 2	GN	33.3	33.0	7.8	0.23	0.82	16.7%	**0.000**
		App	36.2	36.0	7.6	0.21	(0.47-0.93)		
	Specialists Global	GN	35.0	35.0	7.8	0.22	0.89	16.7%	**0.003**
		App	36.3	35.5	7.7	0.21	(0.80-0.94)		
	Global	GN	35.2	34.0	7.9	0.22	0.84	12.5%	**0.009**
		App	36.3	35.5	7.4	0.20	(0.77-0.89)		

TM: Traditional Method; PC: Point Connection Method; SD: Standard Deviation; VC: Variation Coefficient; ICC: Intraclass Correlation Coefficient; AC: Absolute Concordance; * Student's T-Test.

When the IMA was evaluated by the method of connecting points not discriminating the evaluator, the agreement between measurements made by goniometer and by the application was very good (ICC=0.76), with no statistically significant difference between measurements (p-value=0.235).

When the level of expertise was discriminated, the IMA measured by the new method showed no significant difference neither between residents (p-value=0.803) nor between specialists (p-value=0.068). However, specialists showed an excellent agreement (ICC=0.83), while residents showed a very good agreement (ICC=0.71) (Table 2).

When evaluating the agreement between the measurements of the HVA by the traditional method and by the point connection method, both using a goniometer and the application, in all analyses (global analysis, not discriminating the evaluator, within the group of specialists and within the group of residents, and for each evaluator individually) the agreement measured by ICC was not significant (lower limit of the confidence interval smaller than 0.40). Furthermore, it presented a significant difference among measurements (p-value less than 0.001) (Table 3).

When evaluating the agreement between measurements of the IMA by the traditional method and by the point connection method, we had a very good agreement using the goniometer (ICC=0.68). When it comes to the application, despite presenting a very good agreement (ICC=0.65), it did not show statistical significance (lower limit of the confidence interval smaller than 0.40) (Table 4).

Discussion

Angular measurement is an indispensable tool in the classification and surgical planning of HV. However, traditional techniques have often shown low reproducibility[6-8]. In view of this, the search for new techniques that have greater reproducibility and can also be measured in software and smartphone applications becomes imperative.

Table 2. Concordance analysis for the IMA measurements using different instruments: goniometer and smartphone application

Method	Evaluator	Tool	Mean	Median	DP	VC	ICC	AC	p-value*
TM	Resident 1	GN	13.2	13.0	2.5	0.19	**0.41**	10.0%	0.353
		App	12.6	12.5	3.1	0.25	**(0.07-0.67)**		
	Resident 2	GN	14.8	14.0	3.3	0.22	**0.60**	13.3%	**0.001**
		App	13.0	13.0	3.0	0.23	**(0.20-0.81)**		
	Residents Global	GN	14.0	14.0	3.0	0.22	**0.52**	11.7%	0.353
		App	12.8	13.0	3.0	0.24	**(0.30-0.69)**		
	Specialist 1	GN	13.2	13.0	2.9	0.22	0.79	40.0%	0.612
		App	13.0	13.0	2.6	0.20	(0.61-0.90)		
	Specialist 2	GN	13.8	14.0	2.8	0.20	**0.64**	10.0%	0.943
		App	13.8	13.0	3.1	0.22	**(0.36-0.81)**		
	Specialists Global	GN	13.5	14.0	2.8	0.21	0.71	25.0%	0.722
		App	13.4	13.0	2.8	0.21	(0.56-0.82)		
	Global	GN	13.7	14.0	2.9	0.21	0.60	18.3%	**0.010**
		App	13.1	13.0	2.9	0.23	(0.47-0.71)		
PC	Resident 1	GN	14.9	16.0	3.6	0.24	0.66	13.3%	0.511
		App	15.2	15.0	3.0	0.20	(0.40-0.82)		
	Resident 2	GN	15.6	17.5	3.6	0.23	0.77	13.3%	0.258
		App	15.1	15.0	3.4	0.22	(0.57-0.88)		
	Residents Global	GN	15.3	16.0	3.6	0.23	0.71	13.3%	0.803
		App	15.2	15.0	3.2	0.21	(0.56-0.82)		
	Specialist 1	GN	15.1	15.0	2.4	0.16	0.86	26.7%	0.052
		App	14.4	14.5	2.6	0.18	(0.64-0.941)		
	Specialist 2	GN	14.4	14.0	3.1	0.21	0.80	20.0%	0.850
		App	14.3	14.0	2.9	0.20	(0.62-0.90)		
	Specialists Global	GN	14.8	15.0	2.8	0.19	0.83	23.3%	0.068
		App	14.4	14.0	2.7	0.19	(0.72-0.89)		
	Global	GN	15.0	16.0	3.2	0.21	0.76	18.3%	0.235
		App	14.8	15.0	3.0	0.20	(0.67-0.83)		

TM: Traditional Method; PC: Point Connection Method; SD: Standard Deviation; VC: Variation Coefficient; ICC: Intraclass Correlation Coefficient; AC: Absolute Concordance; *Student's T-Test.

In this study, we evaluated the reproducibility and inter-rater agreement of a new method for measuring HVAs both using a goniometer and a smartphone application.

In the analysis of results found, we observed that the HVA measurements present excellent agreement (ICC>0.80) both using the traditional method and the point connection method. However, taking into account the level of expertise of evaluators, specialists showed better agreement using the traditional method, while residents showed better agreement using the point connection method. This result is probably due to a greater familiarity of specialists with the traditional method for radiographic evaluation of their patients.

As for the IMA, the agreement between measurements using both the traditional method and point connection method was very good (0.60<ICC≤0.80). Furthermore, when the level of expertise of evaluators was discriminated, residents showed lower agreement results in both the traditional and point connection methods.

This study also compared the agreement of values found using both measurement methods. As for all analyses of HVA values, we found a significant difference between measurements and a non-significant agreement. This result corroborates the results found in the original study describing the new method issued by Seo et al.[10], where there was a greater difference in HVA when comparing both methods, especially in cases where there was subluxation of the hallux metatarsophalangeal joint.

Observing the agreement of IMA values between the analyzed methods, both showed a very good agreement with the use of a goniometer and with the use of the application, and the latter did not show statistical significance. As in the original study, IMA values showed a higher agreement between the methods in relation to the HVA, although both HVA and IMA showed higher values in the new method[10].

Table 3. Concordance analysis for the HVA measurements using different methods: traditional method and point connection method

Tool	Evaluator	Method	Mean	Median	SD	CV	ICC	AC	p-value
Goniometer	Resident 1	TM	30.1	29.0	10.1	0.33	**0.71**	**13.3%**	**0.000**
		PC	35.6	34.0	8.4	0.24	**(0.09- 0.90)**		
	Resident 2	TM	27.9	28.0	7.4	0.27	**0.55**	**3.3%**	**0.000**
		PC	35.4	34.0	7.7	0.22	**(-0.10-0.84)**		
	Residents Global	TM	29.0	28.0	8.8	0.31	**0.63**	**8.3%**	**0.000**
		PC	35.5	34.0	8.0	0.23	**(-0.05-0.86)**		
	Specialist 1	TM	28.1	26.5	8.4	0.30	**0.57**	**0.0%**	**0.000**
		PC	36.6	35.5	7.5	0.21	**(-0.07-0.87)**		
	Specialist 2	TM	28.2	28.0	8.5	0.30	**0.78**	**0.0%**	**0.000**
		PC	33.3	33.0	7.8	0.23	**(-0.06-0.94)**		
	Specialists Global	TM	28.1	27.5	8.4	0.30	**0.66**	**0.0%**	**0.000**
		PC	35.0	35.0	7.8	0.22	**(-0.08-0.89)**		
	Global	TM	28.6	28.0	8.6	0.30	**0.65**	**4.2%**	**0.000**
		PC	35.2	34.0	7.9	0.22	**(-0.07-0.87)**		
App	Resident 1	TM	27.4	28.0	7.0	0.25	**0.52**	0.0%	**0.000**
		PC	36.1	35.0	7.8	0.22	**(-0.07-0.84)**		
	Resident 2	TM	27.1	26.0	6.5	0.24	**0.44**	0.0%	**0.000**
		PC	36.3	36.0	6.3	0.17	**(-0.04-0.80)**		
	Residents Global	TM	27.3	26.0	6.7	0.25	**0.48**	0.0%	**0.000**
		PC	36.2	35.5	7.1	0.20	**(-0.06-0.81)**		
	Specialist 1	TM	27.1	25.0	7.5	0.28	**0.54**	0.0%	**0.000**
		PC	36.5	35.0	7.9	0.22	**(-0.03-0.86)**		
	Specialist 2	TM	28.8	28.0	8.0	0.28	**0.54**	0.0%	**0.000**
		PC	36.2	36.0	7.6	0.21	**(-0.09-0.83)**		
	Specialists Global	TM	27.9	27.0	7.7	0.28	**0.53**	0.0%	**0.000**
		PC	36.3	35.5	7.7	0.21	**(-0.08-0.83)**		
	Global	TM	27.6	26.5	7.2	0.26	**0.51**	0.0%	**0.000**
		PC	36.3	35.5	7.4	0.20	**(-0.07-0.82)**		

TM: Traditional Method; PC: Point Connection Method; SD: Standard deviation; VC: Variation Coefficient; ICC: Intraclass Correlation Coefficient; AC: Absolute Concordance; *Student´s T-Test.

Conclusion

According to the results of the present study, the point connection technique showed an excellent ICC for HVA measurement and a very good ICC for IMA measurement. When compared to the traditional method, the new technique was not superior. Regarding the use of the smartphone application, the new method showed it can be measured by this tool with good levels of agreement.

Table 4. Concordance analysis for the IMA measurements using different methods: traditional method and point connection method

Tool	Evaluator	Method	Mean	Median	SD	VC	ICC	AC	p-value
Goniometer	Resident 1	TM	13.2	13.0	2.5	0.19	**0.54**	26.7%	**0.002**
		PC	14.9	16.0	3.6	0.24	**(0.17-0.77)**		
	Resident 2	TM	14.8	14.0	3.3	0.22	0.71	43.3%	0.075
		PC	15.6	17.5	3.6	0.23	(0.47-0.85)		
	Residents Global	TM	14.0	14.0	3.0	0.22	0.64	35.0%	**0.000**
		PC	15.3	16.0	3.6	0.23	(0.40-0.78)		
	Specialist 1	TM	13.2	13.0	2.9	0.22	**0.68**	3.3%	**0.000**
		PC	15.1	15.0	2.4	0.16	**(-0.06-0.90)**		
	Specialist 2	TM	13.8	14.0	2.8	0.20	0.80	50.0%	0.083
		PC	14.4	14.0	3.1	0.21	(0.61-0.90)		
	Specialists Global	TM	13.5	14.0	2.8	0.21	**0.73**	26.7%	**0.000**
		PC	14.8	15.0	2.8	0.19	**(0.36-0.87)**		
	Global	TM	13.7	14.0	2.9	0.21	0.68	30.8%	**0.000**
		PC	15.0	16.0	3.2	0.21	(0.43-0.81)		
App	Resident 1	TM	12.6	12.5	3.1	0.25	**0.63**	6.7%	**0.000**
		PC	15.2	15.0	3.0	0.20	**(-0.08-0.88)**		
	Resident 2	TM	13.0	13.0	3.0	0.23	**0.70**	13.3%	**0.000**
		PC	15.1	15.0	3.4	0.22	**(0.00-0.90)**		
	Residents Global	TM	12.8	13.0	3.0	0.24	**0.66**	10.0%	**0.000**
		PC	15.2	15.0	3.2	0.21	**(-0.05-0.88)**		
	Specialist 1	TM	13.0	13.0	2.6	0.20	**0.71**	3.3%	**0.000**
		PC	14.4	14.5	2.6	0.18	**(0.17-0.89)**		
	Specialist 2	TM	13.8	13.0	3.1	0.22	**0.60 (0.31-0.78)**	26.7%	**0.049**
		PC	14.3	14.0	2.9	0.20			
	Specialists Global	TM	13.4	13.0	2.8	0.21	**0.64**	15.0%	**0.001**
		PC	14.4	14.0	2.7	0.19	**(0.33-0.78)**		
	Global	TM	13.1	13.0	2.9	0.23	**0.65**	14.2%	**0.000**
		PC	14.8	15.0	3.0	0.20	**(0.23-0.82)**		

TM: Traditional Method; PC: Point Connection Method; SD: Standard deviation; VC: Variation Coefficient; ICC: Intraclass Correlation Coefficient; AC: Absolute Concordance; *Student´s T-Test.

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Original Article

Transcutaneous electrical nerve stimulation reduces acute pain, and the use of analgesics after ankle fracture surgery

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Abstract

Objective: To evaluate the applicability of transcutaneous electrical nerve stimulation (TENS) as a complementary treatment method to non-opioid analgesics for acute postoperative pain in patients undergoing surgical treatment due to ankle fractures.

Methods: A prospective, randomized, analytical, cross-sectional study performed after ankle fracture surgery. Two groups were randomized as follows: group 1 (Intervention) received TENS and non-opioid analgesic (dipyrone), and group 2 (Control) received non-opioid analgesic (dipyrone).

Results: This study demonstrated that TENS in patients undergoing surgical treatment of ankle fractures reduces the use of rescue opioids significantly to control postoperative pain.

Conclusion: TENS devices may be another safe option to control postoperative pain and reduce the use of opioids, avoiding adverse effects from this class of analgesic.

Level of Evidence II; Therapeutic Studies; Prospective Comparative Study.

Keywords: Pain, postoperative; Ankle fractures; Electric stimulation therapy; Analgesics.

Introduction

According to the International Association for the Study of Pain (IASP), pain is an unpleasant sensory and emotional experience associated with tissue injury, which may be real or potential[1].

An approach that includes pharmacological and non-pharmacological techniques is indicated for postoperative pain control. The objective is to block the generation, transmission, and perception of nociceptive stimuli, which can be done at different central and peripheral nervous system levels[2,3].

As a pharmacological approach, there are analgesics of peripheral and central action[2,3]. The prescription of analgesics should obey two aspects. One is the administration only when there is pain, and the other is the use with a certain regularity to achieve constant plasma levels avoiding acute pain peaks, the latter being a way to ensure greater effectiveness in the control of the painful stimulus[4].

Numerous non-pharmacological techniques exist in the attempt to suppress pain, activating the discriminative sensory system, such as cryotherapy, heat, acupuncture, and transcutaneous electrical nerve stimulation (TENS), among others[5,6].

Study performed at the Hospital Ipiranga, São Paulo, SP, Brazil.

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TENS is widely used for the control of chronic or postoperative pain, replacing or complementing analgesics[7,8]. It is based on the Pain Gate Theory, proposed by Melzack and Wall[9] in 1965, the modulation of pain perception performed by TENS is attributed to the recruitment of afferent Aβ fibers in the posterior horn of the spinal cord, which would prevent or hinder the activation of fine fibers which lead to pain[10]. It is postulated that electrical stimulation through the skin would inhibit the transmissions of painful impulses through the spinal cord and stimulate the release of endogenous opioids by the brain[11]. The device used in the study (Tanyx®) produces a conventional TENS current, characterized by continuous stimulation with high frequency (85 Hz), with a 75 µs wave duration and up to 30 mA intensity, with the potential to achieve painless paresthesia in the painful region or a tingling sensation[12].

Thus, this study aims to evaluate the applicability of TENS as a complementary treatment method to non-opioid analgesics of acute postoperative pain in patients undergoing surgical treatment due to ankle fractures. We hypothesized that the use of TENS in the postoperative period is directly related to the reduction of pain and the use of opioid drugs.

Methods

This study was submitted under the number (CAAE 01563518.0.0000.5488) and approved by the Institution Research Ethics Committee under the number 4,011,157.

A prospective, randomized, analytical, cross-sectional study conducted after orthopedic surgery in ankle fractures Weber A, B, and C, to collect information about patients' perception of postoperative pain. Participants were selected according to the following inclusion criteria: age between 15 and 71 years, diagnosed with ankle fractures. In addition, patients allergic to dipyrone and/or tramadol, outside the age group described, with diseases and/or conditions that contraindicated the use of TENS, who abandoned the postoperative follow-up, who did not accept the proposed treatment, patients with extensive skin lesions and those who did not accept to participate in the research by signing the Informed Consent Form were excluded from the study. The patients underwent surgery from November 2019 to August 2020. Twenty-nine (51.8%) on the right side and 27 (48.2%) on the left side.

Two groups (n=56) were randomized as follows:

Group 1 (Intervention n=28) - TENS and non-opioid analgesic (dipyrone);

Group 2 (Control n=28) - non-opioid analgesic (dipyrone).

All patients were followed up in the immediate postoperative period within 48 hours. TENS was applied to the dermatomes related to the access route used at a distance of approximately 10 cm from the surgical incision. Therefore, if two access routes for osteosynthesis were performed, two devices were used in the dermatome corresponding to the route.

TENS was used for up to 30 minutes with continuous stimulation with a frequency of 85 Hz[12], sufficient time for pain relief at an intensity already pre-determined by the device that provides three options L (low), M (medium), and H (high). Our study used the H (high) intensity in all cases. There is no restriction on the number of daily applications[13].

In case of intense pain and non-responsive to TENS and non-opioid analgesic medications, opioid analgesics, such as tramadol 100mg, were allowed as a rescue medication. The same was done in the control group.

A structured questionnaire was developed to evaluate the following criteria: Visual Pain Scale (6h, 12h, 36h, 48h postoperative (PO), time of TENS for 30 minutes (Immediate PO, 12h, 24h, 36h, 48h), comorbidities (Diabetes mellitus, Systemic Arterial Hypertension (SAH), Gout, Rheumatoid Arthritis, Dyslipidemia, and others), sex, weight, laterality of the operated limb, classification of fracture according to Weber (A, B or C), access pathway (lateral, medial, lateral and medial, posterior or other associated pathways), prescription of dipyrone 2mL + BW EV every 6h (6h, 12h, 18h, 24h, 30h, 36h, 42h, 48h PO), prescription of tramadol 100mg + 100mL SS 0.9% EV every 8h if the pain is exacerbated (8h, 16h, 24h, 32h, 48h PO) and evaluation of the physical examination.

Initially, all variables were analyzed descriptively. For quantitative variables, this analysis was performed by observing the minimum and maximum values and calculating means, standard deviations, and quartiles. Absolute and relative frequencies describe categorical variables.

The Student t-test was used to compare the means of two groups[14].

The chi-square test[14] or Fisher›s exact test[14] was used to test the homogeneity between the proportions.

For groups' comparison throughout the evaluations, the non-parametric Mann-Whitney and Friedman tests with Bonferroni correction were used[14].

