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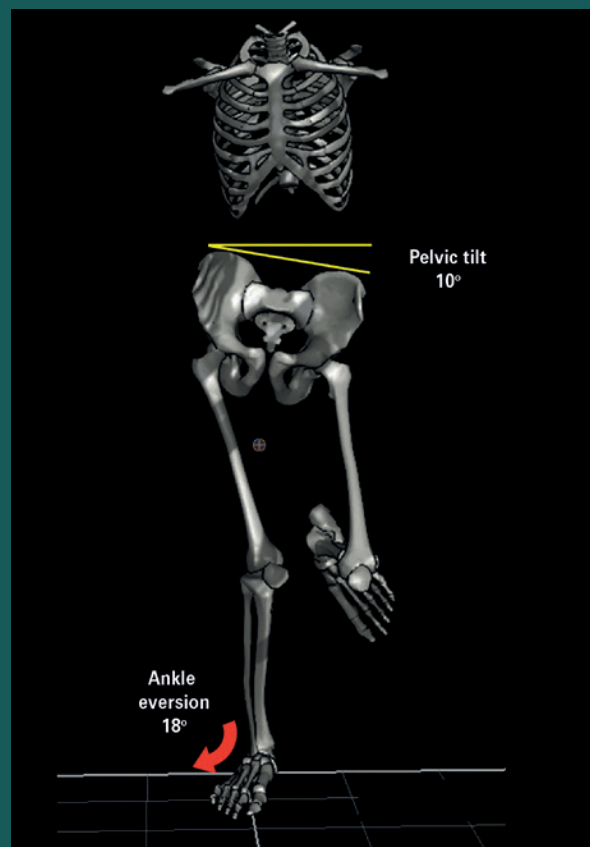

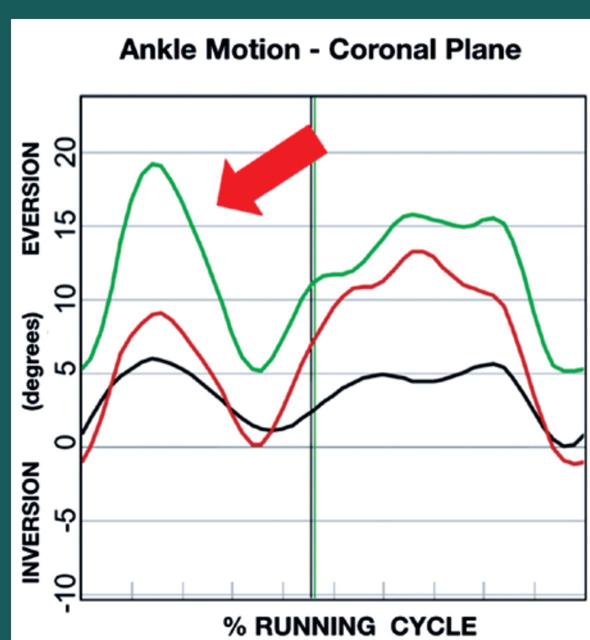

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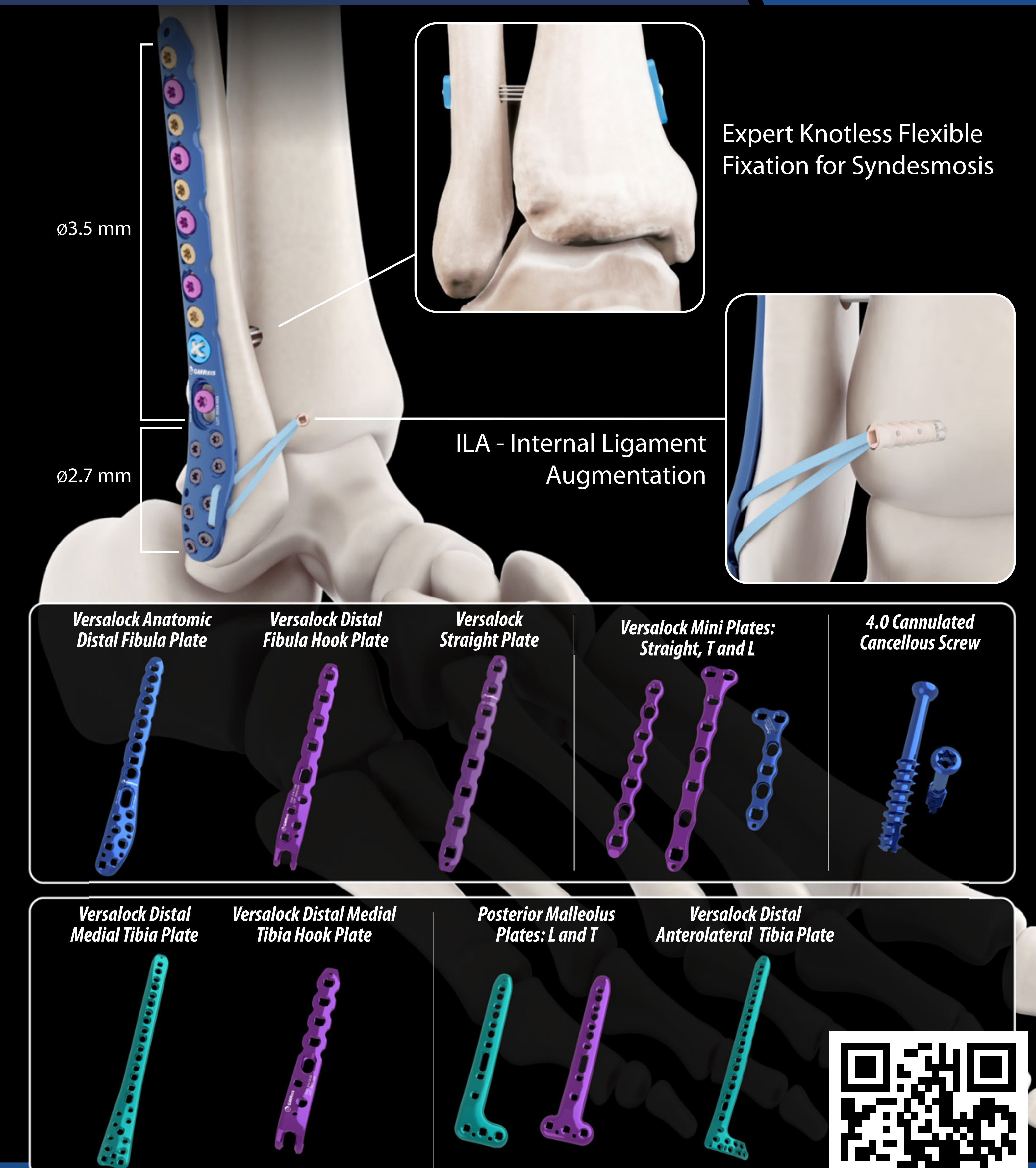

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Volume 14, Issue 2, May-August

Contents

Editorial

Original Article

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JOURNAL OF THE Foot & Ankle JFA

CRISTIAN ORTIZ
CHILE

Changing times

Any forecast of the pandemic dynamics has proven to be far away from what has really happened, particularly in South America. In most of our countries, we are still struggling with what has been called the first wave. The virus has impacted not only our health status but also every aspect of our lives, including our daily work. Spending less time in the operating room has a positive side that each one has experienced differently. It has provided the opportunity for more quality time with the family and an understanding of how vulnerable we all are, how complicated politics and economic decisions are, and how important the way we all communicate and share experiences is.

Most of us have seen our workplaces becoming busy with an increasing number of patients, which has led us to cancel any elective surgery and stay home in isolation. This difficult time we are going through has allowed us to think about our purpose in life, especially as physicians. We have been forced to develop new ways of teaching medicine, researching, and even practicing medicine. Most importantly, difficult times require that we learn a new way of living.

This has led us to reflect on the importance of research and on how important it is that all of us give our best for our patients. Treating patients well impels us to be informed, to be updated about new knowledge, and to practice our skills while continuously looking for answers. The virtuous circle to be a good doctor should always include clinical practice, medical education, and research.

When I was asked to write this editorial, one thought immediately came to my mind: how easily some journalists and public figures get into trouble after making a comment, writing an editorial, or even after publishing a post on social media. A recent example is what happened to J. K. Rowling, the famous author of the Harry Potter series. Last December, she tweeted her support for Maya Forstater, who was fired for what were deemed "transphobic" tweets. Rowling has received accusations and threats from trans activists and many worldwide famous people. A single 'like' was deemed evidence of 'wrongthink', and a persistent level of harassment began. The world has definitely changed, and everyone's comments and behaviors are completely public. We should not be afraid to speak up and express our opinion, we should not be stopped by the fear of having people against us. As physicians, we are all exposed by expressing our medical opinion every day in the office, in a meeting, or even in a remote setting. Every decision and opinion should be based on evidence, but they will inevitably include our personal background-which is a mix of knowledge and personal life experience. Hopefully, these opinions will always express our genuine interest in the patients and their families as our main focus.

As I get older, I pay more attention to the basis of my daily practice, which begins with proper information provided by good sources of medical education such as this journal. However, acquiring reliable information is just the beginning of the path toward good medical practice. The remainder of the path-the most important part of it-must be trodden by a human being truly interested in doing the best for his/her patients every day.

It has always amazed me that everyone who I admire as a physician is, at the same time, a professor, a researcher, and an amazing human being. This journal is the result of the efforts of a group of people who are truly committed to learning, teaching, and investigating, thus producing friendly feedback and updated knowledge.

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Original Article

Acute retrograde tibiotalocalcaneal nailing in osteoporotic periarticular ankle fractures

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Abstract

Objective: This study aimed to report the short-term results of retrograde tibiotalocalcaneal (TTC) nailing in a selected series of patients with fragility ankle fractures.

Methods: This study included 17 patients who underwent primary retrograde TTC nailing from January 2016 to April 2019. The Olerud-Molander ankle score (OMAS) was recorded preoperatively and at the final follow-up.

Results: Mean patient age was 81.5 years (range, 67-91 years), and mean follow-up duration was 20.9 months (range, 8-50 months). No patient was lost to follow-up. Eleven patients had diabetes. Thirteen patients were able to walk with an assistive device, and 4 with help from another person. Two patients died at 8 and 9 months after treatment. Radiographic healing was observed in 100% of the fractures. No deep infection or scarring problems were recorded. Two patients were wheelchair bound after treatment, whereas 15 recovered their previous autonomy. The mean OMAS score changed from 64.1 (range, 55-75) preoperatively to 55.3 (range, 45-65) postoperatively.

Conclusion: Our results suggest that primary retrograde TTC nailing is a valid option in selected patients with fragility ankle fractures, multiple comorbidities, poor soft tissue condition, and difficulty in walking before the fracture.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Ankle fractures; Osteoporotic fractures; Aged; Fracture fixation, intramedullary/methods; Tibial fractures/surgery.

Introduction

Osteoporotic fractures are becoming more frequent due to increasing life expectancy in the developed world, and ankle fractures are no exception. In older adults, ankle fracture is the third most common fracture type, after hip and wrist fracture, with an incidence of 184 cases per 100 000 population[(1)]. Difficulties in managing these fractures in older patients are associated with osteoporosis, which produces more complex fracture patterns with greater inherent instability[(2-4)].

Multiple treatment options are available for ankle fractures, but open reduction and internal fixation (ORIF), aiming to achieve absolute stability, remains the gold standard. However, conventional ORIF is contraindicated in older patients due to injury-related factors (e.g., swelling, dislocation, and skin damage) or patient-related factors (e.g., advanced age, preexisting poor skin condition, systemic disorders, and impaired mobility).

Conservative treatments are often not well tolerated by older people[(5-8)]. Desirable goals in the older population with periarticular ankle fracture include stable fixation of usually unstable fractures, minimally invasive technique to protect soft tissue coverage, the least aggressive surgical procedure (only one surgery, only one anesthesia), and early weight bearing and mobilization to avoid the effects of prolonged immobilization (e.g., deep vein thrombosis, pneumonia, and bed sores).

Tibiotalocalcaneal (TTC) nailing has been a valid treatment option for osteoporotic ankle fractures in the acute phase. Several studies have been published since 2005 with satisfactory functional results in selected patients, with a low rate of complications[(9-18)].

Study performed at Hospital Universitario de Canarias, Tenerife, Spain.

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The objective of this study was to report the short-term functional results of the treatment of osteoporotic periarticular ankle fractures with TTC nailing and to provide an update of the available literature addressing this topic.

Methods

After approval by the Local Ethics Committee, we conducted a retrospective study of a series of 17 consecutive patients treated with a retrograde TTC nail for fragility fractures of the ankle or distal tibia from January 2016 to April 2019. The inclusion criteria were age >65 years, periarticular fragility fracture of the ankle (defined as injury secondary to a low-energy mechanism, such as a simple twist or a fall from one's own height, or any fracture in a patient previously diagnosed with osteoporosis), and surgical treatment with TTC nailing at the surgeon's discretion, with a follow-up of at least 6 months.

Epidemiological variables were recorded, including walking ability (Table 1), intraoperative and postoperative complications, mean hospital stay, and patient outcome. Patients were followed up with regular appointments at 2 weeks postoperatively for wound check, and at 6 weeks and 3, 6, and 12 months postoperatively for clinical and radiographic evaluation. The Olerud-Molander ankle score (OMAS) was used for clinical assessment (Table 2)[19].

Table 1. Demographic characteristics

Population	17
Female	16 (94.1%)
Male	1 (5.9%)
Age (years)	81.5 (67-91)
Female	81.3 (67-91)
Male	84 (84)
ASA score	2.1 (1-3)
Diabetes mellitus	
No	6 (35.3%)
Yes	11 (64.7%)
Type of fracture	
Bimalleolar fracture	5 (29.4%)
Trimalleolar fracture	6 (35.3%)
Fracture-dislocation	5 (29.4%)
Tibial pilon	1 (5.9%)
Preoperative OMAS	64.1 (55-75)
Open/closed fracture	
Closed	12 (70.6%)
Open Gustilo-Anderson I	1 (5.9%)
Open Gustilo-Anderson II	3 (17.6%)
Open Gustilo-Anderson III	1 (5.9%)
Walking ability	
Walks independently	0
Alone with an assistive device	13 (76.5%)
With help from another person	4 (23.5%)

ASA: American Society of Anesthesiology. OMAS: Olerud-Molander ankle score.

Table 2. Olerud-Molander ankle score (OMAS)

Parameter	Degree	Score
Pain	None	25
	While walking on uneven surface	20
	While walking on even surface outdoors	10
	While walking indoors	5
	Constant and severe	0
Stiffness	None	10
	Stiffness	0
Swelling	None	10
	Only evenings	5
	Constant	0
Stair climbing	No problems	10
	Impaired	5
	Impossible	0
Running	Possible	5
	Impossible	0
Jumping	Possible	5
	Impossible	0
Squatting	No problems	5
	Impossible	0
Supports	None	10
	Taping, wrapping	5
	Stick or crutch	0
Work, activities of daily life	Same as before injury	20
	Loss of tempo	15
	Change to a simpler job/part-time work	10
	Severely impaired work capacity	0

Our results were compared with those reported in the literature by searching PubMed electronic database with the following keywords: "fragility ankle fractures and nail", "fragility ankle fractures and retrograde nailing". Articles were included if they treated fractures of the ankle or tibial pilon with retrograde solid nailing. Cadaveric studies, biomechanical studies, and studies using fixation methods other than a nail were excluded.

Surgical technique

Patients received a single dose of antibiotic prophylaxis (cefazolin 2 g). The procedure was performed with the patient in supine position under general or spinal anesthesia at the anesthesiologist's discretion (sciatic nerve block was performed in 3 patients at high anesthetic risk). No tourniquet was applied in any case (Figure 1). The nail entry point was determined in the external plantar region at the center of the lateral column of the calcaneus. The fracture was reduced under radioscopic control. A guide wire was inserted, followed by progressive reaming to 11 mm and insertion of an angled retrograde titanium nail (Expert-HAN, Synthes) of 10 mm in diameter and 18 cm in length (Figure 2). Neither the subtalar joint nor the tibiotalar joint was addressed in any case because the procedure did not pursue the arthrodesis of these joints. The wound was closed, and a compression bandage was applied. The mean operative time was 48 minutes (range, 35–93 minutes). There were no intraoperative complications.

Postoperative protocol

At 48 hours after admission, the wound was checked and the patient was discharged if there were no complications. Full weight bearing was allowed as tolerated and protected by the use of a CAM walker boot for 6 weeks. The stitches were removed after 3 weeks.

Figure 1. Patient in position. Note the poor condition of soft tissues.

Figure 2. Immediate postoperative result.

Results

The sample consisted of 16 women and 1 man, with a mean age of 81.5 years (range, 67–91 years). Mean follow-up duration was 20.9 months (range, 8–50 months). No patient was lost to follow-up, but 2 patients died at 8 and 9 months after treatment (Table 3).

Radiographic healing was observed in 100% of the fractures. In 5 cases, a complete arthrodesis of the ankle joint was achieved with a simple reamed nail (Figure 3).

Complications included 1 superficial infection, 1 symptomatic nonunion of the subtalar joint, and 1 distal screw loosening. No deep infection, scarring problems, peri-implant fracture, or nail failure were recorded. The mean OMAS changed from 64.1 (range, 55–75) preoperatively to 55.3 (range, 45–65) postoperatively.

None of the patients could walk independently before surgery. After treatment, 2 patients could no longer walk and were wheelchair bound, whereas 15 recovered their previous autonomy (Figure 4).

Table 3. Results

Follow-up (months)	20.9 (8-50)
Complications	4 (23.5%)
Deaths	2 (11.8%)
Postoperative OMAS	55.3 (45-65)
Walking ability	
Alone with an assistive device	10 (58.8%)
With help from another person	5 (29.4%)
Wheelchair bound	2 (11.8%)
Radiographic union	17 (100%)
Spontaneous ankle fusion	5 (29.4%)

OMAS: Olerud-Molander ankle score.

Figure 3. An 86-year-old woman who sustained an ankle fracture-dislocation (A). Note the poor condition of soft tissues (B). Spontaneous fusion of the tibiotalar joint without cartilage removal (C).

Figure 4. Good outcome at 3 months.

Discussion

Osteoporotic fractures of the ankle in frail older people present a serious therapeutic challenge for the orthopedic surgeon for multiple reasons: poor bone quality secondary to osteoporosis, poor condition of soft tissue coverage, instability patterns and comminuted fracture, in addition to the high comorbidity in this population[1,4]. These particularly frail patients are poor candidates for conservative treatment, especially in cases of unstable ankle fractures, because long immobilization and non-weight bearing periods can lead to local complications (pressure ulcers, deep vein thrombosis) and medical problems (pneumonia, pulmonary thromboembolism)[2,3,13].

Although ORIF remains the gold standard treatment, it has been associated with a high complication rate in the older population, leading to the use of other methods[5,6]. A surgical technique that meets the requirements of sufficient primary stability and minimal soft tissue aggression and that allows early mobilization and weight bearing in these frail patients would therefore be desirable.

TTC nailing has been used as a salvage procedure after failed osteosynthesis or failure of conservative treatment[7,14,15]. However, over the past 10 years, interest has grown in the use of TTC nailing as a treatment option for unstable fractures in selected patients. Based on data from the literature and our own experience, retrograde TTC nailing as a method of osteosynthesis in unstable osteoporotic periarticular ankle fractures in frail patients with difficulty in walking without assistance is a highly satisfactory technique[9-12].

Since 2005, 10 studies have been published on the treatment of these fractures with retrograde TTC nailing (Table 4). Most of these studies reported satisfactory functional results and low complication rates[9-18]. In 2005, Lemon et al.[9] published the first article on this technique: a case series of 12 patients (mean age, 84 years; follow-up, 67 weeks), achieving good functional results and early full weight bearing in all patients. However, although the patients' medical history was reported, the authors failed to report the inclusion criteria that led to treatment with a TTC nail. In 2008, Amirfeyz et al.[10] published a retrospective study of 13 patients (mean age, 79 years; follow-up, 11 months) and reported early hospital discharge, functional outcome comparable to the preoperative status, fracture healing, and no complications; however, the inclusion criteria were not well defined. In 2010, O'Daly et al.[11] published a series of 9 cases treated with TTC nailing after failure of conservative treatment with closed manipulation. Fracture union was observed in 89%, and 70% of patients returned to their previous functional status without any complication. In 2013, Jonas et al.[12] published a series of 31 cases of unstable ankle fractures treated with TTC nailing. Although the inclusion criteria were not well defined, the authors assessed preoperative mobility, preexisting morbidity, soft tissue condition, and level of patient compliance with non-weight bearing. Despite the good functional results, the rate of complications was high (38.7%), including 3 peri-implant fractures and 2 broken nails, drawing attention to the fact that more active patients could have a higher failure rate when treated with this method. In 2014, Al-Nammari et al.[13] published a retrospective study of 48 frail patients (mean age, 82 years) treated with retrograde nailing using a long femoral nail. The inclusion criteria were an American Society of Anesthesiology (ASA) score ≥3, multiple preoperative comorbidities, and inability to walk independently for more than 200 m. The authors recommended the use of long nails that passed the isthmus of the tibia to avoid peri-implant fractures. At 6 months, 90% of patients had returned to their preoperative functional status, but the rate of complications was high, including deep infection (2%) and broken distal screws (6%), valgus malunion (4%), medical complications (29%), and 1 below-knee amputation. In 2016, Taylor et al.[14] published a retrospective study of 31 patients (mean age, 63 years; follow-up, 13.6 months) and reported the occurrence of 2 superficial infections (6.5%) and 3 deep infections (9.7%). The fracture healed in 90.3% of cases, with satisfactory functional results. The authors did not clearly define the inclusion criteria, but they highlighted obesity and diabetes as risk factors. In 2017, Georgiannos et al.[15] published the only prospective randomized controlled study of ORIF vs TTC nailing. The inclusion criteria for both treatments were age >70 years, closed bimalleolar or trimalleolar fractures, and ankle fracture-dislocations; 37 patients (mean age, 78 years) were recruited. Functional outcome did not differ between the groups (TTC nailing vs ORIF), but the rates of complications, hospital stay, and mortality were lower in the nailing group. In 2018, Baker et al.[16] published a retrospective study of 16 patients with 3 or more comorbidities and unstable ankle fractures. Overall, the results were good, especially the low rate of wound complications and early recovery. In the same year, Persigant et al.[17] published the results of a series of 14 patients treated with a retrograde femoral nail and immediate weight bearing, with a mean follow-up of 12 months.

Table 4. Review of the literature on retrograde intramedullary TTC nailing for fragility ankle fractures

Study	Design	Evidence level	Sample	Age (yrs)	Nail	Postop WB	Follow-up (months)	Complications
Lemon 2005[9]	RT	IV	12	84	Long expandable humeral nail	Full	16	8.3%: 3 DVT.
Amirfeyz 2008[10]	RT	IV	13	78.9	Short humeral nail and short TTC nail	Partial	11	7.7%: 1 minor wound breakdown, 1 delayed union.
O´Daly 2010[11]	RT	IV	9	81	Long humeral nail	Full	34	None.
Jonas 2013[12]	RT	IV	31	77	Short TTC nail	Full	18	38.7%: 2 peri-implant fractures, 2 broken nails.
Al-Nammari 2014[13]	RT	IV	48	82	Long retrograde femoral nail	Full	6	47%: 2 superficial infections, 1 deep infection, 3 broken distal screws, 2 valgus malunion, 1 BKA.
Taylor 2014[14]	RT	IV	31	63	Short TTC nail	*Full/Partial	13.6	29.1%: 3 implant failures, 2 superficial infections, 3 deep infections, 1 BKA.
Georgiannos 2016[15]	PT	II	37	78	Short TTC nail	Full	12	8.1%: 1 superficial infection, 1 DVT, 1 protrusion of the nail.
Baker 2018[16]	RT	IV	16	73	Long retrograde femoral nail	No WB 7-10 days (then full WB)	21	N/R
Persigant 2018[17]	RT	IV	14	79.6	Long retrograde femoral nail	Full	12	20%: 1 deep infection, 1 distal screw loosening.
Ebaugh 2019[18]	RT	IV	27	66	Short TTC nail	No WB until healing of plantar wound (then full WB)	29.6	18.5%: 1 superficial infection, 3 deep infections, 1 nail failure, 1 AKA.
Present series 2020	RT	IV	17	81.5	Short TTC nail	Full	20.9	23.5%: 1 distal screw loosening, 1 painful subtalar nonunion, 1 superficial infection.

TTC: tibiotalocalcaneal; RT: retrospective; PT: prospective; N/R: not reported; WB: weight bearing; DVT: deep vein thrombosis; BKA: below-knee amputation;. AKA: above-knee amputation.
* At the surgeon's discretion.

The authors reported satisfactory functional results, fracture union, and only 1 major complication (deep infection requiring nail removal). Finally, in 2019, Ebaugh et al.[18] published a retrospective study of 27 patients with complicated diabetes treated with TTC nailing and reported high functional and limb salvage rates, few complications, and maintenance of the previous level of autonomy.

The present study included 17 patients (mean age, 81.5 years; follow-up, 20.9 months) and found satisfactory functional results, in accordance with the existing literature. Despite the high prevalence of diabetes (11 of 17 patients were diabetic), there was only 1 superficial infection and no deep infection. Consistent with the published literature, the most common complication was loosening of the locking screws, which led to their removal. There were no cases of peri-implant fracture despite using an intermediate-length nail (18 cm). As previously reported in the literature, except for 1 patient requiring subtalar arthrodesis, patients did not report pain due to limited mobility at level of the subtalar and tibiotalar joint. Finally, a remarkable outcome of this study was the rate of spontaneous fusion of the tibiotalar joint, which occurred in 5 cases, despite not being the objective of the technique.

In sum, the published articles have included in their series frail older patients with difficulty in walking independently and unstable fractures. Despite the short follow-up duration (1 year on average), all of them have reported satisfactory functional results, shorter mean hospital stay, and earlier full weight bearing with TTC nailing than with ORIF, in addition to fewer complications, which is of vital importance to these particularly frail patients.

Study limitations

Our study has some limitations. The first is related to the study design, as all data were collected retrospectively, and there was no control group for comparison. Other potential weaknesses are the relatively small sample size and short follow-up.

Conclusion

Our results suggest retrograde TTC nailing as a valid treatment option for fragility ankle fractures in selected patients in whom both conservative treatment and conventional osteosynthesis are contraindicated. Prospective studies with a larger sample size are needed to confirm our promising results.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MHP *(https://orcid.org/0000-0001-6188-5269) conceived and planned the activities that led to the study, wrote the paper, approved the final version; PMV *(https://orcid.org/0000-0001-9077-3880) participated in the review process and approved the final version; DRD *(https://orcid.org/0000-0003-2059-6289) participated in the review process and approved the final version; JLPB *(https://orcid.org/0000-0001-5196-6225) interpreted the results of the study, participated in the review process and approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

V-Y advancement flap for repair of neglected injuries of the Achilles tendon using 2 mini-incisions

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Abstract

Objective: To find a safe repair site for a proximal mini-incision to expose the fascia at the level of the gastrocnemius medialis (GM) myotendinous junction (MTJ).

Methods: Seventeen anatomic specimens of popliteal fossa, leg, and foot fixed in formalin were dissected, and the perpendicular distance from the apex of the medial malleolus to the GM MTJ was measured.

Results: The minimum and maximum perpendicular distances from the apex of the medial malleolus to the GM MTJ were 14.00cm and 20.5cm, respectively. Average distance was 16.56cm.