The software used for the calculations was SPSS 17.0 for Windows.

The significance level used for the tests was 5.0%.

Results

Fifty-six patients aged between 15 and 71 years (mean of 39.93 with a standard deviation of 16.50 and median of 36) were evaluated.

Thirty-two (57.1%) patients were male, and 24 (42.9%) were female.

Figure 1 shows the descriptive values of weight, height, and Body Mass Index (BMI).

Figure 2 shows the patients' frequency distribution according to the BMI classification.

Most patients (80.4%) did not present any comorbidity or use of medications. Table 1 shows the absolute and relative frequencies of comorbidities and medications.

Considering the Weber classification for ankle fracture, 65.5% of the cases were classified as Weber B. Figure 3 shows the patients' frequency distribution according to the Weber classification.

Regarding the access routes, 51.8% of the cases had two incisions, one lateral and one medial, followed by the group with only lateral incisions (33.9%). Figure 4 shows the patients' frequency distribution according to the access route.

Patients were divided into two groups: 28 (50.0%) received TENS (intervention group), and 28 (50.0%) were selected for the control group.

Two devices were used in 14 (50.0%) patients in the intervention group and one in 14 (50.0%).

The pain was evaluated using the Visual Analog Scale (VAS) at 6h, 12h, 36h, and 48h.

Table 2 shows the descriptive pain values for the 56 patients, and the values reduced as time passed.

Most patients (91.1%) received eight doses of dipyrone in 48 hours, and the distribution of tramal doses varied between 0 and 2 in 48 hours. Table 3 shows the doses of dipyrone and tramal that patients used for pain relief.

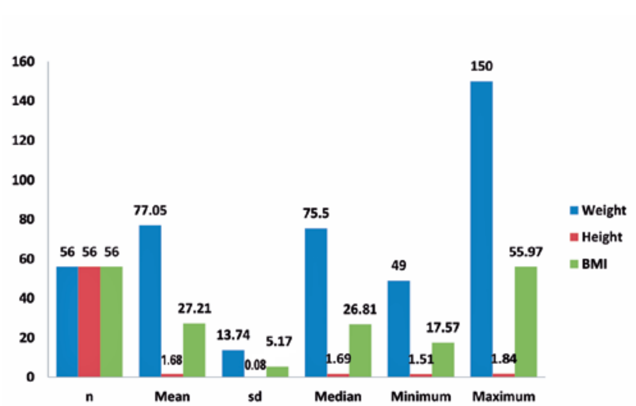

Figure 1. Descriptive values of weight, height, and BMI of the 56 patients.
BMI: Body Mass Index.

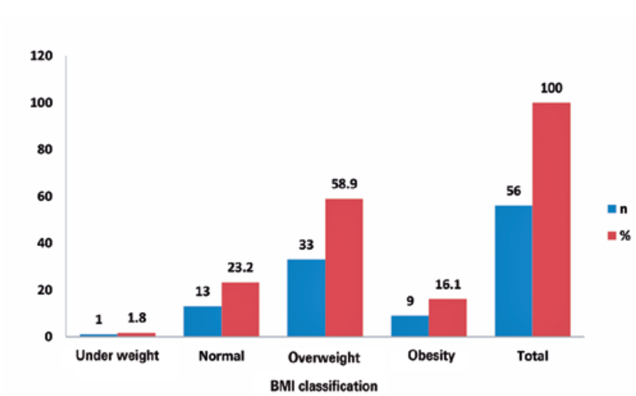

Figure 2. Patients' frequency distribution according to the BMI classification.
BMI: Body Mass Index.

Tables 4, 5, and 6 show the comparison of the two groups.

A certain homogeneity between the groups was observed. Table 4 shows the epidemiology and distribution of the variables analyzed between the groups.

For the pain study, significant differences were considered p<0.008 (use of Bonferroni correction: 0.05/6) (Table 5).

Table 1. Absolute and relative frequencies of comorbidities and medications used by the 56 patients

Variable	n	%
Comorbidity		
No	45	80.4
SAH	8	14.3
Diabetes	5	8.9
Bipolarity	1	1.8
Asthma	1	1.8
Medication		
Does not use	45	80.4
Hydrochlorothiazide	3	5.4
Enalapril	3	5.4
Losartan	3	5.4
Metformin	3	5.4
Captopril	2	3.6
Amlodipine	2	3.6
Insulin	2	3.6
Lithium	1	1.8
Quetiapine	1	1.8
Glicazide	1	1.8
Salbutamol	1	1.8

SAH: Systemic Arterial Hypertension

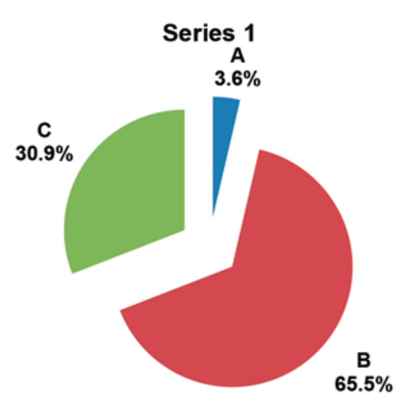

Figure 3. Patients' frequency distribution according to the Weber classification.

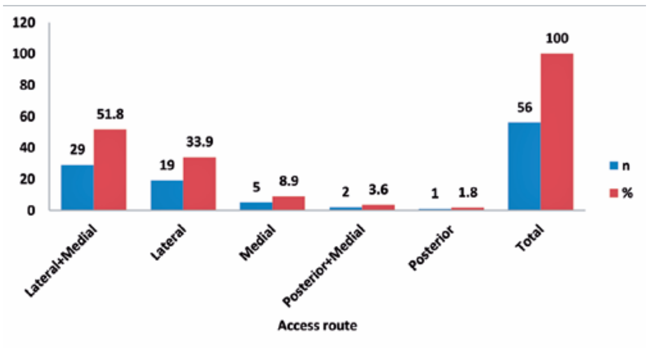

Figure 4. Patients' frequency distribution according to the access route.

Table 2. Descriptive pain values at the time of evaluation

Moment	n	Mean	sd	Median	Minimum	Maximum
6 hours	56	5.02	2.76	5.00	0.00	9.00
12 hours	56	4.50	2.56	5.00	0.00	8.00
36 hours	56	3.46	2.83	3.00	0.00	10.00
48 hours	56	2.02	2.00	2.00	0.00	6.00

Table 3. Relative and absolute frequencies to the number of doses of dipyrone and tramal used for pain relief by the 56 patients

Number of doses	n	%
Dipyrone		
2	3	5.4
3	2	3.6
8	51	91.1
Tramal		
0	15	26.8
1	19	33.9
2	11	19.6
3	7	12.5
4	2	3.6
5	2	3.6

It was observed in the non-parametric Mann-Whitney test the groups did not present significant differences at 6 hours ($p=0.360$), 12 hours ($p=0.797$), and 48 hours ($p=0.016$). At 36 hours, the intervention group had a lower significant value when compared to the control group ($p=0.004$).

Friedman's non-parametric test showed that both groups presented significant changes in pain at the moments evaluated ($p<0.001$).

Table 4. Descriptive values of pre and intraoperative variables according to the group

Variable	Group		p
	Intervention (n=28)	Control (n=28)	
Age	38.2+16.45	41.57+16.68	0.461(1)
Sex			0.105(2)
Female	9 (32.1%)	15 (53.6)	
Male	19 (67.9%)	13 (46.4%)	
BMI	27.51 + 2.73	26.92 + 6.84	0.674(1)
Comorbidity			
Absent	24 (85.7%)	21 (75.0%)	0.313(2)
SAH	3 (10.7%)	5 (17.9%)	0.705(3)
Diabetes	2 (7.1%)	3 (10.7%)	1,000(3)
Medication use	4 (14.3%)	7 (25.0%)	0.313(2)
Side			0.422(2)
Right	16 (57.1%)	13 (46.4%)	
Left	12 (42.9%)	15 (53.6%)	
Weber			0.885(3)
A	1 (3.7%)	1 (3.6%)	
B	17 (63.0%)	19 (67.9%)	
C	9 (33.3%)	8 (28.6%)	
Access			0.750(3)
Lateral	10 (35.7%)	9 (32.1%)	
Lateral + Medial	14 (50.0%)	15 (53.6%)	
Medial	3 (10.7%)	2 (7.1%)	
Posterior	1 (3.6%)	0 (0.0%)	
Posterior + Medial	0 (0.0%)	2 (7.1%)	

(1) Descriptive level of probability of Student's t-test
(2) Descriptive level of probability of chi-square test
(3) Descriptive level of probability of Fisher's exact test
SAH: Systemic Arterial Hypertension; **BMI:** Body Mass Index

At 6 hours, there is a significant difference ($p<0.001$) compared to the results at 48 hours.

At 12 hours, there is a significant difference ($p<0.001$) compared to the results at 48 hours.

At 36 hours, there was no significant difference at 48 hours ($p=0.100$).

The control group was observed:

- At 6 hours, a significant value higher than 48 hours ($p<0.001$).
- At 12 hours, a significant value higher than 48 hours ($p=0.025$).
- At 36 hours, a significant value higher than 48 hours ($p=0.025$).

Figure 5 shows the pain score according to the moment of evaluation and the group.

Table 6 shows that the groups had no significant difference in the number of dipyrone doses.

Table 5. Descriptive values of pain according to the moment of evaluation and the group

Group	Moment	n	Mean	sd	Minimum	Maximum	P25	Median	P75
Intervention	6 hours(b)	28	4.68	2.88	0.00	9.00	2.00	5.00	7.00
	12 hours(b)	28	4.57	2.62	0.00	8.00	3.00	5.00	7.00
	36 hours(a)	28	2.39	2.42	0.00	9.00	0.00	2.50	4.00
	48 hours	28	1.36	1.68	0.00	6.00	0.00	0.50	2.00
Control	6 hours(b)	28	5.36	2.64	0.00	8.00	3.25	6.00	8.00
	12 hours(b)	28	4.43	2.54	0.00	8.00	3.00	5.00	6.00
	36 hours(b)	28	4.54	2.83	0.00	10.00	2.25	5.00	6.75
	48 hours	28	2.68	2.11	0.00	6.00	0.00	3.00	4.75

Significant difference from the control group; (b) Significant difference at 48 hours.

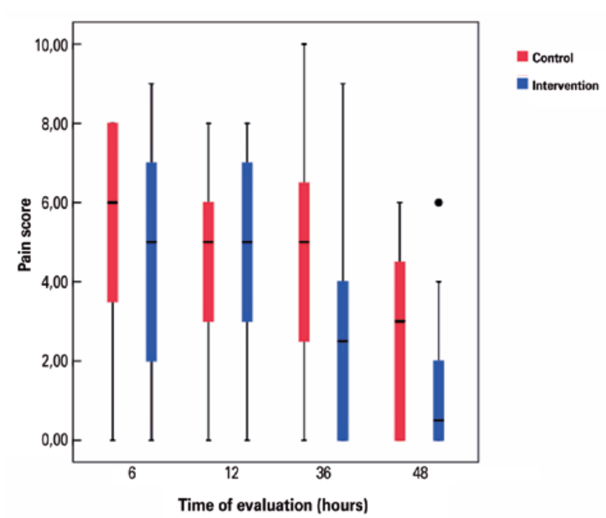

Figure 5. Box-plot of the pain score according to the moment of evaluation and the group.

Table 6. Absolute and relative frequencies of the number of doses of dipyrone and tramal used by patients, according to the study group

Number of doses	Group		p*
	Intervention (n=28)	Control (n=28)	
Dipyrone			1.000
2	1 (3.6%)	2 (7.1%)	
3	1 (3.6%)	1 (3.6%)	
8	26 (92.8%)	25 (89.3%)	
Tramal			0.045
0	11 (39.3%)	4 (14.3%)	
1	10 (35.7%)	9 (32.1%)	
2	6 (21.4%)	5 (17.9%)	
3	1 (3.6%)	6 (21.4%)	
4	0 (0.0%)	2 (7.1%)	
5	0 (0.0%)	2 (7.1%)	

(*) Descriptive level of probability of Fisher's exact test

The control group had a higher percentage of cases that used more than three doses of tramal when compared to the intervention group.

Most patients in the intervention group were administered fewer tramal doses when compared to the control group. Figure 6 shows the percentage of the number of doses of tramal according to the group.

Discussion

It was observed that using TENS in postoperative cases of ankle fracture may contribute to minimizing the patients' pain since they used fewer rescue analgesics compared with the control group.

In this study, it was observed that all patients used the prescribed analgesics, alone or in combination, in the postoperative period. This practice is seen as a positive factor, as it helps reduce pain during hospitalization and as an adjuvant in reducing infectious processes and hospitalization costs; in addition to reducing the incidence of readmissions[15,16], reducing morbidity and mortality, and providing a faster start of physiotherapy rehabilitation and earlier ambulation[17].

Tramadol is the second drug prescribed according to the pain scale described by the World Health Organization[18], is widely used in the orthopedic field in the control of moderate pain[19], and may or may not be associated with adjuvant drugs[20], as performed in this study.

Therefore, tramadol was used by most patients undergoing surgical treatment. However, this rescue opioid was used in 60.7% of the patients in the intervention group and 85.6% in the control group. Compared with the control group, the number of patients who used three or more doses of tramadol reduced significantly in the intervention group. In 39.3% of the patients in the intervention group, no rescue opioid dose was used, while in the control group, only 14.3% did not use tramadol. Another positive point when comparing the groups is the reduction of tramadol doses in the intervention group; therefore, the potential for side effects triggered using opioids such as nausea, vomiting, sweating, fatigue, sedation, and dry mouth. More severe side effects include angioedema, increased anticoagulant effects, and serotonin toxicity[21].

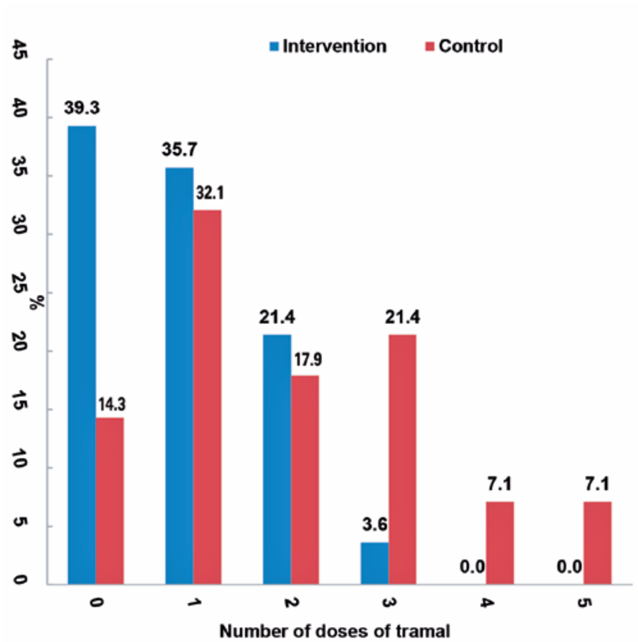

Figure 6. Percentage of the number of doses of tramal according to the group.

Lauretti et al.[22] demonstrated in a study with 44 patients with cervical pain that there was a reduction in analgesics with the introduction of TENS to control pain, also demonstrating an improvement in comfort and well-being after using this technology.

Hess and Bonaca[23] demonstrated in a study with 42 patients that the use of TENS indicated a benefit of 46% in the initial distance covered by individuals with claudication due to peripheral arterial obstructive disease, indicating, once again, that this type of stimulation causes an improvement in the quality of life of patients[23,24].

The results of this study reinforce some data found in the literature and may be related to the decrease of the painful threshold since it acts as an opioid sparer in the postoperative follow-up; thus, the lower use of these analgesics considerably reduces their adverse effects, improving treatment adherence and quality of life of patients[25]. Furthermore, such adverse effects[21] were evaluated in a meta-analysis on knee osteoarthritis, which indicated that patients receiving opioids were more likely to give up treatment[25].

As seen in these studies, TENS has its role in pain control as an adjunct in the multimodal treatment of pain processes and also contributes to the decrease in the use of analgesic opioids.

The same was demonstrated in a study in patients undergoing surgical treatment for hallux valgus, and the group that underwent neurostimulation received fewer opioids for pain control[26].

Parseliunas et al.[27] used TENS in the acute postoperative period of inguinal hernia with an improvement of the painful condition and decreased opioids in the group that used it.

Lauretti et al.[28] demonstrated TENDS's efficacy in reducing pain in patients with fibromyalgia with improved results when two devices are applied simultaneously at different sites such as the cervical and lumbar spine. The same author also reported pain improvement in patients with dysmenorrhea and cramps using TENS devices[29].

Conclusion

This study demonstrated the applicability of TENS as a complementary treatment method to non-opioid analgesics of acute postoperative pain in patients undergoing surgical treatment due to ankle fractures and observed that the TENS in the postoperative period is directly related to reducing the use of opioid drugs.

There was a reduction in the use of opioids in the intervention group compared to the control group.

Given the results, using TENS may be another safe option to control postoperative pain and reduce the use of opioids.

Author's contributions: Each author contributed individually and significantly to the development of this article: RRM *(https://orcid.org/0000-0002-2563-2085) Conceived and planned the activities that led to the study, wrote the article, participated in the review process; ASF *(https://orcid.org/0000-0001-7110-696X) Data collection, interpreted the results of the study; IMOS *(https://orcid.org/0000-0001-6171-9092) Conceived and planned the activities that led to the study, data collection; MLND *(https://orcid.org/0000-0002-0565-4973) Data collection, interpreted the results of the study; RLGL *(https://orcid.org/0000-0001-5058-3986) Data collection, bibliographic review; EF *(https://orcid.org/0000-0002-8068-3440) Bibliographic review, participated in the review process; IDA *(https://orcid.org/0000-0002-4074-0412) Participated in the review process, interpreted the results of the study; LMRR *(https://orcid.org/0000-0001-6891-5395) Participated in the review process, interpreted the results of the study; RYI *(https://orcid.org/0000-0001-7718-1186) Conceived and planned the activities that led to the study, 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

Distal Metatarsal Metaphyseal Osteotomy (DMMO) for lesser toe metatarsalgia: a case series of 195 osteotomies

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Abstract

Objective: The aim of the study was to radiographically evaluate the result of this minimally invasive technique for the surgical treatment of metatarsalgia.

Methods: Radiographic images of 195 osteotomies in 48 patients (65 feet) who were exclusively submitted to the Distal Metatalsal Metaphyseal Osteotomy (DMMO) technique in the central rays (second, third, and fourth metatarsals) with a minimum follow-up of six months were analyzed. Bone healing, metatarsal shortening, and bone healing positioning (central, lateral, or medial) were evaluated. All statistical analysis was performed using the R software, and Wilcoxon statistical tests and Student's *t*-test paired for continuous variables were used.

Results: The mean length of the second metatarsal reduced 7.0mm ($p<0.001$), the third 6.8mm ($p<0.001$), and the fourth 6.6mm ($p<0.001$). In only one case, there was no bone consolidation (second metatarsal). Most osteotomies were consolidated in a central position of the distal fragment.

Conclusion: DMMO showed a high rate of bone healing (99.5%), metatarsal shortening, and consolidation in the central position of the distal fragment when performed in the surgical treatment of metatarsalgia.

Level of Evidence IV; Case Series.

Keywords: Forefoot, human/injuries; Metatarsalgia; Metatarsal bones; Minimally invasive surgical procedures; Osteotomy.

Introduction

Primary metatarsalgia is caused by an anatomical imbalance due to the relative length of the metatarsal bones[1,2]. Without this, harmony can create an unequal mechanical overload, resulting in callosities, pain, and plantar plate rupture[3]. Therefore, initial treatment is conservative with modification of shoes, symptomatic medication, and physiotherapy. When this approach is unsuccessful, surgical procedures are indicated[2].

The surgical procedure aims to shorten and elevate the metatarsal head to relieve pressure in the plantar region of the forefoot and restore optimal harmony to the metatarsal parabola. Some open osteotomies have been described, and one of the most used is Weil osteotomy[4]. Although it has been considered an effective, safe procedure and used by several surgeons, the osteotomy described by Weil has been associated with some complications, such as the so-called floating toe, transfer metatarsalgia, and stiffness[5].

Study performed at the Orthopaedics and Traumatology Unit, Prevent Senior, São Paulo, SP, Brazil.

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In the development of minimally invasive techniques for foot and ankle surgery, Redfern and Vernois[6] described a percutaneous metatarsal osteotomy described as Distal Metatarsal Metaphyseal Osteotomy (DMMO).

The advantages surrounding this minimally invasive osteotomy include the reduced time of surgery with less soft tissue dissection. Furthermore, the technique showed fewer scars while maintaining a range of motion and faster recovery due to immediate weight-bearing in the postoperative period[1,3].

Although the pioneers of the technique claim that DMMO can be used to correct metatarsophalangeal dislocations requiring up to 5mm of metatarsal shortening[7], others concluded that due to the limitation in restoring the ideal foot morphology, this procedure should not be indicated in cases of metatarsophalangeal dislocation[8].

Thus, measuring the length of shortening and the position of metatarsal consolidation after the osteotomy is important, as DMMO is not performed with fixation.

The aim of the study is to radiographically evaluate the result of this minimally invasive DMMO technique for the surgical procedures of metatarsalgia through the outcomes of bone non-union rate, shortening of the metatarsals, and the position of osteotomy consolidation.

Methods

The study was approved by the local ethics committee (CAEE: 32875620.8.0000.5474) and followed the Declaration of Helsinki and the Guidelines for Good Clinical Practice.

The radiographic images of 48 patients diagnosed with metatarsalgia submitted to surgical correction using the DMMO technique were retrospectively evaluated, totaling 65 feet, between December 2017 and December 2019.

All patients were operated on at two orthopedic centers and always by the same team of experienced surgeons specialized in the foot, ankle, and percutaneous surgery.

Inclusion and exclusion criteria

The study included patients with metatarsalgia (pain with callosities in the plantar region of the forefoot or metatarsophalangeal instability) submitted to conservative treatment without improvement for at least six months and undergoing surgical treatment using the DMMO technique. The radiographs included in the study were the preoperative and the last available in the system.

The exclusion criteria were: 1) DMMO associated with metatarsal osteotomies for hallux valgus correction; 2) Inappropriate radiographs; 3) Radiographs not taken at the research centers; 4) The last radiograph less than six months after the surgical procedure; 5) Patient under 18 years of age.

Radiographic evaluation

Four authors performed the radiographic evaluation (HNF, VO, GAN and ACB) after the senior researcher reached a consensus and agreed with the evaluation (MVPF). The analysis was performed digitally using the Centricity® Universal Viewer Zero Footprint software system (GE Healthcare, Barrington, IL, USA). All radiographs were taken in a weight-bearing, standing position.

Radiographs were the method to define bone union and the position of the distal fragment (lateral, central, or medial). It was considered lateral or medial deviation if the cortex of the distal fragment exceeds the center of the diaphysis of the proximal fragment, either laterally or medially. The bone union was defined as the formation of bridging calluses in two radiographic views.

The length of second, third and fourth metatarsals (pre-/postoperative) was also measured digitally, from the center of the base to the center of the head. Follow-up period was defined as the difference between the surgical procedure and the last radiograph.

Surgical technique and postoperative care

The surgical procedure was performed in the supine position with the feet at the end of the table, without a tourniquet, and submitted to spinal anesthesia as an institutional protocol. The technique followed the description in the study by Redfern and Vernois[6].

A 2.0mm Shannon-type burr, a scalpel blade for percutaneous surgery and an image intensifier was used to locate the osteotomy and the final check. First, the incision was performed using a specific scalpel blade and located with an image intensifier. Then, the periosteum detacher is used for the soft tissue dissection and the metatarsal. Finally, the DMMO was performed in the distal metaphysis in a plane of 45 degrees to the metatarsal axis in the sagittal plane and ending at 90 degrees. The procedure is performed through a rotational movement with supination of the wrist.

After the osteotomy, local cleaning was performed with saline solution and skin suture with 4-0 nylon. Next, the dressing was prepared with sterile gauze and then finished with an elastic bandage.

Postoperative care recommended early ambulation with a stiff soled sandal and full load as tolerated, weekly dressing change, and control radiographs after six weeks.

Statistical Analysis

The statistical analysis was performed using the R software[9] (The R Foundation, Vienna, Austria). Mean, standard deviation (SD), maximum and minimum were calculated for numerical variables, and descriptive statistics for nominal variables. The Shapiro test was used to assess the distribution of the continuous variables, the paired Student's *t*-test[10] for variables with parametric distribution, and the Wilcoxon[11] signed-rank test for non-parametric variables. The $p \leq 0.05$ value was adopted as the level of statistical evidence.

Results

DMMO was performed in 195 metatarsals, 65 feet, in 48 patients. The mean age was 65.9 years, and the SD was 10.1 years. Patients were predominantly female (89.5%), and the left was the most common side (50.8%). The mean follow-up period was 18.2 months (SD 8.3).

Bone union was individually assessed by metatarsal, and only one case of bone non-union was found representing 0.5% (second metatarsal). All third and fourth metatarsals had bone union. Table 1 shows the metatarsal head deviation.

The mean length of the second metatarsal reduced 7.0mm ($p<0.001$), the third 6.8mm ($p<0.001$), and the fourth 6.6mm ($p<0.001$). Figure 1 shows the length distribution.

Discussion

DMMO is an extra-articular metatarsal osteotomy performed percutaneously without any fixation, in which metatarsal lengths are automatically adjusted upon weight-bearing through the interaction of soft tissue structures[1]. On the other hand, DMMO has been accompanied by swelling, longer consolidation time, limitation in recreating the ideal foot morphology, and greater metatarsal shortening[3,8].

Our study presented one case of metatarsal bone non-union among 195 osteotomies performed, representing a union rate of 99.5%. This complication was smaller when compared to Weil's open technique, described in around 3%[12].

In the study by McMurrich et al.[13], the authors performed the DMMO with bone consolidation in all osteotomies and were evaluated by radiographic images. Haque et al.[1] performed DMMO in a total sample of 30 patients and had one case of bone non-union.

Bone non-union or delayed union may be a complication with clinical repercussions such as pain and swelling. Although this study did not perform the patients' clinical evaluation, the only case with bone non-union was not submitted to surgical revision, inferring the probable fibrous union, as described by Ferreira et al.[14], in the percutaneous oblique distal osteotomy of the fifth metatarsal.

After the DMMO, there was an expected shortening of the metatarsals: the second metatarsal represented the greatest reduction, followed by the third and fourth. This shortening differs from the McMurrich et al.[13] study, where the third represented the greatest difference, followed by the fourth and second metatarsal.

In addition, the mean shortening was higher in our study. Still, the comparison with other studies may show a measurement bias due to the absence of the pattern of radiographic images and different digital software.

The position of bone consolidation of the distal fragment was classified as central in most osteotomies. This result could be due to the non-inclusion of cases in which osteotomies were performed to correct the hallux valgus because the distal fragment tends to be displaced to the lateral region, for example, in the Percutaneous Chevron-Akin technique[15]. Weight-bearing computed tomography would be ideal for performing these measurements, but availability is still very limited.

Table 1. Postoperative radiographic results

Outcome	Second metatarsal	Third metatarsal	Fourth metatarsal
Position of the Distal Fragment	Central = 80.0% Medial = 0% Lateral = 20.0%	Central = 75.4% Medial = 3.1% Lateral = 21.5%	Central = 81.5% Medial = 12.3% Lateral = 6.2%
Bone Union	98.5%	100%	100%

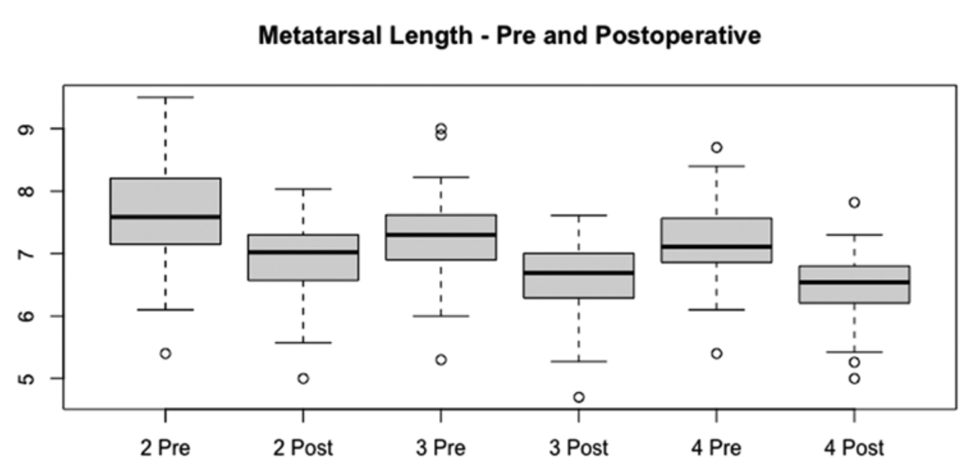

Figure 1. Distribution of metatarsal length before and after the surgical procedure.

The results suggest that the DMMO technique has a high rate of bone union in osteotomies and that the surgeon often must wait at least six months in cases where there is a delay in the bone union process.

Our study has some limitations. First, clinical and functional analyses were not included. Second, radiographic measurements show intra- and inter-examiner variations. Third, the study did not assess bone union time. Finally, the study would have more strength if weight-bearing computed tomography was used for pre-/postoperative evaluation.

Conclusion

DMMO showed a high rate of bone healing (99.5%), metatarsal shortening, and consolidation in the central position of the distal fragment when performed in the surgical treatment of metatarsalgia.

Author's contributions: Each author contributed individually and significantly to the development of this article: GFF *(https://orcid.org/0000-0001-8032-3077) Performed the surgeries, wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study, statistical analysis and collected the data; HNF *(https://orcid.org/0000-0002-9261-3757) Wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study and collected the data; VO *(https://orcid.org/0000-0002-1087-046X) Wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study and collected the data; GAN *(https://orcid.org/0000-0003-4431-5576) Wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study; ACB *(https://orcid.org/0000-0002-2894-9715) Wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study; MVPF *(https://orcid.org/0000-0002-2320-9769) Performed the surgeries, wrote the article, participated in the review process, bibliographic review, formatting of the article, interpreted the results of the study, statistical analysis and collected the data. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Primary subtalar arthrodesis in the treatment of comminuted calcaneal fractures: a functional and quality of life analysis

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Abstract

Objective: To survey literature findings on primary arthrodesis in Sanders type III and IV fractures and analyze functional and quality of life outcomes in patients submitted to this initial surgical procedure.

Methods: This study described the profile of 12 patients diagnosed with severe comminuted intra-articular calcaneal fractures of Sanders type III and IV operated by a foot and ankle team. Patients attended from January 2016 to August 2021 with pre-/postoperative follow-up and application of the Orthopedic Foot and Ankle Score (AOFAS) questionnaire and Short Form Health Survey 36 (SF-36) quality of life questionnaire, along with clinical evaluation, were included. Data search was performed using the following online databases: PUBMED, MEDLINE, LILACS, and SCIENCE.

Results: Most patients had a good range of motion, a mean AOFAS score of 81.71 points, and high mean scores in the domains physical functioning (84.44 points), role-physical (5.55 points), bodily pain (23 points), and general health (96.11 points) according to the SF-36 questionnaire. In general, there was bone consolidation after primary arthrodesis of the subtalar joint, and the functional status of patients was satisfactory.

Conclusion: Primary arthrodesis is a relevant choice in fractures with more than three fragments, with a better postoperative outcome, including pain and maintenance of the hindfoot axis. Larger studies should be performed to assess more results of primary arthrodesis as a first treatment option for Sanders type III and IV fractures.

Level of Evidence IV; Therapeutic Study; Case Series.

Keywords: Calcaneus; Fractures, bone; Orthopedic procedures/methods; Quality of life; Surveys and questionnaires.

Introduction

Calcaneal fractures are the most prevalent foot fracture, accounting for 65% of tarsal bone fractures and 2% of all body fractures(1,2). The treatment of comminuted intra-articular calcaneal fractures is controversial in some randomized studies published in the literature; however, both the surgical and the conservative treatments undoubtedly present pros and cons, as well as relevant risk factors for unfavorable evolution(3). Patients with this type of injury may develop painful post-traumatic subtalar arthritis, requiring fusion regardless of the initial choice of treatment(1).

Calcaneal fractures result from low- or high-energy injuries, and bilateral involvement is rare in less than 10% of cases(4). Regarding the mechanism of injury, the main contributing force of the mechanism of fracture in more than 60% of cases is the axial load, often due to a fall from height(4). The excessive axial load transferred to the Gissane's angle determines a primary fracture line that affects the neutral triangle (region with sparse trabeculae under the subtalar bone)(4).

The population segment most affected by this condition is working-age adult men. Almost 75% of cases are intra-articular fractures and commonly evolve with a poor functional

Study performed at the Hospital de Urgências de Goiânia, Goiânia, Goiás, Brazil.

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outcome, including not being able to return to work with full working capability, which generates clinical and socioeconomic effects[4].

In 1952, Essex-Lopresti[5] described a classification system that divided calcaneal fractures into two types: intra-articular and extra-articular types, also known as joint depression fractures and tongue fractures. This classification is based only on plain radiograph, specifically lateral view.

The Sanders classification for calcaneal fractures is based on coronal computerized tomography sections. It considers the displacement and the number and location of fracture lines below the surface of the posterior facet of the talus, which is divided into three columns (the lateral, central, and medial columns) by three lines (A, B, and C) from the lateral to the medial column[4,6]. This classification can be briefly divided into:[6]

- Type 1: Fractures with less than 2mm of displacement;
- Type 2: Fractures into two parts with one fracture line, divided into three subtypes based on the fracture line location: lateral (IIA), central (IIB), or medial (IIC);
- Type 3: Fractures into three parts with two fracture lines, divided into the following subtypes: IIIAB (one lateral and one central to the posterior facet and subtalar joint); IIIAC (one lateral and one medial to the posterior facet and subtalar joint); IIIBC (one central and one medial to the posterior facet and subtalar joint); and
- Type 4: Comminuted fractures[6].

Surgical treatment of calcaneal fractures was first described in 1948 by Palmer apud Wei et al.[6] and, later, by Essex-Lopresti[5], in 1952, aiming to reduce the subtalar joint, as incomplete reduction causes unsatisfactory functional outcomes and an 1mm deviation was sufficient to alter the posterior facet and cause gait disturbances.

Though conservative treatment eliminates the risks associated with the surgical procedure, there is often a symptomatic malunion when no attempt is made to restore the height, hindfoot alignment, and talus inclination based on the subtalar and calcaneocuboid joints[1].

Sanders and other authors observed that surgical treatment could relieve the pain, reestablish a plantigrade foot, and improve patient function[1]. In comminuted intra-articular fractures of the calcaneus into three or more parts (Sanders type III and IV), it is more difficult to restore the joint anatomy and congruency, the calcaneal height, and the talus-calcaneus relationship; thus, studies evidenced that primary subtalar arthrodesis is beneficial as an initial surgical intervention and as a definitive treatment for these fracture types[1,3].

Methods

This study was approved by the Research Ethics Committee. All participants signed an informed consent form.

This study presents a retrospective, descriptive analysis of 12 patients with calcaneal fractures operated at an emergency tertiary public hospital with residency training in orthopedics and traumatology. These patients were attended from January 2016 to July 2021 and submitted to primary arthrodesis of the subtalar joint after receiving an initial diagnosis of Sanders type III or IV intra-articular calcaneal fracture, not requiring bone graft. All patients were operated on by the same ankle and foot surgical team, observing their clinical and soft tissue conditions for osteosynthesis, with implants available in the public health system.

The following descriptive variables were analyzed: age, sex, involved side, accident type, number of surgeries, consolidation time, and mean follow-up period. The parameters calcaneal axis and measure of Böhler and Gissane's angles after surgery were also analyzed.

All patients were evaluated, and radiographs were performed in all outpatient follow-up visits, at least 2, 4, 8, 12 weeks, 6 months, and 1 year after surgery. This study describes the mean score for each follow-up visit of Orthopedic Foot and Ankle Score (AOFAS) and Short Form Health Survey 36 (SF-36) questionnaires.

The standardization of the clinical and functional outcome analyses is represented using the AOFAS Ankle-Hindfoot Scale and SF-36 quality of life questionnaires.

The AOFAS Ankle-Hindfoot Scale is composed of nine items distributed into three categories: pain (40 points), functional aspects (50 points), and alignment (10 points), totaling 100 points. The score is found by adding points, where 80-100 is excellent; 60-80, good; 40-60, fair; and >40, poor[7].

The SF-36 questionnaire is an instrument for quality-of-life and is composed of 36 items distributed into eight domains: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. Scores range from 0 to 100, from the worst to the best health status[8].

Surgical Technique

All patients were operated in full lateral decubitus position with an elastic tourniquet. Extended lateral approach was performed in 'L' in a single plane, with direct subperiosteal dissection and no skin delamination to avoid skin necrosis and suffering for an extended approach. Dissection of the plane close to the bone at the lateral calcaneal wall must be performed using a sharp dissector, as the lateral wall comminution may hinder such dissection close to the cortical surface. Dislocation of fibular tendons must be performed along with this skin flap, and spacing must be performed with due care. Anchoring with 1.5mm Kirschner wire in the fibula and talus is used as fixed space maintainer, avoiding soft tissue distancing and traction and minimizing the risk of injuries to the skin, leaving the hands of a surgical assistant free.