Conclusion: We were able to establish a constant value and the average GM MTJ height, which allows for V-Y lengthening through 2 mini-incisions. In reviewing the literature, there was no description of the approaches proposed in this study.

Level of Evidence VI; Therapeutic Studies; Case Series.

Keywords: Achilles tendon/surgery; Rupture/surgery; Tendon injuries; Fascia; Treatment outcome.

Introduction

V-Y advancement flap was originally described for repair of neglected Achilles tendon injuries in 1975 by Abraham and Pankovich[1] through an inverted V incision which is then repaired in a Y fashion to allow for end-to-end suture of the tendon.

Such technique involves an extensive posteromedial incision from the Achilles tendon distal insertion at the calcaneus which shifted medial at the proximal area to visualize the gastrocnemius medialis (GM) myotendinous junction (MTJ).

Resection of devitalized (fibrotic/scar) tissue of the neglected Achilles injury is performed, then an inverted V incision of the fascia is made at the myotendinous junction, and distal traction is performed to achieve lengthening of the fascia-gastrocnemius-Achilles complex, which is subsequently reinserted into the calcaneus (chronic insertional disease) or sutured to the remaining distal portion of the healthy tendon (non-insertional chronic disease or chronic ruptures). The approach of this technique consists of a single extensive incision, which leads to complications that increase morbidity.

No study was found in the literature describing a two-incision approach: one distal incision at the site of the injury and another proximal incision near the GM MTJ.

The aim of this study was to find a safe repair site for a proximal mini-incision (4cm) to expose the fascia at the level of the GM MTJ and to perform a V-Y advancement flap, thus making it possible to apply the technique using 2 mini-incisions, which reduces morbidity rates as compared to the traditional large incision.

Methods

The dissection team of the *Segunda Cátedra de Anatomía* at Universidad de Buenos Aires, Argentina, evaluated 17 anatomic specimens of popliteal fossa, leg, and foot fixed in 5% formalin, of which 7 were right lower limbs and 10 were left lower limbs.

Study performed at the Instituto Dupuytren, Buenos Aires, Argentina.

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The specimens were dissected, and a millimeter ruler was used to measure the perpendicular distance from the apex of the medial malleolus to the MTJ of GM (due to its lower insertion compared to gastrocnemius lateralis) with the knee at 90° dorsiflexion. Measures for all specimens were then used to calculate the average distance between these two sites.

Results

Seventeen anatomic specimens of popliteal fossa, leg, and foot, of which 7 were right lower limbs and 10 were left lower limbs, were dissected and measured. There were no differences regarding sex (Table 1).

The minimum and maximum perpendicular distances from the apex of medial malleolus to the GM MTJ were 14.00cm and 20.5cm, respectively. Average distance was 16.56cm. All measurements were obtained with knee of the anatomical specimen at 90° dorsiflexion (Table 1).

Discussion

V-Y advancement flap is performed to achieve an appropriate length for the Achilles tendon, thus restoring its anatomical continuity, muscle strength, and functionality, as well as patients' symmetrical and an proper one-leg raising[2-5].

According to Us et al., V-Y advancement flap is able reduce defects measuring from 4 to 6cm[6]. Other studies, such as that of Kissel et al.[7], coincide in the distance of defects (above 5cm) to be fixed using this technique. A study by Leimer et al. increased the length of fixable defects to up to 10cm[8].

Table 1. Measurement for each cadaveric specimen: perpendicular distance (cm) from the apex of the medial malleolus to the gastrocnemius medialis myotendinous junction

Specimen	Distance (cm)
1	15.9
2	20.0
3	16.4
4	16.5
5	14.9
6	15.2
7	17.4
8	19.2
9	13.6
10	14.4
11	16.4
12	16.7
13	20.5
14	16.2
15	14.0
16	16.8
17	17.5

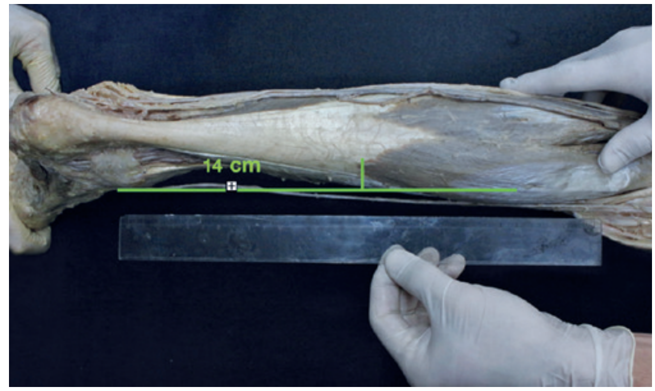

Figure 1. Image showing anatomical repair sites to be considered (internal saphenous vein and sural nerve) in the mini-incision (4-cm) approach.


Figure 2. Mini-incision approach showing fascia with inverted V incision.

All referenced authors used a surgical approach consisting of a single extensive incision.

Based on the results of anatomical dissections and measurements, we described a safe area for proximal approach, which was established at 14cm of the medial malleolus.

With the patient in the prone position, a tourniquet cuff is placed at the thigh, and enhancement is applied to the dorsal side of the foot to be operated on. A distal incision of skin and subcutaneous cell tissue is made on the Achilles tendon portion that needs repair, and the tendon is repaired.

A second approach for tendon lengthening is made at 14cm from the medial malleolus and following the axis of distal incision. An incision of skin and subcutaneous cellular tissue is made, extending 2cm proximally and 2cm distally; furthermore, the internal saphenous vein, which runs along the sural nerve, is identified and held away (Figure 1). It is then possible to reach the fascia, where an inverted V incision is made (Figure 2).

Subsequently, the subcutaneous cellular tissue of the deep fascia is detached in the portion between the two incisions to provide a greater enable distal for length to allow for distal traction of the end of the tendon that should be reinserted or sutured to the remaining tissue.

Next, the fascia is sutured with an inverted V incision, which becomes a Y incision. Finally, the tourniquet cuff is removed, the surgical wound is closed, and the limb is protected with a walking boot walker or equine valve when applicable.

Conclusion

V-Y advancement flap is one of the techniques for the repair of segmental defects measuring more than 5cm (from 5 to 10cm) after resection of devitalized tissue in neglected injuries of the Achilles tendon.

Based on this anatomical study, we were able to establish a constant value and the average for GM MTJ height, which allows for the implementation of this technique using 2 mini-incisions, thus reducing morbidity and improving esthetic outcomes in our patients.

In reviewing the literature, there was no description of the approaches proposed in this study.

Authors' contributions: Each author contributed individually and significantly to the development of this article: GA *(https://orcid.org/0000-0001-9209-7660) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; LC *(https://orcid.org/0000-0003-1187-0864) wrote the article, participated in the review process; SL *(https://orcid.org/0000-0002-5212-5257) wrote the article, participated in the review process; GMJ *(https://orcid.org/0000-0001-9998-190X) wrote the article, participated in the review process; DNG *(https://orcid.org/0000-0002-7870-5882) wrote the article, participated in the review process. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Assessment of imaging, pathoanatomy and terminology in posterior tibial tendon dysfunction

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Abstract

Objective: This study aimed to determine damage/change occurring in the posterior tibial tendon of patients undergoing surgery for posterior tibial tendon dysfunction (PTTD) and to correlate preoperative imaging and intraoperative findings with histology to determine the most appropriate investigations for diagnosis. The secondary aim was to clarify terminology used in describing the tendon pathology, to improve descriptive terminology for research, assessment, and treatment of PTTD.

Methods: The records of patients who had undergone surgery for stage 2 PTTD were retrospectively reviewed. Cases in which preoperative diagnostic imaging was done and a posterior tibial tendon specimen was sent for histology were included. Ultrasound (US) and MRI findings, surgical notes and histopathological reports were evaluated.

Results: Nineteen patients met the inclusion criteria. Fourteen had US showing degenerative changes and synovitis. Five had MRI showing tendon degeneration, with rupture in two cases. Intraoperatively, all tendons showed gross abnormality, with surrounding synovitis. Microscopically, no acute inflammation was noted within any tendon specimens. All had non-specific reactive changes within the visceral synovium.

Conclusion: This study confirms clear histological degeneration within the posterior tibial tendon of patients undergoing corrective surgery for PTTD. Preoperative imaging and surgical findings identified tendon sheath synovitis. Pre-operative ultrasound imaging and intraoperative confirmation of PTTD is accurate; thus, histological confirmation is unnecessary. The pathological changes in PTTD have been described as a tendinopathy in the literature. We suggest using the term pantendinopathy, which is a combination of peritendinitis with tendinosis, as it better describes the pathological process.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Posterior tibial tendon dysfunction/surgery; Posterior tibial tendon dysfunction/pathology; Diagnostic imaging; Tendinopathy.

Introduction

Adult acquired flatfoot deformity (AAFD) is a common disorder characterised by progressive collapse of the medial longitudinal arch, valgus deformity of the hindfoot and forefoot abduction and supination[1,2]. Posterior tibial tendon dysfunction (PTTD) is thought to be the most common cause in adults. The aetiology of PTTD is multifactorial and includes abnormal loading of the arch (commonly seen in middle-aged obese women), inflammatory disorders, and trauma. Risks factors such as hypertension or diabetes can also be present. The damage often occurs in a zone of hypovascularity, 2-6cm from the navicular insertion site[3].

PTTD was classified by Johnson and Strom[4] in 1989, and subsequently modified by Myerson[5] into four stages. Stage II disease is characterised by enlargement and elongation of the posterior tibial tendon (PTT), rendering it functionally incompetent. This results in a pes planovalgus. Failing initial conservative management, surgical treatment of PTTD consists of joint-sparing surgery, including osteotomies and tendon transfers to rebalance the foot, or fusions[6].

Initial imaging in PTTD consists of weightbearing x-rays, which allow evaluation of bony alignment, osseous changes, and joint arthrosis. Ultrasound (US) and/or MRI assist in making a diagnosis of PTTD. US is preferable and is reported

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to be up to 100% sensitive and 88% specific in detecting tears of the PTT when performed by a competent musculoskeletal ultrasonographer[7]. It also allows for dynamic assessment of the PTT in the area of tenderness and can identify possible differentials such as gout. It is an inexpensive and easily accessible modality[8]. MRI allows visualisation of the entire ankle and foot, which can help identify other pathologies around the ankle joint. It can identify fatty degeneration and muscle atrophy in cases of complete PTT rupture[9]. Oedema within the bone can also be appreciated[10-12]. MRI should be considered for patients with inconclusive US examinations and to look for other possible signs of PTTD[9,13].

Historically, it was believed that a tendinitis or tenosynovitis led to PTTD. Trevino et al., in 1981, were the first to describe the histopathology of PTTD. They identified a change from normal parallel collagen bundles to a wavy, loose configuration. Later studies reported that changes consist of mucoid degeneration, neovascularisation, and tendon sheath hypertrophy. This was hypothesised to eventually lead to tendon rupture[14,15]. Delmi et al.[16], in 1995, described a tenosynovitis associated with myxoid degeneration, disorganised collagen bundles and calcific deposits. Mosier et al.[17] described a degenerative tendinosis of the PTT, characterised by an excess of mucin deposition, a lack of inflammatory cells, neovascularisation and fibroblast hypercellularity[18]. These reports support a degenerative process within the tendon rather than inflammatory changes.

Maffulli et al.[19] suggested using the terms "tendinosis", "paratendinitis" and "tendinitis" when describing general tendon pathology based on histological examination. They proposed using the term "tendinopathy" to describe the clinical syndrome of pain, swelling and reduced performance. Van Dijk et al.[20] noted that the terminology for Achilles tendon pathology had become inconsistent and confusing and that clear terminology was necessary, especially for research purposes. The authors similarly felt that the terminology currently used in describing the pathology of PTTD is vague and needed to be clarified.

This study aimed, by correlating preoperative imaging and intraoperative findings with histological samples, to determine the pathological change that may occur in the posterior tibial tendon of patients undergoing surgery for PTTD and to determine the most appropriate investigations for diagnosis. The secondary aim was to clarify terminology used in the description of this tendon pathology so as to improve the descriptive terminology used when researching, assessing and treating PTTD.

Methods

Approval for this research was obtained from the institution's ethics and research committee. Records of patients with AAFD who had undergone surgery for stage 2 PTTD correction between January 2016 and January 2020, at a private clinic, were retrospectively reviewed. All cases in which preoperative diagnostic imaging (US or MRI), complete surgical records and histological evaluation of the PTT had been performed were included. Ultrasound is our preferred investigation for PTTD as it can be done dynamically and is inexpensive; MRI is reserved for complex cases with suspected associated pathologies. Cases were excluded if their records were incomplete or data were missing. Seven cases were excluded due to a lack of preoperative imaging. Patient demographics including age, sex and comorbidities were recorded. US, MRI, and surgical findings, as well as histopathological reports, were evaluated. At the time of surgery, specimens of the PTT were obtained, placed in formalin and sent to the anatomical pathology service for microscopic evaluation. All samples were processed at the same laboratory. Data were analysed qualitatively, using descriptive statistics. We reported categorical data in tables with frequencies and percentages and tested normality of the data qualitatively.

Results

Nineteen patients met the inclusion criteria and were included in the study. Of these, 14 had US examinations and 5 had MRI performed pre-operatively. There were 16 females and 3 males, with a mean age of 59 (range, 45 to 68) years. Patient comorbidities included hypertension (5 patients), diabetes mellitus (4 patients), hypercholesterolaemia (3 patients), and thyroid dysfunction (2 patients) (Table 1).

The 14 preoperative US investigations reported moderate to marked degenerative changes/tendinopathy in all cases (Table 2). Further details, including the size and number of longitudinal intratendinous tears and the degree of cross-sectional tendon involvement and fraying, were documented. These changes were noted predominantly at the level of the medial malleolus or distal to it. Fluid was documented within the PTT sheath, more so proximal to the medial malleolus. In all cases, synovial sheath inflammation (synovitis) was also reported.

Five MRI scans were performed. All documented evidence of split tears within the PTT substance with varying degrees of tendon degeneration. Two cases were reported as complete tendon rupture noted proximal to the medial malleolus. Intraoperatively, only one of the two was confirmed to be ruptured. The other had a scarred-down, attenuated tendon.

Intraoperatively, all tendons were thickened and showed gross abnormality with dull, greyish-white discolouration rather than the normal, glistening white appearance, as well as disorganisation of the tendon fibres (Figure 1). Macroscopically, the surrounding sheath appeared reactive, with synovitis, and fluid was expelled when the sheath was incised.

Table 1. Comorbidities

Comorbidity	Number
Hypertension	5
Diabetes	4
Hypercholesterolaemia	3
Depression	2
Thyroid dysfunction	2

Table 2. Imaging and histology results

Case	USS/MRI report	Histology findings
1	USS: Degenerate PTT. No defined tear. Severe hypertrophic synovitis with increased surrounding fluid	Chronic degenerative changes in the form of oedema, polypoid change and fibrinoid degeneration. Synovium shows neovascularisation. TENDONITIS
2	USS: Tendinopathy throughout tendon. Tear in the distal tendon. Tendon is double its normal size at the malleolus	Neovascularisation and focal accumulation of ground substance. No active inflammation. NON-SPECIFIC REACTIVE TENDONITIS
3	USS: Severe tendinosis of the PTT with high grade distal intrasubstance tears and surrounding granulation tissue	Neovascularisation within visceral synovium and tendon with reactive fibrosis evident. No active inflammation. REACTIVE TENDONITIS
4	USS: Degenerative changes with hypoechoic tendon occupying 30% of the total cross sectional area	Degree of pallor and neovascularisation. No active inflammation. NON-SPECIFIC REACTIVE TENDONITIS
5	USS: Extensive tendinopathy. Small intratendinous tears. Surrounding fluid in keeping with tenosynovitis	Neovascularisation. Areas of reactive fibroblastic proliferation within tendon. No active inflammatory process. NON-SPECIFIC REATIVE TENDONITIS
6	USS: Tendinopathy distal to MM. Small tear in the region. Minimal increased vascularity	Inflammation and neovascularisation. No acute inflammation. MILD INFLAMMATION/CHRONIC TENDINITIS
7	USS: Severe degeneration distally with softening and fraying. Synovial hypertrophy. Fluid proximal to malleolus.	Focal neovascularisation of the tendinous tissue. No active inflammatory process present. NON-SPECIFIC REATIVE SYNOVITIS
8	USS: Inflammation proximal to malleolus. Distally, there is a tendon defect of approx. 24% of tendon cross sectional area	Neovascularisation of the visceral synovium. No significant degenerative/inflammatory changes of tendon. NON-SPECIFIC REACTIVE TENDONITIS
9	USS: Inflammation of the synovial sheath. Small longitudinal intratendon tear just proximal to the navicular	Chronic inflammatory cell infiltrate accompanied by neovascularisation. MILD CHRONIC INFLAMMATION
10	USS: Degenerative tendon changes. Tendinopathy at level of MM involves >50% cross-sectional area	Neovascularisation within the visceral synovium. No active inflammation. REACTIVE TENDONITIS.
11	USS: Degenerative changes. Marked tenosynovitis present with fluid collection and inflamed synovium	Eosinophilic degeneration with chronic inflammatory cell infiltrate with neovascularisation. No active inflammation.
12	USS: Tendinous disrepair distal to malleolus with inflammatory response. Moderate amount of fluid proximal to the malleolus	Vascularization in the visceral synovium with increased cellularity in tendon. No inflammatory process. NON-SPECIFIC REACTIVE TENDONITIS
13	USS: Tear at malleolus. Degeneration involving 60% cross sectional area. Fluid within the sheath with marked hypertrophic synovium	Fibrosis and neovascularisation with increased cellularity within tendon. No active inflammatory process. NON-SPECIFIC REACTIVE TENDONITIS
14	USS: Tendinopathy at the level of the MM involving 60% of tendon. Surrounding fluid in keeping with tenosynovitis	Reactive vascular changes within visceral synovium. No specific degenerative changes in the tendon. BENIGN NON-SPECIFIC REACTIVE SYNOVITIS
15	MRI: Rupture 2.5cm above malleolus. Partial tear at the musculotendinous junction. Retraction and thickening of proximal and distal ends	Degeneration of central collagen of tendon with a shredded appearance and neovascularisation. No active inflammation. TENDONITIS WITH MILD SYNOVITIS
16	MRI: Rupture ± 2cm above the MM. Retraction and thickening of proximal and distal ends	Non-specific reactive synovitis of the visceral synovium. No active inflammation. REACTIVE TENDONITIS.
17	MRI: Acute on chronic tendinitis/tenosynovitis. Underlying interstitial tear of tendon	Neovascularisation and fibrosis within visceral synovium extending into tendon. No active inflammatory process.
18	MRI: confirms PTTD with inflammation and a long split in the PTT	Neovascularisation within visceral synovium extending to the tendon where there is increased fibroblastic activity. No acute or chronic inflammation. NON-SPECIFIC REACTIVE TENDONITIS
19	MRI: Central split tear from the musculotendinous junction to the level of the talar head. Tendinosis. Fluid within entire length of sheath	Focal areas of eosinophilic degeneration of the collagen. Associated mild synovitis. CHRONIC NON-SPECIFIC TENDONITIS & SYNOVITIS

MM: Medial malleolus; PTT: posterior tibial tendon; PTTD: posterior tibial tendon dysfunction; USS: ultrasound scan, MRI: magnetic resonance imaging.

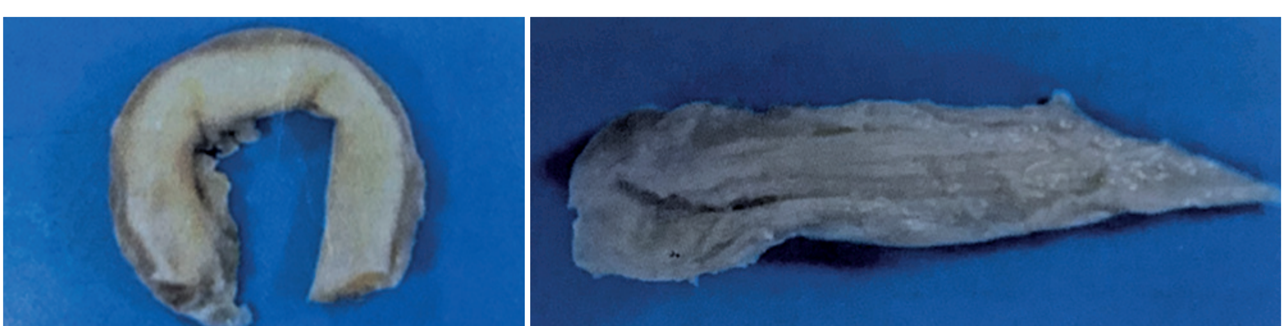

Figure 1. Examples of the gross appearance of the excised posterior tibialis tendon.

Microscopically, no acute inflammation or granulomatous inflammation was noted within any of the tendon specimens. Sixteen were documented to have non-specific reactive changes within the visceral synovium, in the form of neovascularisation. The remaining 3 cases had documented chronic inflammation and synovitis, but neovascularisation was not specifically mentioned. Changes within the tendon ranged from the description of a "shredded appearance" to reactive fibrosis and fibroblastic proliferation (Figure 2), with increased cellularity and neovascularisation extending into the tendon itself. Most cases were summarised as a "non-specific reactive tendonitis" or "reactive tendonitis" (Table 2).

Two cases had histology reports that stated no specific degenerative change noted within the tendon. The US examinations for these 2 cases noted moderate to marked inflammation of the PTT and tendinopathy at the level of the medial malleolus involving 24% and 60% of the tendon, respectively. Of these 2 cases, one histology report was concluded as "non-specific reactive synovitis" and the other was summarised as "non-specific reactive tendonitis". The surgical notes in both cases noted synovitis of the tendon sheath with marked tendon thickening and degeneration. Taking into account these 2 cases, correlation of ultrasound with histology findings was 86% (12/14 cases) for diagnosing marked tendon degeneration/tendinopathy. Although the histology was inconclusive in these 2 cases, the US and intraoperative findings confirmed degeneration of the PTT in all 14 cases. MRI correlated with histology findings in all 5 cases (100%), but in only 80% (4/5) of cases with intraoperative findings, as the one reported rupture was not present intraoperatively.

Discussion

The PTT lies posterior to the tibiotalar joint and medial to the subtalar joint. Its primary function is to support the arch and invert the foot. The portion of the PTT that abuts the medial malleolus is characterised by the presence of fibrocartilage, differentiating it from classic tendon structure. This area is referred to as the gliding tendon[21]. The longitudinal intratendinous tears and degree of cross-sectional tendon involvement noted on US and MRI in our study were predominantly at the level of the medial malleolus (in the gliding tendon) or distal to it. This correlates with the hypovascular zone of the tendon but also with an area of increased mechanical shear force on the tendon as it changes course by approximately 80° at the medial malleolus, suggesting an interplay of factors rather than a single aetiology[10,21].

Previous studies cite 100% sensitivity with the use of US in the detection of tears within the PTT. It is useful in confirming the diagnosis, but also in ruling out possible differentials. The finding of fluid predominantly proximal to the medial malleolus on US in this study is due to the increased space available for fluid to accumulate as opposed to the area within the tendon sheath at and below the level of the medial malleolus. This fluid was evident at surgery upon incising the sheath, and is in keeping with a paratendinitis. The distal 1-2cm of the tendon is not normally surrounded by a tendon sheath, and fluid is normally not identified here[7,22].

Conti et al.[23] reported that MRI may be more accurate than intraoperative visualisation, as an intramural lesion noted on MRI may not be visible macroscopically. The authors concluded that MRI should be considered the gold standard in assessing PTTD. A recent article by Lesiak and Michelson highlighted that MRI is useful in the diagnosis of PTT tears, but that surrounding inflammation can make a normal PTT appear torn. It is hypothesized that surrounding inflammation causes changes in the MRI signal in the PTT that resemble those seen in rupture. For this reason, MRI in the setting of PTT ruptures should be interpreted with caution[11,12]. MRI also has the drawback of not being dynamic. In our study, MRI results correlated in all cases (5/5) with histology, but in only 80% (4/5) of cases intraoperatively, as one case reported as being ruptured on MRI was found intact intraoperatively. Arnoldner et al.[9] compared US with 3T MRI in the diagnosis of PTTD. Nine intraoperative diagnoses of PTTD were compared to preoperative US and MRI. The authors concluded that US is slightly more accurate and should be used as the initial diagnostic tool, as it is easily available, cost-effective and visualises the PTT clearly. These findings were in keeping with our results.

Intraoperatively, all 14 specimens correlated with US findings and showed macroscopic evidence of synovitis of the tendon sheath and chronic degenerative tendon change (100% correlation). Correlation of US with histology findings was 86% (12/14 cases) in diagnosing marked tendon degeneration/tendinopathy. Two cases were reported as being normal histologically, but with surrounding mild visceral neovascularisation. The corresponding US described a tendinopathy and a degree of tendon degeneration. Possibly the section of tendon examined histologically was not the section described on preoperative imaging.

The histological description of increased cellularity and neovascularisation within the visceral synovium and the tendon

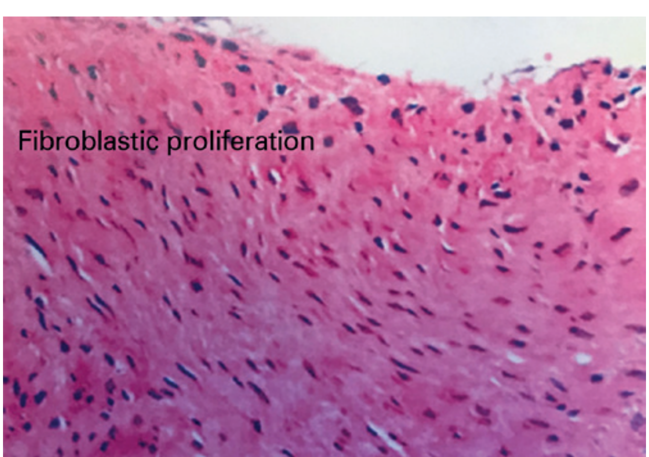

Figure 2. Fibroblastic proliferation noted within the tendon.

indicates an attempt at repair[17]. No tendinous inflammation was noted to be present in any of the cases in our series. This has been previously documented in similar studies examining the histology of the Achilles tendon and in ACL injuries[24-26]. As hypothesised by Fowble et al.[27], the process is most likely due to overuse and stretching of the posterior tibial tendon, which activates tenocytes of the synovial tendon lining. This results in an angiogenic response and neovascularisation, as was noted in all our cases presenting as paratendinitis. Regarding surgical options for these patients, future histological studies might examine for the presence of mechanoreceptors within the tendon, its sheath, and the distal stump. This may indicate a proprioceptive function, much as it does in the ACL[23], supporting preservation of at least part of the damaged posterior tibial tendon, or its stump, in the reconstruction of AAFD. By maintaining these mechanoreceptors, patients may rehabilitate faster.

All specimens in this study were taken at the time of surgery and therefore represented tendons in an advanced disease stage, having gone through cycles of injury, repair, and remodelling. This may explain why no inflammation was found to be present in these study specimens, but rather evidence of attempted repair. Degeneration of the tendon begins well before clinical presentation of the patient[21,28]. A recent study by Klatte-Schutz et al.[26] examined acute versus chronic Achilles tendon injuries. In the study group of acute and chronic ruptures and tendinopathies, the authors detected an inflammatory infiltrate using immunohistochemical examination. These were noted to be significantly lower in the chronic rupture group when compared to the acute ruptures. Since PTTD is a chronic disorder, this would support our findings of no inflammation in the histological specimens. Immunohistochemical examination does appears to offer a more precise histological diagnosis. Further studies are needed to investigate possible genetic predisposition to tendon degeneration, particularly examining the collagen and matrix remodelling gene pathways in individuals. Histology is useful in cases of suspected inflammatory arthritis, which is commonly associated with PTTD. This is typically supported by the presence of characteristic pathological findings in synovial tissue. However, no single histological feature is diagnostic[29].

Recent literature has made a concerted effort to avoid the blanket term "tendonitis" when referring to diseased tendons. This has led to a confusing expansion in the descriptive vocabulary used, with terms such as tendonitis, tendinosis, peritendinitis, paratendinitis and paratendinopathy being used somewhat interchangeably to provide more detailed depictions of the underlying processes. According to the MedTerms Medical Dictionary (<www.medicinenet.com>), *peri-* is a prefix meaning around or about. *Para-* is also a prefix with many meanings, including alongside, beside, near or resembling. *-osis* is a suffix denoting a process, condition, or state, usually abnormal or diseased. *-opathy* is a suffix meaning a disease or disorder. The suffix *-itis* denotes an inflammatory disease process[30].

It follows that tendonitis is the inflammation of a tendon. Tendinosis is the preferred term for degenerative changes purely within a tendon without an identified inflammatory component. Peritendinitis and paratendinitis denote an inflammatory process involving the surrounding or nearby tendon sheath, and are not necessarily associated with an intratendinous process. These terms are all dependent on operative confirmation of the condition. Puddu et al.[31], in their study of Achilles tendon pathology, surgically identified cases with only peritendinous inflammation, while others showed degeneration of the tendon itself in addition to peritendon involvement. They suggested the term "peritendinitis" for this type of inflammation and distinguished an isolated peritendinitis from a combination of peritendinitis with tendinosis. The current literature defines PTTD as a tendinosis with no inflammation[21,31]. All our cases had both synovitis of the tendon sheath and tendinosis of the PTT. As supported by the findings in this study of PTTD, the correct nomenclature, based on the clinical presentation and preoperative imaging, would be that of a pantendinopathy, which was confirmed on the surgical and histological findings of a peritendinitis with tendinosis. We believe "pantendinopathy" is a better description of the pathological process in PTTD, rather than simply calling it a tendinosis.

Strengths of this study include the availability of preoperative imaging, intraoperative findings and histology results, allowing for a chronological examination of the disease process and clear correlation of investigations with findings. Limitations include the retrospective nature of the study and relatively small sample size.

Conclusion

This study confirms clear histological degenerative changes within the substance of the posterior tibial tendon together with inflammation of the paratenon, found on preoperative imaging and intraoperative findings, in patients who undergo corrective surgery for PTTD. These findings are in keeping with a pantendinopathy, i.e., peritendinitis with tendinosis. We suggest using the term "pantendinopathy" when describing the pathological changes present in PTTD. Preoperative ultrasound imaging and intraoperative confirmation of PTTD is accurate; histological confirmation is unnecessary.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MW *(https://orcid.org/0000-0002-7999-9069) performed bibliographic review, survey of the medical records, formatting of the article and approved the final version; NS *(https://orcid.org/0000-0002-5566-7588) conceived and planned the activities that led to the study, performed the surgeries and data collection and approved the final version; PF *(https://orcid.org/0000-0003-4639-0326) interpreted the results of the study, formatted the article, participated in the review process and approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Hallux interphalangeal involvement after metatarsophalangeal joint arthrodesis. Treatment and results

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Abstract

Objective: To assess the involvement of the hallux interphalangeal (IP) joint after first metatarsophalangeal joint (MTPJ) arthrodesis and propose a treatment consisting of MTPJ resection arthroplasty associated with phalangeal osteotomy or IP joint arthrodesis.

Methods: We retrospectively analyzed 9 patients treated with MTPJ resection arthroplasty associated with phalangeal osteotomy or hallux IP joint arthrodesis from November 2006 to January 2017.

Results: The main causes of MTPJ arthrodesis that subsequently evolved to IP involvement were severe hallux valgus and sequelae or complications of previous hallux valgus operations. Additionally, the reasons leading to rescue surgery were pain, deformity, and/or discomfort.

Conclusion: This therapeutic modality is able to relieve symptoms by a simple procedure, with acceptable functional and esthetic results.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Arthrodesis; Metatarsophalangeal joint; Toe joint; Hallux; Arthrosis.

Introduction

First metatarsophalangeal joint (MTPJ) arthrodesis is a procedure commonly used for the treatment of severe hallux valgus, hallux rigidus, rheumatoid arthritis, hallux varus, and recurrence or failure of previous operations[1-13]. Reported complications include nonunion, malposition, consolidation defects, hardware-related pain, dissatisfaction due to loss of joint mobility, difficulty in wearing shoes, and interphalangeal (IP) joint arthrosis[2,3,8-11,13-18]. The latter is one of the major causes of discomfort after first MTPJ arthrodesis in the long term[16,17].

The IP joint may also be affected by pain, dislocation, or instability (Figure 1), but the literature on the treatment of these conditions is scarce. In the present study, we assessed hallux IP involvement after first MTPJ arthrodesis and proposed a treatment consisting of first MTPJ resection arthrodesis combined with phalangeal osteotomy or IP arthrodesis.

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Methods

This study was approved by the Institutional Review Board.

Of 180 first MTPJ arthrodeses performed between November 2006 and January 2017, 9 patients were retrospectively evaluated for IP involvement after first MTPJ arthrodesis requiring surgical treatment (Table 1).

Eligible participants were patients aged 18 years or over who had undergone first MTPJ arthrodesis and evolved with pain or deformity in the IP joint of the hallux on the consolidated first MTPJ arthrodesis and who did not respond favorably to conservative treatment (analgesics, finger separators, and changes in footwear).

Assessment was based on clinical history, imaging scans, and telephone questionnaire. Information was entered into a table according to the following criteria: postoperative pain according to a visual analog scale, forefoot function, esthetics, possibility of wearing shoes, and patient's overall satisfaction (Table 2).

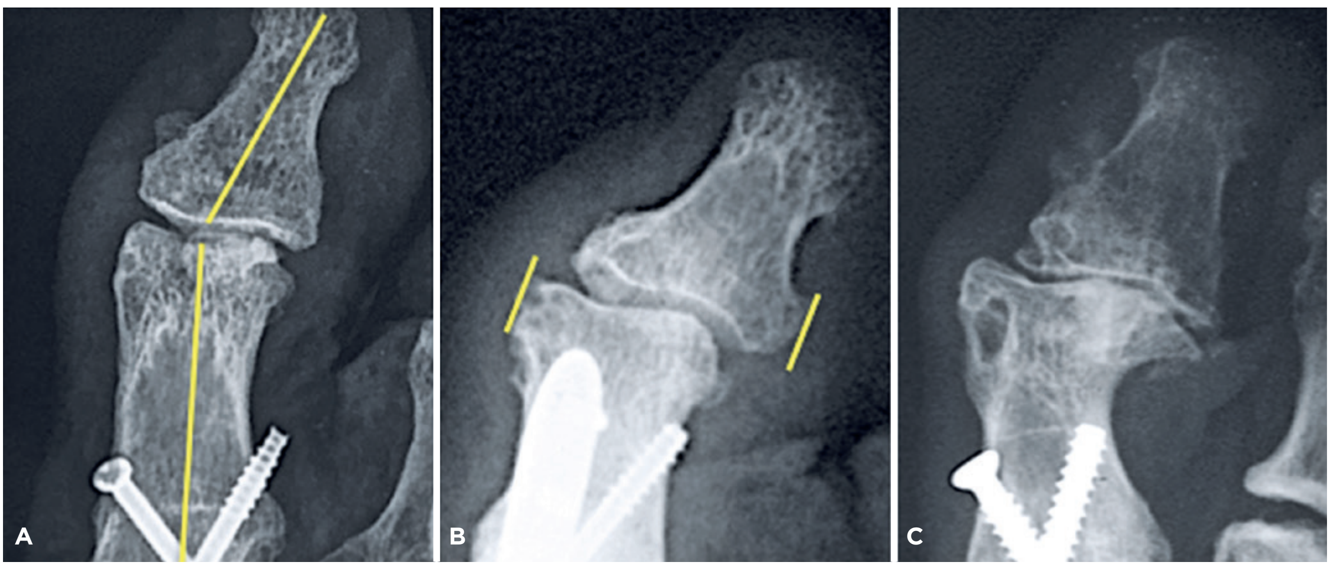

Figure 1. Types of interphalangeal involvement. A. Dislocation. B. Instability. C. Arthrosis.

Table 1. Patients' characteristics

Pt	Age	Foot	Reason for MTPJ arthrodesis	Date of MTPJ arthrodesis	Date of disarthrodesis	IP	IP observation	Result
1	66	L	Failed HV operation	February 99	December 16	Arthrodesis	Arthrosis	Good
2	56	L	HV	November 03	November 06	None	Hyperextension	Good
3	45	L	Post-treatment deformity	April 09	September 09	None	Pain	Good
4	61	R	Failed HV operation	June 09	May 10	Arthrodesis	Instability	Very good
5	61	R	Failed HV operation	March 09	October 13	Akin	Instability	Good
6	68	L	Rheumatoid arthritis	October 99	November 14	Arthrodesis	Arthrosis	Very good
7	64	L	Severe HV	August 09	October 15	Arthrodesis	Instability	Good
8	65	R	Severe HV	February 15	February 16	Arthrodesis	Instability	Fair
9	76	L	Failed HV operation	March 08	January 17	Arthrodesis	Instability	Good

Pt: patient; L: left; R: right; HV: hallux valgus; MTPJ: metatarsophalangeal joint; IP: interphalangeal.

Table 2. Result evaluation chart

Result	Pain	Function	Esthetics	Footwear	Satisfaction
Very good	0, 1, 2	Very good	Very good	Fashionable shoes	
Good	3, 4, 5	Good	Good	Wide range of shoes	Satisfied
Fair	6, 7, 8	Fair	Fair	Orthopedic shoes	
Poor	9, 10	Poor	Poor	Not wearing shoes	Dissatisfied

Surgical technique

All patients were operated by the same surgical team, after outpatient hospitalization, under local/regional anesthesia of the ankle combined with intravenous sedation, in supine position, with sterile drapes covering leg, ankle, and foot, and a hemostatic cuff placed at the supramalleolar level.

A medial or dorsomedial metatarsophalangeal approach was used, depending on where the previous incision was located, the initial scar was resected, and the surgical field was distally expanded to include IP joint in cases requiring some procedure on this joint, with caution not to injure the dorsomedial cutaneous nerve.

After the capsule was longitudinally incised and periarticular adhesions were released, the previously used hardware was identified and removed.

On the arthrodesis site, which was determined by radioscopy, a bone resection of approximately 0.5 to 1cm was performed to restore mobility, and caution was taken not to over resect in an attempt to not shorten the first ray. At this last moment, we considered second toe length as a reference. Subsequently, an oblique dorsal incision was made at the level of the first metatarsal bone at an angle from 30° to 40° with respect to the diaphyseal axis in the sagittal plane to simulate cheilectomy so that to allow at least 40° of dorsiflexion of the metatarsophalangeal joint (Figure 2). In cases requiring IP arthrodesis (Table 3), it was routinely performed with a intramedullary screw at a neutral position regarding varus-valgus, flexion-extension, and rotation angles (Figure 3).

Surgical closure was performed by planes, with the capsule being closed with absorbable multifilament suture and the skin with non-absorbable multifilament suture.

Postoperative management consisted of complete support according to patient's tolerance to forefoot postoperative foot 48 h after initial rest with the foot elevated and the heel supported.

After sutures were removed, from 15 to 20 days after surgery, patients were allowed to use normal shoes and started with assisted active and passive mobilization of the forefoot, with kinesiologic assistance when necessary.

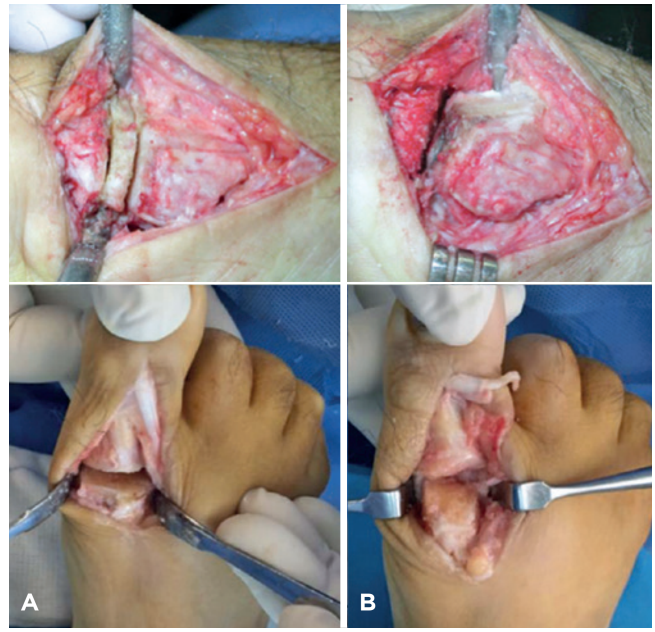

Figure 2. Intraoperative image. A. Bone resection. B. Dorsal remodeling.

Table 3. Involvement and treatment

Involvement	Treatment
IP pain with radiographic involvement	Isolated MTPJ resection arthroplasty
IP dislocation	MTPJ resection arthroplasty + Akin phalangeal osteotomy
IP instability	MTPJ resection arthroplasty + Arthrodesis
IP arthrosis	MTPJ resection arthroplasty + Arthrodesis

IP: interphalangeal; MTPJ: metatarsophalangeal joint.

Results

Mean age at the time of surgery was 62 years (range, 45 to 76 years). Among the participants, 8 were women and 1 was a man, with involvement of the right foot in 3 patients and of the left foot in 6.

The reason for the initial first MTPJ arthrodesis was severe hallux valgus in 3 patients (33.33%), failure of previous hallux valgus surgery in 4 patients (44.44%), rheumatoid arthritis in 1 patient (11.11%), and post-traumatic deformity in 1 patient (11.11%).

The reason for rescue surgery were IP dislocation and/or instability in 5 cases (55.55%), IP arthrosis in 1 case (11.11%), IP pain in 1 case (11.11%), and malposition of first MTPJ arthrodesis in 2 cases (22.22%).

Figure 3. Postoperative radiograph. Metatarsophalangeal arthroplasty combined with interphalangeal arthrodesis.

The percentage of IP involvement requiring surgical treatment was 5% (9 rescue operations among 180 first MTPJ arthrodeses).

Mean time elapsed from initial to rescue surgery was 6 years and (range, 5 months to 17 years).

IP arthrodesis was performed in 6 cases (66.66%), Akin phalangeal osteotomy in 1 case (11.11%), and the IP joint was not addressed in 2 cases (22.22%).

Mean follow-up was 5.4 years (range 1 to 12 years). Seven patients (77.77%) did not report pain, and 2 (22.22%) presented with intermittent mild pain. IP function was very good in 3 cases (33.33%), good in 5 (55.55%), and fair in 1 (11.11%). The esthetic result was good in 7 patients (77.77%) and fair in 2 (22.22%) due to over-shortening of the first ray. The 9 patients could wear standard shoes, 4 of them (44.44%) with fashionable shoes. 8 patients (88.8%) expressed satisfaction with the procedure, and 1 patient (11.11%) did not.

Overall assessment was very good in 3 cases (33.33%), good in 5 cases (55.55%), and fair in 1 case (11.11%).

Discussion

First MTPJ arthrodesis is a procedure described for the treatment of many painful conditions of this joint when its involvement prevents joint preservation surgery, and most authors agree that it is a safe procedure with high rates of success and patient satisfaction. There are several forms and systems of joint preparation. Likewise, several methods or configurations of osteosynthesis have been described to achieve a higher consolidation rate on the arthrodesis site and to promote the ability to bear weight and early rehabilitation[1,4,6,7,9,11,12,14,15].

The following complications were observed after first MTPJ arthrodesis: nonunion, malposition, pain related to hardware requiring reintervention for removal, discomfort due to loss of mobility, metatarsalgia, and IP joint arthrosis or pain[1-3,8-11,13,14-18]. IP joint involvement is one of the most frequent complications, with a prevalence ranging from 30 to 60%[10,13,16,17]. This condition is not always symptomatic, and one third of patients are estimated to present with painful symptoms beyond radiographic involvement[17].

A number of studies have evaluated the functional results of first MTPJ arthrodesis and its complications, and all of them mention IP involvement as a frequent and disabling complication[10,13,16]. However, only a few studies have proposed or described specific treatment procedures for this particular condition[17].

Most authors agree that IP involvement is closely related to the position of arthrodesis, and it is well know that this complication may be mitigated by reducing overload or stress on the IP joint and that the fixation angle of MTPJ should be from 15° to 30° of valgus in the sagittal plane and from 15° to 30° of dorsiflexion in the lateral plane[7,10,13,14,16]. Moreover, these authors found that a dorsiflexion angle below 20° was associated with a greater rate of IP arthrosis[7,14,16].

We believe that, besides the final fusion position, the preexisting disease that motivated initial arthrodesis, associated diseases, such as neurological disorders, and chronic medications may also have an influence on changes in IP joint, thus contributing not only to the percentage of onset but also to the time when these changes develop. The IP joint may condition the final results of first MTPJ arthrodesis, and this conditioning not only results from the development of arthrosis but may also manifest as pain, dislocation, and instability. We believe that it is an evolutionary process in which arthrosis and/or deformity is the final result of disease progression.

Coughlin described a classification of hallux IP joint arthrosis according to the degree of radiological involvement[13]. We consider that determining the overall problem occurring in the joint by performing an imaging and clinical assessment provides greater information and guides decision-making (Table 3).

The literature describes the following treatment options for failed first MTPJ arthrodesis: corrective osteotomies, rescue surgery with MTPJ prosthesis, rescue surgery with resection and interposition of tissues (either local or obtained from distant areas), and IP arthrodesis[1,17,19,20]. Studies that compared long-term results in primary surgery between prosthetic implants and first MTPJ arthrodesis showed controversial results, with no study being categorically favorable to arthroplasty[8,21]. Only one study describes an option for the treatment of hallux IP arthritis after first MTPJ arthrodesis consisting of rescue surgery arthroplasty of the MTPJ with arthrodesis resection combined with interposition of soft tissue (semitendinosus tendon) obtained from the ipsilateral knee and IP fusion[17].

According to the advantages and disadvantages of each therapeutic option described here and based on the evaluation of each particular case, we propose the following treatment algorithm: isolated MTPJ resection arthroplasty in cases of IP pain with no radiological involvement; MTPJ resection arthroplasty associated with Akin phalangeal osteotomy when there is IP dislocation; and MTPJ resection arthroplasty and IP joint arthrodesis in cases of IP instability or arthrosis (Table 3).

CONCLUSION

We believe that the described procedure is useful for selected patients who present with pain, dislocation, instability, or arthrosis of the hallux IP joint after first MTPJ arthrodesis. This therapeutic modality makes it possible to relieve pain symptoms, deformity, and discomfort by a simple procedure that allows early weight-bearing with no need of excessive postoperative protection and with acceptable functional and esthetic results (Figure 4).

Figure 4. A. Initial severe hallux valgus. B. Short-term postoperative image. C. Long-term postoperative image showing interphalangeal dislocation and instability. D. Metatarsophalangeal resection arthroplasty combined with interphalangeal arthrodesis. E. Hallux deformity. F. Final correction. G. Postoperative passive mobility.

Authors' contributions: Each author contributed individually and significantly to the development of this article: AMV *(https://orcid.org/0000-0002-0384-4044) conceived and planned the activities that led to the study, interpreted the results of the study, performed the surgeries, approved the final version; ES (https://orcid.org/0000-0001-5028-9584 conceived and planned the activities that led to the study, interpreted the results of the study, approved the final version, performed the surgeries, approved the final version; MR *(https://orcid.org/0000-0003-1947-8218) interpreted the results of the study, performed the surgeries, approved the final version; AB (https://orcid.org/0000-0003-1690-025X) interpreted the results of the study, performed the surgeries, approved the final version; MI *(https://orcid.org/0000-0002-6336-6080) interpreted the results of the study, performed the surgeries, approved the final version; IT *(https://orcid.org/0000-0001-9210-9051) bibliographic review, clinical examination, approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Arthroscopic Brostrom technique: clinical and functional results

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Abstract

Objective: To present the clinical and functional results of surgical treatment of patients with chronic instability of the ankle using the arthroscopic Brostrom technique.

Methods: This is a case series of patients who underwent surgical treatment for chronic instability of the lateral ligament of the ankle using the arthroscopic Brostrom technique. Clinical assessments of ankle stability were performed preoperatively and at the last follow-up using the American Orthopedic Foot and Ankle Score (AOFAS), a visual analog scale (VAS) for pain, and the anterior drawer and talar inversion tilt tests. Surgical complications and patient satisfaction ratings were also analyzed.

Results: A total of 16 patients were analyzed, with a mean follow-up of 14 months. There was a statistically significant ($p<0.001$) improvement in mean AOFAS, which increased from 67.2 to 90.8 points and the mean VAS for pain score reduced from 6.5 to 1.5 points. All ankles were stable and had normal results for the anterior drawer test and the talar inversion tilt test. Three patients (19%) reported that resumption of sporting activities provoked subjective pain in the ankle, which improved progressively during follow-up. Two patients (12.5%) exhibited neurapraxia of the superficial peroneal nerve. A majority of the patients (81%) rated treatment as good or excellent.

Conclusion: Treatment of chronic instability of the ankle ligament using the arthroscopic Brostrom technique restored ankle stability and achieved good clinical results. There was a high rate of early complications, but the majority were transitory and underwent complete remission during follow-up.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Joint instability; Ankle; Arthroscopy.

Introduction

Ankle ligament injuries are among the most common causes of orthopedic consultations. They account for around 25% of all musculoskeletal system injuries[1,2]. They most frequently affect young patients, who regularly engage in physical activities. These injuries occur when the ankle is sprained in supination, inversion, and plantar flexion. The ligaments most often injured are the anterior talofibular ligament (ATFL), in 80% of cases, and the calcaneofibular ligament (CFL), in 15%[3-5].

In general, excellent results are achieved with conservative treatment, primarily consisting of functional rehabilitation with support and early mobilization. However, approximately 20% of these injuries may develop instability refractory to non-surgical treatment, and remain painful, swollen, and prone to instability and recurrent sprains[3,6]. In cases of residual instability, surgical repair of the ligaments should be considered[7-9].

Several surgical techniques have been proposed for management of chronic lateral instability of the ankle[10-14] and,

Study performed at the Hospital Universitário Ciências Médicas (FCMMG), Belo Horizonte, MG, Brazil.

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even after many years, the open Brostrom-Gould technique is considered the gold standard for treatment of this pathology[15,16]. With the advent of ankle arthroscopy, offering benefits such as lower surgical morbidity, early return to normal and sporting activities, and the ability to assess and treat intraarticular pathologies[17], several authors have developed a technique for lateral ligament repair assisted by arthroscopy in a single percutaneous stage[3,5,7]. This technique, known as arthroscopic Brostrom repair, attempts to stabilize the ankle by placing anchors in the fibula under arthroscopic guidance and passing the sutures percutaneously under the lateral ligament and the inferior extensor retinaculum (IER)[5].

Although several different studies have described excellent clinical results with this technique, a high rate of complications (5.3% to 29%) has been reported, primarily with relation to nerve damage and prominent implants[4,5,7,8].

The objective of this article is to present the clinical and functional results of patients with chronic ligament instability treated with the arthroscopic Brostrom technique.

METHODS

This study was approved by the Institutional Review Board and registered on the Plataforma Brazil database under CAAE (Ethics Evaluation Submission Certificate) (86807618.9.0000.5122). All patients signed a free and informed consent form to be included in the study.

This is a retrospective study that assessed 16 patients, six men and ten women with diagnoses of chronic instability of the ankle, who were treated surgically using the arthroscopic Brostrom technique between August 2016 and November 2018 and followed-up for a mean of 14 months (range: 12 to 18 months).

Clinical assessments of ankle stability were conducted preoperatively and at the last follow-up consultation using the anterior drawer and inversion tilt tests. These tests were always conducted on the basis of comparison and were considered positive when there was greater anterior excursion of the talus in the drawer test and greater inversion in the talar tilt test, when compared with the contralateral ankle.

All ankle X-rays in anteroposterior view and anteroposterior with 20 degree internal and lateral rotation were normal in all patients. No X-rays with manual stress were taken. Magnetic resonance showed chronic anterior talofibular ligament injury in all patients.

The inclusion criteria for the study were adult patients with diagnoses of chronic ankle ligament instability with no improvement after 6 months of conservative treatment using orthopedic ortheses, analgesics, and functional physiotherapy and rehabilitation. A diagnosis of instability was defined as patients with recurrent ankle sprains combined with pain, swelling, and insecurity to perform sporting activities, positive drawer and inversion tilt tests, and ligament injuries seen on magnetic resonance. Patients were excluded from the study if they had additional injuries found on clinical examination or magnetic resonance that needed other surgical procedures, such as: osteochondral talus lesion, peroneal tendon injury or pes cavovarus. Patients were also excluded if they had prior surgery, deformities, hypermobility syndromes, collagen diseases, or neuromuscular diseases.

The American Orthopedic Foot and Ankle Score for the hindfoot and ankle (AOFAS)[18] and a visual analog scale (VAS) for pain[19] were administered preoperatively and at the last follow-up consultation. Surgical complications were assessed and recorded during follow-up. Patients' satisfaction with treatment was assessed using the classification described by Coughlin[20] and recorded.

Normality of data distribution was assessed using the Kolmogorov-Smirnov test. Since it exhibited normal distribution, statistical analysis was conducted using the *t* test for paired samples to compare means before and after intervention.

Surgical technique

The patient, under spinal anesthesia and sedation, is placed on the operating table in supine decubitus with a bump under the ipsilateral buttock.

Anatomic landmarks are marked out to ensure risk structures were avoided when establishing arthroscopy portals and a "safety zone" is marked out on the lateral part of the ankle, and a safety zone is market out on the lateral part of the ankle, including the distal fibula, the superior margin of the peroneal tendons, and the intermediate branch of the superficial peroneal nerve . The inferior extensor retinaculum is marked 1.5 cm from the distal fibula (Figure 1).

The traditional ankle arthroscopy portals are made (anteromedial and anterolateral). No manual distraction is performed.

The ankle joint is inventoried to assess presence of injuries.

Exploration of the lateral groove, with debridement of the anterior inferior tibiofibular ligament (AITL, Bassett's ligament). We use this ligament as an anatomic landmark to locate the "footprint" of the ATFL on the fibula. We attempt to identify and obtain a good view of the ATFL, to preserve it during exposure of the anterior margin of the fibula.