Upon the fracture realignment, the first parameter to be considered is the depressed posterior facet that needs to be elevated using the talus facet as a control to reestablish the calcaneal height and width. Keeping the parallelism between the posterior calcaneal facet and the talus helps restoring these height and pitch parameters, maintaining such reduction with Kirschner wires. Then, the exeresis of subtalar joint surface cartilages is performed, and the arthrodesis is fixed with radioscopic aid using two or three 7.0mm cannulated screws inserted from the plantar to the dorsal aspect through the calcaneus to the talus. In some cases, a calcaneal plate was also used at the lateral wall-a decision made intraoperatively when there is an important lateral comminution and a central void with no bone support, causing a great lateral instability (Figure 1). The calcaneal plate was fixed using 3.5mm cortical screws in the posterior and anterior portions with no pattern, but according to the fracture personality, keeping the calcaneus positioning with a 0-5 valgus degree. In cases of major lateral comminution, the supporting plate reduces the calcaneus width and adds stability. In all cases, a suction drain was placed, and a two-layer closure was performed using 2-0 absorbable sutures subcutaneously and 4-0 nylon sutures on the skin layer. The drain was removed on the second postoperative day, always immobilizing the limb in plaster cast. All patients initiated the ankle joint early mobilization with no weight-bearing for eight weeks. Full weight-bearing was allowed when subtalar joint fusion and consolidation were evidenced, on average, 10 to 12 weeks postoperatively (Figure 2).

Results

From January 2016 to July 2021, 12 patients were submitted to surgery for calcaneal fractures. All patients were followed up at 2, 4, 8, 12 weeks, 6 months, and 1 year postoperatively. Patients were clinically evaluated using the AOFAS scale and SF-36 questionnaire. During the follow-up period, comparative radiographs were performed to assess the joint fusion, bone consolidation, and possible signs of osteoarthritis in adjacent joints. The operated hindfeet presented neutral or valgus alignment, and the calcaneal axis was fully restored in all cases. All patients ambulated without crutches.

Subtalar joint range of motion in operated feet was 0º in all patients, and ankle instability was not observed. Most patients did not report pain; only one patient reported pain after weight-bearing was allowed.

Male sex was the most prevalent (66.7%), the right side was the most involved (58.3%), and the mean age was 42.75 years (range 23 to 61 years), with a median of 44.5 years and a standard deviation of 13.15727. Fractures were caused by high-energy injuries-nine by falls from height and three during motorcycle accidents-, and all of them were closed fractures.

All fractures were firstly evaluated in the emergency care setting, and below-knee plaster cast immobilization was performed. Surgeries were performed as soon as an edema reduction and improvement in the soft tissue condition were observed, about 15 days from fracture. No skin necrosis was

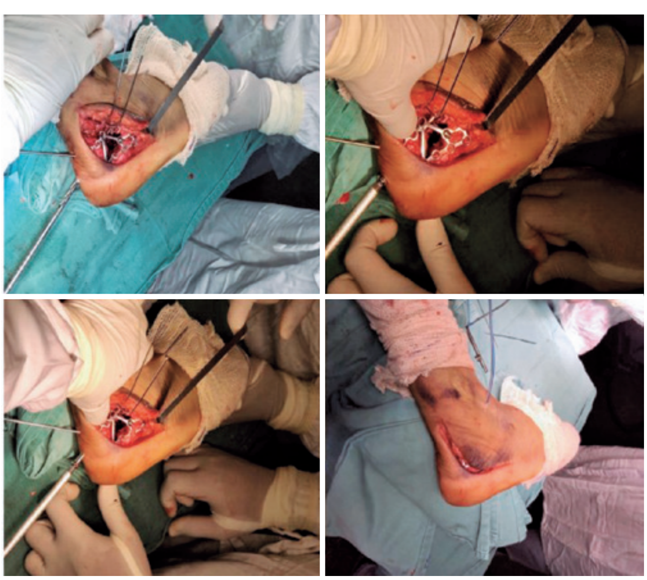

Figure 1. Lateral approach in 'L'; Kirschner wires keeping the spacing between soft tissues and aiding in the reduction; and calcaneal fracture fixation with lateral support plate and cannulated screws.

Source: Author's personal archive.

Figure 2. Follow-up radiograph of a 47-year-old patient at 90 days postoperatively showing complete subtalar joint fusion after arthrodesis with plate and cannulated screws.

Source: Author's personal archive.

seen in operated patients; however, there was a skin infection in the cannulated screw route, with synthesis material removal after bone consolidation.

Most patients presented a good range of motion, obtaining a mean AOFAS score of 82.25 points (out of 100 possible points), with a median of 80.5 points and a standard deviation of 5.41, a minimum value of 76, and a maximum of 92 points. The AOFAS scores are detailed in table 1. As for the SF-36 questionnaire, high means were observed in physical functioning, role-physical, bodily pain, and general health, with 84.16, 93.75, 78.5, and 90.58 points, respectively. It should be stressed that, in the role-physical or bodily pain scores, the closest the score to the 100 points possible, the better the patient outcome, the lesser the incapacity, or the lesser the pain during postoperative follow-up. Data related to the SF-36 questionnaire are shown in table 2.

Table 1. AOFAS questionnaire result per patient

Patient	AOFAS Score
N. 1	76
N. 2	89
N. 3	81
N. 4	84
N. 5	80
N. 6	92
N. 7	79
N. 8	78
N. 9	76
N. 10	78
N. 11	88
N. 12	86

Table 2. SF-36 quality of life questionnaire result

Patient	Evaluated Aspects			
	Physical Functioning	Role-Physical	Bodily Pain	General Pain
N. 1	90	100	69	97
N. 2	90	100	79	92
N. 3	70	75	90	100
N. 4	70	75	58	100
N. 5	95	100	69	82
N. 6	90	100	90	100
N. 7	70	100	90	100
N. 8	90	100	79	97
N. 9	95	100	69	97
N. 10	65	75	62	62
N. 11	90	100	95	77
N. 12	95	100	92	83

Description 1: 0 = worst condition and 100 = best condition
Source: Microsoft Excel version 16.54, 2021.

All parameters considered in the study are detailed in table 3.

Discussion

Intra-articular fractures with acute calcaneal comminution cause a loss in the hindfoot height, directly hindering the force vectors of a stable, functional gait and quality of life aspects, such as wearing shoes[1].

Many authors agree that treating Sanders type III and IV calcaneal fractures is challenging and that the calcaneal joint surface is often extensively damaged[7,8].

Surgical treatment is indicated in intra-articular calcaneal fractures with displacement, especially when the posterior facet is affected, aiming to restore the anatomy of joint surfaces and reestablishing the joint function[9,10].

General analysis of Liu et al.[3] showed that surgery is still required in case of intra-articular calcaneal fractures with displacement (RR 4.40, 95% CI [2.62-7.39], p<0.001) to restore the Böhler's angle and the calcaneus height and width, enable patient to return to their former professional activities with a better functionality, and restore the anatomical structures of the calcaneus[2].

According to Sanders et al.[11] and Wei et al.[6], about 70% of Sanders type IV comminuted calcaneal fractures evolve to post-traumatic arthritis, while 73% of fractures evolve to secondary subtalar arthrodesis. Several studies corroborate the idea that cases with major depression of the Böhler's angle are at high risk of developing painful post-traumatic arthrosis, despite all operative fixation and anatomical joint reduction techniques available, ultimately evolving to subtalar arthrodesis[9,10,12-15]. Recognizing this fact indicates an increase in the incidence of primary subtalar arthrodesis[12,16], in addition to other functional and radiographic data demonstrating that patients who underwent primary arthrodesis obtained more favorable functional outcomes than those who underwent primary reconstruction with residual subtalar motion[12,15,17,18]. Likewise, in this study, which involved 12 patients, the mean AOFAS score was 82.25 points, and high means were observed in the SF-36 domains of physical functioning (84.16), role-physical (93.75), bodily pain (78.5), and general health (90.58). As the closest to 100 points, the better the outcome, all patients achieved little limitation and pain, a better health condition, and better physical functioning. This study's data corroborate the literature, reiterating that primary subtalar arthrodesis may be considered in patients with Sanders type III and IV intra-articular fractures with important displacement[8,17,18].

Buckley et al.[2] gathered data from 14 patients with comminuted intra-articular fractures of the calcaneus treated with primary subtalar arthrodesis and followed up for 26 months postoperatively. The mean AOFAS score was 72.4 points, and the authors concluded that primary subtalar fusion is the treatment of choice for Sanders type IV fractures and that primary arthrodesis produces better clinical outcomes than secondary arthrodesis[2].

Table 3. Statistical data, such as fracture time until surgery, and post-arthrodesis correction parameters, such as valgus, Böhler's angle, and Gissane's angle

Patient	Sex	Laterality	Age	Fracture Time	Sanders Type	Valgus	Böhler's Angle	Gissane's Angle	Fixation Type
1	Male	Right	38	15	III	0	36	120	Plate and cannulated screws
2	Male	Left	47	13	IV	2	32	130	Plate and cannulated screws
3	Female	Left	44	10	IV	3	41	122	Plate and cannulated screws
4	Male	Right	52	8	I I I	5	31	126	Cannulated screws
5	Male	Right	57	9	II I	0	27	136	Cannulated screws
6	Male	Left	61	11	I V	1	28	127	Cannulated screws
7	Male	Right	35	9	I V	0	25	135	Plate and cannulated screws
8	Female	Right	30	10	I II	4	30	124	Plate and cannulated screws
9	Male	Left	45	12	IV	3	29	140	Plate and cannulated screws
10	Male	Right	58	13	I II	2	23	137	Cannulated screws
11	Female	Right	23	11	IV	0	26	133	Cannulated screws
12	Female	Left	23	14	IV	5	34	128	Cannulated screws

Holm et al.[12] conducted a comparative study involving 17 patients with extremely comminuted calcaneal fractures submitted to primary arthrodesis to assess which radiographic parameters were predictive of functional outcome. Patients were operated through an extended incision made over the sinus tarsi instead of through an extended lateral approach to reduce soft tissue damage. The mean AOFAS score was 78.4 (range 56 to 92), with a mean follow-up duration of 34 months. The authors considered that the best functional outcomes were achieved in younger patients (p=0.028), with a greater percentage of Böhler's angle and talocalcaneal restoration (p=0.038 and p=0.049, respectively)[12]. In this study, the laterality (p=0.355), sex (p=0.371), age (p=0.313), fracture time (p=0.374), Sanders classification (p=0.355), and post-arthrodesis valgus (p=0.410) parameters were not statistically significant as predictive of the AOFAS functional score. It should be stressed that the essential Böhler and Gissane's angles and the calcaneus height were restored with a good correction, and all patients presented bone consolidation, corroborating the findings described in the literature, which the bone fusion rate is 65-100%[19] and the pseudoarthrosis rate is 0-24%[20] after primary arthrodesis.

Conclusion

Primary arthrodesis of the subtalar joint is a treatment option for patients with Sanders type III and IV calcaneal fractures, promoting good outcomes by observing the injury profile. In addition, it is widely recognized as a good method to be considered during surgical procedures.

In care settings facing difficulties performing secondary arthrodesis, such as lack of beds and other inputs, primary subtalar arthrodesis may be considered the main treatment for Sanders type III and IV calcaneal fractures, as already described in current literature.

Larger studies should be performed to evaluate more results of primary arthrodesis as the treatment of choice for Sanders type III and IV fractures, disregarding the short sample used in this study.

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Case Report

Idiopathic hallux saltans an unusual presentation of flexor hallucis longus tendinopathy: a case report

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Abstract

Hallux saltans is a rare condition characterized by an entrapment of the flexor hallucis longus. Its tendon passes through the retromalleolar groove below the flexor retinaculum, directing the plantar aspect of the foot through a fibro-osseous tunnel below the sustentaculum tali. This study presents a young active patient without any of the conditions or etiological agents previously described in the literature that could explain the cause of this rare condition. After failing conservative treatments, an arthroscopic release of the tendon and the fibrous tunnel was performed, achieving direct visualization and minimal soft tissue injury. At six month follow-up, the patient resumed sports and daily living activities without symptoms.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Tendinopathy; Tendon entrapment; Trigger finger disorder; Arthroscopy; Case reports.

Introduction

Hallux saltans is a rare condition characterized by an entrapment of the flexor hallucis longus (FHL) tendon in its pathway through the intercolicular fibro-osseous tunnel of the talus. It is mainly caused by the tendon thickening before entering the distal part of its sheath, which could also be thickened and stenotic, increasing the tendon's nodular changes[1].

The FHL is a muscle of the posterior leg compartment that arises from the posterior part of the fibula and interosseous membrane. Its tendon passes through the retromalleolar groove below the flexor retinaculum, directing the plantar aspect of the foot through a fibro-osseous tunnel below the sustentaculum tali, ending up inserted at the base of the hallux distal phalanx. Its main function is flexion of the hallux metatarsophalangeal and interphalangeal joints[2].

This infrequent pathology has commonly been related to sports that require excessive plantar flexion, such as classical ballet dancers, soccer, downhill runners, and gymnasts, between the second and fourth decades of life[1,3]. The typically described locations for FHL entrapment are the retromalleolar FHL sheath (most frequent), within the fibro-osseous tunnel below the sustentaculum tali, at Henry's master knot, and behind the intersesamoid ligament[2].

Causes depend upon the site of entrapment. Although considered an idiopathic condition, some authors have implied a relationship between FHL entrapments to Os Trigonum, an osteochondral structure created by a secondary chondral ossification center at the level of the posterior margin of the talus and Stieda process[3]. Other less common causes may be space-occupying cystic formations, accessory flexor digitorum longus, calcaneal fractures, ankle arthrodesis, and tumors such as chondromas within the tendon sheath and lipochondromatosis[3,4].

Symptoms are similar to its analog in hand: a preserved flexion movement with a sudden release during extension caused by the thickened tendon (trigger effect). However, the degree of movement restriction could vary from a simple snapping to a joint blocked in flexion that needs a manual extension to release deformity, with variable associated retromalleolar pain[3].

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

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A patient was diagnosed with the symptoms above and confirmed by dynamic ultrasound reproducing the tendon snapping through a restricted tunnel or a magnetic resonance imaging showing tendon enlargement upon tunnel entrance(5).

Conservative treatments such as rest, ice, non-steroidal anti-inflammatory drugs (NSAIDs), physiotherapy, bracing, or local corticosteroid injections sustain satisfactory results in 46% to 64% of cases. However, surgical approaches are recommended when those treatments fail(6).

Case description

The study was approved by the Research Ethics Committee of the institution and the patient signed the informed consent form.

A 23-year-old male patient with no previous trauma had a two-year history of audible painless snaping of the great toe during active flexion and intermittent locking in a flexed position that needed passive correction.

The radiographs showed no bone deformities such as os trigonum or Stieda process. A musculoskeletal radiologist performed dynamic sonography with a high-frequency linear transducer. FHL tendon was thickened and hypoechoic, determining tendon entrapping with active and passive flexion at the fibro-osseous FHL tunnel at the posterior ankle chamber, along with narrowing of the tunnel itself. No images of fibrillar ruptures were found. The magnetic resonance imaging revealed significant fusiform thickening of the FHL tendon, at the level of the posterior margin of the talus, with a slight thickening of the synovial sheath, without evidence of dislocation or rupture and increased amount of fluid with inflammatory alteration of the proximal synovial sheath (Figure 1).

Conservative treatments were performed with an orthopedic boot, physiotherapy, NSAIDs, sports rest for 21 days, and ultrasound-guided corticosteroid infiltration. At three month follow-up, the patient returned to consult with the symptoms still present, and surgical treatment was indicated.

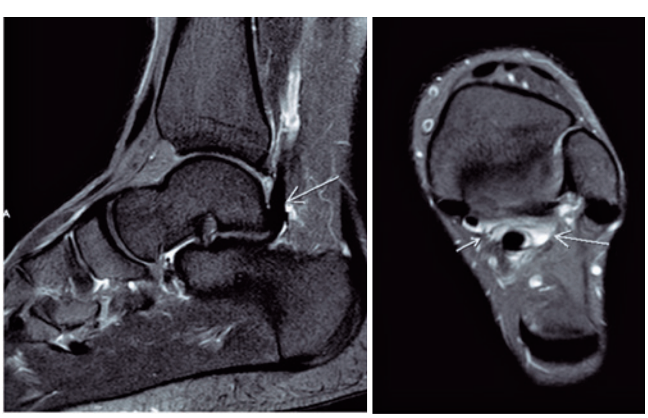

Figure 1. Sagital and axial section of the ankle in T2 showing fusiform thickening of the FHL tendon, at the level of the posterior margin of the talus and tenosynovial inflammatory infiltrate of the medial retromalleolar FHL tendon.

The patient was in a prone position, under regional anesthesia and using a tourniquet hemostatic. A posterior arthroscopic with a 3.0 mm 30° arthroscope and 3.5 shavers was performed by an experienced orthopedic surgeon in a district general clinic.A peritendinous sheath release was performed, partial resection of the fibro-osseous tunnel, and tendon thinning by resecting the excessive scar tissue (Figure 2). No accessory muscles, low muscle belly, or tendon rupture were identified. Due to muscle relaxation, the snapping could not be reproduced during surgery. Despite this, a careful release to avoid stenosis of the tendon in the tunnel was performed. After tenosynovectomy and release, the ankle and FHL were mobilized, directly visualizing its free movement through the tunnel.

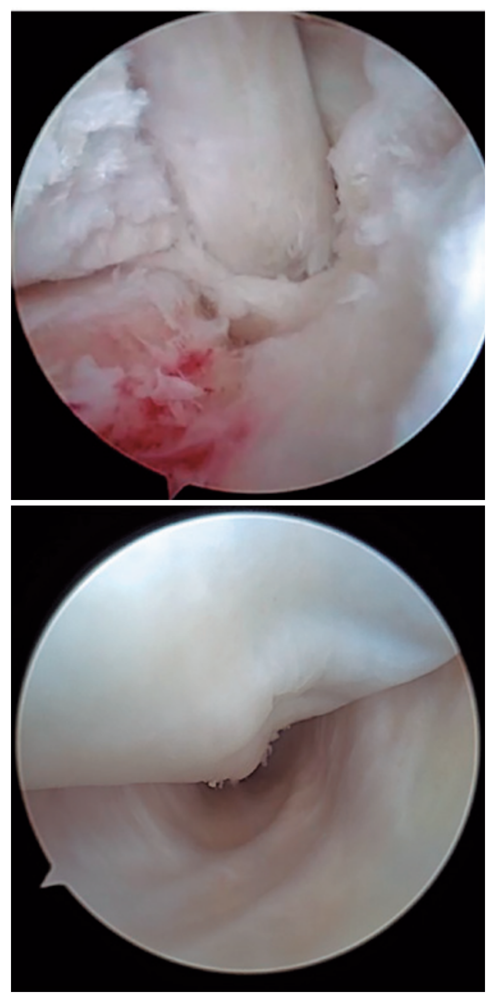

Figure 2. Posterior arthroscopic visualization, showing thickened FHL tendon with extensive tenosynovitis and narrowing of the fibroosseous tunnel.