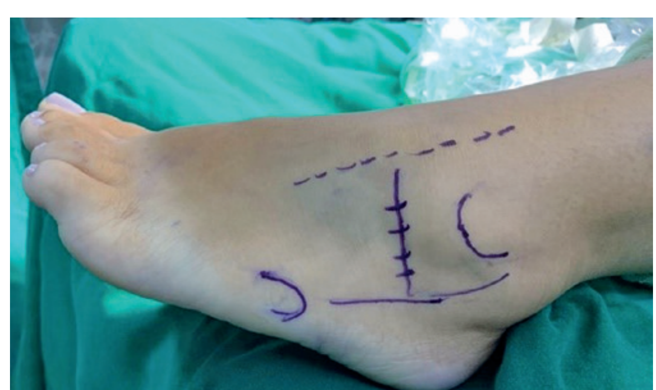

Figure 1. Safety zone marked out on the anterolateral aspect of the ankle

Via the anterolateral portal, the first 3.5mm metallic anchor is inserted, 1 cm above the point of the lateral malleolus. Maintaining the ankle in neutral dorsiflexion and slight eversion, with the aid of a long needle (Suture-lasso, Arthrex®, Naples, United States), sutures are threaded separately from the anterolateral portal to the previously marked extensor retinaculum, exiting through the most inferior region of the safety zone, spaced at a distance of approximately 1.0 cm (Figure 2 A and B).

The second anchor is inserted 0.5 to 1.0 cm above the first (close below the talar dome) and its sutures are threaded in a similar manner, but exiting through the most superior region of the safety zone. (Figure 3 A, B). A final arthroscopic inventory is performed to check that the sutures had not become entangled internally.

Two small incisions are made, between the exit holes of each suture, which are paired and tied together. Two arthroscopic knots are made with the ankle in neutral dorsiflexion and slight eversion, re-tensioning the ligament structures, capsule, and extensor retinaculum.

Postoperative

During the first week, patients did not put weight on the foot and wore an orthopedic boot to maintain the ankle in a neutral position. During the second and third week, they were allowed to partially load the ankle, with support from crutches. From the fourth week on, patients substituted the boot with a semi-rigid orthosis and started a physiotherapy rehabilitation program.

Patients stopped wearing the orthoses in the sixth week, but continued their physiotherapy rehabilitation programs.

RESULTS

In this study, 16 patients with diagnoses of chronic instability of the ankle were treated surgically using the arthroscopic Brostrom technique.

There was a statistically significant ($p<0.001$) improvement in mean AOFAS, from 67 points at baseline to 90 points during the postoperative period, and in the mean VAS for pain score from 6 points at baseline to 2 points during the postoperative period (Table 1). All of the ankles were stable with normal anterior drawer test and talar tilt inversion test results.

With regard to complications, two patients (12.5%) exhibited neurapraxia of the superficial peroneal nerve. After drug-based clinical treatment, one patient had full resolution of the condition while the other only achieved partial recovery. There were no cases of infection or of recurrence of instability.

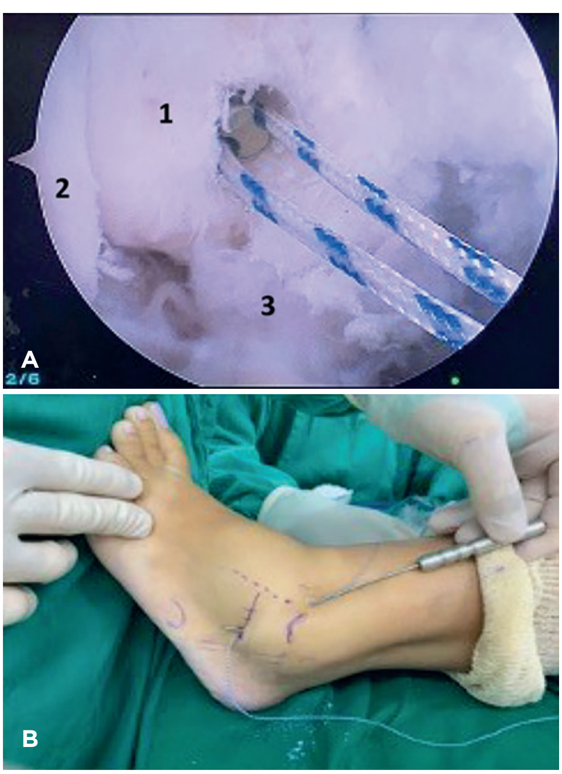

Figure 2. (A) First anchor arthroscopically inserted into the lateral malleolus (1) Distal fibula (2) Lateral wall of the talus (3) Anterior talofibular ligament. (B) Sutures passed percutaneously

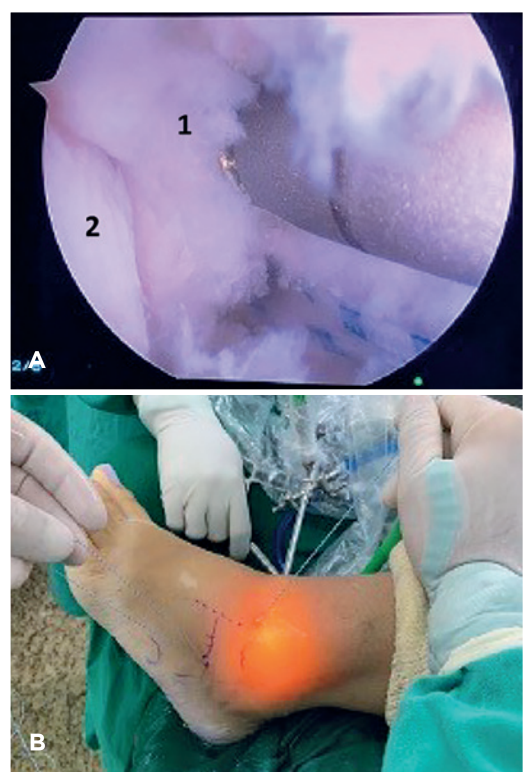

Figure 3. (A) Second anchor arthroscopically inserted into the lateral malleolus (1) Distal fibula (2) Lateral wall of the talus. (B) Sutures passed percutaneously

Table 1. Pre- and postoperative data

Patients	Age (years)	Sex	Follow-up (months)	Preop. vas	Postop. vas	Preop. aofas	Postop. aofas	Satisfaction	Complication
1	37	M	12	5	2	72	93	Good	No
2	42	F	14	5	3	76	89	Good	No
3	26	F	12	8	5	75	79	Regular	Transitory pain
4	28	F	16	5	1	72	95	Excellent	Transitory pain
5	21	M	18	5	0	84	100	Excellent	No
6	35	F	13	6	2	81	97	Excellent	No
7	18	M	18	3	0	95	100	Excellent	No
8	39	F	12	6	2	71	96	Excellent	No
9	46	M	14	7	1	45	79	Regular	Transitory pain
10	37	F	17	9	2	62	94	Excellent	No
11	36	M	14	8	1	49	86	Good	Neurapraxia
12	40	F	16	7	2	47	78	Regular	Neurapraxia
13	32	M	15	6	2	64	87	Excellent	No
14	38	F	15	8	3	63	86	Excellent	No
15	24	F	13	8	2	58	100	Excellent	No
16	36	F	12	8	2	68	94	Excellent	No
Mean	33		14	6,5	1,8	67,2	90,8		

Preop. vas: (Preoperative visual analog scale for pain); Postop. vas: (Postoperative visual analog scale for pain); Preop. aofas: (Preoperative American Orthopedic Foot and Ankle Score); Postop. aofas: (Postoperative American Orthopedic Foot and Ankle Score).

During their return to sporting activities, approximately 4 months after surgery, three patients (19%) reported subjective discomfort in the ankle when running. Clinical examination revealed that the discomfort occurred during plantar flexion. There was also discrete reduction in plantar flexion in the operated ankle compared with the contralateral ankle. This difference in amplitude was detected during the lateral inspection when performing maximum active plantar flexion of both ankles. Flexion was performed with the patient seated, maintaining the knee flexed at 90 degrees and the lower extremities hanging over the edge of the examination table. These patients needed an additional period of physiotherapy lasting approximately 3 months, delaying their return to usual sporting activities (road running), which occurred uneventfully after this period. These complaints were considered early and transitory complications, because the patients exhibited complete remission of symptoms over the course of follow-up.

Assessment of subjective satisfaction with treatment showed that 13 patients (81%) classified the result as excellent or good, and another three (19%) as regular. Two of the patients who rated the treatment as regular had complained of subjective discomfort in the ankle during sporting activities and the third had complained of neurapraxia, which only improved partially. There was no need to reoperate on any of the patients before the end of the follow-up period.

Discussion

In this study, surgical treatment of chronic ankle ligament instability performed using the arthroscopic Brostrom technique achieved good clinical results in terms of a reduction in VAS for pain scores from 6.5 to 1.8 points and improved AOFAS from 67.2 to 90.5 points and was effective for reestablishing ankle stability. There were no recurrence or need for surgical reintervention. There was an elevated rate of early complications (31.5%), but they were transitory and the majority progressed to complete remission during follow-up.

Ligament repair using the Brostrom technique via arthroscopy has been described before, with similar results to our study[7,9,10]. In a case series with 40 patients, Cottom and Rigby observed an improvement in AOFAS from 41.2 to 95.4 points and VAS improved from 8.2 to 1.1 points, with no cases of relapse[10]. Similarly, Acevedo and Mangone reported a high rate of satisfaction and a low rate of recurrence in a case series with 73 patients and mean follow-up of 28 months[21]. Although some studies have demonstrated excellent results and low recurrence rates employing just a single anchor and two suture threads with this technique[3,7], Feng et al. reported that using two anchors produced better results[22], which is why the authors opted for two anchors in this study.

During their return to sporting activities, approximately 4 months after surgery three patients (19%) in this series reported subjective pain and discomfort in the ankle when running. It is worth mentioning that although these patients achieved complete remission of symptoms during follow-up, this complaint delayed their return to running and had a negative impact on their satisfaction with the treatment. During clinical examination, it was found that the discomfort was triggered during plantar flexion of the ankle. It was also found that there was a slight reduction in the amplitude of plantar flexion of the operated ankle compared to the contralateral ankle during maximum active plantar flexion of both ankles. Since the difference in the amplitude of movement was discrete, it was not detected objectively. Moreover, methods for assessment of the amplitude of ankle movement are still considered imprecise, particularly those used to measure plantar flexion[22,23]. This finding was only considered of importance by the authors because it was accompanied by pain, since it is normal that there is some degree of restriction of movement in an ankle that has undergone ligament repair[11]. Considering that all of the patients in the study followed the same postoperative rehabilitation protocol, the authors hypothesize that this may have taken place because the arthroscopic Brostrom-Gould technique does not result in a fully anatomic ligament repair. The technique tensions the ligament and the same suture takes in the capsule, the retinaculum, and the sural fascia, creating a large fibrosis at the lateral groove of the ankle. The suture also pierces the capsule at several points, resulting in a large plication. It is likely that the additional period of physiotherapy needed by patients who reported this discomfort was necessary to release the fibrosis generated at the lateral groove of the ankle.

Another complication was neurapraxia of the fibular nerve, observed in two patients (12.5%). Other studies have reported similar rates of this neurological complication[5,7,12]. A 15% rate of neurapraxia of the superficial peroneal nerve was observed in a case series described by Pellegrini et al. Although this is an elevated rate, patients improved over the course of follow-up[12]. Studies by Acevedo et al.[5] and Corte-Real et al.[7] observed 6.8% and 10.7 % respectively. A safety zone has been defined to protect anatomic structures in the lateral part of the ankle during suturing and it is essential to be able to visualize the superficial peroneal nerve in order to draw this zone[5]. However, as has been described elsewhere in the literature[24], we encountered difficulty with visualizing this nerve in patients with high body mass index and elevated quantities of subcutaneous fat. The plantar flexion inversion maneuver may create a false sense of security in these cases, because the location of the peroneal nerve changes with the different positions of the ankle. The nerve moves approximately 2.4 mm laterally when the ankle is displaced from plantar flexion in inversion to a neutral position or dorsiflexion[24,25]. Another hypothesis for the cause of this neurological complication comes from an anatomic study by Daumau-Pastor et al. They describe the IER as aponeurotic tissue that is contiguous with the sural fascia and has imprecise limits, so, when we traction this structure we are also indirectly tractioning the sural fascia and the superficial fibular nerve[26].

Our study presents the results of surgical treatment of chronic ankle ligament instability using the arthroscopic Brostrom Gould technique, with results and late complications rates compatible with current literature[7,9,10,12]. We report an early complication rate (31.5%) higher than in the current literature, which we believe that can be result of measurement bias, with more stringent criteria for detection of complications.

One limitation of this study is that the AOFAS is not a validated scale for results to assess ankle instability and, consequently, certain clinical features could have been ignored[27]. A clinical score specifically for assessing ankle instability would have enhanced the study's validity. Other limitations include the absence of a control group, and a mean follow-up time considered short for assessment of certain complications, in particular relapse of instability, in addition to failure to measure the amplitude of ankle movement in all of the cases operated.

Conclusion

Treatment of chronic ankle ligament instability using the arthroscopic Brostrom technique effectively restored ankle stability and achieved good clinical results according to the improvements in AOFAS and VAS pain scores. There was a high rate of early complications, but the majority of them were transitory, with complete remission was achieved during follow-up.

Authors' contributions: Each author contributed individually and significantly to the development of this article: TPMF *(https://orcid.org/0000-0003-4835-7618) wrote the article, interpreted the results of the study; MMM *(https://orcid.org/0000-0002-6963-5704) wrote the article, interpreted the results of the study; FMB *(https://orcid.org/0000-0001-6700-0513) wrote the article, interpreted the results of the study; OOJ *(https://orcid.org/0000-0001-7766-9974) wrote the article, interpreted the results of the study; GAN *(https://orcid.org/0000-0003-4431-5576) conceived and planned the activities that led to the stud, wrote the article, approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Comparative study of the FAOS and FAAM questionnaires as functional assessment instruments for patients with hallux valgus

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Abstract

Objective: To compare the Portuguese translations of the Foot and Ankle Activity Measure (FAAM) and the Foot and Ankle Outcome Score (FAOS) questionnaires as functional assessment instruments for patients with hallux valgus and assess correlations between scores and severity of deformity.

Methods: A total of 28 patients were assessed and the functional scores provided by the FAAM and FAOS questionnaires were compared and their correlations with clinical and radiological severity were analyzed.

Results: Mean age was 46.88 years (range: 18 to 64). Laterality was distributed as follows: 57.1% had the deformity on the right foot (16 cases) and 42.9% on the left (12 cases). The deformities identified were graded as follows: 26.1% of patients had mild deformity (6 cases), 45.3% had moderate deformity (14 cases), and 28.6% had severe deformity (8 cases). It was observed that the distribution of scores for the different grades of deformity was the same for both questionnaires.

Conclusion: There was no significant difference between the results obtained using the FAAM or the FAOS questionnaire or in the relationship of proportionality between radiological deformity grade and the functional scores obtained using the two tests.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus; Diseases of the foot; Surveys and questionnaires.

Introduction

Hallux valgus, known popularly as bunion, is a complex disorder of the first ray of the foot that is often seen in conjunction with deformities and symptoms involving the smaller toes[1,2]. The pathophysiology of this deformity is related to extrinsic factors (footwear, trauma) and intrinsic factors (pes planovalgus, hypermobility of the first metatarsal-cuneiform joint, short or varus first metatarsal, ligamentous laxity, or an inclined hallux interphalangeal joint)[3].

The prevalence of this deformity varies from 23 to 64.7% in the general population and clinical presentation can include pain, deformity, and limitations to wearing footwear, which can interfere with daily activities and sports[4-9]. A recent population based study demonstrated that 76.8% of patients with hallux valgus have painful feet, compared with 6.5% of the population without deformities[4].

Studies have compared the questionnaires often used in the international literature on a range of orthopedic diseases, assessing their methodological quality and evidence level, and showing that the Foot and Ankle Outcome Score (FAOS) and the Foot and Ankle Ability Measure (FAAM) questionnaires are frequently used and have comparable validity to the Short Form Health Survey (SF-36). Use of questionnaires in orthopedic practice has increased considerably, both to assess patient satisfaction with the results within health services and as a method for comparing different surgical approaches[10-14].

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

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There are several questionnaires in the specialist literature on diseases of the foot and ankle for assessing the functional results after patients have undergone surgical treatment. The choice of functional assessment method should take into consideration use of questionnaires that have been validated in both the original language and in the version translated into the patients' native language[11,12].

However, there is no consensus on which questionnaire is the best for functional assessment of hallux valgus patients or whether translation of these questionnaires into Portuguese may have interfered with comparison of their results, preventing comparison of the results of different studies focused on the same condition[13].

A recent study demonstrated that 83% of surgeons use questionnaires for routine assessments, for research, and for keeping records for quality control[13]. However, there is a lack of published data to show whether the different questionnaires employed agree with other when used to assess patients with deformities of the forefoot.

The objective of this study is to compare the Portuguese translations of the FAAM and FAOS questionnaires as instruments for functional assessment of patients with hallux valgus and test whether their scores correlate with the severity of deformity assessed radiologically.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 16913018.9.0000.5126.

After each patient had been informed about the objectives of the study and given their consent, the "Foot and Ankle Ability Measure" (FAAM) and the "Foot And Ankle Outcome Score" (FAOS) questionnaires were administered and physical examinations and radiographic assessments were conducted[14].

Patients were recruited who were over the age of 18 years, female, had hallux valgus and no other disorders of the forefoot, agreed to take part, and signed free and informed consent.

All patients were assessed from 2011 to 2016, consecutively, by the same surgeon, and their demographic, clinical, and radiographic data and FAOS and FAAM functional scores were analyzed. Hallux valgus deformities were classified as mild, moderate, or severe according to the Coughlin classification[2]. This classification takes into consideration the valgus angle of the hallux (AVH) and the intermetatarsal angle (IMA) between the first and second rays, measured on orthostatic X-rays taken in the dorsoplantar view. Measurements were taken by tracing lines and measuring the angles between them using X-ray image analysis software. The same researcher measured angles on all X-rays and the results were verified by a second evaluator at a later date.

Cases in which the AVH was less than 20 degrees and the IMA was between 9 and 11 degrees were classified as mild. Deformities with an AVH from 20 to 40 degrees and an IMA from 12 to 15 degrees were classified as moderate. Cases with an AVH exceeding 40 degrees and an IMA exceeding 16 degrees were classified as severe.

Inclusion criteria were adult, female patients whose only complaint was a bunion, with no other deformities of the forefoot, confirmed by clinical and radiographic examination. Exclusion criteria were age over 65 years, skeletal immaturity, chronic diseases such as cardiac and vascular diseases, which could influence physical activity, making them confounding factors by selecting patients with preexisting limitations of sporting functional capacity, and patients who were professional or semiprofessional sportswomen. Male patients and professional or semiprofessional sportswomen were excluded in order to avoid introducing selection bias by comparing the impact of the deformity on physical activity across different sexes or between patients with different levels of sporting ability.

Sample size and statistical analysis

The sample size was calculated on the basis of a two-tailed test, with 5% significance level, 95% confidence level, and 80% test power. The resulting sample size was 24 individuals. After accounting for an expected 15% loss from the sample, a sample size of 28 individuals was defined.

Statistical analysis of the data was conducted using SPSS (IBM) to conduct Student's *t* tests and compare the questionnaire scores using variance tests and the Wilcoxon signed-rank test. For the categorical variables, descriptive statistics were calculated, expressing variables as frequencies and percentages with a 95% confidence interval for the FAOS and FAAM questionnaires. Scores were also compared using the Wilcoxon signed-rank test and correlations between scores were estimated. The confidence level was defined as 0.05.

Results

Twenty-eight female patients with hallux valgus were assessed clinically and functional assessment scores were calculated by administration of the FAAM and FAOS, with help from the researcher. Mean age was 47 years (range: 18 to 64) (Table 1).

Laterality was distributed as follows: 57.1% had the deformity on the right foot (16 cases) and 42.9% on the left (12 cases). The grades of deformity identified were as follows: 26.1% of patients had mild deformity (6 cases), 45.3% had moderate deformity (14 cases), and 28.6% had severe deformity (8 cases).

Table 1. Paired correlations

		N	Correlation	Sig.
Pair 1	FAAM & FAOS	28	0.439	0.019
Pair 2	FAAM & deformity	28	-0.058	0.771
Pair 3	FAOS & deformity	28	-0.232	0.234

Paired correlation tests demonstrating absence of significant difference between the scores obtained using the FAAM and FAOS questionnaires (p=0.19) and absence of significant correlation between the scores and severity of hallux valgus deformity (p>0.05).

Mean preoperative FAAM scores were 59.5 in the group of patients with mild deformity, 46.3 in the moderate group, and 48.25 in the severe group, while late postoperative scores were 84 for the mild, 82 for the moderate, and 84 for the severe groups.

No significant relationship was observed between radiographic severity of hallux valgus and functional limitation measured by this questionnaire, according to the Mann Whitney test (p=1).

Mean preoperative FAOS scores were 89.17 in the group of patients with mild deformity, 74.4 in the moderate group, and 71.5 in the severe group, while postoperative scores were 99.5 in the mild, 98 in the moderate, and 99.5 in the severe groups.

No significant relationship was observed between radiographic severity of hallux valgus and functional limitation measured by this questionnaire, according to the Mann Whitney test (p=0.182).

After testing correlations, we observed that there was no significant difference between scores using the FAAM or the FAOS questionnaire in relation to degree of hallux valgus deformity (p=0.19) (Table 2).

Discussion

The FAOS and FAAM questionnaires have both been translated and cross-culturally adapted[14]. However, these questionnaires are very often used in patients with different types of diseases, which impacts on interpretation of the results observed and their applicability in relation to specific disorders of the foot and ankle that have high prevalence in the population.

Table 2. Frequency by age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18	1	3.6	3.6	3.6
	23	1	3.6	3.6	7.1
	26	1	3.6	3.6	10.7
	27	1	3.6	3.6	14.3
	34	1	3.6	3.6	17.9
	35	2	7.1	7.1	25.0
	36	1	3.6	3.6	28.6
	38	1	3.6	3.6	32.1
	39	3	10.7	10.7	42.9
	41	1	3.6	3.6	46.4
	47	1	3.6	3.6	50.0
	54	1	3.6	3.6	53.6
	55	1	3.6	3.6	57.1
	56	1	3.6	3.6	60.7
	58	3	10.7	10.7	71.4
	60	2	7.1	7.1	78.6
	61	1	3.6	3.6	82.1
	62	2	7.1	7.1	89.3
	63	1	3.6	3.6	92.9
	64	2	7.1	7.1	100.0
	Total	28	100.0	100.0	

Frequency distribution of hallux valgus pathology by age.

To date, there is no functional assessment questionnaire specifically for deformities of the forefoot, making it difficult to compare functional results between studies that use the different questionnaires validated in Portuguese, even when they study the same disorder. There is not yet any consensus on the impact of forefoot deformities in terms of limitations to activities of daily life and sports.

The Foot And Ankle Outcome Score questionnaire (FAOS) was created by adapting the Knee Injury and Osteoarthritis Outcome (KOOS) questionnaire and was developed to provide an instrument to assess functional limitations in different conditions of the foot and the ankle[15]. It comprises 42 items that cover presence of pain and a range of different symptoms, and daily activities, recreational activities, and sporting activities. Each item has a multiple-choice five-point Likert response scale[16]. The sum of the item scores is then transformed to a scale from 0 (worst result) to 100 (best result).

The Foot and Ankle Ability Measure questionnaire (FAAM) was developed to be a self-report questionnaire completed by the patient[17], but studies conducted with the Portuguese version have administered the questionnaire with the patient helped by the researcher. It was designed to be used for functional assessment in different diseases of the foot and ankle. Items are answered on five-point Likert scales and are split into two sub-scales, one covering activities of daily living (21 items) and the other covering sporting activities (8 items). The sum of the item scores is transformed to a scale from 0 (worst function) to 100 (best result). There is also a supplement that assesses overall functional status from 0 to 100.

This study did not find significant differences between the FAAM and FAOS questionnaires when used as tools for assessment of the functional limitations perceived by patients with hallux valgus deformity. The functional results using the FAAM and FAOS questionnaires do not appear to have a significant relationship of proportionality with radiographic severity of the deformity, regardless of which questionnaire is used (FAAM p=1.000, FAOS p=0.182).

More studies should be conducted to investigate the level of agreement between widely-used questionnaires, investigating the most frequently treated diseases individually in order to improve reliability of comparison of results. One of the limitations of this study is its restriction of the sample to adult female patients. Other studies could test whether results are similar with elderly and male populations. Another limitation is the sample size and significant differences might be detected if the number of patients studied is increased.

Conclusion

No significant differences were observed in terms of the functional limitations perceived by patients with hallux valgus deformity using the FAAM or the FAOS questionnaires.

There was no significant relationship of proportionality between radiographic deformity grade and scores on the FAAM and FAOS questionnaires.

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Original Article

Minimally invasive bunionette treatment: clinical and radiographic results

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Abstract

Objective: To report the clinical and radiographic results of surgical treatment of bunionette deformity with a minimally invasive technique without the use of hardware.

Methods: This is a case series of 13 patients (14 feet) with a diagnosis of bunionette surgically treated with a minimally invasive osteotomy of the fifth metatarsal. All patients completed the American Orthopedic Foot and Ankle Society (AOFAS) score and a visual analog scale (VAS) for pain preoperatively and in the last follow-up visit. Radiographic measurements included the fourth-fifth intermetatarsal angle (4-5 IMA) and the fifth metatarsophalangeal (MTP-5) angle. Complications and level of patient satisfaction were also documented.

Results: Mean follow-up was 12.3 months. The mean AOFAS score increased from 51.3 to 94.0, and the VAS score decrease from 7.5 to 1.1. The MTP-5 angle decreased from 11.5º to 2.3º, and the 4-5 IMA decreased from 9.8º to 3.6º. These outcomes showed a statistically significant difference ($p<0.001$). The only complication was hypertrophic callus formation observed in 3 feet (21.4%). There were no cases of infection, neurapraxia, wound dehiscence, nonunion, or deformity recurrence. Ten patients rated their outcome as excellent and 3 as good.

Conclusion: Treatment of bunionette with percutaneous osteotomy of the fifth metatarsal without the use of hardware showed good clinical and radiographic results, with a low complication rate and a high level of patient satisfaction.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Bunion, Tailor's; Minimally invasive surgical procedures/methods; Metatarsal bones/surgery; Forefoot, Human/surgery; Treatment outcome.

Introduction

Tailor's bunion or bunionette is a deformity of the fifth metatarsal head characterized by a bony prominence on the lateral, dorsolateral, or plantar aspect of this bone. The etiology is multifactorial and includes anatomic and biomechanical factors[1]. Du Vries and Coughlin classified the anatomic variations of this deformity into 3 types. In type 1 (16-33%) there is an increase in size of the lateral fifth metatarsal head condyle, in type 2 (10%) there is a lateral deviation at the metadiaphyseal junction, and in type 3 (57-74%) there is an increased intermetatarsal angle between the fourth and fifth metatarsals[2,3].

Bunionette deformity typically presents with pain in the lateral and/or plantar region associated with callus formation and difficulty wearing closed toe shoes. Clinical examination clearly shows an increased intermetatarsal angle with abduction of the fifth metatarsal and a varus fifth toe. Initial treatment is generally conservative and consists of orthopedic

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

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shoes, insoles, and symptomatic medication[4]. If this approach fails, surgical intervention is indicated[1,5].

Surgical options to treat bunionette include chevron osteotomy, Sponsel's osteotomy, and lateral condylar resection, among others[3,6,7]. Some complications associated with these procedures are soft-tissue irritation, infection, and hardware-related problems[8,9]. The description by De Prado of a low invasive technique without the use of hardware boosted the minimally invasive approaches for the treatment of fifth metatarsal deformity[10,11].