The patient was allowed to partial weight-bearing according to tolerance assisted by two crunches for one week. Antibiotic was indicated, venous thromboembolism prophylaxis was prescribed, and there were no complications or adverse outcomes.

At six-month follow-up and after ten physiotherapy sessions, the patient presented no tenderness along the FHL or any snapping sensation during mobilization of his ankle and hallux.

Discussion

FHL tenosynovitis is a rare condition, more prevalent among a special subset of patients like ballet dancers or athletes who perform repetitive plantarflexion movements[3]. They usually respond to conservative treatments such as NSAIDs, corticosteroid infiltration, and physiotherapy[5]. In some patients, a more complex problem arises when FHL tenosynovitis is associated with a significant fibro-osseous tunnel or tendon thickening, resulting in tendon entrapment before entering the tunnel in the back of the talus, limiting its free movement and generating a palpable and sometimes audible snapping, which is the clinical manifestation of hallux saltans.

After failing conservative treatments, surgical treatment is warranted for symptomatic patients. The literature has shown an 80 to 90% success rate after either open or arthroscopic FHL release[7]. Open treatment is a reasonable option, Purushothaman et al.[8] released through an open incision over the posteromedial aspect of the ankle the FHL entrapment in a non-previously reported location, proximal to the medial malleolus in an unskilled manual laborer. They found a thickening of the fascial sheath overlying the FHL tendon and performed a complete release of this thickened sheath. Unlike our approach, this group performed surgery with the patient under local anesthesia, asking the patient to demonstrate triggering and confirm the relief. Despite the good results of open approaches, we prefer arthroscopically for better visualization and less soft tissue damage.

Chinzei et al.[1] reported a case of stenosing tenosynovitis, and the treatment consisted of arthroscopically releasing the FHL. When performing the posterior arthroscopy, a partial degenerative FHL lesion was identified, and the proximal scar at zone 1 was thickened by forming a fibrous band near the fibro-osseous tunnel below the sustentaculum tali.

Komiya and Terada[9] reported the case of FHL entrapment in the osseo fibrous tunnel below the sustentaculum tali after a calcaneal fracture with an osseous fragment, corrected after releasing the fibro-osseous tunnel and resecting the bone fragment that limited free tendon motion.

When conservative treatments fail, arthroscopic release becomes a useful tool with little morbidity and favorable functional results in the short and medium term. However, when tendon damage is present, resecting up to 50% of the tendon is considered if necessary, compromising the concept applied to peroneal tendons where resection of up to 66% of a tendon with tenosynovitis could be performed[10].

The limitation of this case report was the type of anesthesia chosen. Regional instead of local anesthesia would be preferred to ask for the patient to reproduce the snapping sound while debriding the tendon and fibro-osseous tunnel resection.

Conclusion

Hallux saltans is a rare condition, mostly idiopathic in its origin. After failing conservative treatments, surgical treatment is an option. It consists of resecting FHL enlargement to its original width and freeing the fibro-osseous tunnel in the back of the talus to solve the space conflict during its normal gliding. An arthroscopic approach is optimal as it allows a good visualization without harming soft tissues and faster recovery.

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Case Report

Diabetic foot salvage: breaking paradigms through a case report

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Abstract

Diabetic foot (DF) is one of the most frequent and disabling complications of diabetes mellitus 2 (DM2). This study presents the case of a 66-year-old female patient with DM2 and DF complicated by extensive infected necrosis involving more than 50% of the foot. She was not a candidate for revascularization and, due to the poorly controlled septic focus and the extent of necrosis, infracondylar amputation was indicated. However, as the patient refused to undergo amputation, the case was re-evaluated at another health institution and a multidisciplinary therapeutic plan for DF salvage was proposed. The protocol included antibiotic therapy, surgical debridement, periodic outpatient dressing, and negative pressure wound therapy (NPWT). After ten months of treatment, the limb showed almost complete healing, and amputation was not necessary. Management of complicated DF is currently one of the greatest clinical-surgical challenges, requiring a highly trained multidisciplinary team to propose an optimal limb salvage program.

Level of Evidence V; Case Report; Expert Opinion.

Keywords: Diabetic foot; Necrosis; Amputation; Wound healing; Negative pressure wound therapy.

Introduction

Diabetic foot (DF) is one of the most frequent and debilitating complications of diabetes mellitus 2 (DM2). It is estimated that about 15–34% of patients suffer from complicated DF, and 20% of them end up undergoing minor and major amputations[1]. The condition is often associated with skin disorders, necrosis, and sepsis, and can extend to deeper structures, such as musculoskeletal structures, causing osteomyelitis (26.4%) and fasciitis (11.8%)[2]. The main etiology of DF is ischemic (28%), neuropathic (21%), and mixed (51%), and it can be triggered by various extrinsic factors, such as trauma (75.9%) and burns (4%)[2,3]. In recent years, the rate of amputations caused by DF has increased to 1.5–3 per 1,000 patients with DM2, and these amputations are associated with a poor 5-year patient survival due to disability, prolonged immobilization, long hospital stays, and infections[3].

The DF salvage plan includes a multidisciplinary assessment by clinical specialties, such as endocrinology, internal medicine, physical medicine, and rehabilitation, and surgical specialties, such as traumatology and orthopedics and vascular and plastic surgery. Management of the internal environment and antibiotic treatment should always accompany surgical therapy, the latter consisting of surgical and chemical debridement of necrotic tissue, negative pressure wound therapy (NPWT, silver sponges), ambulatory wound healing (ionic silver hydrogels), and exudate management[1,3]. The whole process involved in the limb salvage protocol requires strict monitoring and control of risk factors, which allow the main conditions associated with the limb to be controlled.

Case description

The present case report was approved by the Research Ethics Committee of the institution.

Study performed at the Delgado Auna Clinic, Lima, Peru.

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A 66-year-old woman with a long history of uncontrolled DM2 presented with a DF complicated by limited plantar necrosis (3x5cm) with a disease period of three months prior to hospital admission. The lesion was not treated or cured due to the patient's lack of knowledge; it gradually increased in extent until it involved more than 50% of the foot, and pain, fever, and significant functional limitation were added. Patient was admitted to the hospital emergency department, where she was classified as having complicated DF with a WIfI score IV (Wound, 3; Ischemia, 2; Foot Infection, 3), with a high risk of amputation.

Physical examination revealed a febrile condition (39.2°C), tachycardia, and arterial normotension. Extensive wet necrosis (17x10cm) was observed involving the plantar region, forefoot, ankle, and, partially, the right pretibial region, with exposure of osteomuscular tissue (calcaneus) associated with local inflammatory signs, abundant seropurulent discharge, and bad smell (Figure 1). In addition, femoral and popliteal arterial pulse, posterior tibial and pedal were identified. Laboratory tests showed mild anemia (10.3g/dL), leukocytosis with left shift ($18x10^3$L), creatinine (0.96mg/dL), urea (48mg/dL), glycaemia (185mg/dL), hemoglobin A1C (12%), high-density lipoprotein (HDL) (40mg/dL), low-density lipoprotein (LDL) (180mg/dL), and triglycerides (200mg/dL). Arterial Doppler ultrasound showed a significant, moderate posterior tibial and pedal artery stenosis (50%), and radiography of the affected area showed no indirect signs of osteomyelitis.

The initial treatment plan proposed was antibiotic therapy, evaluation by vascular surgery, and traumatology. Patient was not a candidate for open or endovascular revascularization and, due to uncontrolled sepsis and the large extent of necrosis, left infracondylar amputation was considered. Patient refused this treatment and left the hospital by voluntary withdrawal, seeking another health institution.

The second assessment was multidisciplinary, and the DF salvage protocol was activated, which included antibiotic therapy according to the wound culture (vancomycin and meropenem for *Staphylococcus aureus* and gram-negative bacteria), management of the internal environment (insulin therapy), possibility of subsequent revascularization due to the moderate degree of arterial insufficiency, surgical debridement, and ambulatory healing of lesions for nine months. These last two interventions were aimed at removing necrotic material from the wound (subcutaneous tissue, fat, and muscle), allowing adequate granulation and regeneration of the DF. The microbiological and anatomopathological study of the lesion confirmed the presence of gram-positive and negative bacteria, with abundant polymorphonuclear cellularity in all stages.

Figure 1. A-B) Salvage of complicated DF. C-D) DF with extensive infected necrosis of the right foot. E-F) DF after initial surgical debridement. Use of NPWT with silver sponges. G-H) DF with granulation tissue and ambulatory healing. I-J) DF after 8–9 months with almost complete tissue recovery.

After surgical cleanings, the use of topical negative pressure (TPN) with silver sponges (intermittent pressure of 125mmHg/three weekly changes for three weeks) and daily ambulatory cures with ionic silver hydrogels were proposed for the following nine months. During ambulatory controls, a satisfactory evolution of the wound was observed, with total removal of the necrotic tissue and presence of abundant granulation tissue over the entire affected surface.

Among outpatient indications, oral antibiotic therapy was indicated to treat the soft tissue infection (ciprofloxacin and clindamycin/three weeks according to the previously described cultures for sensitive gram-positive and negative bacteria), insulin therapy, analgesia, and the use of physical aids (crutches) to support walking, besides avoiding bearing weight on the affected limb and providing timely pressure relief for optimal healing of the DF. Finally, ten months after salvage intervention, the limb regained full integrity and amputation was avoided (Figure 2). Currently, the patient continues with her outpatient controls by outpatient consultation and under constant functional rehabilitation of the limb. Patient is currently able to walk 150–300 meters in approximately 10-15 minutes.

Figure 2. Final result. A-D) Total healing of complicated DF after nine months of DF salvage protocol.

Discussion

Skin lesions caused by DF can be complicated by infection and sepsis and even require amputation of the affected limb, negatively affecting the diabetic patient's quality of life. According to the multicenter study published by Yovera-Aldana et al.[4], in Peru, the estimated prevalence of the main complications of DF was 60% for neuropathy and ischemia, 40% of lesions involved muscle and tendon involvement, 5% of lesions presented bone and joint involvement, and approximately 8.6% of DF cases led to the amputation of the affected limb. Standard treatments for DF include surgical debridement of the wound, moist wound healing by dressing and saline irrigation, offloading the affected limb, revascularization techniques, infection treatment, and strict glycemic control[1,3]. However, using these treatment methods, only 30% of DF patients heal within the first 20 weeks, which is mainly conditioned by the resistance profile of the related pathogenic microorganisms, irreversibility of vascular damage, and healing technique used[2-4].

One of the most widespread healing techniques in recent decades is NPWT, whose main mechanism of action works at the tissue level through "macrodeformation", which consists of contracting the edges of the lesion producing a decrease in the overall diameter, and "microdeformation", stimulating cell proliferation, migration and differentiation, generation of granulation tissue, angiogenesis, and epithelialization[1,3]. Recently, in a systematic review, Dehghan et al.[3] and Yovera-Aldana et al.[4] described that NPWT efficacy is associated with increased granulation tissue formation, a low incidence of amputation, and reduction of wound area and depth. Similarly, Lavery et al.[5] compared the efficacy of NPWT+saline irrigation with that of NPWT+polyhexanide-betaine 0.1% irrigation in patients with infected DF, finding that the latter did not demonstrate significant improvements in wound healing relative to saline. In our case, NPWT was applied for four weeks and, then, we proceeded to ambulatory healing for approximately ten months-these periods have been the subject of multiple studies, such as the one described by Węgrzynowski et al.[6], who evaluated NPWT for "extended time" (±4 weeks) in patients with DF and observed a significant decrease of 92% in the risk of amputation compared to that seen in the short-time NPWT group. The abovementioned study also highlights the importance of microbial control in DF lesions, describing the lack of any benefit from the use of NPWT in infected ischemic lesions or active sepsis. Other investigations have attempted to compare NPWT with conventional saline irrigation healing; however, the former demonstrated superiority due to a significant affected area reduction, better granulation rates, and even complete regeneration (98.7%) of the affected area compared to saline alone, with a complete healing rate of 26% at 3-month follow-up[7]. On the other hand, an analysis on NPWT considering the type of sponge used, Malmsjö and Ingemansson[8], determined the efficacy of black and green polyurethane sponges, which, due to their pore size, have shown optimal regeneration of granulation tissue compared to that produced when only gauze is used on the lesion.

DF complicated by necrosis and infection is one of the spectra seen in late vascular manifestations of DM and is by now one of the leading causes of limb loss in the world. The severity of soft tissue and bone involvement adds to the systemic consequences of infection, generating a proinflammatory and immunosuppressive state that conditions a poor prognosis for survival in more than 50% of cases[1,3]. The role of antibiotic therapy directed to the micro-organism identified by culture is one of the main therapeutic weapons available and, together with surgical debridement, has demonstrated cure rates of up to 72%. However, it is necessary to add further curative strategies such as NPWT, the use of sponges, and, if necessary, after vascular assessment, the coverage of extensive lesions with skin grafts[5,8].

In our case, patient had a history of poor and inadequate glycemic control for approximately 30 years, conditioning the development of late complications of DM2, such as DF. This was initially managed in two stages, in-hospital and out-of-hospital-the first one basically for surgical cleaning, stabilization of the internal environment, intravenous antibiotic therapy, and use of NPWT, while the second phase was exclusively focused on daily outpatient dressings and maintenance of DM2 management measures. This whole process has been almost systematically established as a part of the DF salvage protocol and is now a therapeutic model that has been progressively implemented in major healthcare institutions nationwide[5,6,9].

Conclusion

Currently, despite the wide dissemination of different DF management techniques, there is still limited information on studies with combined therapy for the management of this condition, which is why, according to the results obtained, we highlight the importance of implementing the DF salvage protocol to establish continuous and long-term multidisciplinary management of this type of lesions. Likewise, it is essential to educate patients with DM2 at risk of DF, their families, and caregivers to prevent injuries associated with the disease and care for them, avoiding their progression and promoting early healing with low rates of limb loss.

Authors' contributions: Each author contributed individually and significantly to the development of this article: IC *(https://orcid.org/0000-0002-4274-8370) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination and approved the final version; JQ *(https://orcid.org/0000-0002-4014-4952) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination and approved the final version; HM *(https://orcid.org/0000-0001-8405-9373) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination and approved the final version; MVS *(https://orcid.org/0000-0003-4504-4050) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination and approved the final version; WSC *(https://orcid.org/0000-0002-5380-7372) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Novel management of sizeable calcaneal UBC with autograft and allograft amalgamation: a case report and review of literature

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Abstract

Calcaneal unicameral bone cyst (UBC) is uncommon benign tumor that can be managed either conservatively or with different surgical interventions described in the literature. However, surgical intervention is usually preferred when the lesion is an active UBC significant in size, as there is the risk of pathological fracture due to thin bone, especially in load-bearing bones like the calcaneus. We report a case of calcaneal UBC considerable in size managed by open curettage and graft reconstruction using a combination of autograft and allograft in a 30-year-old male at two-years follow-up.

Level of Evidence IV; Therapeutic Studies; Case Report.

Keywords: Bone cysts; Calcaneus; Radiography; Adult.

Introduction

Unicameral bone cyst (UBC), also known as a solitary or simple bone cyst, is a cavity filled with a yellow-colored fluid and radiographically seen as a mildly expansile, lytic thin-walled lesion without periosteal reaction. It is considered benign since it does not spread beyond the bone. UBCs are more common in males. Most UBCs do not cause any symptoms and are discovered as incidental findings on radiographs or computed tomography (CT) scans for other reasons. However, large lesions can cause nearby areas of bone to thin, resulting in a fracture and causing pain. Most cases of UBCs present with pathological fractures due to thinning of bone. Less commonly, a patient may notice a painless bump if the cyst has caused the bone to enlarge in a local area. UBCs can be managed conservatively or by surgical interventions[1].

Case description

We report a case of a 30-year-old salesman with a Body Mass Index (BMI) of 35. He attended our emergency room with left ankle pain and swelling for the last three days. He had a history of blunt trauma to the left talocrural region following a fall from a bike. Clinical evaluation revealed significant swelling around the left ankle, tenderness around the calcaneum region, and inability to fully weight bear, giving an impression of bony injury. Surprisingly, the radiographs were not suggestive of any fracture, but an incidental finding of lytic, expansile lesion, noticed in the calcaneus body (Figure 1A-B). CTs of the left foot and ankle were advised to investigate further, suggesting a well-defined expansile lytic lesion with lobulated non-sclerotic margins measuring 4.4x 3.2x 2.4cm in the anterior part of calcaneum (Figure 2A-B). There was thinning of medial cortex of calcaneum without cortical breach. Different diagnoses of simple bone cyst, giant cell tumour (GCT), and aneurysmal bone cyst (ABC) were given, and magnetic resonance imaging (MRI) was indicated for further evaluation. MRI of the left foot revealed a well-defined, expansile, sub-articular, eccentrically located lesion in the calcaneum body with minimal blood fluid levels at the subtalar joint (Figure 3A-B). A few internal septations were noted within the lesion; however, no obvious enhancement was seen within the mass. These findings on MRI were corroborative of features of ABC, unlikely of GCT due to the absence of soft tissue within. CT-guided biopsy was performed before any intervention confirming the diagnosis of calcaneal UBC.

Study performed at the Grant Medical College and JJ Group of Hospitals, Mumbai, Maharastra, India.

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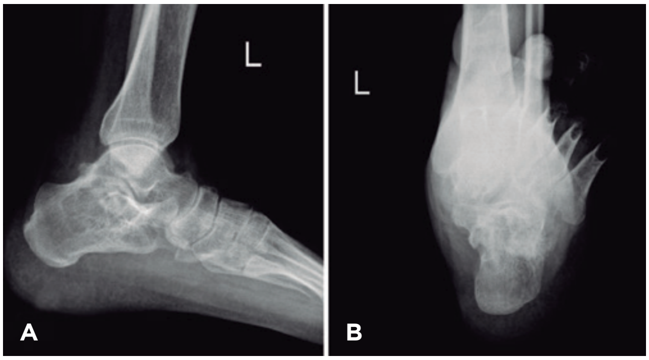

Figure 1. Plain radiographs. A) Lateral view. B) Harris axial view suggest expansile, lobulated, lytic lesion in the body of calcaneum encroaching subtalar joint.

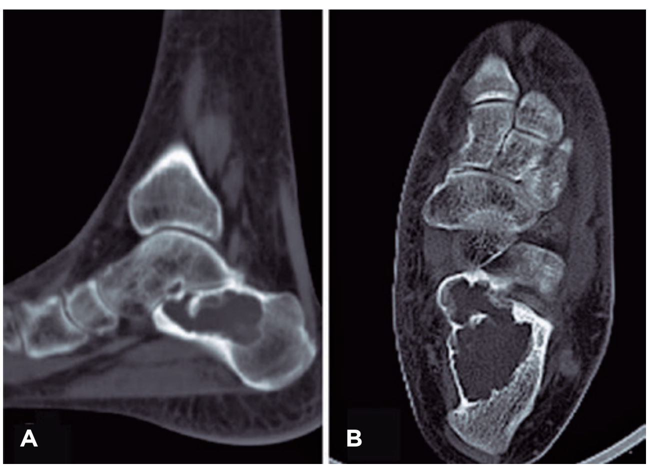

Figure 2. Computed tomography (CT scan). A) Sagittal section. B) Axial section suggestive of eccentric, expansile, lytic lesion with thinned out medial cortex and about to breach subtalar joint.

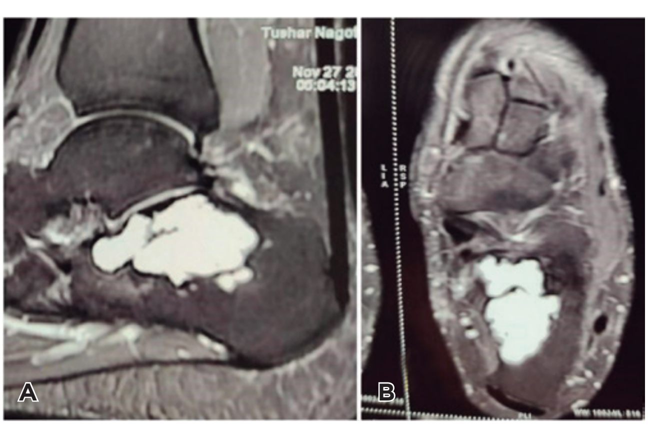

Figure 3. MRI T2 weighted image. A) Sagittal. B) Axial sections suggest well-defined, expansile, sub-articular, eccentrically hyperintense lesion in the body of calcaneum with minimal blood fluid levels at subtalar joint.

Open curettage and bone graft augmentation were planned to ameliorate the patient's symptoms due to poor response to rest, immobilization and analgesics.

The lesion was approached using a standard 'L' shaped incision taken over the lateral aspect of the calcaneum, passing behind the lateral malleolus and then curving just distal to it, extended up to the base of the 5th metatarsal. The incision was then deep to create a full-thickness flap containing the peroneal tendons and the sural nerve and held in place to expose the lateral aspect of the calcaneus. Corticotomy on the lateral wall was performed, and curettage was done to remove the necrotic tissue of the cyst (Figure 4A). Samples collected during curettage were sent for culture and histopathological examination. Debridement and thorough betadine wash were given throughout the cavity. The bone defect created after curettage was large enough which was then filled with amalgamation of cancellous autograft harvested from the iliac crest and cancellous allograft (lyophilised and irradiated) (Figure 4B-C). The wound was then closed in layers with 3-0 ethilon by Allgöwer-Donati suture technique (Figure 4D). Post-operatively, below knee slab was given for three weeks, and nil weight-bearing mobilization with a walker started in the immediate post-op period. Physiotherapy with ankle range of motion (ROM) started after three weeks, and full weight-bearing started after eight weeks.

Histopathological evaluation sent intra-operatively revealed necrotic bone and muscular tissue with no evidence of malignant cells. On sequential follow-up at one, three, six, twelve months, and two years functional ankle ROM and around 5

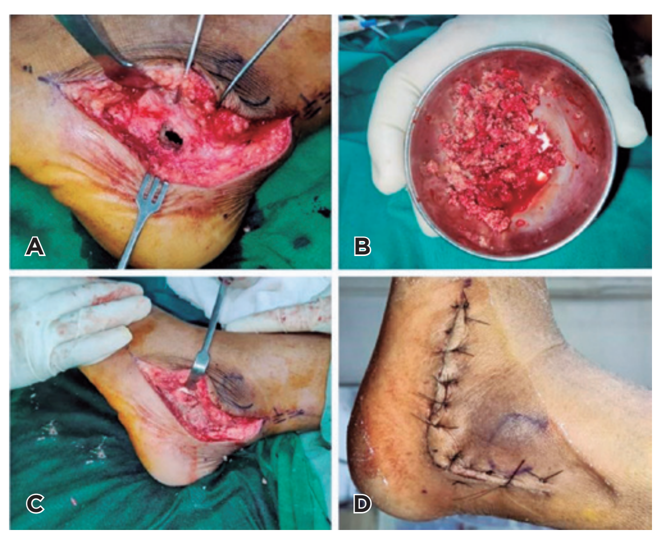

Figure 4. Intra-operative clinical pictures. A) Curettage and decompression with lateral wall corticotomy through a standard lateral approach. B) Mixture of cancellous autograft harvested from iliac crest and cancellous allograft procured from lyophilised, irradiated bone graft. C) Packing and impaction of the cavity with bone graft. D) Final closure of the wound with Allgöwer-Donati suture.

degrees of pain-free prono-supination movement were possible at subtalar joint, and radiographs were taken to assess osseointegration (Figure 5A-D). Currently, the patient is two years post-op and has no complaints and no signs of recurrence to date. The future probability of subtalar arthritis and the requirement of subtalar fusion was explained to the patient.

Discussion

The calcaneum is a relatively uncommon site for UBC occurrence, especially a large one, as was seen in this case. The risk of pathological fractures is very significant when the cyst is so large and the walls surrounding it so thin. Therefore, CT-guided biopsy is the gold standard investigation for diagnosis. Chang et al.[2] formulated a radiological classification for UBCs based on findings on sequential follow-up radiographs and divided them into four categories – Healed, Healing with defect, persistent cyst, and recurrent cyst.

Different treatment for calcaneal UBC management have been mentioned in the literature, such as curettage with bone grafting, total/subtotal resection with bone graft, deroofing of cyst wall, curettage with combination of multiple drilling and decompression through a cannulated screw, autogenous bone marrow injected percutaneously, steroids or tricalcium phosphate ceramic injections, and curettage and autologous cancellous bone incorporation, done endoscopically[2-5]. In a case series consisting of calcaneal cysts alone, among the described techniques, curettage combined with bone grafting was reported to be the best treatment in obtaining the desired outcome in one of the largest series of calcaneal bone cysts[6].

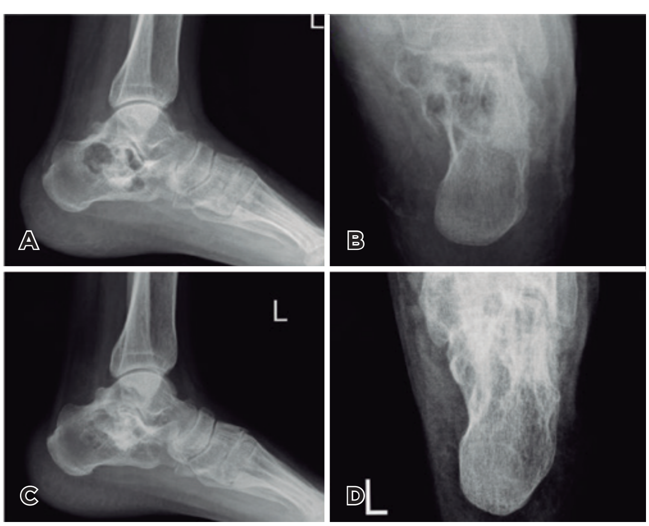

Figure 5. Immediate post-operative radiographs. A) Lateral view. B) Axial view immediately after open curettage and bone augmentation with a mixture of autograft and allograft. After two years of follow up. C) Lateral view. D) Axial view showing bony consolidation and remodeling with diminution of previous lytic lesion and evidence of early subtalar arthritis.

Our case presented a challenge due to the size and juxta-articular location of the lesion, particularly due to the lesion eroding into the subtalar joint. The lesion was quite large for just autograft to suffice in filling the void that would be created. To counter this problem, our operating team devised an approach of using both autograft and allograft to fill the bone void created after curettage. Our report demonstrated satisfactory results in terms of subtalar, ankle ROM, and pain-free weight-bearing, although currently proven only in the short term, in a challenging case due to the proximity of the lesion to the subtalar joint as well as the size of the lesion itself. There was minimal pronation-supination movement at subtalar joint of around 5 degrees which was painless. We considered the possible alternatives for intralesional medroxyprogesterone acetate (MPA) injection or percutaneous bone cement injection. Still, the size of the cyst made us lean toward the management method we eventually chose.

Simple bone cysts can be managed conservatively if the cyst is small and does not significantly affect the bone structural integrity. In weight-bearing bones like the calcaneus, however, operatively filling the bone defect creates a much more stable and sturdier construct and reduces the risk of pathological fractures significantly. Park et al.[3] in a study including 23 calcaneal cysts management, compared the results of open chip allogeneic bone graft versus percutaneous injection of demineralized bone powder with autogenous bone marrow and concluded that a mixture of it injected percutaneously, is one of the less invasive procedures in the calcaneal UBC management. Minimally invasive procedure was associated with lesser postoperative morbidity, shorter hospital stay, and more compliance with the patient's unrestricted activity. A study performed by Ulici et al.[4] suggested that an autogenous bone marrow injection is a safe and effective treatment method for simple bone cysts when compared with surgical management, but sometimes-repeated injections are necessary. Sung et al.[5] summarized in a retrospective comparative study that open curettage with or without bone grafting is still the main treatment for simple bone cysts and superior to steroid injection in terms of healing rate. However, this technique is too aggressive, with occasional postoperative complications and recurrence after surgery. Rougraff et al.[7] included 23 patients in their study, with an active UBC treated with trephination and injection of allogeneic demineralized bone matrix and autogenous bone marrow. They concluded that injecting this combination percutaneously as a minimally invasive procedure is a compelling alternative for UBCs. Complete cortical remodeling was evident radiographically by the end of one-year follow-up with five patients requiring a second injection because of cyst recurrence. All five had a clinically and radiographically quiescent cyst after a mean follow-up of 36 months. Seven of the 23 patients had incomplete healing manifested by small, persistent radiolucent areas within the original cyst. None of these cysts increased in size or resulted in pain or fracture. In a novel prospective study, Yildirim et al.[8] compared and analyzed the outcome of open versus endoscopic curettage and bone grafting for simple calcaneal bone cysts treatment. The study concluded that endoscopic curettage and percutaneous grafting are minimalistic and effective treatments for calcaneal UBCs compared to those following open reduction. A drawback of this study was the incapacity to segregate the treatment effects of cyst puncture from those due to injection of steroids or bone marrow. To determine the role of mechanical disruption of the cyst in its resolution would require a prospective, randomized study comparing mechanical disruption of the cyst by multiple perforations with drills or awls with and without steroid injection. Monetary constraint was a convincing reason for not opting for endoscopic/percutaneous grafting procedures in our scenario.

In one of the largest series of 12 calcaneal UBCs, Glaser et al.[9] compared the efficacy of MPA injection versus curettage and bone grafting. They concluded that curettage combined with bone grafting produced consistently great results in their series. However, they added that although steroid injections have given better results for UBCs at different sites, calcaneal UBCs might not be the ideal path of management.

In a systematic review of various methods of simple bone cysts treatment performed by Kadhim et al.[10], the healing rate was higher with MPA injection than with inner wall disruption. The healing rate of UBCs managed by surgical curettage was resemblant (around 90%) irrespective of whether either autograft or allograft was used (90%). Surgical curettage is thus an excellent treatment when combined with filling the defect with an auto or allograft. Although significant evidence supports active intervention of calcaneus UBCs, careful evaluation is required in every case to select the right treatment since no concrete evidence exists to support any treatment over the other. This is challenging due to the rarity of calcaneal bone cysts and their generally symptomless nature. Most practitioners, however, usually lean towards curettage and bone augmentation as a definitive procedure with acceptable functional outcome and least recurrence.

Conclusion

This report highlights a case of symptomatic calcaneal UBC with considerable size managed by curettage and a combination of autograft and allograft with no evidence of recurrence and complete osseointegration at two years follow-up. Amalgamation of autograft and allograft can be an acceptable option for large UBCs with cavitory defects after thorough curettage, particularly in weight-bearing areas like calcaneum. High BMI and preceding history of trauma in asymptomatic patients might present in an acute scenario with the clinical picture of fracture; such patients would require active intervention for calcaneal UBCs management.

Author's contributions: Each author contributed individually and significantly to the development of this article: TM*(https://orcid.org/0000-0002-5167-5273) Data collection, bibliographic review; SP *(https://orcid.org/0000-0002-9327-9623) Performed surgeries, formatting of the article; SA *(https://orcid.org/0000-0002-8313-1844) Statistical analysis, clinical examination; SG *(https://orcid.org/0000-0003-3114-6937) Conceived and planned the activities that led to the study, approved the final version; PT *(https://orcid.org/0000-0001-8624-0213) Participated in review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Isolated talus dislocation: a case report

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Abstract

Peritalar dislocation is a rare injury, usually associated with fractures. It mainly affects males in high-energy traumas such as falls from height, car accidents, or even torsional traumas during the practice of sports activities. This study illustrates a case attended by the authors to discuss peritalar dislocation and its diagnosis, classification, treatment, and prognosis. Such injury may evolve with complications if not properly managed, including ankle movement pain, joint stiffness, deformities, post-traumatic arthrosis, and even osteonecrosis.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Joint dislocations; Talus; Subtalar joint; Case reports.

Introduction

Peritalar dislocations, without associated fractures, are rare injuries (1 to 2% of all traumatic dislocations), occurring dislocation of the talocalcaneal and talonavicular joints[(1)]. The literature shows that the talonavicular and talocalcaneal ligaments are injured, but the calcaneonavicular ligament remains intact in most cases. In addition, it was also shown that about 80% of the dislocations are medial[(1)]. These are injuries with a good prognosis, especially those closed if diagnosed correctly and properly reduced, followed by six weeks of immobilization and intensive rehabilitation[(2)].

The aim of this study is to illustrate a case attended and follow-up by the authors to discuss peritalar dislocation and its diagnosis, classification, treatment, and prognosis.

Case description

This study was submitted to the Research Ethics Committee of the institution, and the patient signed an informed consent form.

A 51-year-old male patient with a history of right ankle torsional trauma, evolving with an inability to ambulate and apparent deformity. Before the injury, he did not present any musculoskeletal disorders or trauma.

On orthopedic physical examination, he presented apparent deformity in the right ankle region, significant pain, joint incongruence, intact skin, and no neurovascular damage. The peritalar dislocation without associated fracture was evidenced in the first radiograph. After intraarticular local anesthesia, the patient was subjected to a reduction maneuver through traction and movement against the deformity, and then a plaster cast immobilization was made. Post-reduction control radiography was performed. After verifying the joint congruence reestablishment, the patient was submitted to computed tomography. At the end of the consultation, the patient was referred for outpatient follow-up (Figures 1, 2, 3 and 4).

On outpatient return one week after the trauma, the plaster cast immobilization was in good condition. Upon immobilization removal, intact and uninjured skin, preserved neurovascular of the foot and right ankle, and the stable joint was observed. New plaster cast immobilization was made, and the patient was instructed again regarding the injury and its severity, maintaining the conservative treatment. A nuclear magnetic resonance examination was requested for documentation and verification of the evolution of ligament injuries.

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

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Discussion

Peritalar dislocation is defined as the dislocation of the subtalar and talonavicular joints without the involvement of the ankle or calcaneocuboid joint[(3)].

The talus is composed of the foot joint with the ankle, and together with the calcaneus, they are important for ambulation. In addition, the talus is involved in various planes of movement and is responsible for the pressure and traction forces of the foot.

It has a cuboid shape divided into three parts: head, neck, and body, 66% covered by cartilage. The head articulates anteriorly with the navicular bone, responsible for the adduction and abduction movement. The body articulates inferiorly with the calcaneus, accountable for the inversion and eversion movement. Its upper portion articulates with the tibia and fibula, responsible for the ankle dorsiflexion and plantarflexion movement. The neck does not have articular cartilage and receives ligament and capsular insertions (anterior and posterior talofibular and deltoid ligament, the latter composed of the talocalcaneal, tibionavicular, and tibiotalar ligament). The talus vascularization occurs by the blood supply of the capsule and ligaments (vulnerable to injury) and mainly by the anastomosis formed by the tarsal canal and the tarsal sinus arteries. In addition, the deltoid artery (posterior tibial artery branch) supplies to the medial body; the fibular artery contributes to the posterior supply, and the dorsal artery supply the talus head. Therefore, due to the rich vascularization, avascular necrosis of the talus is a rare occurrence after peritalar dislocation[(4)] (Figures 5, 6 and 7).

Figure 1. Photograph of the patient's right foot and ankle, the prominence of the talus head in the region of the tarsal sinus. Note the calcaneus in inversion and plantarflexion.

Figure 2. Initial radiograph of the right ankle showing talus dislocation without fractures.

Figura 3. Radiography of the right ankle post-reduction of talus dislocation, using a plaster cast immobilization, being possible to visualize the tibiotalar joint congruence reestablishment.

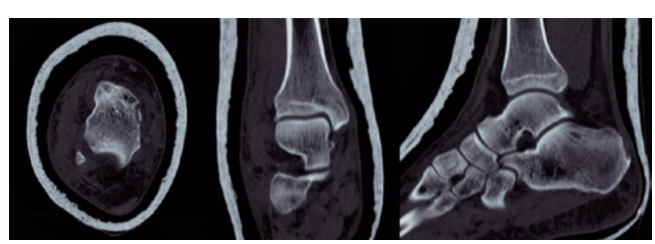

Figura 4. Computed tomography (axial to the left, sagittal in the center, and coronal to the right) post-reduction of pure talus dislocation, showing no associated fractures.