The objective of this study was to report the clinical and radiographic results of surgical treatment of bunionette deformity with a minimally invasive technique initially described by De Prado without the use of hardware.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brazil database under CAAE (Ethics Evaluation Submission Certificate) number: 12744119.0.0000.5122 and written informed consent was obtained from each study participant.

We retrospectively assessed patients with a diagnosis of bunionette who were surgically treated with a minimally invasive osteotomy of the fifth metatarsal from March 2018 to August 2019. Eligible participants were all patients with a diagnosis of bunionette who did not improve with conservative treatment consisting of shoe modification and symptomatic medication use. Patients undergoing other concomitant surgical procedures were not included. Exclusion criteria were a previous history of surgery/deformity of the hindfoot and midfoot and rheumatological, neurological, or vascular diseases.

Preoperative evaluation included the application of the American Orthopedic Foot and Ankle Society (AOFAS) score[12] and a visual analog scale (VAS) for pain in all patients. Complementary preoperative studies included anteroposterior (AP) and lateral non-weight-bearing radiographs. The fifth metatarsophalangeal (MTP-5) angle and fourth-fifth intermetatarsal angle (4-5 IMA) were measured[13].

In the last follow-up visit, patients again completed the AOFAS and VAS and a second radiographic examination was performed. Presence of radiographic union (determined by bridging bone spanning 3 or more cortices on orthogonal radiographs), complications, and level of patient satisfaction based on Coughlin's classification (excellent, good, fair, poor, very poor) were also documented[14].

Statistical analysis was performed using GRETL software (2017c). Student's *t* test was used to compare pre-intervention and post-intervention measurements. A p-value <0.05 was considered significant.

Surgical technique

The procedure was performed with the patient lying supine with the legs hanging off the table and feet resting on the image intensifier tube. No tourniquet was used. A 3-mm incision was made on the dorsal aspect of the fifth metatarsal and lateral to the extensor tendon of the fifth toe. The soft tissues were dissected by carefully scraping them off, thus creating a safe working space for osteotomy.

In most cases, osteotomy was performed in the distal third of the metatarsal. Only in type 2 bunionette, osteotomy was performed at the apex of the curvature of the deformity. A 2×12mm Shannon burr was positioned approximately 45° to the fifth metatarsal sagittal axis to obtain an oblique osteotomy from dorsal distal to plantar proximal.

The osteotomy was performed by moving the burr from lateral to medial. During osteotomy, with the non-dominant hand, the surgeon applied external manual pressure to the distal fragment in a medial direction. After completion of osteotomy, the distal part of the fifth metatarsal migrated medially with correction of the deformity (Figure 1).

Figure 1. Intraoperative sequence of the surgical technique; A) Clinical image; B) Radiographic image.

Finally, a gauze-and-tape dressing and compression bandage were applied to maintain the correction achieved.

Postoperative period

In the first postoperative week, patients were instructed to keep the lower limb elevated during rest to alleviate postoperative edema. Immediate full weight-bearing wearing a rigid flat-bottom orthopedic shoe was allowed.

The dressing was changed on a weekly basis for 4 weeks, when there is fibrous union and a certain degree of stability at the osteotomy site. After 4 weeks, the dressings were replaced with silicone strips and patients were allowed to ambulate in a rigid-soled shoe with a wide toe box.

Radiographs were obtained at 2 and 6 weeks postoperatively, and at 3, 6, and 12 months postoperatively (Figure 2).

Results

A total of 13 patients (14 feet) with a diagnosis of bunionette were evaluated in this study. All were women, with a mean age of 42.7 years (range, 26 to 60 years). One patient underwent bilateral treatment in the same surgical procedure. Mean follow-up was 12.3 months (range, 8 to 14 months).

The mean AOFAS score increased from 51.3 to 94.0, and the VAS score decreased from 7.5 to 1.1. The MTP-5 angle decreased from 11.5° to 2.3°, with a mean improvement of 9.2°. The 4-5 IMA decreased from 9.8° to 3.6°, with a mean improvement of 6.2°. All parameters showed improvements of statistical significance ($p<0.001$). The data of the study participants and their individual results are shown in table 1.

The only complication was hypertrophic callus formation observed in 3 feet (21.4%). In the last follow-up visit, these patients reported complication resolution, and radiographs showed bone remodeling of the hypertrophic callus. There were no cases of infection, neurapraxia, wound dehiscence, or deformity recurrence. No delayed unions, nonunions, or malunions were observed. All patients returned to their usual activities with no shoe restrictions. Ten patients rated their overall subjective satisfaction as excellent and 3 as good.

Figure 2. Radiograph obtained at postoperative week 6. A) Anteroposterior view. B) Oblique view. C) Lateral view, highlighting the obliquity of osteotomy and contact between fragments.

Discussion

This study presented the clinical and radiographic outcomes of a series of patients with bunionette surgically treated with a minimally invasive osteotomy without the use of hardware. An important radiographic correction was demonstrated with improvement of the MTP-5 angle and 4-5 IMA and a favorable clinical outcome with significant improvement in pain, as assessed by VAS, AOFAS, and satisfaction rate. The main complication was hypertrophic callus formation, which improved during follow-up. No serious complications occurred, and there was no need to reopen the osteotomy.

Some authors have already demonstrated the efficacy of the surgical treatment of this deformity using the same minimally invasive technique described in the present study. Michels et al.[15] published a case series in which the 20 operated patients had an improvement in mean AOFAS score from 54.4 to 96.5, and a mean correction of 14.2° for MTP-5 angle and 5.7° for 4-5 IMA. Laffenêtre et al.[16] retrospectively evaluated 49 operated feet and reported an improvement in mean AOFAS score from 58 to 97, and a mean correction of 12° for MTP-5 angle and 4.4° for 4-5 IMA. The present study showed similar clinical and radiographic results, with a final AOFAS score of 94 and a mean improvement of 9.2° for MTP-5 angle and 6.2° for 4-5 IMA.

The minimally invasive technique used in the present study stands out as an effective approach because, via percutaneous access without the use of hardware, it produces radiographic results comparable to those of open techniques[17]. Surgical wound infection and local hardware irritation are the most commonly described complications in open techniques and in techniques that use hardware for fixation of the osteotomy[4,11]. The results of the present study reinforce this advantage, since there were no cases of infection, wound dehiscence, or need for surgical reintervention. Heckman et al.[18] evaluated 63 patients treated with distal osteotomy of the fifth metatarsal using an open technique and reported an infection rate of 9.5%, of which 50% required surgical reintervention with resection of the metatarsal head. Recently, Necas et al.[19] retrospectively evaluated 34 feet with bunionette treated with a scarf osteotomy using an open technique and fixation with screws and reported complications in 5 cases (14.7%). Although within acceptable limits, surgical reintervention was required in 3 of these cases (8.8%) due to postoperative infection, transfer metatarsalgia, and hardware migration[19].

A challenge posed by unfixed osteotomies used to treat fifth metatarsal deformity is the risk of developing transfer metatarsalgia. Although unfixed osteotomy offers the advantage of no hardware, dorsal migration of the distal fragment can occur, and the load can be transferred medially. Kea-

Table 1. Study patient data and individual results

Foot No.	Age	Sex	Side	Type*	MTP-5 angle		4-5 IMA		AOFAS		VAS	
					Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
1	54	F	R	3	16	6	12	6	50	95	8	2
2	60	F	L	3	12	2.5	12	6.5	40	95	9	0
3	55	F	R	3	16	2	10.5	5	53	95	9	0
4	33	F	R	3	8	2.5	10	4	53	95	6	1
5	40	F	L	3	10	2	11.5	4	53	95	6	1
6	52	F	R	2	14	4	5	2	63	95	5	0
7	33	F	R	3	8	2	12	6	49	95	8	2
8	40	F	L	3	8	0	10	3.5	53	95	7	2
9	26	F	R	3	12.5	3	13	4.5	35	93	10	3
10	26	F	L	3	12	4	9	1	40	93	8	2
11	43	F	L	3	12.5	3.5	8	2.5	62	95	5	0
12	35	F	L	2	15	3	9	2	40	95	10	0
13	60	F	L	2	8	-1	9	1.5	58	95	9	0
14	42	F	L	1	9	0	7.5	2.5	70	85	5	3

*Deformity type as classified by Du Vries and Coughlin.

ting et al.[20], evaluating bunionette deformities treated with Sponsel's osteotomy using an open technique, with a straight incision on the sagittal axis and an oblique incision on the axial axis, without internal fixation, showed a high rate of transfer metatarsalgia (76%). In the present series, although no internal fixation was used, there were no cases of transfer metatarsalgia. We believe that the absence of this complication resulted from a technical detail of the osteotomy described in this study, which is performed with an oblique incision on the sagittal plane at 45º from dorsal distal to plantar proximal. This configuration helps to maintain contact between the distal and proximal fragments on the sagittal axis, preventing the distal fragment from moving dorsally and, consequently, avoiding excess load transfer to the neighboring metatarsals (Figure 2C).

The osteotomy described in the present study is associated with some complications, but the main one is hypertrophic callus formation during the healing process. Several authors treating this deformity with a percutaneous technique without fixation have reported this complication[15,16,21,22]. In the series published by Laffenêtre et al.[16], 7 patients had hypertrophic callus formation, and the authors related this type of complication to cases operated bilaterally. In the present case series, the only complication was hypertrophic callus formation, which occurred in 3 feet (21.4%), with 1 case occurring in a patient operated bilaterally. During follow-up, there was callus remodeling and symptom improvement; however, this process is slow and may delay the return of patients to their usual activities and reduce their satisfaction with the treatment. This probably occurs due to residual instability of these unfixed osteotomies associated with early weight-bearing on the operated limb, which is more evident in patients treated bilaterally.

This study has a strength that deserves to be highlighted. Patients in this series underwent bunionette correction alone, without any additional procedure. This makes the assessment of bunionette treatment more reliable than that of most series reported in the literature, which evaluated the results of this technique in patients undergoing concomitant hallux valgus correction and other metatarsophalangeal osteotomies.

Limitations of this study include the small sample size, short follow-up, and lack of a control group. Comparative studies with higher scientific level and a larger number of participants are necessary to confirm the observed findings.

Conclusion

Treatment of bunionette with percutaneous osteotomy of the fifth metatarsal without the use of hardware showed good clinical and radiographic results, with a low complication rate and a high level of patient satisfaction.

Authors' contributions: Each author contributed individually and significantly to the development of this article: AFVL *(https://orcid.org/0000-0001-8897-232x) conceived and planned the activities that led to the study, interpreted the results of the study, wrote the article and participated in the review process; TSB *(https://orcid.org/0000-0001-9244-5194)) conceived and planned the activities that led to the study, interpreted the results of the study, and approved the final version; BMB *(https://orcid.org/0000-0003-3712-1247) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version; DSB *(https://orcid.org/0000-0001-5404-2132) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version; GC *(https://orcid.org/0000-0002-7035-3931) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version; GAN *(https://orcid.org/0000-0003-4431-5576) conceived and planned the activities that led to the study, interpreted the results of the study and approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Suprapatellar intramedullary nailing of the tibia

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Abstract

Objective: To report our experience with intramedullary fixation and osteosynthesis of the tibia with suprapatellar approach and semiextended positioning.

Methods: This study retrospectively assessed 6 patients with tibial fracture treated with suprapatellar intramedullary nail fixation and osteosynthesis from September 2015 to September 2018.

Results: There was acceptable bone fixation. Mean healing time was 6 months (range: 4-10 months). Postoperative pain was assessed using a visual analog scale, and the knee was divided into 9 quadrants to help locate the specific site of pain; all participants reported that pain was located at distal quadrants. Knee function was completely restored.

Conclusion: Suprapatellar approach with the knee in the semiextended position is a good surgical technique for extra-articular proximal tibial fractures or those associated with soft tissue involvement at the conventional infrapatellar entry site. Thus, this analysis led us to believe that the technique should also be applicable to middle diaphyseal fractures or fractures in general, regardless of their location.

Level of Evidence IV, Therapeutic Studies; Case Series.

Keywords: Patellofemoral joint/surgery; Tibial fractures/surgery; Fracture fixation, intramedullary; Treatment outcome.

Introduction

Tibial fractures are the most common long bone fractures, and extra-articular proximal tibial fractures account for 5-11% of all tibial shaft fractures. They are usually caused by high-energy trauma and often associated with soft tissue injuries(1).

The treatment of choice for extra-articular tibial fractures, regardless of their location (epiphysis, metaphysis, or diaphysis), is fixation and osteosynthesis with intramedullary nails(2), which are inserted through an infrapatellar portal with the knee in the maximum flexion position(3). There are two problems with this approach. First, it requires maximum flexion of the knee, meaning that fixation of proximal fractures is affected by the patellar tendon, which shows antecurvatum deformity; second, the nail entry site is often compromised by soft tissue injuries resulting from these fractures. Therefore, a new technique emerged to treat these fractures using a suprapatellar approach and semiextended positioning(1).

The aim of this study was to report our experience with intramedullary fixation and osteosynthesis of the tibia with a suprapatellar approach and semiextended positioning.

Methods

This study was approved by the Institutional Review Board.

The present study retrospectively assessed 6 patients with tibial fracture treated with suprapatellar intramedullary nail fixation and osteosynthesis from September 2015 to September 2018.

Inclusion criteria were patients aged 18 years or over with extra-articular proximal tibial fractures or with fractures associated with soft tissue injuries at the conventional infrapatellar entry site, regardless of their location, who were followed up for at least 12 months.

Study performed at the Sanatorio Finochietto, Ciudad Autónoma de Buenos Aires, Buenos Aires, Argentina.

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Patient assessment included clinical history, imaging scans, and functional testing of the knee. The following variables were investigated: type of fracture according to AO classification, quality of fracture fixation according to acceptable angle values (angle deviations below 6° at any plane)[4], radiographic bone healing (bridging of two or more cortices)[5], postoperative pain intensity according to a visual analog scale, site of pain, and knee function (Table 1).

Surgical technique

Patients were placed in the supine position on a radiolucent table with the knee semiextended at an angle from 15° to 30°. No hemostatic tourniquet was applied (Figure 1). First, a 2-3cm longitudinal incision was made along the midline at 2 cm proximal to the upper portion of the patella. After dissection through the quadriceps tendon, a guide pin was inserted into the tibia under radioscopic control, using the following landmarks: a line medial to the lateral intercondylar tubercle of the tibia in the coronal plane, and ventral edge of the joint surface in the sagittal plane (Figure 2). Subsequently, we placed a patellofemoral protection sleeve, whose internal and external parts were made of metal and thermoplastic material, respectively. Afterwards, surgery proceeded with the usual procedures of the infrapatellar technique.

Results

Mean age at the time of surgery was 48 years (range: 22 to 82 years); all patients were male. Five fractures affected the left leg and one affected the right leg. Five fractures were located at the proximal third of the diaphysis and one was located at its distal third (Figure 3).

Two fractures were open, both classified as Gustilo-Anderson 3A, and four were closed. Four fractures were caused by high-energy trauma, of which two were caused by a motor vehicle collision, one by fall from height, and another by a high-risk sport. Two fractures were associated with contralateral leg fracture, one with homolateral patellar fracture, and one with severe multiple trauma.

Mean time elapsed from fracture to surgery was 10 days (range: 3 to 25 days). Of note, the longest times were found for the two cases of open fracture, which required surgical cleaning and temporary external stabilization. Mean follow-up duration was 22 months (range: 12 to 48 months).

Acceptable bone fixation was achieved in all cases, as shown by adequate alignment (mean frontal axis of 1° and mean lateral axis of 4.36°), length, and rotation in control panoramic frontal and lateral radiographs of the leg.

Mean time for bone healing was 6 months (range: 4 to 10 months) (Figure 4).

Three patients reported postoperative pain, of whom two had moderate pain and one had mild pain according to the visual analog scale.

To enable the assessment of site of pain, the knee was divided into three thirds (purely articular third, extra-articular proximal third, and extra-articular distal third), and each of these thirds was further divided into another three thirds (internal, middle, and external) (Figure 5).

All cases of pain were located at the distal third, i.e., the lower extra-articular third. One of these cases, which was located at the internal distal third and was related to the proximal locking nail used in osteosynthesis, resolved soon after nail removal. The other two, which were located at the middle distal third and were related to fracture focus or bone exposure area and soft tissue injury, did not require any other procedure. There were no reports of pain at the proximal middle third (surgical site) or at the articular middle third (patellofemoral compartment).

Knee function was completely restored in all patients, and maximum knee extension and flexion angles were restored to those reported prior to the fracture or to those found in the healthy contralateral knee (Figure 6). There were no soft tissue complications at the surgical site.

Table 1. Patients

	1	2	3	4	5	6
Age	65	36	22	44	82	40
Sex	M	M	M	M	M	M
Type of fx	42-A2 P	42-A1 P	42-A2 P	42-B2 D	42-A2 P	42-A3 P
Affected side	L	L	L	L	L	R
Associated events	Patellar fx	Contralateral tibial fx	Open fx	Open fx	Contralateral tibial fx	-
Days from fx to sx	3	6	25	15	6	7
Fixation	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Healing time	6 m	4 m	10 m	4 m	6 m	5 m
Follow-up duration	48 m	18m	18 m	15 m	12 m	12 m
Postoperative pain	6	0	5	0	2	0
Site of pain	7	-	8	-	7	-
Function	Complete	Complete	Complete	Complete	Complete	Complete

Fx: fracture; Sx: surgery.

Figure 1. Patient positioning.

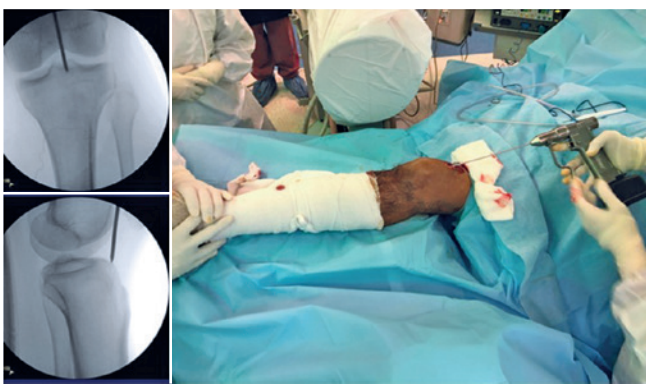

Figure 2. Placement of guide pin and radioscopic control.

Figure 3. Frontal and lateral radiograph of a typical proximal tibial fracture.

Discussion

According to the literature, proximal tibial fractures are difficult to manage using the infrapatellar approach. Traction of patellar and hamstring tendons usually leads to malalignment and more complex fixation(4). Malalignment is reported to range from 58 to 84%(5).

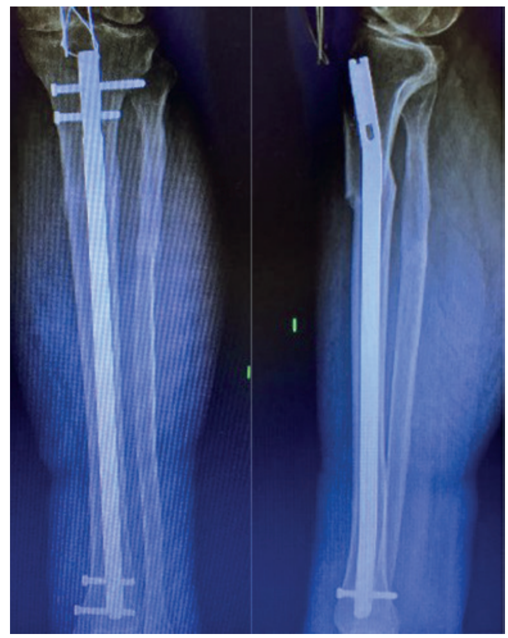

Figure 4. Frontal and lateral radiographs showing bone healing.

Figure 5. Quadrants to assess sites of pain.

Figure 6. Complete flexion and extension of the knee, asymptomatic.

Therapeutic alternatives include plates that allow for direct visualization and anatomic fixation. However, they have some disadvantages, such as poor axial fixation and poor varus stability, in addition to greater risk of infection and dehiscence in cases requiring large dissections for the placement of these plates[1].

The two main indications for suprapatellar approach are extra-articular proximal tibial fractures and those associated with soft tissue involvement at the infrapatellar entry site. Secondary indications may include patients with knee flexion deficit, *patella baja*, or patellar tendon calcification[1].

In 1996, Tornetta and Collins[6] were the first to treat proximal tibial fractures with the knee in the semiextended position and using a suprapatellar approach by performing a subluxation of the middle patella. However, Cole was the author who proposed, in 1998[7], a minimally invasive suprapatellar insertion technique that approaches the midline of the quadriceps. In 2018, Wang et al.[8] conducted a review that showed advantages of the suprapatellar approach with regard to shorter radioscopy duration. We agree that semiextended positioning facilitates the operation of the radioscopy equipment.

We believe that the semiextended knee position makes surgical management easier in patients with multiple trauma and in those with soft tissue involvement at the infrapatellar entry site. Compared to findings from the literature, we did not observe anterior knee pain related to nail insertion using the suprapatellar approach. Higher levels of knee pain after infrapatellar nailing may result from knee flexion during nail insertion or from the transpatellar tendon approach[3,7,8].

Suprapatellar approach is questioned due to possible patellofemoral joint damage. Gelbke et al.[9] compared patellofemoral contact pressure of infrapatellar and suprapatellar nailing of the tibia in human cadaver specimens and found that was the maximum pressure recorded during the suprapatellar procedure was 3.83 MPa, which was three times higher than that recorded during the infrapatellar procedure (1.26 MPa). However, the suprapatellar value is still below the 4.5 MPa at which apoptosis of chondrocytes occurs and, therefore, suprapatellar nailing did not pose significant risks to patellofemoral joint integrity.

Sanders et al.[3] assessed a series of 26 cases undergoing arthroscopies before and after nail insertion to investigate the presence of osteochondral lesions and found no such lesions in these patients. Similarly, our analysis did not find any patient with symptoms suggesting patellofemoral involvement.

The limitations of our study include its small sample size (6 patients) and lack of accurate angle measurements with weight-bearing panoramic radiographs, which would help to diagnose arthroscopically damage to the patellofemoral cartilage.

Conclusion

Suprapatellar approach with the knee in the semiextended position is a good surgical technique for extra-articular proximal tibial fractures or those associated with soft tissue involvement at the conventional infrapatellar entry site. Thus, this analysis led us to believe that the technique should also be applicable to middle diaphyseal fractures or fractures in general, regardless of their location.

Authors' contributions: Each author contributed individually and significantly to the development of this article: AMV *(https://orcid.org/0000-0002-0384-4044) conceived and planned the activities that led to the study, interpreted the results of the study, performed the surgeries, approved the final version; ES *(https://orcid.org/0000-0001-5028-9584) conceived and planned the activities that led to the study, interpreted the results of the study, performed the surgeries; YA *(https://orcid.org/0000-0001-8926-5088) data collection, bibliographic review; AB *(https://orcid.org/0000-0003-1690-025X) data collection, clinical examination; MI *(https://orcid.org/0000-0002-6336-6080) wrote the article, bibliographic review; IT *(https://orcid.org/0000-0001-9210-9051) data collection, clinical examination. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Evaluation of foot and ankle injuries in professional soccer – prospective analyses of the Paulista Soccer Championship 2016

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Abstract

Objective: To evaluate the profile of foot and ankle injuries in professional soccer.

Methods: Data were collected prospectively during the 2016 São Paulo Soccer Championship using two electronic forms: an initial form (10 variables) and a follow-up form (6 variables). The results were standardized and evaluated in SPSS 23.0.

Results: A total of 259 injuries were reported: 106 to the thigh (40.9%), 42 to the foot and ankle (16.2%), 39 to the knee (15.1%), 39 to the head or face (15.1%) and 33 in other locations (12.7%). Of the 42 foot and ankle injuries, 20 were lateral ankle sprains (47.6%), 5 were medial ankle sprains (11.9%), 3 were to the triceps surae (7.1%), 3 were leg contusions (7.1%), 3 were foot contusions (7.1%), 2 were myalgias (4.8%), in addition to 5 other types (11.9%). There was physical contact in 73.8% of the injuries ($p < 0.001$), and six injuries (14.3%) were considered severe, i.e., involving a time loss of at least one month. Of the severe injuries, four were treated surgically (three by osteosynthesis and one by tenorrhaphy). The mean time loss due to injury was 19.7 days, and the overall incidence rate was 3.5 injuries per 1000 hours of exposure, with 2.1 ligament injuries per 1000 hours. X-rays and magnetic resonance imaging were the most requested tests in the follow-up of these patients.

Conclusion: Foot and ankle injuries were the second most frequent injury in Brazilian professional soccer, 73.8% of which resulted from physical contact ($p<0.001$). Lateral ankle sprains accounted for 47.6% of these injuries, which reaffirms their high prevalence and importance for sports medicine.

Level of Evidence III; Prognostic Studies; Prospective Study.

Keywords: Foot injuries; Soccer; Athletes.

Introduction

Soccer is one of the most popular sports in the world[1]. It is estimated that the sport generates more than 30 billion dollars per year worldwide and is played by more than 240 million people[2]. Since it involves running, sprinting, jumping and quick changes of direction, soccer athletes are exposed to several types of injuries to the muscles and ligaments, as well as contusions and even fractures[1,3,4]. Studies have shown that soccer has a higher injury rate than other sports, including handball, volleyball, basketball, judo, and swimming[5,6].

The injury rate in this sport can reach 70 per 1000 hours of exposure[3]. Recent data show that the leg is the main site of these injuries, which are mainly traumatic in origin[2,3,7,8]. Depending on the force of the trauma, these injuries can be serious, sidelining players for long periods, damaging both the player and the team[2,9].

In Brazil, the exhaustive training regimen and frequency of matches appear to increase the players' exposure to injuries. Nevertheless, studies on the profile of these injuries are still scarce in the national literature[3,10-14]. To date, we have found

Study performed at the Centro de Traumatologia do Esporte, Universidade Federal de São Paulo, São Paulo, SP, Brazil.

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no Brazilian studies on foot and ankle injuries in professional soccer, only rare articles assessing recreational and pre-professional levels, which have found that lateral ankle sprain is the most prevalent diagnosis[15-17].

Thus, our group proposed to prospectively asses foot and ankle injuries in the 2016 Paulista Soccer Championship (leagues A1 and A2), with the primary objective of understanding and describing these injuries.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brazil database under CAAE (Ethics Evaluation Submission Certificate) number: 20242919.1.0000.5505.

Data collection was carried out prospectively with a specially developed electronic form that was filled out by the team doctor after each game. Two questionnaires were applied at different points in the study. The initial form contained 10 items: basic data about the match, whether an injury occurred, the injured player's date of birth, his position (goalkeeper, forward, etc.), the part of the match in which the injury occurred, injury topography, injury laterality, injury type, whether there was shock/trauma, and probable diagnosis. The second form, which followed up cases of injury, consisted of 6 items: complementary exams, whether surgery was required, the date of the player's return, total time loss in days, injury severity, and final diagnosis.

The concept of injury conformed to the Injury Consensus Group statement in Fuller et al. (2006): "Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities"[18].

All injuries reported in full through the two questionnaires were included. Questionnaires filled out incorrectly or incompletely were excluded. The results were standardized according to Brazilian Football Confederation consensus[19]. The injuries were classified into five severity categories based on time loss: mild (up to 3 days), minor (4 to 7 days), moderate (8 to 28 days), major (29 days to 8 weeks) and severe (over 8 weeks)[19]. The matches were divided into 3 parts: beginning (0-15 minutes), middle (16-30 minutes) and end (31-45 minutes + additions)[18].