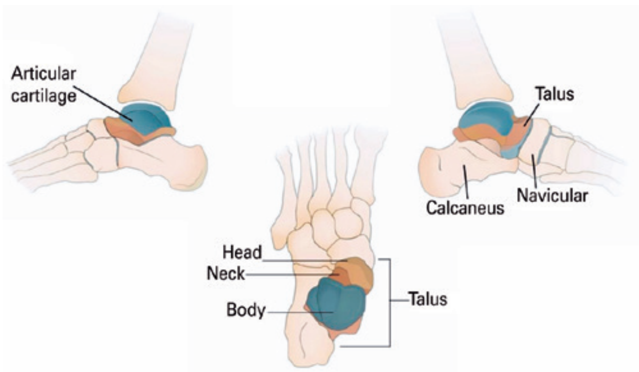

Figura 5. Bone anatomy of the talus.

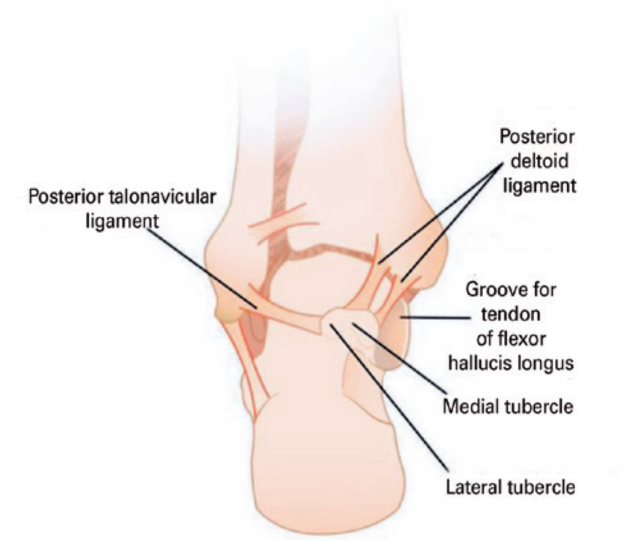

Figure 6. Ligamentous anatomy of the talus.

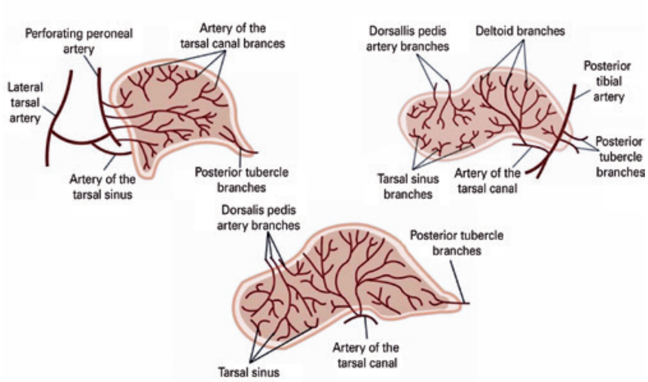

Figure 7. Blood supply of the talus.

Usually, a dislocation or a fracture of this bone results from severe trauma related to falls from height, automobile accidents, torsional trauma, or even during sports[1,2,5,6]. It mainly affects young males around 30 years of age[1,5,6].

They are considered rare injuries due to their ligament complex and the capsule that surrounds the ankle, which is strong and well structured. However, we must also consider that the trauma must be high-energy and multidirectional[1]. In cases of medial peritalar dislocation, the most common, low-energy torsional trauma ("basketball foot") was reported[1,6,7]. According to DeLee[5] posteromedial dislocations are the most reported, followed by anterior tibiotalar dislocation and dislocations with tendon interposition.

The mechanism of trauma most associated with tibiotalar dislocations combines inversion, maximum plantarflexion, and high-energy axial trauma.

In the orthopedic evaluation, the patient reports severe pain, functional incapacity of the affected limb, and visible deformity. In the case of medial injuries, like in this report, the talus head is prominent in the sinus tarsi region, with the calcaneus in inversion and the foot in plantarflexion. In lateral injuries, the talus head is evident in the medial region of the foot, with the calcaneus in the lateral position and the lateral column of the foot apparently shortened. In posterior dislocations, the foot appears elongated, and in anterior dislocations, the foot seems to be "shortened" to the contralateral foot.

Often there may be neurovascular injury due to compression of the neurovascular bundle and the inability to palpate the pulses distally to the injury[7,8].

The diagnosis is confirmed through foot and ankle radiographs, also computed tomography to search for fractures not easily identified on radiographs[1] and evaluate possible osteochondral injury in the subtalar or talonavicular[1,5,8]. In addition, magnetic resonance imaging can also be performed since they are important to search for musculoligamentous injuries.

Regarding the descriptive classification proposed by Broca in 1853, peritalar dislocations were subdivided into medial, lateral, and posterior[1,5,9,10]. In 1856, Malgaigne added the anterior dislocation, which is even rarer[1,6,11]. This classification considers the position of the foot to the talus:

- Medial: peritalar most common dislocations, when the foot moves medially to the leg, resulting in a deformity in inversion, plantarflexion, and adduction;
- Lateral: the foot moves laterally to the leg axis, with severe deformity in eversion, abduction, and pronation. More related to high-energy trauma, with soft tissue integrity at risk, with risk of exposed injury and associated fractures;
- Posterior: rare, the foot seems shortened in posterior peritalar dislocations and elongated in anterior dislocations due to the flattening of the hindfoot (important plantarflexion);
- Anterior: even rarer, there is rupture of the interosseous ligament due to anterior traction, with anterior dislocation of the foot to the talus.

Treatment begins with immediate reduction, decreasing the risk of skin necrosis and vascular impairment. Closed reduction is possible in most cases, performed with the knee flexed, seeking relaxation of the gastrocnemius muscles, and completing the opposite dislocation movement[1]. It is necessary to pay attention to the presence of compartment syndrome. Again, it is important to emphasize the importance of performing computed tomography to search for fractures not easily identified on radiographs[1] and evaluate possible osteochondral injury in the subtalar or talonavicular[1,5,8]. Closed reduction is not possible in up to 30% of cases due to soft tissue interposition or significant edema caused by diagnostic delay. In these situations, an open reduction is indicated, manual removal of the extensor retinaculum involving the talus head, interposition of the deep fibular nerve, the flexor hallucis longus tendon, the fibular tendon, the talonavicular capsule or even the impact between the navicular and the talus head[1,3].

The access route is in the prominent region of the talar head, and other accesses may be performed depending on the associated injuries. The immobilization time is variable: if the peritalar dislocation is isolated, that is, without fractures or other associated injuries, the plaster cast can be used for three to 12 weeks[7]. Another point still under discussion is the immobilization time since the short time favors subtalar instability and, if prolonged, subtalar stiffness[7,8]. If the reduction is unstable, it is decided to fix the subtalar through the Kirschner wires and associated fractures, if present. Primary subtalar arthrodesis is indicated in cases with large osteochondral fragments and joint surface involvement. In exposed injuries, the external fixator is used as a treatment option[1,3].

In cases where there is a delay in reducing dislocation, the talus head can lead to ischemia and, in later cases, skin necrosis. If soft tissues are compromised, debridement of this devitalized tissue is indicated and, when possible, its coverage[8]. Neurovascular injury is more related to exposed injuries and lateral dislocations since they involve high-energy trauma.

The residual instability remains insignificant, and there are no other losses in cases of adequate diagnosis and treatment[2]. As for the immobilization time, no consensus was reached, but immobilization for at least six weeks is of great value. Another important factor for the patient's rehabilitation is to follow up the physiotherapy to maintain good functional resolution.

Most patients do not develop complications. However, in some patients, it was observed that there was subtalar arthrosis, the ones treated with leg-foot orthoses or, in some cases, triple arthrodesis. In addition, it is known that lateral injuries, exposed medial injuries, or dislocations associated with fracture, have a worse prognosis[8].

Conclusion

The objective of this study was to present a case of talus dislocation correctly conducted and diagnosed, in which the patient evolved with a satisfactory final result. A good evaluation in primary care with adequate orthopedic physical examination, subsidiary examination, and a well-applied reduction maneuver associated with appropriate plaster cast immobilization contribute to the patient's recovery. In addition, it is important to highlight the physiotherapy protocol as an ally of a good clinical result.

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Case Report

Reconstruction of extensive bone loss of the first metatarsal with osteodistraction and homologous graft in an immature skeleton: case report

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Abstract

Reconstruction of extensive bone loss in the foot requires a set of strategies involving various surgical techniques and orthopedic devices. Semicircular Ilizarov external fixator combined with a structural homologous bone graft may be advantageous in pediatric patients. This case report describes the technique of reconstructing an extensive bone loss of the first metatarsal with osteodistraction and homologous graft in an immature skeleton. The combination of the external fixator and the homologous graft provided sufficient bone volume without recurrent infection, minimal complications, substantial length gain of the metatarsal bone, and improved soft tissue conditions. It is a viable treatment option for severe foot injuries in immature skeletons.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Metatarsus; Foot deformities; Bone transplantation; Child; Growth.

Introduction

Reconstruction of bone loss in the foot requires a set of strategies involving surgical techniques and orthopedic devices. Bone losses between 2 and 4 cm can be treated with an autogenous bone graft[1,2]. Bone grafts have a well-established role in orthopedic surgery, but filling metaphyseal defects is associated with complications that include postoperative pain and morbidity[3].

In treating large bone defects, extensive grafts are often required, which is limited to the amount of autologous bone available. Furthermore, in skeletally immature patients, the choice of the autologous graft should consider the risk of damage to the growing physis and the amount of graft available. Thus, a structural homologous bone graft may be advantageous due to biocompatibility, the capacity for bone stock restoration, and potential of ligament reinsertion[4].

There are a limited number of case reports and scientific articles regarding the reconstruction of bone loss in the foot using osteodistration and homologous graft in pediatric patients. The aim of this case report is to describe the technique of reconstructing an extensive bone loss of the first metatarsal with osteodistraction and homologous graft in an immature skeleton for five years of follow-up.

Case Report

The patient and her legal guardian consented to this case report and signed the informed consent form. The study was approved by the Ethics Committee under registration CAAE n. 56135522.5.0000.0033.

A female patient, hit by a car at age five, suffered severe trauma to the left foot, large soft tissue injury, and exposed fracture Gustillo and Anderson IIIB. Returns to the outpatient clinic at the age of 11 to treat the left hallux shortening in the extended position, associated with scar retraction, great functional limitation, ability to walk, and difficulty wearing closed shoes (Figure 1). Reconstruction of bone loss was performed with osteodistraction and homologous graft according to the surgical procedure described below.

Study performed at the Hospital de Urgências de Goiânia, Goiânia, Goiás, Brazil.

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The patient was in dorsal decubitus under spinal anesthesia with a lateral cushion and tourniquet at thigh level. The external fixator Ilizarov semicircular (Figure 2) was placed with a planned assembly of three rings, one in the medial and middle foot wedge, one in the head remnant of the first metatarsal, and one in the proximal and distal phalanx of the hallux, fixed with 4.0mm Schanz pins for bone distraction and soft tissue elongation and arthrodiastasis. A zetaplasty incision was made to correct the scar retraction and deviation in the hallux extension. It was instructed to proceed with soft tissue elongation and bone 1mm per day, four times of 0.25mm in the two distal half-rings, ten days after surgery, for 60 days. The patient presented superficial soft tissue infection, treated with cefadroxil 500mg every 12 hours for ten days. After 90 days, the circular external fixator was removed, and weak bone regeneration was observed, improving the appearance of soft tissues and scar retraction (Figure 3). The patient was submitted to new surgery with a soft tissue incision, dissection by planes, and preparation of the receiving area (Figure 4). Metatarsophalangeal arthrodesis was performed without joint preparation, only decortication due to the poor quality of the joint, as described below. The tricortical iliac graft was removed from the mother, and the bone loss was filled with two unblocked plates and mini fragments. The patient evolved with a good appearance wound, mild dehiscence treated with dressings, and resolution of the soft part aspect. After six months of follow-up, good bone consolidation, no signs of infection, osteolysis, or loosening of materials were observed through clinical and radiological evaluation (Figure 5). The patient reported high satisfaction with the surgical, aesthetic, and functional results and mild pain[2] evaluated through the Visual Analog Pain Scale[5]. In the five years of follow-up (Figure 5) of the initial approach, the patient does not want

Figure 1. Patient with left hallux shortening.

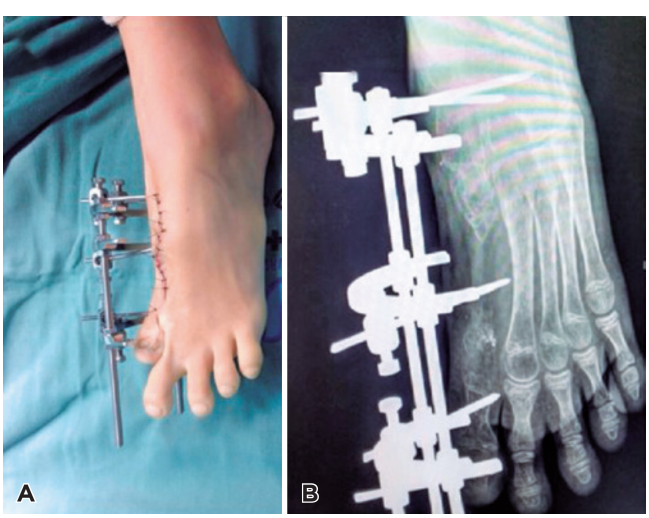

Figure 2. A) Clinical and radiological. B) Postoperative aspects with semicircular Ilizarov external fixator.

Figure 3. A) Postoperative appearance and radiography. B) After external fixator removal.

Figure 4. A) Intraoperative after bone elongation and B) Intraoperative after grafting and placement of plates.

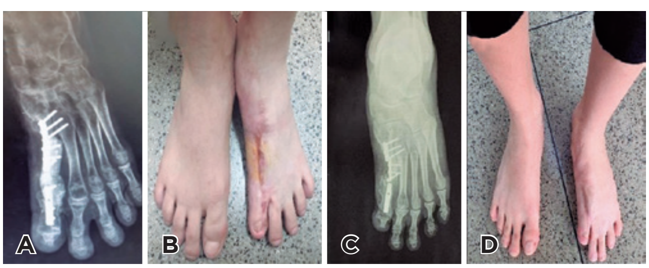

Figure 5. A-B) Radiological and clinical evaluation after six months and C-D) five years of follow-up.

any subsequent surgery, even with functional shortening, reporting being satisfied with this result.

Discussion

In the scientific literature, there are few studies on restoring complex foot injuries in immature skeletons[6]. Osteogenic distraction by the Ilizarov method is one of the most used techniques in treating fractures with bone loss. This method includes a circular external fixator and the translocation of a bone segment from a healthy donor area to the bone loss region[7]. The combination of osteogenic distraction and zetaplasty allows the skin and soft tissue elongation to be achieved, avoiding the recurrence of contractures and the use of skin grafts[8].

In reconstructing bone loss in immature skeletons, the use of iliac bone graft remains the "gold standard"[9]. However, in this case, the skeletal immaturity, the possibility of growing physis involvement, the scarring in the graft donor area, and the limited amount of material were considered negative points in the choice of autologous graft. Thus, the homologous graft was chosen considering the disadvantages presented, the absence of a bone bank available in the region and the possibility of the mother as a donor of the bone graft.

Canzi et al.[10] reported two successful cases of large cranial loss reconstruction using structural homologous bone grafts in pediatric patients. The authors highlighted that the risk of infections was minimal when compared to high quality, biomechanical stability, and absence of evident interference in long-term growth.

In a recent study, Jogani et al.[6] reported the bone reconstruction of the first metatarsal after severe foot trauma using the external fixator associated with the Masquelet technique in a 62-year-old male patient with injury of the first metatarsal and proximal part of the phalanx, after 24 months postoperatively satisfactory functional results were obtained and the total incorporation of the fibular graft.

In this study, the combination of osteogenic distraction associated with the homologous graft in an immature skeleton presented satisfactory results, without recurrent infection, with minimal complications from external fixators and substantial length gain of the metatarsal bone.

Conclusion

The reconstruction of extensive bone loss of the first metatarsal with osteodistraction and homologous graft in an immature skeleton was able to promote an almost total restoration of bone length and improve soft tissue conditions, being a viable treatment option in severe foot injuries in pediatric patients.

Authors' contributions: Each author contributed individually and significantly to the development of this article: PHSB *(https://orcid.org/0000-0002-0275-1401) Conceived and planned the activities that led to the study, participated in the review process, participated in the writing of the article, data collection, approved the final version; ACA *(https://orcid.org/0000-0002-9983-1888) Participated in the review process, formatting of the article, participated in the writing of the article, approved the final version; JEHP *(https://orcid.org/0000-0002-9340-2337) Participated in the review process, bibliographic review, survey of the medical records, participated in the writing of the article, approved the final version; SEK *(https://orcid.org/0000-0003-3132-924X) Participated in the review process, formatting of the article, participated in the writing of the article, approved the final version; WFJ *(https://orcid.org/0000-0001-7340-870X) Interpreted the results of the study, participated in the review process, participated in the writing of the article, approved the final version; JSM *(https://orcid.org/0000-0003-4742-1905) Interpreted the results of the study, participated in the review process, participated in the writing of the article, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Technical Tips

Open tibial pilon fracture with an extensive osteochondral defect: Staged reconstruction

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Abstract

The surgical treatment of large post-traumatic osteochondral defects related to open tibial pilon fractures is challenging. Staged treatment with soft tissue damage control and bone reconstruction in the second half is often the best therapeutic option. We present a technical tip using osteochondral allograft to reconstruct an area with extensive bone loss in the distal tibial epiphysis after a gunshot wound, describing the treatment stages and good clinical results.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Trauma; Allograft; Tibial fractures.

Introduction

The treatment of multi-fragmented open tibial pilon fractures associated with bone loss due to gunshot wounds is a challenging and rare situation outside the war/armed conflict environment. Special care should be taken with firearms-related injuries, especially due to skin loss, contamination, and significant osteochondral loss.

There are a few reports in the literature due to the low incidence of this situation(1,2). In the final stage of treatment, reconstruction and repair of the articular surface using autograft, allograft, or fresh osteochondral allograft are reported(3,4). However, most patients with open tibial pilon fractures and bone defects are treated with tibiotarsal arthrodesis(5).

We present a technical tip using osteochondral allograft to reconstruct an area with extensive bone loss in the distal tibial epiphysis after a gunshot wound, describing the treatment stages and good clinical results.

Clinical symptoms and radiological findings

A 35-year-old male victim of an open tibial pilon fracture to a gunshot wound (Figure 1A-B) submitted to initial emergency treatment at another institution.

Four days after the first procedure, the patient requested discharge and was transferred to our hospital. On physical examination, the surgical wound on the lateral face of the ankle presented edges under tension and blisters on the anterior face associated with local hyperemia, negative expression, and hypoesthesia on peroneal nerve area (Figure 1C-E).