To assess the incidence (I) of foot and ankle injuries, we first calculated the total hours of exposure (Exp), resulting in the formula: $Exp = Nm \times Np \times Dm/60$ where Nm is the number of matches, Np is the number of players, and Dm is the duration of the match. Finally, we calculated the incidence (I) as: $I = NIfa \times 1000/Exp$, where NIfa is the number of foot and ankle injuries and Exp the exposure (in hours). The final product of this calculation is given in injuries per 1000 hours of exposure.

Descriptive analyses of categorical and numerical variables were performed, and the significance of their differences was measured with the chi-square test in SPSS 23.0. P-values <0.05 were considered significant.

Results

In a total of 353 matches (150 in the A1 league and 203 in the A2 league), 259 injuries were reported: 106 to the thigh (40.9%), 42 to the foot and ankle (16.2%), 39 to the knee (15.1%), 39 to the head or face (15.1%), and 33 to other locations (12.7%), which corresponds to a rate of 0.73 injuries per match. Of the 42 injuries to the foot and ankle, 20 were lateral ankle sprains (47.6%), 5 were medial ankle sprain (11.9%), 3 were to the triceps surae (7.1%), 3 were leg contusions (7.1%), 3 were foot contusions (7.1%), 2 were myalgias (4.8%), and 1 was a cramp (2.4%). Four injuries required surgical treatment (9.5%): 1 calcaneal tendon rupture, 1 tibia fracture, 1 unimalleolar fracture, and 1 midfoot fracture, while surgical treatment was indicated in only 6.9% of the injuries to other anatomical regions (p>0.05).

The mean age of athletes with foot and/or ankle injuries was 25.4 years, compared to 27.0 years for all other injury types (p>0.05). The mean time loss for athletes with foot and/or ankle injuries was 19.7 days, compared to 23.7 days for other injury types (p>0.05). The incidence rate for all foot and ankle injuries was 4.4/1000h exposure in the A1 league, 2.8/1000h in the A2 league and 3.5/1000h overall (8349 total hours of exposure) (p>0.05). The overall incidence rate for ligament injuries alone was 2.1/1000h. No significant differences were found regarding the other factors (position, laterality, etc.) (p>0.05) – see table 1.

Table 1. Comparison of ligament and non-ligament injuries

		Ligament lesion		*p*
		No	Yes	
Position	Goalkeeper	2	0	***0.30***
	Fullback	4	4	
	Defender	0	4	
	Defensive midfielder	3	4	
	Midfielder	4	6	
	Forward	4	7	
Side	Left	8	14	***0.57***
	Right	9	11	
League	A1	9	14	***0.85***
	A2	8	11	
Time of day	Morning	1	1	***0.89***
	Afternoon	7	12	
	Night	9	12	
Point in match	Beginning	3	3	***0.85***
	Middle	5	7	
	End	9	15	
Contact	Yes	11	20	***0.27***
	No	6	5	

Table 2 shows the differences between foot and ankle injuries and all other types. It should be pointed out that 73.8% of the foot and ankle injuries involved physical contact (p<0.001), while 92.5% of thigh injuries did not (p <0.001). Finally, table 3 summarizes the complementary exams requested during follow-up treatment.

Discussion

After the thigh (40.9%), the foot/ankle was the second most affected region of the body in this study (16.2%). This is in line with data from other championships. A seven-season (2001-2008) study of the Union of European Football Associations found prevalences of 37% and 31% for thigh and foot/ankle injuries, respectively, while prevalences of 41.1% of and 21.1% thigh and foot/ankle disorders, respectively, were reported in the 2016 Brazilian Championship. However, such findings are inconsistent with other international championships, such as the 2002 World Cup, in which the injury prevalences were 39.8% and 24% in the foot/ankle and the thigh, respectively, as well as the 2011 Copa América, in which the injury prevalences were 34.9 % and 27% in the foot/ankle and the thigh, respectively[2,5,8,12,20].

In the present study, traumatic events were frequent, occurring in 73.8% of foot and ankle injuries, which approaches the upper limit of the 58% to 86% range described in the literature[6–8,21-26]. The highest reported rate of traumatic events occurred during the 1998-2001 FIFA competitions, which included the 1998 World Cup and the 2000 Olympic Games[7,9,19,20,23]. The similar injury profile between the FIFA championships and our findings suggests that the Brazilian competitions are just as hotly disputed [7,9,19].

The overwhelming majority of thigh injuries, however, occurred without direct contact from other players. Trauma was mentioned in only 8 of the 106 thigh injuries (p<0.001), and the remaining 98 were due to muscle strains. Of all reported injuries in the sample, strains occurred in 39.8%, with a further 20.5% due to sprains and 16.6% to contusions. The remaining 23.1% involved dislocations, fractures and concussions. These proportions differ significantly in other countries; in Japan, for example, 32.2% of injuries are sprains, 27.0% contusions, and 18.4% strains[23]. They also differ from other major FIFA championships, where the frequency of contusions has reached 59%[7]. These regional differences in muscle strain prevalence suggest differences in the quality of physical training and corroborate the hypothesis that Brazilian competition is more physically demanding[1,13,19]. However, more studies are needed to substantiate this hypothesis, especially since we live in a tropical country and other factors, both intrinsic and extrinsic, can influence the occurrence of these injuries[1].

Among the foot and ankle injuries, the most frequent type (47.6%) was lateral ankle sprain, followed by medial ankle sprain (11.9%), triceps surae (7.1%), and contusions of the leg (7.1%) and foot (7.1%). According to the literature, lateral ankle

Table 2. Comparison of foot and ankle injuries

Physical contact	Yes	No	p
Other	96	121	***<0.01***
Foot and ankle	31	11	

League	A1	A2	p
Other	102	115	*0.357*
Foot and ankle	23	19	

Severity	Mild	Minor	Moderate	Major	Severe	p
Other	57	45	76	24	15	*0.217*
Foot and ankle	10	13	13	1	5	

Part of the day	Morning	Afternoon	Night	p
Other	25	75	117	*0.253*
Foot and ankle	2	19	21	

Part of the match	Beginning	Middle	End	p
Other	54	69	94	*0.192*
Foot and ankle	6	12	24	

Position	Goalkeeper	Fullback	Defender	Defensive midfielder	Midfielder	Forward	p
Other	12	36	37	38	35	59	0.755
Foot	2	8	4	7	10	11	

Table 3. Complementary examinations

None	15 (35.7%)
Magnetic resonance imaging	15 (35.7%)
X-ray	11 (26.2%)
Ultrasound	2 (4.7%)
Computed tomography	1 (2.4%)

sprains are one of the most common sports injuries (up to 30%), with an incidence ranging from 1.7-2.0/1000h[1,2,4,24,25,27]. They are a common injury even in sports played with the hand, such as basketball, volleyball and handball[2,6]. Our value of 2.1/1000h is consistent with these data[1,2,4,24,25,27]. In the most severe cases, sprains can produce syndesmosis injuries, however no such case was reported in our sample[25,27]. The mean time loss due to injury in our study was 19.7 days, which was less than that found in the literature (34-37 days)[20,25].

Of the 20 lateral ankle sprains, none were treated with surgery, while in eight cases no imaging exam was performed. The main requested complementary exam was magnetic resonance imaging. This discrepancy in the way cases were handled and the differing criteria for requesting exams suggests a heterogeneity among the teams regarding the treatment of ankle sprains and reflects a need for standardized care and follow-up by specialized professionals.

This study has certain limitations. The main challenge was to ensure that the data were recorded correctly and completely by the team doctors. Although we standardized the data, the diagnostic criteria were not uniform and this may have added some observational bias. Another obstacle was a lack of in-depth data on the evolution of each injury, including its classification, the exams performed, and the physical therapy rehabilitation protocols for each team, as well as data on training injuries. However, despite its limitations, this is the first Brazilian study on foot and ankle injuries in professional soccer, which opens the door for future research that will improve our understanding of these injuries and direct our efforts toward increasingly effective therapeutic interventions[28,29].

Conclusion

This study provides initial data on the profile of foot and ankle injuries in Brazilian professional soccer. Foot and ankle injuries were the second most frequent topography, and 73.8% of these injuries resulted from physical contact ($p<0.01$). A total of 47.6% of the foot and ankle injuries were lateral ankle sprains, which reaffirms their prevalence and importance, especially in professional soccer.

Authors' contributions: Each author contributed individually and significantly to the development of this article: DPK *(https://orcid.org/0000-0003-1858-2718) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; ESM *(https://orcid.org/0000-0002-8572-7764) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; NSBM *(https://orcid.org/0000-0003-1067-727X) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; ERM *(https://orcid.org/0000-0002-8245-2945) wrote the article, participated in the review process, approved the final version; GGA *(https://orcid.org/0000-0003-4371-5041) wrote the article, participated in the review process, approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Percutaneous surgery practice in Brazil: the profile of Brazilian foot surgeons

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Abstract

Objective: The objective of this study was to evaluate current percutaneous foot surgery practice among Brazilian specialists.

Methods: A cross-sectional observational study was conducted, surveying members of the Brazilian Foot and Ankle Society (ABTPé) by emailing electronic questionnaires in 2017 and 2019. The information requested included demographic data and the profile of their practice with relation to percutaneous foot surgery. A total of 74 participants completed the survey questionnaire in 2017 and 82 in 2019 (response rates of 15 and 14% respectively).

Results: A total of 49 participants in 2017 (65.33%) and 57 in 2019 (69.51%) were performing percutaneous foot surgery. Among respondents who were not performing percutaneous foot surgery, 15 in 2017 (57.69%) and 10 in 2019 (40%) stated that they believed in the method, but had not been trained to perform it. Exclusively spinal anesthesia was used by 19 surgeons in 2017 (38.77%) and 23 in 2019 (40.35%). When correcting Hallux Valgus, 13 surgeons in 2017 (26.53%) and 3 in 2019 (5%) did not use any type of fixation. The most frequently reported complication was poor reduction in both periods, reported by 36 (73.46%) participants in 2017 and 39 (68.42%) in 2019.

Conclusion: In Brazil, a lack of specific training is one factor that limits the practice of percutaneous foot surgery. The technique is used by a greater number of younger surgeons. The most frequent complication is poor reduction and there is a growing trend to employee fixation hardware.

Evidence Level V; Expert Opinion.

Keywords: Minimally invasive surgical procedures; Hallux valgus; Foot; Orthopedic surgeons.

Introduction

Percutaneous surgery is an additional tool for treatment of diseases of the foot, in particular the forefoot(1). Whereas in minimally invasive surgery, corrections are made under direct visualization of structures via small incisions, in percutaneous surgery, corrections are made via minimal incisions, without direct visualization of the structures involved, using tactile sensations and radioscopy.

The first generation of percutaneous surgery was introduced in the 1970s by Stephen Isham, in the United States, and was later improved upon by Mariano de Prado and the anatomist Pau Golano in Spain, up to the establishment of GRECMIP (*Groupe de reserche et d'enseignement em chirurgie mini-invasive du pied*), which today is an international group interested in teaching and developing arthroscopy and percutaneous surgery. The method has attracted interest because of its potential for smaller scars, less postoperative pain, faster recovery and early mobilization, shorter rehabilitation time, and lower risk of complications related to the operating wound(1).

Use of the technique has grown considerably over recent years(2), but its use by members of the Brazilian Foot and Ankle Society (ABTPé) has not been surveyed previously. The objective of the present study was to determine the profile of current percutaneous foot surgery practice among foot and ankle surgery specialists in Brazil, using electronic questionnaires sent by email (Google forms).

Study performed at the Universidade Estadual de Campinas (UNICAMP), Campinas, SP, Brazil.

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Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 11311119.4.0000.5404.

The study was initiated by sending out a questionnaire via email and via a multiplatform instant messaging program (WhatsApp) to all members of the Brazilian Foot and Ankle Society (ABTPé) in 2017 and again in 2019. The questionnaire contained a total of 33 questions on foot and ankle percutaneous surgery practices. Questions were closed, but more than one response was permitted, following a logical sequence, facilitating completion of the questionnaire. Twelve of the questions covered patterns of percutaneous foot surgery practice, such as the number of operations performed per year, aspects related to professionals' training in the method, distribution of practicing surgeons by regions of Brazil, indications and specific techniques employed, use of any type de fixation, type of anesthesia employed, use of tourniquets, and the main complications observed.

Data were analyzed using STATA v14.2 statistical software (StataCor, Texas, United States). Chi-square or Fisher's exact tests were used to compact percentages from 2017 against those from 2019 and a 95% significance level was adopted. Quantitative and qualitative descriptions of the responses to each item are included in the results.

Results

A total of 75 participants out of the total of 504 Society members in 2017 82 out of the total of 635 Society members in 2019 completed the questionnaire (response rates of 14.88% and 12.91%, respectively). A majority of the participants were from the Southeast region, with 48 (64%) in 2017 and 55 (67.07%) in 2019, followed by the South, with 15 (20%) in 2017 and 13 (15.85%) in 2019 (Figure 1).

The majority (n=52, 69.33%) of Society members who answered the questionnaire in 2017 had more than 10 years' experience in foot and ankle surgery. In 2019, the number with more than 10 years' experience was 40 (48.78%). In both surveys, a majority of those who did conduct percutaneous surgery performed from 10 to 30 procedures per year: 14 (28.57%) in 2017 and 21 (36.84%) in 2019 (Figure 2).

In 2017, 75 Society members answered the questionnaire, 49 (65.33%) of whom were performing percutaneous foot surgery. Among the remaining 26 members who were not conducting percutaneous foot surgery, 22 (84.61%) stated that they believed in the method, but lacked either the training or the equipment needed and just 3 (11.53%) stated that they did not believe in the method. In 2019, 57 (69.51%) were conducting percutaneous surgery and 25 (30.49%) were not. Sixteen (64%) of those who were not, did believe in the method, but lacked either the training or the equipment needed, and 6 (24%) did not believe in the method.

Exclusively spinal anesthesia, was used by 19 surgeons in 2017 (38.77%) and 23 in 2019 (40.35%). Locoregional anesthesia with sedation was used by 14 surgeons in 2017 (28.57%) and 14 in 2019 (24.56%), while a further 12 surgeons in 2017 (24.48%) and 18 in 2019 (31.57%) used two types of anesthesia.

In regard to use of a tourniquet, in 2017, 9 (18.36%) surgeons used one and 39 (79.59%) did not. In 2019, just 4 (7.01%) were using a tourniquet and 53 (92.98%) were operating without one.

In both 2017 and 2019, the pathologies most often treated with percutaneous surgery were Hallux Valgus, Metatarsalgia, Bunionette, and deformities of the smaller toes. The least treated condition was arthritis (Figure 3).

The techniques for correcting Hallux Valgus most used by Society members were the Akin and Reverdin Isham in 2017, and the Akin and Chevron in 2019 (Figure 4).

With regard to use of fixation in osteotomies to correct Hallux Valgus, 13 surgeons in 2017 (26.53%) and 3 surgeons in 2019 (5.26%) did not use any kind of fixation, whereas 36 in 2017 (73.46%) and 54 in 2019 (94.73%) used fixation in one or more correction technique, and osteotomy of the base of the first metatarsal was the technique most often performed with fixation in 2017 (42.85%), whereas in 2019 it was the Chevron (87.71%) (Figure 5).

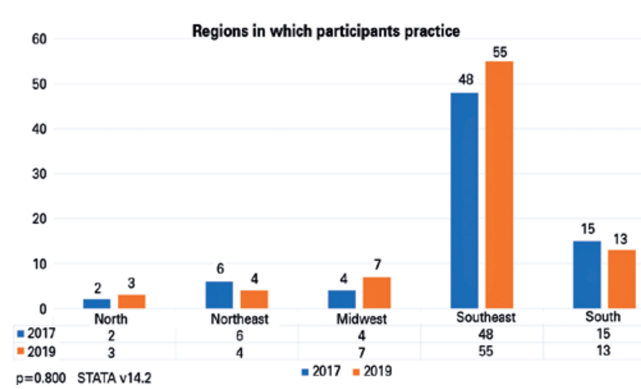

Figure 1. Regions in which participants practice.

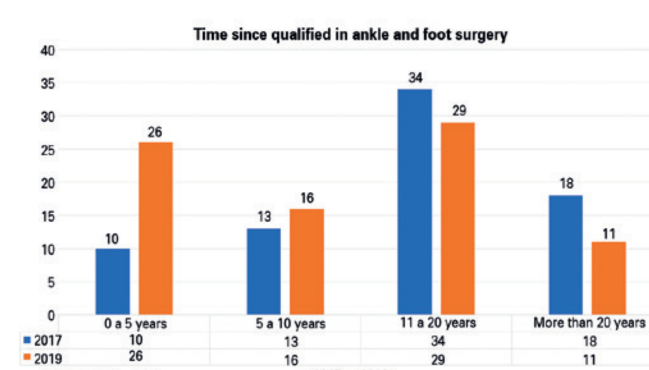

Figure 2. Time since qualified in ankle and foot surgery.

The majority of participants, 24 (48.97%) in 2017 and 28 (49.1%) in 2019, prescribed from 4 to 6 weeks with dressings. In conjunction with dressings, 7 (14.28%) participants in 2017 and 9 (15.78%) in 2019 stated that they also used a silicone spacer.

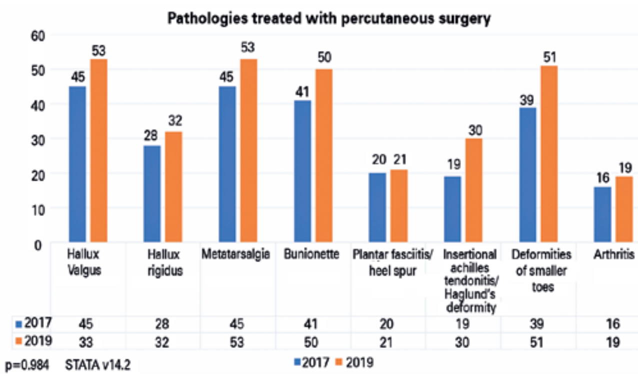

Figure 3. Pathologies treated with percutaneous surgery.

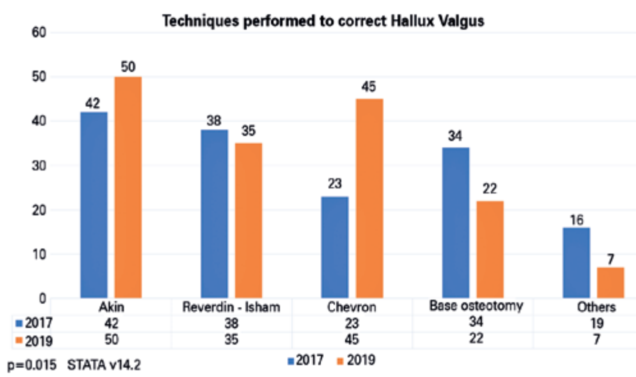

Figure 4. Techniques performed to correct Hallux Valgus.

The most frequently reported complication was poor reduction in both survey years: 36 (73.46%) in 2017 and 39 (68.42%) in 2019. Pseudarthrosis was the least frequently reported complication in both years, with 7 (14.28%) reports in 2017 and 19 (33.33%) in 2019 (Figure 6).

Both in 2017 and in 2019, the most common source searched for information was textbooks, endorsed by 40 (81.63%%) and 49 (85.96%) participants respectively.

With regard to the professionals' training or qualifications, just 7 (14.28%) participants in 2017 reported being trained during specialty residency, increasing to 22 (38.59%) in 2019. The most frequent type of training was courses attended in Brazil and abroad, with 30 (61.22%) and 33 (57.89%) in 2017, and 31 (63.26%) and 28 (49.12%) in 2019, respectively. Additionally, 17 participants (34.69%) in 2017 and 21 (36.84%) in 2019 described training supervised by professionals with experience in the technique (p=0.190).

Discussion

Many different open techniques have been described for treatment of Hallux Valgus and deformities of the toes, but we do not yet have consensus on which of them is the most effective[3,4]. Although the initial results of percutaneous techniques are encouraging, there is a lack of randomized studies comparing them with open techniques. In a systematic review, Trnka et al. showed that the majority of published studies have level IV evidence. They found one level II study and three level III studies in a total of 21 studies, including reviews[5]. The literature still lacks studies with control groups[6], although several studies have substantial sample sizes and long follow-up periods, such as one by Giannini et al. (1000 feet followed-up for 5 years) and another by Faour-Martín et al. (115 feet followed-up for 10 years)[7,8].

Percutaneous surgery offers certain advantages over conventional techniques, such as, for example: ambulatory surgery with locoregional anesthesia, small incisions or punctures, fixation hardware not employed as routine, immediate mobilization, and lower intensity of postoperative pain. Di-

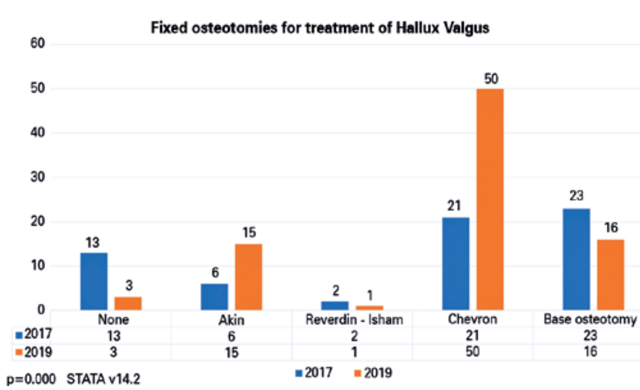

Figure 5. Fixed osteotomies for treatment of Hallux Valgus.

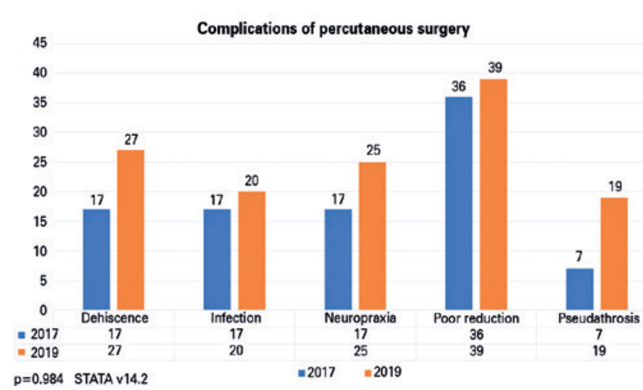

Figure 6. Complications of percutaneous surgery.

sadvantages originate from the fact that the technique is performed without direct visualization of the structures involved, the need for intraoperative fluoroscopy, the need for specific materials, and the long learning curve[9,10].

Complications include: undercorrection or overcorrection, thermal injuries, transference metatarsalgia, nonunion or pseudarthrosis, and rigidity or limited movement of the first metatarsophalangeal joint. This last appears to be more frequent when the Reverdin Isham technique is used, precisely because this is an intracapsular osteotomy[1,9,4,11]. Many of the complications reported may be more related to incorrect application of the technique, rather than being a true limitation of the technique, since it has a long learning curve and a specific protocol for postoperative dressings and rehabilitation must be followed[12,13].

In our study, the most frequently reported complication was poor reduction, endorsed by 73.46% in 2017 and 68.42% in 2019. These values were not statistically significant when the two survey years were compared (p=0.255). The high values for this complication are an important finding. Poor reduction is a complication that also occurs with traditional techniques, but which is not necessarily correlated with patient satisfaction.

Indications have been increasing and now include treatment for Hallux Valgus, Hallux Rigidus (except for cases of revision, prior infection, or inadequate bone stock), deformities of the smaller toes, hindfoot pathologies (Haglund syndrome) and soft tissue disorders (plantar fasciitis)[14,15].

For the traditional Reverdin – Isham technique, there is still a lack of studies to show the efficacy of adding a fixation[16].

This is the first survey of percutaneous surgery conducted in Brazil. We achieved response rates of 14.88% and 12.91% in 2017 and 2019, respectively.

Surveys conducted by sending questionnaires by e-mail are faster and cost an estimated 5 to 20% of the cost of postal surveys. The response rates are generally low using this type of method, at approximately 20%. However, it is believed that the responses provided may be more trustworthy than with surveys conducted by telephone or by post[17,18]. Our response rate was lower than expected for this type of survey. In view of the impersonal nature of this survey format, we believe that the principal reason is that the Society members were not interested in answering this type of questionnaire.

The majority of participants were concentrated in the Southeast region of Brazil, with 48 (64%) in 2017 and 55 (67.07%) in 2019, followed by the South region. Although this is similar to the distribution of Society members across Brazil, this finding was not statistically relevant (p=0.800).

In our study, the percutaneous technique was used by a greater number of younger surgeons (p=0.026). Although there was a considerable increase in the number of respondents who were trained in the technique during their specialty residency in the 2019 survey, when the majority of participants had less than 10 years' experience, we cannot conclude that this was statistically important for this group's use of the technique. The technique was primarily learnt on courses attended in Brazil and abroad, or by observing colleagues who already used these methods.

Nowadays, the techniques have evolved and there is a trend to fix certain osteotomies such as osteotomies of the base of the first ray, Chevron and Akin osteotomies, and the combination of these two to correct moderate and severe Hallux Valgus (Minimally Invasive Chevron and Akin – MICA)[19]. This runs counter to the principles described by Mariano de Prado[14], but is in alignment with the AO (*Arbeitsgemeinschaft fur Osteosynthesefragen*) group's principles of rigid internal fixation and preservation of soft tissues inviolate[20]. Other techniques, such as that described by Bosh and modified by Giannini (SERI - simple, effective, rapid, and inexpensive) always employ fixation, a Kirschner intramedullary wire[8,21], as does the technique described in 2014 by Brogan et al., which is a mixture of the MICA and original Bosh techniques, which also obligatorily uses fixation hardware[22,23].

With regard to Hallux Valgus, majorities of the participants do not use a tourniquet during surgery, most often use the Chevron technique (p=0.015), and fix osteotomies according to the current model (p=0.000). We believe that these changes reflect evolution of knowledge about the subject, and that the study participants are in tune with current tendencies in percutaneous treatment of pathologies of the foot. The only point that runs counter to the technique described is use of spinal anesthesia, since the majority of services abroad use locoregional blocks[1,14]. However, this finding was not statistically relevant (p=0.831).

The majority of participants believe in the method and among those who do not use it, a lack of adequate training and access to equipment appear to be the greatest factors limiting growth of the practice.

The major limitation of this study is the low number of participants in the survey, below the rate expected for this method. As the first survey of the practice of Percutaneous Surgery in Brazil, the study contributes epidemiological and technical information and profiles the trend among surgeons in Brazil, providing a reference point for future studies of the subject.

Conclusion

The majority of foot surgeons who responded to the survey believe in the percutaneous surgery method. The lack of specific training in the percutaneous technique is a factor that may limit its growth in Brazil. Poor reduction was the most common complication. The technique is conducted by a greater proportion of younger surgeons and there is a trend to employ fixation.

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Original Article

Tendoscopic management of posterior tibial tendinitis: 24-month outcomes

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Abstract

Objective: The aim of this study was to present a case series of patients undergoing posterior tibial tendoscopy, assess their clinical outcome, and describe surgical findings and treatment complications.

Methods: This is a clinical, retrospective, observational study of 11 consecutive cases of tenosynovitis of the posterior tibial tendon. All 11 patients underwent tendoscopy of the posterior tibial tendon. All procedures were performed by the same surgeon in 2 different hospitals. Minimum follow-up was 2 years.