The imaging investigation in our institution, radiographs, and ankle computed tomography shows the shortening of the tibial fracture, remnant of the intra-articular firearm projectile, and bone loss of the anterolateral aspect of the distal tibia (Figure 2A-K).

Technical tip

Given the complexity of the bone and soft tissue injuries, we opted for the 3-staged treatment.

First stage

- Removal of the external fixator.
- Open reduction and internal fixation of the tibial shaft through combined anteromedial and medial access to reestablish the tibia length using compression screw and neutralization plate (Figure 3A, 3D-E).

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

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- External tube to tube fixation – 2 Schanz wires in the proximal tibia, 1 Schanz wire in the medial calcaneus, and 1 Schanz wire at the base of the first metatarsal (Figure 3B).
- Collection of samples for culture and antibiogram.
- Incisional negative pressure wound therapy for soft tissue injury (Figure 3C).

Five days after the first stage and negative culture results, a good clinical appearance of the lateral soft tissue was observed, with no clinical signs of local infection.

Second stage

- Removal of the external fixador (Figure 4A).
- Open reduction and internal fixation of posterior malleolus (anti-shear plate + compression screw through the plate) and lateral malleolus (plate with 2.8mm locked screws). (Figure 4B-D, 4G-H).
- Incisional negative pressure wound therapy for soft tissue injury.

Figure 1. Patient admission. A and B) Radiographic images of the ankle in anteroposterior and lateral views taken upon admission to another hospital. C-E) Photographic images of the patient's leg on admission to our institution showing external fixation and local hyperemia.

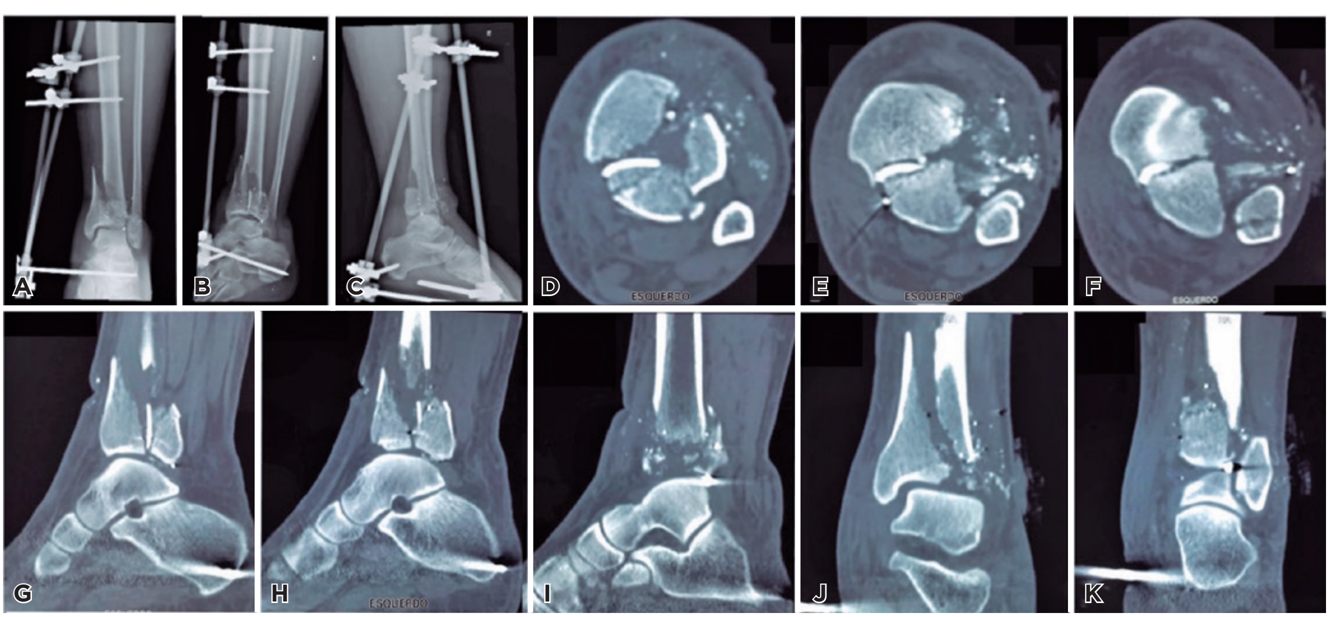

Figure 2. Radiological examinations performed upon admission to our institution. A-C) Radiographic images demonstrating a simple fracture trace of the fibula and comminuted distal tibia fracture. D-K) Computed tomography showing multi-fragmented open tibial pilon fractures with articular trace and extensive bone defect in the anterolateral aspect of the distal tibia.

Four weeks after the second stage, the appearance of the soft tissue was excellent. The patient was already undergoing physiotherapy gaining range of motion, muscle strengthening, and progressive partial load training. Therefore, we considered the opportune time to address bone loss in the anterolateral aspect of the distal tibia.

Third stage

- Reconstruction of the osteochondral failure through the anterolateral access route and use of a distal tibial allograft modeled in the shape of the osteochondral lesion and fixation with a compression plate and screws (Figure 5A-E).

Figure 3. First stage. A) Photographic image of the posteromedial and anteromedial pathway for anteromedial fragment reduction and fixation. B) Photographic image of the open wound after cleaning and debridement. C) Photographic image after new external fixation and incisional negative pressure wound therapy on the lateral wound. D-E) Postoperative fluoroscopic images demonstrating the larger fragment fixation, thus maintaining the length of the medial column restoration.

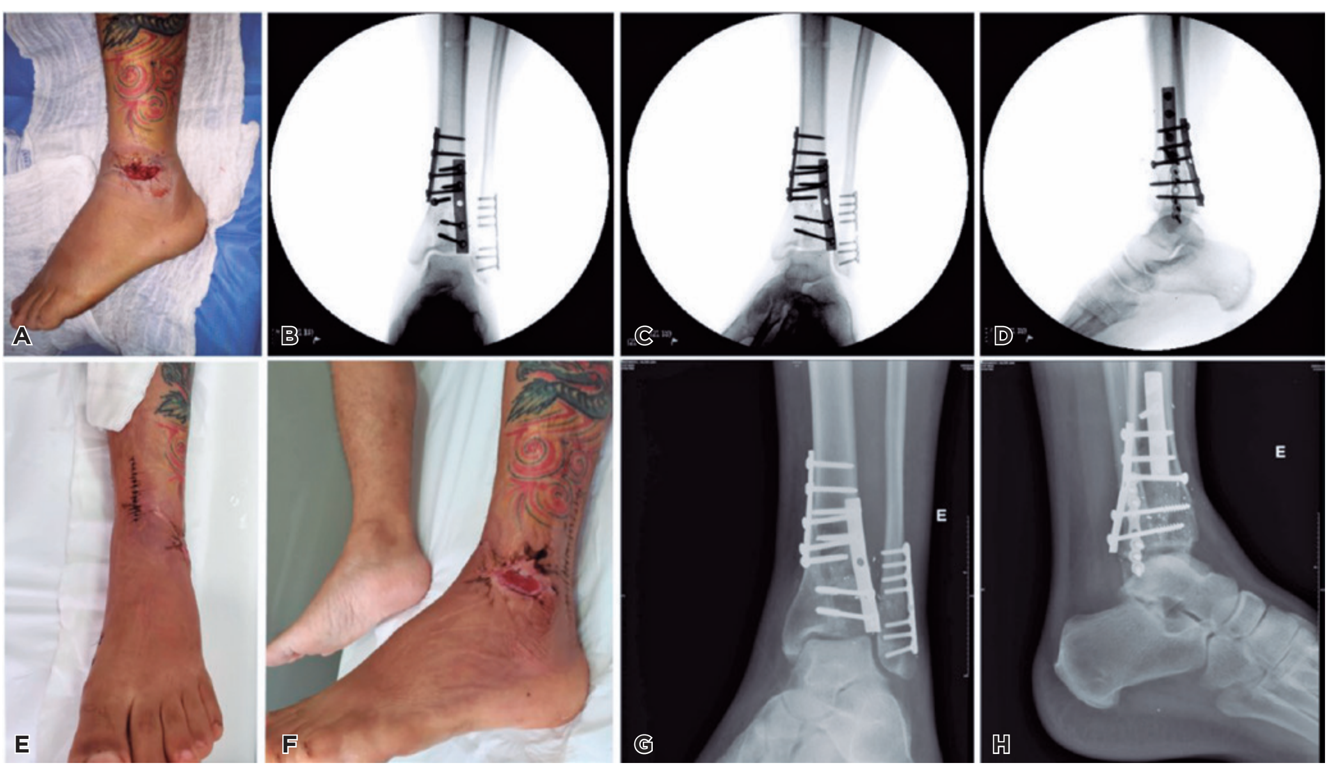

Figure 4. Second stage. A) Photographic image with an improvement of the lateral wound after removal of the external fixator. B-D) Fluoroscopic images in the anteroposterior, mortise, and lateral views of the ankle observing the fixation method of the posterolateral fragment of the tibia and fibula through a posterolateral ankle approach. E-F) Photographic images at two weeks after surgery showing wounds without inflammation with progressive improvement of the edema. G-H) Radiographic images in mortise and lateral views of the ankle at four weeks after surgery demonstrating bone healing with anterolateral osteochondral failure.

- Incisional negative pressure wound therapy for soft tissue injury.

The patient resumed physiotherapy gaining range of motion, muscle strengthening, and progressive partial load training until reaching full load without help six weeks after surgery. (Figure 6A-F).

Image control shows consolidation of the allograft and tibiotarsal joint congruence.

Discussion

Multi-fragmented open tibial pilon fractures associated with bone loss to gunshot wounds are typically related to high energy mechanisms and significant soft tissue injuries[1]. Therefore, the main objective of treating these complex fractures is to avoid soft tissue necrosis, minimize postoperative infection, and preserve the joint surface[6].

There are many techniques for this type of injuries such as open reduction and internal fixation in a single or staged time, primary ankle arthrodesis, joint surface reconstruction using autologous graft, allograft, or even fresh osteochondral allograft, and ankle arthroplasty[3,4].

Primary arthrodesis shows a good functional prognosis but increases the risk of degeneration in adjacent joints and may cause limb shortening[7].

In 1969, Rüedi and Allgöwer combined four key principles for treating tibial pilon fractures: restoration of length, reconstruction of the articular surface, bone graft to fill metaphyseal defects, and internal fixation with plate and screws[8]. However, the allograft is indicated when the fracture is associated with a joint defect greater than 3cm[9].

The incisive reduction and external fixation and the open reduction and internal fixation present a comparable functional prognosis. However, the external fixation tends to have a higher risk of postoperative complications, including infection, osteoarthritis, and pseudarthrosis[4].

The donor areas of autologous osteochondral bone graft are restricted; therefore, for major defects, the allograft represents an option for the tibiotarsal joint with large osteochondral lesions of the talus[10]. Few articles describe this technique for tibial defects[11].

When there is a bone defect greater than 5cm, the allograft is an option to be considered for arthrodesis because the

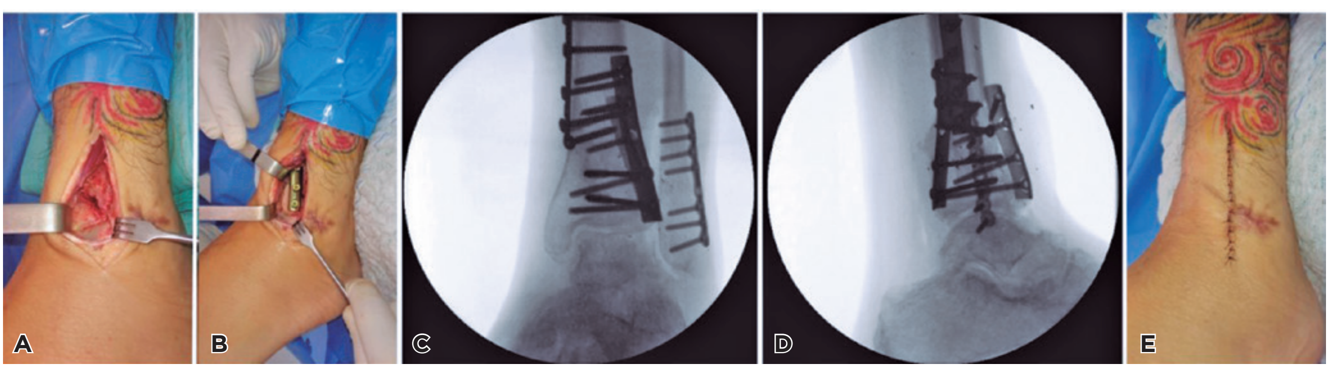

Figure 5. Third stage. A-B) Photographic images of the anterolateral view of the ankle with allograft positioned in the region of the osteochondral defect and method of allograft fixation. C-D) Fluoroscopic images in anteroposterior and lateral views of the ankle demonstrated allograft positioning and fixation method. E) Photographic image after suturing the anterolateral approach.

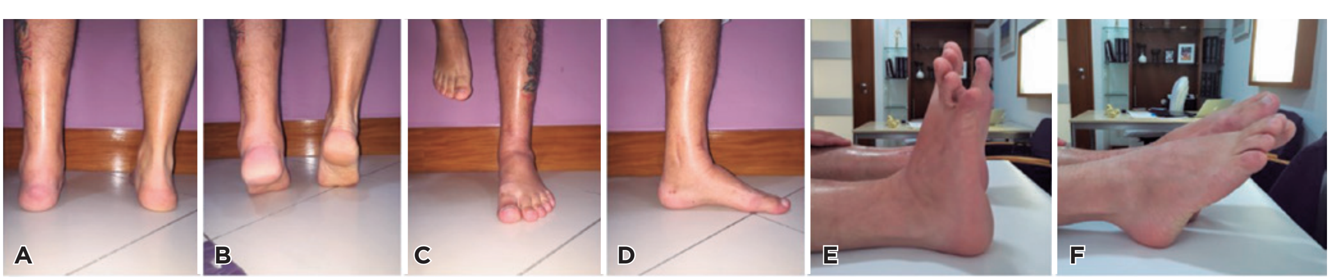

Figure 6. Six weeks after filling the osteochondral defect. A-F) Photographic images demonstrating patient with full weight-bearing without help and good ankle range of motion.

joint function can be preserved. Only two successful studies of this alternative in the literature were found[12,13]. Some complications inherent to this procedure, such as graft failure, arthrofibrosis, advanced osteoarthritis, and partial or complete osteonecrosis, are reported in the literature[10].

We describe a joint reconstruction technique using bone allograft with excellent postoperative recovery. Injuries of this type are rare, treatment experiences are not comprehensive and systematic, and treating these injuries is difficult, given the limited published literature available to guide surgeons.

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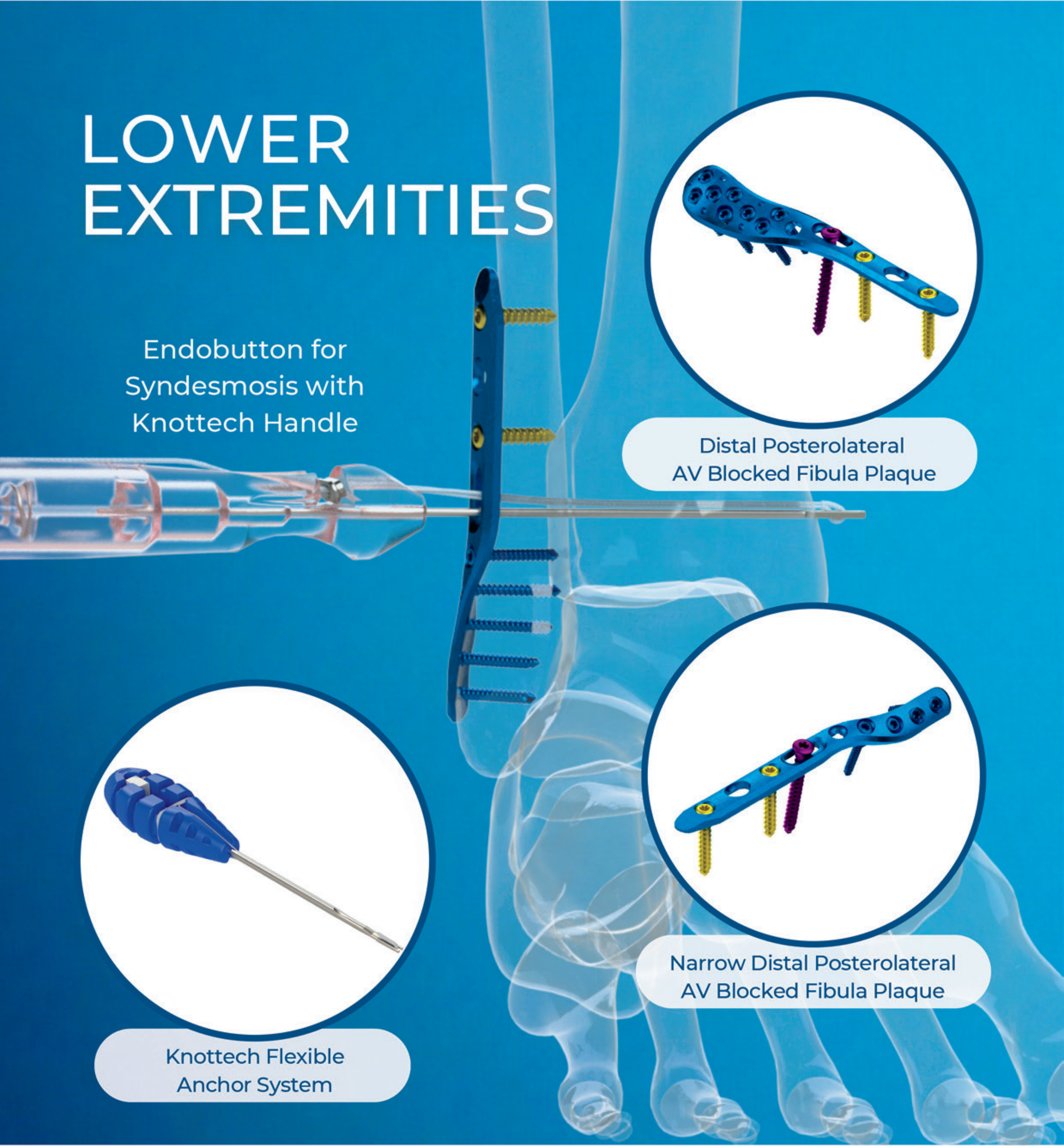
LOWER
EXTREMITIES
Endobutton for
Syndesmosis with
Knottech Handle
Distal Posterolateral
AV Blocked Fibula Plaque
Narrow Distal Posterolateral
AV Blocked Fibula Plaque
Knottech Flexible
Anchor System