Results: All patients had their preoperative and postoperative AOFAS and VAS scores assessed. Both scores had an important improvement at 12 months that persisted at 24 months. Moreover, 72.72% of the patients were very satisfied with the procedure, and no patient reported to be dissatisfied. Additionally, 90.91% of the patients had no postoperative complications. The present results are consistent with those previously reported in the literature.

Conclusion: Endoscopic or tendoscopic repair of the posterior tibial tendon is a simple and reproducible procedure that provides good functional and cosmetic outcomes with a low complication rate. It is important to increase the number of patients in this series in order to expand our conclusions.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Arthroscopy/methods; Tendinopathy; Posterior tibial tendon dysfunction; Treatment outcome.

Introduction

Posterior tibial tendinitis is commonly observed in patients who participate in sports activities. It may be caused either by excessive overload or sudden strain on the tendon. Some studies with runners report incidences of posterior tibial tendinitis ranging from 2.3 to 6%[1,2]. It was possible to determine that sports activities are not the only cause of tendinitis. Most patients present with associated anatomical changes (accessory navicular, hyperpronation of the foot) or previous knee or foot injuries (osteophytes, fracture sequelae). Partial or total posterior tibial tendon rupture is extremely rare in young patients, although very few cases among athletes have been reported in the literature[3,4].

In non-sports settings, tendinitis is the early stage of posterior tibial tendon insufficiency or dysfunction. This occurs mainly in middle-aged women with systemic inflammatory diseases associated with rheumatoid arthritis, which predisposes them to tendon rupture. In cases of stage I posterior tibial tendon dysfunction (PTTD) according to Johnson and Strom classification[5], the treatment of choice is based on temporary immobilization with immobilization boots for 4 to 6 weeks, followed by an appropriate rehabilitation program and gradual return to sports. This approach has a high rate of resolution of pain. In some cases, the treatment may be supplemented with the use of insoles with longitudinal arch support. Topical corticosteroids are contraindicated since they increase the risk of tendon rupturte[6].

Study performed at the Hospital Medica Sur, Mexico City, Mexico and Hospital General Dr. Manuel Gea Gonzalez, Mexico City, Mexico.

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Athlete patients who do not show a positive evolution between 3 and 6 months after implementation of initial management become candidates for surgical intervention to explore the tendon, and tenosynovectomy is conducted in cases of tenosinovitis[2]. In stage II patients or in stage I patients who do not respond to conservative management, endoscopic management provides an appropriate visualization of the tendon and has shown good results[7-9]. Advanced cases presenting with major tendon injuries require procedures of tendons transfers and bone realignment to reduce workload on the posterior tibial tendon, with a prolonged recovery period[10,11].

The diagnosis of tibial tendinitis is not always possible with imaging studies such as conventional radiography. Magnetic resonance imaging (MRI) is a very useful diagnostic tool. However, 20% of partial tears may go undetected even by MRI[12].

With the development of minimally invasive techniques and aiming to prevent complications secondary to extensive skin wounds, especially in patients with concomitant diseases (diabetes, rheumatoid arthritis), endoscopic and tendoscopic techniques have emerged as valuable tools in the treatment of patients unresponsive to conservative management[8-10].

The aim of this study was to present a case series of patients undergoing posterior tibial tendoscopy, assess their clinical outcome, and describe surgical findings and treatment complications.

Methods

This retrospective, observational, clinical study assessed the medical records of 11 consecutive patients who underwent endoscopic surgery from 2014 to 2017. All participants had stage I and IIa posterior tibial tenosynovitis and PTTD, according to Johnson and Strom classification. Exclusion criteria were patients with advanced PTTD and those with previous knee surgery. All patients were operated on by the same surgeon in 2 different hospitals.

Preoperative clinical evaluation revealed medial retromalleolar pain. Pain and sensitivity increased when patients stood on their toes, although they showed negative results for Rodriguez Fonseca maneuver. Ancillary examinations confirmed the disease. Plain radiographs revealed the presence of osteophytes at the medial malleolus in 2 cases (18.18%). MRI showed posterior tibial tenosynovitis and presence of increased fluid in the tendon sheath in 100% of cases, in addition to partial posterior tibial tears in 3 cases (27.27%). All patients were unresponsive to conservative treatment, which consisted of non-steroidal anti-inflammatory drugs, rest, and physical therapy for at least 3 months.

Study participants underwent preoperative and postoperative monitoring. Such monitoring included the following clinical variables: American Orthopaedics Foot and Ankle Society (AOFAS)[13] score or ankle and hindfoot, whose results were subdivided into excellent (91-100 pts), good (81-90 pts), fair (61-80 pts), and poor (<60 pts); visual analog scale (VAS) for pain; and level of satisfaction as measured through a Likert scale at the end of a 24-month follow-up[14].

Surgical technique

Patients were placed in the supine position with the maximum external rotation of the hip and the feet to expose the medial region of the tendon. The procedure was conducted under local anesthesia with subarachnoid blockade. Ischemia was induced with tourniquet at 250mmHg. Two 3-mm portals were made; one at nearly 2cm proximal to the distal end of the medial malleolus and another at 2cm distal to the distal end of the medial malleolus along the path of the posterior tibial tendon (Figure 1), as described by Van Dyck et al.[9].

All procedures were performed using a 30-degree angled lens for small joint arthroscopy measuring 2.7mm. Tendoscopic examination allowed to explore almost the entire posterior tibial tendon. The following surgical findings were identified: roughening of the tendon surface, partial tears, impingement with the medial malleolus, and presence de fibrous bands. Partial tears and fibrous bands were removed with a shaver blade and a radiofrequency probe for small joints (Figure 2). The roughened area was debrided using radiofrequency ablation. Surgical wounds were sutured with one simple nonabsorbable stitch for each wound.

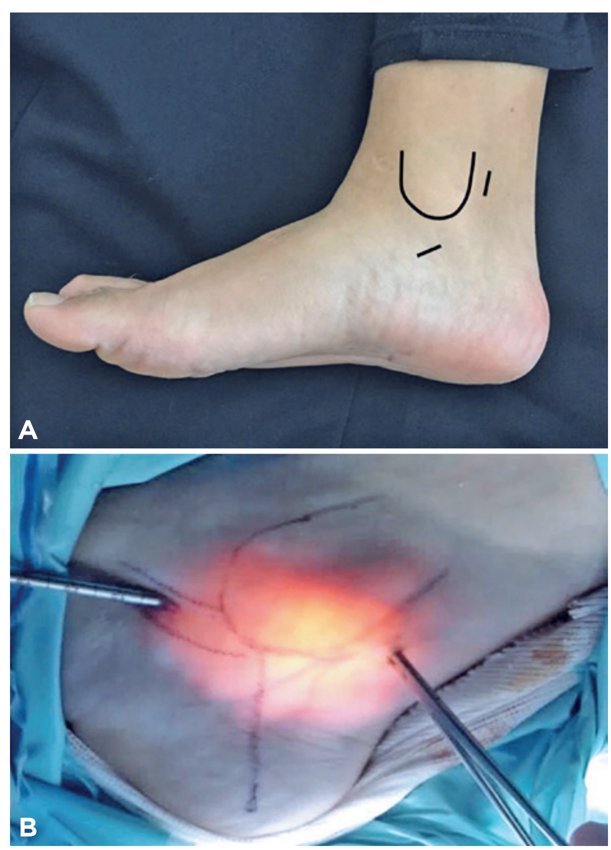

Figure 1. Tendoscopy portal layout. A. Planning of portals. B. Intraoperative identification of proximal portal site.

Postoperative care

During the postoperative period, immobilization was done with ankle CAM Walker walking boots. Crutches were also used to support walking for the first 2 weeks. Subsequently, patients followed a rehabilitation program for restoration of mobility, muscle strengthening, and ankle range of motion for 8 weeks.

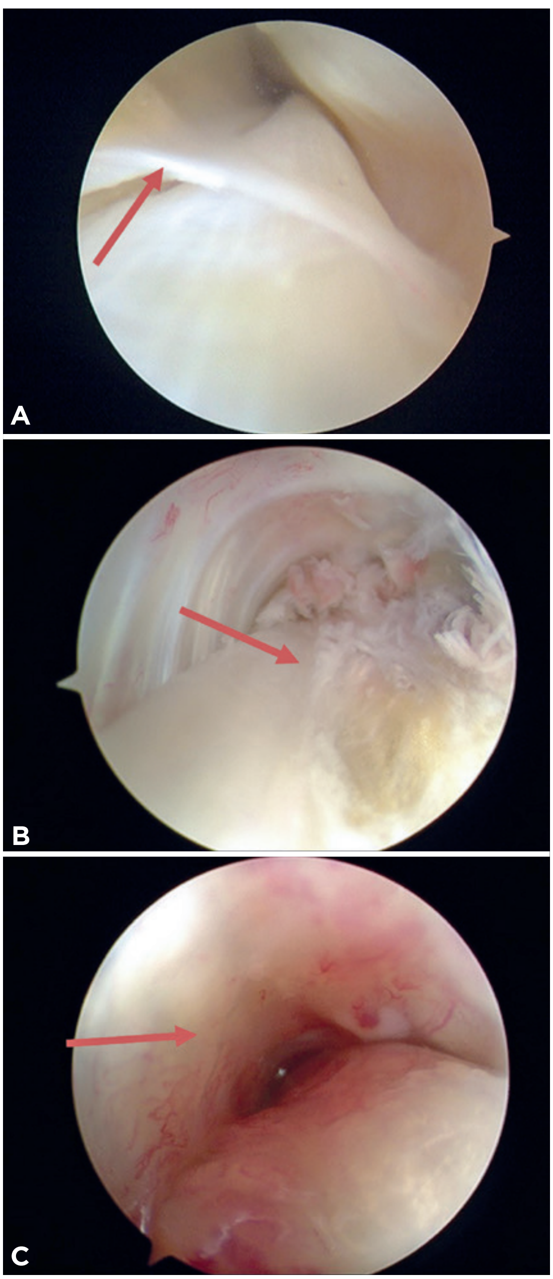

Figure 2. Surgical findings. A. Fibrous band. B. Partial tear. C. Tenosynovitis.

Statistical analysis

Statistical analysis was performed using SPSS, version 13 (SPSS Chicago, IL). Descriptive analysis was performed using measures of dispersion and central tendency for continuous variables and frequencies for categorical variables. The paired t test was used to measure the difference between means for continuous variables. The level of statistical significance was set at <0.05.

Results

Eleven patients were surgically treated, with a mean age of 37.54 years (SD, 20 years). Study sample included 2 men and 9 women. Seven patients were operated on the right ankle, and 5 patients on left ankle. Minimum patient follow-up was 24 months.

As for the level of athletic activity according to the competitive, leisure, active, sedentary (CLAS) classification, 3 patients were competitive athletes, with more than 2 training sessions per week, 4 patients were athletes performing regular recreational sports activities, none performed occasional sports activities, and 4 were sedentary (Table 1). The 7 physically active patients returned to their usual sports activity 8 weeks after surgery and to the same sports activity level 5.2 months after surgery, on average.

Clinical assessment included AOFAS functional scale (whose maximum value is 100 points) and VAS for pain (from 0 to 10), as shown in table 2. Mean AOFAS score at preoperative baseline was 75.7 points, and then increased to 94.36 points at 1-year follow-up and to 95.54 point at 2-year follow-up. The Mann Whitney test showed a statistically significant difference between the preoperative score and the final postoperative score, with p-value <0.001. VAS for pain also showed a significant improvement from baseline (preoperative) to 1-year follow-up and a slight improvement from 1-year to 2-year follow-up.

Table 1. Patient demographics

		n	%
Age	<37.54	6	54.54
	>37.54	5	45.45
Sex	Male	2	18.18
	Female	9	81.81
Side	Right	32	61.54
	Left	20	38.46
CLAS system	C: competitive	3	27.28
	L: leisure	4	36.36
	A: active	0	0
	S: sedentary	4	36.36
Sport	Running	3	27.28
	Soccer	1	9.09
	Weightlifting	1	9.09
	Zumba	1	9.09
	Ballet	1	9.09
	None	4	36.36

Table 2. Difference between AOFAS and VAS scores before and after posterior tibial tendoscopy

	Baseline (preoperative)	1-year follow-up	Final follow-up	t-value baseline-24 months)	p-value
AOFAS score	75.72±11.24	94.36±6.12	95.54±5.68	13.27	<0.00001
VAS score	7±1.67	1.54±1.02	1.27±0.93	2.78	<0.00001

AOFAS: American Orthopaedics Foot and Ankle Society; VAS: visual analog scale

With regard to surgical findings, there were 8 cases of posterior tibial tenosynovitis (73%), 4 cases (36.4%) of fibrous bands, especially in contact with the medial malleolus, 3 cases (28%) of partial tear affecting less than 25% of tendon thickness, and 2 cases (18%) of osteophyte on the medial malleolus (Figure 3, Table 3). Of the 6 cases of PTTD, 4 (66.7) were classified as stage I, and 2 as stage IIa. In the latter case, tendoscopy was combined with subtalar arthroereisis.

As for personal satisfaction, 72.72% of patients reported to be very satisfied with the procedure, and 27.28% reported to be satisfied, according to a Likert scale for personal satisfaction.

No complications were observed in 90.91% of cases. One patient (9%) presented with residual pain that disappeared after 3 months.

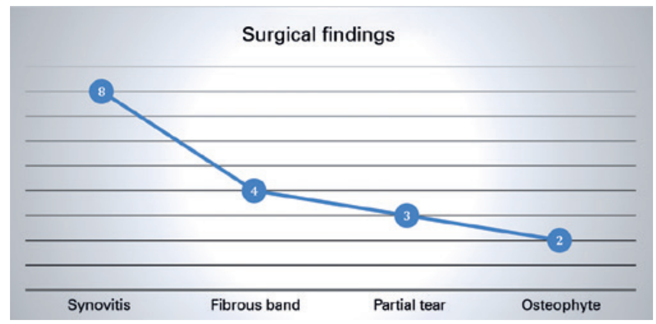

Figure 3. Surgical findings during tendoscopy.

Table 3. Surgical findings during tendoscopy

Number of Cases	Synovitis	Fibrotic band	Partial tear	Osteophyte
1	-	+	+	-
1	-	+	-	-
1	-	-	+	+
1	+	-	-	+
1	+	-	+	-
2	+	+	-	-
4	+	-	-	-

Discussion

McCormack et al.[15] reported good outcomes in 7 out of 8 high-performance athletes, with a mean age of 22 years, treated with debridement; in the same study, cases refractory to conservative treatment were treated with surgical debridement of tenosynovitis. In our case series, 7 (66.6%) of 11 patients were physically active, of which 3 (27%) were high-performance athletes. All these patients returned to the same sports activity level after a mean of 5.12 months (4 to 7 months).

Van Dyck et al.[16] reported 31 successful posterior tibial tendoscopies and found as complications 3 cases of hyposensitivity limited to the posterior portion of the hindfoot; the authors also reported that, in cases involving partial ruptures, tendoscopy was combined with an open technique. Conversely, our study observed only cases of partial tears affecting less than 25% of tendon thickness, which allowed treatment with endoscopic debridement. One of these cases developed residual pain that disappeared after 3 months.

Our case series reported an improvement in VAS scores for pain from 7 points at baseline (preoperative) to 1.27 points at 24 months. This notable difference is consistent with the findings of Bernasconi et al.[17], who reported an improvement in VAS mean scores from 7.9 to 3.5 points and found low complication rates after the procedure.

Bulstra et al.[18] reported a symptomatic improvement with early mobilization of the joint in a series of 17 patients, of whom 2 required a second endoscopic intervention due to symptom relapse caused by adhesions that did not lead to progression of tibial dysfunction. Gianakos et al.[19] also reported relapse of symptoms, but with no evidence of progression of tendon dysfunction. In our series, only one patient complained of persistent pain that lasted for 3 months and was resolved after physical therapy. No reinterventions were required in our series.

Surgical management of stage I PTTD consisted of synovectomy and open tendon debridement. Teasdall and Johnson[20] reported good outcomes for 14 out of 19 patients (74%) and treatment failure for 2 patients (10%), who required subtalar arthroereisis. The following complications were also reported: 2 cases of superficial infection and 1 case of wound dehiscence 3 weeks after surgery.

Chow et al.[21], in a series of 6 cases of stage I PTTD treated with tendoscopy and partial synovectomy, found no complications and observed functional outcomes similar to those obtained with open procedures; the authors also reported the following advantages of tendoscopy: smaller skin wounds, less postoperative pain, and shorter hospital stay. Khazen and Khazen and Khazen[22] performed tendoscopy in 9 patients with stage I PTTD. Improvement of pain was reported in 8 patients, although no scales for pain assessment were described. Gianakos et al.[19], in a study assessing 12 patients (8 with stage I PTTD and 4 with stage II PTTD), showed that 75% of patients had good outcomes. Similarly, Bernasconi et al.[17] reported 75% of positive outcomes among 16 patients with stage II PTTD. Positive outcomes were achieved in 90% of our series; moreover, of the 6 cases of PTTD, 4 were classified as stage I and two as stage IIa. In the latter case, tendoscopy was combined with subtalar arthroereisis. Results found in our sample were consistent with those reported in the global literature.

The weaknesses and limitations of this study include its retrospective design, the lack of a control group, and its small sample size. Conversely, a strength is the fact that patients were assessed after a minimum of 24-month follow-up, which enabled us to show that favorable changes both in AOFAS and VAS scores observed at 12 months persisted at 24 months.

Conclusion

Posterior tibial tendinitis has a good outcome with conservative treatment (immobilization and rehabilitation) in most cases. However, for recurrent cases or those refractory to non-surgical treatment, endoscopic or tendoscopic treatment is a simple reproducible technique that provides excellent functional and cosmetic outcomes. In the early stages of PTTD, tendoscopy offers symptomatic improvement and good short-term and mid-term outcomes in assessment scales. Studies with a larger sample size and a control group are required to assess the long-term outcomes of tendoscopy for the treatment of posterior tibial tendinitis in our population.

Authors' contributions: Each author contributed individually and significantly to the development of this article: ACA *(https://orcid.org/0000-0002-6129-954X) Conceived the study and performed the surgeries, wrote the article and approved the final version; ACKM *(https://orcid.org/0000-0003-2457-9654) wrote the article and participated in the review process. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Technical description of a low-cost ankle arthroscopy simulator

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Abstract

Objective: To describe a low-cost, accessible, reproducible ankle arthroscopy simulator model which, after validation, will allow the development and improvement of technical skills required in arthroscopic surgical practice.

Methods: This study describes the production of an ankle arthroscopy model that simulates camera, arthroscope, and ankle joint.

Results: The simulator works properly when connected to a monitor, television, computer, or cell phone.

Conclusion: A reproducible, accessible, low-cost ankle arthroscopy simulator can be developed using components available from local and online stores, with an approximate cost of R$232.00.

Level Evidence V; Economic and Decision Analyses – Development of an Economic or Decision Model; Expert Opinion.

Keywords: Arthroscopy; Simulation training; Low cost technology.

Introduction

Technological advances have allowed the development and growth of minimally invasive surgical techniques(1). This type of surgical approach has become increasingly common in recent years and offers some important advantages, such as reduced trauma to patients and lower costs(2). Within this context, ankle arthroscopy has become popular with expanded surgical indications. In contrast, the procedure is technically complex, requiring a high degree of dexterity, coordination, triangulation, and knowledge of ankle anatomy(3).

The learning curve of the arthroscopic technique may require extended training, making teaching methods the target of constant improvements. In a traditional surgical training method, students first acquire theoretical knowledge, then observe more experienced surgeons performing operations, and finally start to perform more complex procedures under supervision(4). This traditional method has some disadvantages, including inefficiency in terms of time and cost, and is associated with iatrogenic injuries(5). To minimize these disadvantages, arthroscopic training models have become increasingly available. In addition to allowing increased practice with consequent improvement of the technique, they have proved to be an inexpensive and highly effective tool(2).

Some arthroscopic training modalities can be used together with traditional training methods. Options include cadaver, animal, virtual reality, and dry models. Cadaver models, despite being the most reliable option, pose problems related to cost, availability, and storage, as well as the potential biological risk(6). Animal experiments present difficulties in logistics, such as handling and disposal, in addition to ethical and bureaucratic issues. Virtual reality models simulate very well the three-dimensional environment of arthroscopy, but its main limiting factor is high cost. Thus, the use of dry models emerges as an alternative method characterized by easy production, good availability, and low cost; additionally, quality of training using dry models is comparable to that of training using cadavers(7).

Training with arthroscopic simulators in orthopedic residency programs significantly improves the residents' surgical skills, contributing to a better in vivo performance in the operating room(8,9). In 2013, the American Board of Orthopaedic Surgery (ABOS) demanded the implementation of skills training programs outside the operating room. The reality in Brazil, with recurrent budget cuts in education and research, leads to a search for affordable, reproducible, low-cost alternative tools to improve orthopedic resident training.

Study performed at the Hospital de Clínicas da Universidade Federal do Paraná, Curitiba, PR, Brazil.

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Given this situation, our study aimed to describe a low-cost, accessible, reproducible ankle arthroscopy simulator model, which, after validation, will allow the development and improvement of technical skills required in arthroscopic surgical practice.

METHODS

Camera and optics

The arthroscope simulator consisted of an NKJ-2M endoscopic camera manufactured by B-MAX, used for cell phones and computers. We chose this camera model because of its availability, dimensions, and malleability similar to that of an actual arthroscope, in addition to its low cost, approximately R$32.00. This allowed us to produce a functional instrument very similar to the usual arthroscope.

The features of the camera include a resolution of 640x480 pixels and 6 built-in white LED lamps with adjustable lighting; it is 7mm thick and is attached to a 2-m USB 2.0 cable, which can be connected to a computer or cell phone. The camera was introduced into a metal tube 8mm in diameter and 21.5cm in length (simulating the body of the arthroscope), and the ends were bonded with acrylic adhesive.

To simulate the arthroscope handle and sheath, the other end of the metal tube was inserted into a set of three 20-mm polyvinyl chloride (PVC) fittings (90° tee, weldable adapter, and 90° elbow). The structures were bonded with polyester resin (Figure 1).

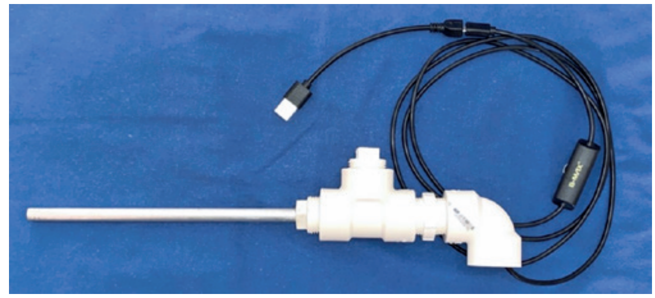

Figure 1. Arthroscope simulator.

Ankle model

The material used to produce the ankle simulator was a PVC tee described as 100mm with a 75-mm view, in which 100mm refers to the diameter of the pipe ends and 75mm to an opening hole on the top. One pipe end was closed with a specific cap (100mm), to which a synthetic left foot model was attached after being cut and fitted so that the articular component of the model (talus) was placed in the center of the pipe. The other end was closed with a wooden support through which a nail was inserted, transfixing the calcaneus, which increased the stability of the model inside the pipe and prevented external light from entering.

The proximal end of the ankle joint (tibia) was fixed to a PVC cap (75mm) with 2 screws and then fitted into a straight PVC pipe 75mm in diameter and 24.5cm in length. This set was connected to the upper hole on the PVC tee.

Two holes 1.8cm in diameter were made in the body of the PVC tee, close to the connection to the upper hole, to simulate the anteromedial and anterolateral portals of ankle arthroscopy. The simulator kit was placed on a wooden support that provided a straight surface for use (Figures 2-4).

Figure 2. Components of the ankle model.

Costs

The total costs of the simulator, including the synthetic ankle model, the endoscopic camera, and other products used to prepare the external and internal structures, were approximately R$232.00, as shown in table 1.

Figure 3. Ankle model – front view.

Figure 4. Ankle model – side view.

Table 1. Costs for making an arthroscopy simulator

Item	Cost (R$)
Synthetic ankle model	150.00
Endoscopic camera for cell phone + adapter	32.00
Materials for making the body of the arthroscope, external and internal structure of the simulator (PVC components, metal tube, wood, adhesive, various construction supplies)	50.00

PVC: polyvinyl chloride.

Figure 5. Final simulator kit in use.

Results

The simulator works properly when connected to a monitor, television, computer, or cell phone (Figure 5). The model also allows triangulation (Figure 6).

Discussion

The surgical technique initially developed through large incisions and direct visualization of the anatomical structures. With advances in research and technology, traditional open surgery was found to lead to high morbidity and greater risks to patients; therefore, the concept of minimally invasive surgery was developed and then disseminated worldwide. Within the context of orthopedics, intra-articular injuries were most favored by minimally invasive procedures. With the development of arthroscopy using small incisions and indirect visualization, the surgeon was able to visualize the structures on a screen. The technique requires additional training to obtain visuospatial coordination for interpreting three-dimensional structures on a two-dimensional image[5]. It also requires triangulation, which is the meeting of the arthroscope and instruments within a joint[10].

Figure 6. Triangulation.

The advantages of arthroscopy include the visualization of anatomical structures in their natural state, reduced loss of synovial fluid, lower morbidity, shorter length of stay, and faster recovery of the patient[2,10]. While the technique offers several advantages, it requires unconventional technical skills and practical abilities that are very different from those of open surgery. Thus, arthroscopy has a longer learning curve.

Historically, the surgical unit has been the place where trainees have acquired and developed their initial surgical skills. Today, this training model faces some difficulties, such as the increasing institutional demand for the procedure to be as fast as possible, the ethical factor related to in vivo training, and the complexity of some cases that require experienced professionals[7]. Surgical simulation is therefore a method to address multiple problems inherent to teaching arthroscopic skills in a traditional setting, as it avoids surgical prolongation and reduces patients' exposure to risks[11].

Training with low-cost arthroscopic models provides technical growth similar to that with high-tech simulators, improving surgical skills and thus the quality of patient care. A randomized study that included a control group showed that arthroscopic training with low-cost cameras and devices has the same effectiveness as training with commercial arthroscopic models, as both significantly improved skills and reduced surgical time[2].

The development of surgical skills is the hallmark of education in orthopedic residency. As previously mentioned, the traditional training method increases surgical time and hospital costs, in addition to exposing the patient to potential risks of adverse outcomes[11]. In a study that included orthopedic residents divided into an arthroscopic training simulator group and a control group, the simulator group was found to have greater intraoperative technical development, with shorter distances traveled by the camera, less time to perform the same task, and fewer moves to achieve the same target[12].

Commercially available ankle arthroscopy simulator models are usually expensive, preventing most orthopedic training institutions in Brazil from purchasing those tools. Moreover, most of them cannot be reused, which is another limiting factor.

Our ankle simulator model is easy to reproduce and inexpensive, does not require frequent synthetic bone replacements, allows for continuous training, and is available for most residency programs. Our simulator also allows triangulation and simulates the inventory of the ankle joint despite suboptimal anatomical replication because of the use of synthetic, noncadaveric models. In the future, simulations of conditions such as anterior ankle impingement and osteochondral injuries may be designed in order to improve the development of surgical skills in ankle arthroscopy.

In addition to ignoring some intra-articular changes in the ankle, our simulator provides limited learning of some surgical steps, such as patient positioning, arthroscopic portals, and intra-articular exposure techniques. Another limitation is that this study is only descriptive and still needs validation in Brazil. Thus, the simulator must be validated as an arthroscopic training tool.

Conclusion

A reproducible, accessible, low-cost ankle arthroscopy simulator can be developed using components available from local and online stores, with an approximate cost of R$232.00. The simulator still requires validation to then be considered a tool that will improve the acquisition of arthroscopic surgical skills.

Authors' contributions: Each author contributed individually and significantly to the development of this article: EDS *(https://orcid.org/0000-0002-4238-8539) wrote the article, model development, participated in the review process, approved the final version; JLVS *(https://orcid.org/0000-0002-9038-2895) conceived and planned the activities that led to the study, participated in the review process, approved the final version; LAFM *(https://orcid.org/0000-0002-0861-9401) participated in the review process, approved the final version; JEFB *(https://orcid.org/0000-0002-4058-8166) wrote the article, approved the final version iD.

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Original Article

Incidence of early complications in the posterolateral approach to posterior malleolus fractures

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Abstract

Objective: To ascertain the incidence of early complications in the posterolateral approach to open reduction and internal fixation of posterior malleolar fractures and identify possible risk factors related to occurrence of these complications.

Methods: Retrospective study carried out in three tertiary hospitals. Patients who underwent open reduction and internal fixation of posterior malleolus fractures via the posterolateral route were divided into two groups: with versus without delayed postoperative healing. To assess risk and protective factors for the outcome of delayed healing, we evaluated the time between trauma and surgery, whether the patient had a fracture-dislocation of the ankle, and whether external fixation was performed before surgery. We also evaluated whether improvement in operative technique led to a reduction in complication rates.

Results: A total of 43 individuals who underwent surgical correction of posterior malleolus fractures via the posterolateral route between 2013 and 2018 were included. Of these, 19 (44.2%) had skin complications that led to delayed healing. Skin complications occurred more frequently at the beginning of the learning curve of the surgeons involved; the incidence up to the year 2016 was 56.3%, decreasing significantly to 37% from 2017 onward.

Conclusion: Patients who undergo open reduction and internal fixation of posterior malleolus fractures via the posterolateral route at the beginning of the learning curve are a greater risk of developing skin complications, demonstrating the importance of this approach being restricted to more experienced surgeons.

Level of Evidence III; Prognostic Studies; Retrospective Study.

Keywords: Ankle; Internal fixation; Surgical wound; Tibial fractures.

Introduction

Malleolar fractures are extremely common injuries in the foot and ankle surgeon's routine practice. Indeed, they are the fourth most common indication for orthopedic surgery, with an incidence of 187 per 100,000 person-years[(1)]. Isolated lateral malleolus fracture accounts for 66% of ankle fractures; 25% are bimalleolar, and only 7% are trimalleolar[(2-4)].

Posterior malleolus fracture (PMF) carries a worse prognosis, since it is associated with higher odds of subsequent osteoarthrosis[(5,6)] (Figures 1A to D). Internal fixation of the posterior malleolus remains a controversial procedure. Traditionally, it is indicated when the fragment contains more than 25% of the articular surface, as measured on lateral radiography, and is displaced more than 2mm[(7)]. In the last decade, research attention has increasingly focused on the posterior malleolus fragment itself, as involvement of the fibular notch of the distal tibia and the presence of an interposed articular fragment were understood to be of greater therapeutic relevance than fragment size and the extent of the fractured joint surface area[(5)].

Simple, undisplaced PMFs can be fixed percutaneously with minimally invasive techniques[(8)]. However, this technique has

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

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some limitations, such as indirect anatomical reduction. For comminuted fractures or those with interposed fragments, open reduction and internal fixation (ORIF) is recommended[9].

The posterolateral approach (PLA) provides an alternative for effective ORIF of any type of posterior malleolar fracture[10]. This approach also provides access to the distal fibula, where a plate can be placed posteriorly[11-13]. Despite the advantages of the PLA, early complications can affect healing for still-unknown reasons[14].

Within this context, the present study was designed to ascertain the incidence of early complications in the posterolateral approach to ORIF of posterior malleolar fractures and identify possible risk factors related to occurrence of these complications.

Methods

This study was approved by the relevant Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number 28763919.9.0000.5128.

This is a retrospective study to determine the occurrence of complications after open reduction and internal fixation of posterior malleolus fractures via the posterolateral approach. All consecutive patients with fracture or fracture-dislocation of the ankle who underwent ORIF via the posterolateral route for a PMF with displacement greater than 2mm or interposition of joint fragments, between the years 2013 and 2018, at three tertiary hospitals were included in the study.

Patients were divided into two groups: those who had postoperative skin complications and those who did not. For the purposes of this study, skin complications were defined broadly, from wound dehiscence treated conservatively to superficial and deep infections requiring more aggressive treatment, and healing was considered delayed if it took longer than 3 weeks. The exclusion criterion was failure to perform PMF correction via the posterolateral approach.

To assess for risk and protective factors for the outcome (skin complications), we evaluated the time between trauma and surgery, whether the patient had a fracture-dislocation of the ankle, and, finally, whether external fixation was performed for damage control before surgery.

For statistical analysis of whether any factors contributed to the presence of skin complications, a univariate analysis was initially carried out via logistic regression, using the stepwise method[15] to select the variables of interest. For multivariate analysis, the backward method[15] was applied. A significance level of 5% was adopted, and variables with a p-value slightly above that value were also accepted, although considered only marginally significant. To assess the goodness of fit and predictive ability of the logistic regression model, the Hosmer–Lemeshow test[16], Nagelkerke's pseudo-R^2[17], and the AUC (area under the ROC curve) were used. All statistical analyses were carried out in R version 3.6.3. To ascertain whether operative technique improved while the surgeon was learning and once the surgeon had acquired experience with the posterolateral approach and subsequent technique, Fisher's exact test was performed with the years 2013 to 2018 and occurrence skin complications as the variables.

Surgical technique

The patient is placed in the prone position. A posterolateral incision is made longitudinally on the distal aspect of the leg, midway between the Achilles tendon and the fibula (Figure 1E). The sural nerve and small saphenous vein are identified and protected, since the nerve runs from central to lateral to the Achilles tendon, approximately 10cm from the attachment of the latter at the calcaneus[18]. The posterior fascia of the leg is incised down to the flexor hallucis longus muscle and tendon. This structure is reflected laterally, simultaneously providing access to the posterior malleolus and protecting the midline neurovascular structures.

Fixation of the posterior malleolus can be performed with a posterior antishear plate or with traction screws placed in the posterior to anterior orientation, depending on the need for stabilization and fragment size. The posterior malleolus must be fixed before any other lesions, in order to allow better manipulation and fluoroscopic visualization of the reduction without other hardware getting in the way (Figures 1F to J).

The same route is habitually used at our service for identification and fixation of the fibular fracture, when present. The proximal fascia of the fibular tendons is incised and opened longitudinally, and the tendons may be reflected medially or laterally. Fixation is performed posterior to anterior, which, in certain fracture patterns, can provide greater biomechanical stability and an antishear stop[19].

Results

A total of 43 individuals were included, 28 of whom were female, with a mean age of 41.5 years (range, 25-65). All had PMF. Delayed healing occurred in 19 patients (44.2%).

External fixation for damage control was performed prior to definitive surgical treatment in 31 patients (72.1%). Twenty-three patients (53.4%) presented with a fracture dislocation. The mean time elapsed between trauma and definitive treatment was 7.6 days (range, 0-30; standard deviation [SD], 6.2). The mean time from surgery to complete healing of the operative wound was 4.7 weeks (range, 2-17; SD, 4.4) (Tables 1 and 2).

The incidence of skin complications was not significantly associated with time between trauma and surgery (p=0.766), fracture-dislocation of the ankle (p=0.920), or use of external fixation before definitive repair (p=0.376) (Table 3).

Skin complications occurred more frequently at the beginning of the learning curve of the surgeons involved; the incidence up to the year 2016 was 56.3%, decreasing significantly to 37% from 2017 onward (Figure 2). No patient needed major intervention for wound closure.

Sample size calculation showed that, for a significance level of 5%, a moderate effect size, and a statistical power of 80%, each group required a minimum of 67 patients.

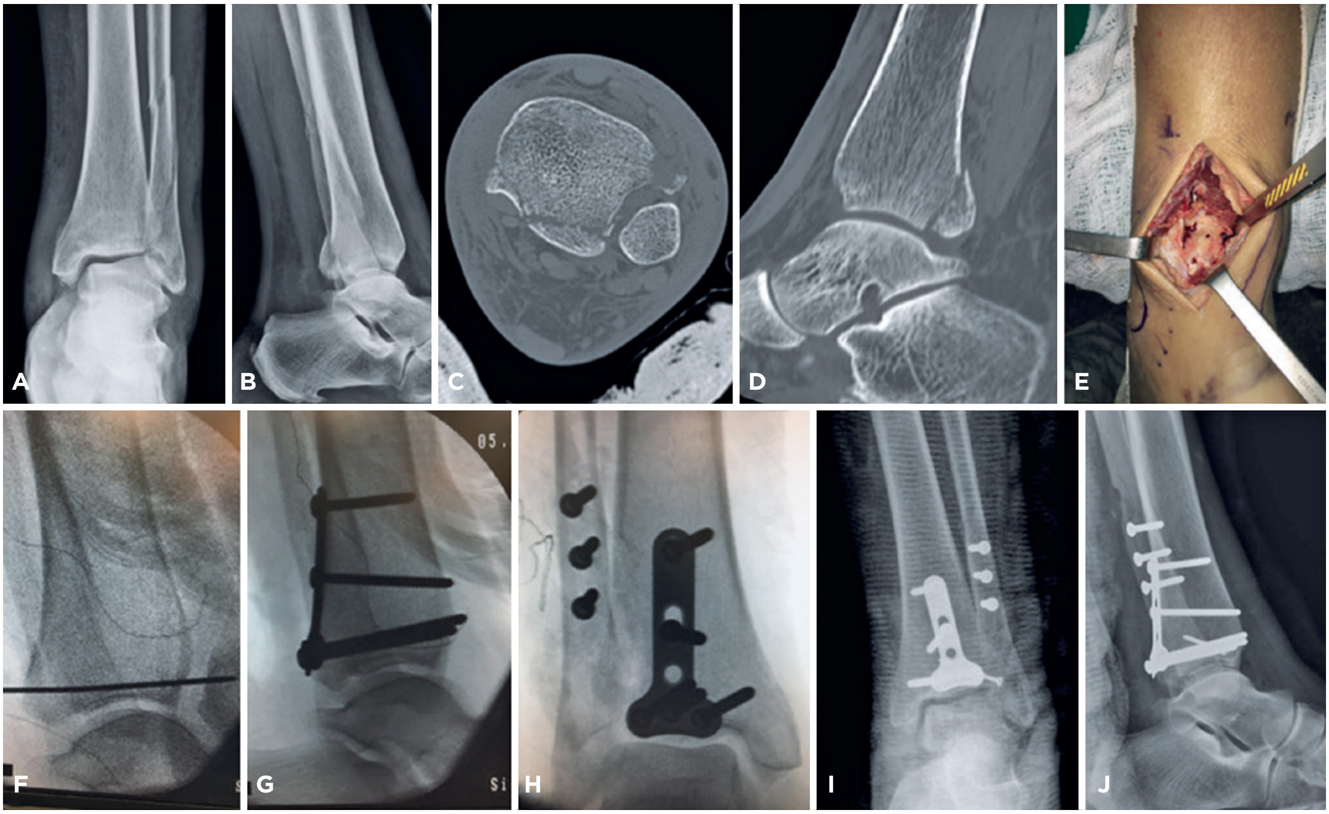

Figure 1. Posterior malleolus fracture (A to D). Posterolateral access with structures reflected for visualization of the posterior malleolus (E); internal fixation of the posterior malleolus and fibula through the posterolateral approach (F to J).

Table 1. Descriptive analysis of qualitative variables

Variable		N	%
Skin lesion	No	24	55.8%
	Yes	19	44.2%
Posterior malleolus fracture	No	0	0%
	Yes	43	100%
Fracture-dislocation	No	23	53.5%
	Yes	20	46.5%
External fixation	No	31	72.1%
	Yes	12	27.9%

Table 2. Descriptive analysis of quantitative variables

Variable	N	Mean	SD	Minimum	Maximum
Days elapsed from trauma to surgery	43	7.6	6.2	0	30
Weeks elapsed from surgery to healing	43	8.3	4.4	3	17

Discussion

We did not find any significant risk factors for the occurrence of skin complications in patients undergoing surgical treatment of PMFs via the posterolateral approach. Time between trauma and definitive surgery, presence of fracture-dislocation, and use of external fixation before definitive repair were not significantly associated with either presence or absence of such complications. However, when we compared the rate of complications up to 2016 versus in 2017–2018, we observed a major reduction in the latter period, i.e., a higher risk of delayed healing in patients who underwent surgery at the beginning of the surgeons' learning curve.

The most prevalent complications of the posterolateral approach are related to the surgical wound, occurring in approximately 11% of cases[20]. A systematic review of 19 articles including a total of 768 patients found that 39 (5%) had skin complications[21]. In a large study, Little et al.[22] evaluated the postoperative outcomes of 112 patients who underwent ORIF of ankle fractures via the posterolateral approach. Skin infection occurred in 5 patients. Another study evaluated 51 patients with PMF operated via the posterolateral approach, and found that 4 (7.8%) developed skin complications in the postoperative period[20]. Conversely, another similar study found a twofold-higher incidence of skin complications (15.5%)[12]. In our study, the overall incidence of skin complications was

Table 3. Comparison of explanatory variables between individuals with and without skin lesions

		Skin lesion				OR	95% CI	P-value
		No		Yes				
		N	%	N	%			
Fracture-dislocation	No	13	56.5%	10	43.5%	1.00	-	-
	Yes	11	55.0%	9	45.0%	1.06	[0.32; 3.55]	0.920
External fixation	No	16	51.6%	15	48.4%	1.00	-	-
	Yes	8	66.7%	4	33.3%	0.53	[0.13; 2.14]	0.376
Days elapsed from trauma to surgery	Mean	7.8		7.3		0.98	[0.89; 1.09]	0.766

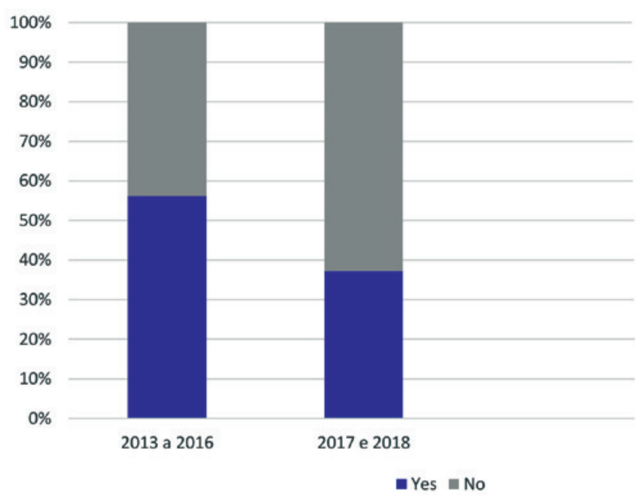

Figure 2. Patients who experienced skin complications, stratified by years.

44.2%. One of the reasons for this discrepancy between our data and the literature is the fact that surgeons continue to adapt to the unique features of this approach. Furthermore, the cutoff used to define delayed healing was not reported in any of the articles found in the literature. This may bias analysis of the time point at which delayed healing can be considered an early complication.

Abdelgawad et al.[23] argue that surgical wound dehiscences after the posterolateral approach are less disastrous than those occurring with the anterior, lateral and medial approaches, as the hardware is placed deeper and there is greater soft-tissue coverage. The results of the present study corroborate this hypothesis, as no patient needed major intervention to address skin complications.

Unlike in the aforementioned study, however, we did not find any publications in the literature that considered the rate of skin complications to be a relevant factor in defining the optimal surgical approach to ankle fractures. We consider the PLA to be an excellent approach in addressing more complex fractures, but it has a steep learning curve. This is confirmed by the progressive decrease in incidence of complications over the years in the present study. Our decision to include patients who underwent surgery at three tertiary hospitals further highlights the importance of caution and expertise when performing ORIF via the posterolateral route.

The present study has some limitations. The retrospective design prevented further analysis of risk factors for the development of complications. The sample was small, consisting of only 43 individuals. Thus, the study was underpowered by our own calculation, which required a minimum of 134 patients divided into two groups to enable reliable comparison. Further studies with adequate sample sizes, a prospective design, and a clear definition of the main risk factors are needed to understand which factors have a negative impact on early complications of the posterolateral approach.

Conclusion

Patients who undergo open reduction and internal fixation of posterior malleolus fractures via the posterolateral route at the beginning of the learning curve are a greater risk of developing skin complications, demonstrating the importance of this approach being restricted to more experienced surgeons. However, these complications had no impact on the need for revision surgery. The posterolateral approach thus remains an important route in the treatment of complex ankle fractures.

Authors' contributions: Each author contributed individually and significantly to the development of this article: CMPT *(https://orcid.org/0000-0002-2503-8721) conceived and planned the activities that led to the study, wrote the article, approved the final version; RSC *(https://orcid.org/0000-0001-5388-475X) conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, approved the final version; FASL *(https://orcid.org/0000-0001-5214-2420) conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, approved the final version; DSB *(https://orcid.org/0000-0001-5404-2132) conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, approved the final version; TAAS *(https://orcid.org/0000-0003-2333-2334) conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, approved the final version; RZAP *(https://orcid.org/0000-0001-9692-5283) conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Glomus tumors in the foot: two case reports

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Abstract

Glomus tumors are rare, benign neoplasms arising from components of the glomus apparatus. They are uncommon in the foot, often leading to misdiagnosis or a delay in diagnosis. This can have a significant impact on a patient's quality of life and may result in incorrect surgical procedures being performed. Correct recognition leads to timeous diagnosis and marginal excision, which is curative. A glomus tumor should be considered in patients with no obvious cause for localized, severe foot pain. We report two different presentations of a glomus tumor in the foot.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Glomus tumor; Neoplasm; Foot; Diagnosis.

Introduction

The glomus apparatus is a component of the reticular dermis and is found throughout the body. It is a thermoregulatory arteriovenous shunt controlled by sympathetic activity to regulate blood flow when exposed to cold or hot temperatures. It thus helps regulate temperature by increasing or decreasing blood flow[(1)].

A glomus tumor is a painful, benign neoplasm arising from components of the glomus apparatus. It accounts for only 1.6% of all soft tissue tumors. It occurs most commonly in women aged between 30 and 50 years and is frequently associated with delayed diagnosis. The peripheries are most affected with up to 75% of cases involving the hand. Less than 30% of tumors are found in extradigital locations, including head, limbs, tongue, trachea, lungs, mediastinum, stomach, and rectum, but a predominance is noted in thigh, leg, and forearm[(2)]. Extradigital glomus tumors are more common in men[(3)].

The largest series of glomus tumors not located in the hand was published by the Mayo Clinic. Out of 56 cases, they described only 2 cases in the foot[(4)]. Trehan et al.[(1)] described a large series of 11 patients with glomus tumors in the foot. Ten of these were subungual and one was in the plantar pulp of the terminal phalanx. Due to such a low incidence, a glomus tumor in the foot is often misdiagnosed. A high index of suspicion and good clinical acumen are required to make the diagnosis.

We report two different presentations of a glomus tumor in the foot.

Case reports

This study was approved by the Institutional Review Board at the authors' institution.

Case 1

A 33-year-old man presented with recent development of excruciating pain and sensitivity on top of his right foot. On examination, he had an exquisitely tender 1x1-cm bluish mass on the dorsolateral aspect of the midfoot. He also had a 2x2-cm mass on the plantar aspect of the foot. It was soft and completely asymptomatic.

Magnetic resonance imaging (MRI) revealed an ellipsoid lesion on the plantar foot surface under the fourth metatarsal and a lobulated lesion anterior to the lateral malleolus. These demonstrated increased T2 signal and contrast enhancement. The margins of the lesions were well defined. A provisional diagnosis of multifocal neuromas was made. Consent was obtained for an excisional biopsy.

Study performed at the Netcare Linksfield Clinic; Johannesburg, Gauteng, South Africa.

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At surgery, an incision was made in the dorsolateral aspect of the foot over the underlying mass. A pigmented, lobulated tumor resembling a hemangioma was excised. Then a lazy-S incision was made on the plantar aspect of the foot, and a large pigmented tumor was excised. These specimens were sent for histology.

Histology reported a vascular neoplasm in keeping with a glomus tumor. Both lesions were well circumscribed but had no fibrous capsules. The lesions consisted of tightly packed capillary-sized vessels surrounded by sheets of glomus cells.

All preoperative symptoms resolved at 10 weeks post-surgery. The patient returned 1 year later with a history of developing similar symptoms posterior to the initial dorsal glomus tumor. Clinically, he had sensitivity over the new mass suggestive of a glomus tumor. He again underwent an excisional biopsy. An obvious glomus tumor was excised and sent for histology, which showed no evidence of malignancy and confirmed the diagnosis.

The patient made an uneventful recovery with complete relief of symptoms at 12 weeks and no recurrence at 1-year follow-up.

Case 2

A 63-year-old man presented with intense sensitivity over the tip of the left second toe for a few years with cold intolerance. He had seen several specialists who were unable to give him a diagnosis and was told he needed to live with it.

Clinically, he had bogginess over the cuticle with extreme sensitivity to touch but no nail changes. Radiography was unremarkable, but MRI did show hyperintense signal in the medial nailbed of the second toe (Figure 1). This measured approximately 5 mm in diameter. A glomus tumor was suspected, and the patient consented to an excisional biopsy.

Intraoperatively, the toenail was removed and the cuticle elevated (Figure 2). A purplish lesion, approximately 5 mm in circumference, was identified within the germinal layer of the nailbed (Figure 3). This was excised and sent for histology (Figures 4 and 5). As the lesion involved the germinal layer of the nailbed, the entire germinal layer was excised using a Zadek procedure.

Histology reported a well-circumscribed mass consisting of vascular channels surrounded by cuboid epithelioid cells and confirmed a benign glomus tumor (Figure 6). The patient had complete resolution of symptoms at 8 weeks.

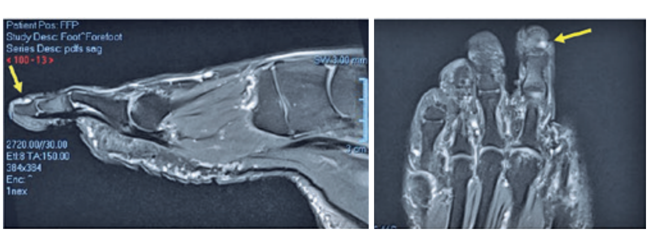

Figure 1. Sagittal and coronal magnetic resonance images showing a dorsomedial hyperintense lesion on the second toe.

Figure 2. Planned skin incisions for elevation of cuticle.

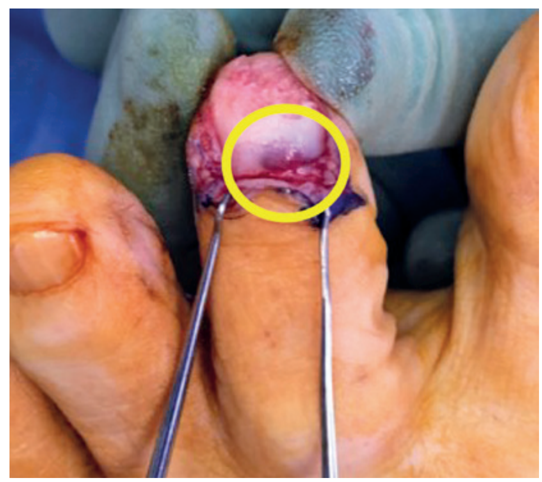

Figure 3. Appearance of glomus tumor in the germinal layer of the nailbed.

Figure 4. Excision of glomus tumor together with ablation of the nailbed.

Figure 5. Excised specimen from nailbed of second toe.

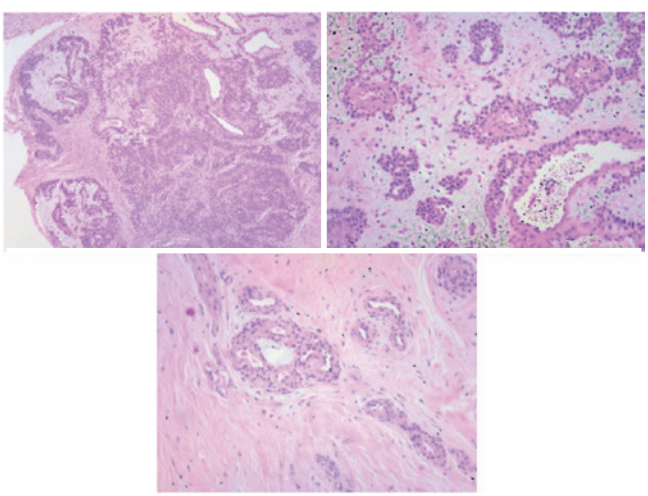

Figure 6. Histology slides showing fibrofatty connective tissue with vascular channels. Vascular channels are surrounded by cuboidal epithelial cells. There is mild edema between these islands.

Discussion

Glomus tumors are usually solitary, although there are several reports of multiple lesions. These occur more commonly in the lower limbs. Patients with multiple lesions have been known to have similarly affected family members, and these tumors have sometimes been found simultaneously with neurofibromatosis type 1 and multiple endocrine neoplasia[4]. Multiple glomus tumors tend not to be painful, which explains why the plantar tumor in case 1 was not painful. This may delay diagnosis. Case 1 shows an atypical presentation of a glomus tumor in the foot, multiple in type, with recurrence. Case 2 highlights the more typical presentation of a patient with the classical clinical triad and delayed diagnosis.

Pathology

These tumors usually measure about 5 mm in diameter. Four histological subtypes have been described, namely angiomatous, paucivascular, neuromatous, and mucoid-hyaline, but there is often a mixture of these. These variants are not known to influence recurrence or metastatic potential[2]. They may, however, result in atypical presentations. For example, an angiomatous predominance is often multifocal, as in case 1. This variation in presentation can make diagnosis challenging. Malignant glomus tumors are exceedingly rare and occur in less than 1% of cases. A risk of malignancy correlates with deeper location, size greater than 2 cm, atypical mitotic figures, and moderate-to-high nuclear grade. Six examples have been reported in the hand literature[5].

Clinical examination

Diagnosis of a glomus tumor is primarily clinical. A patient may present with the triad of severe pain, point tenderness, and cold hypersensitivity. There may be an associated mass with blue-purplish discoloration below the nail. The nail may be curved or ridged[5]. The Hildreth test is 92% sensitive and 91% specific for diagnosing glomus tumors. It is performed by inflating a tourniquet to just above systolic blood pressure proximal to the tumor. It is considered positive if there is immediate pain relief. The Love test induces pain when pinpoint pressure is applied over the lesion using a pencil or toothpick, while using the same device in adjacent tissues does not elicit pain. According to Giele, the Love test is 100% sensitive and 0% specific[6]. Application of ice or cold water results in pain due to increased cold sensitivity. Netscher et al.[7] reported this test to be 100% sensitive and 100% specific.

Radiography

Radiographs are usually normal, but cortical depressions may uncommonly occur due to pressure from an adjacent tumor. On rare occasions, radiography may show bony erosion. This occurs with intraosseous glomus tumors, which are extremely rare[8].

Ultrasound

Ultrasound is often the first imaging modality used for investigating these lesions. The lesion is typically hypoechoic, circumscribed, and oval. It is usually firm and not compressible. There is variable vascularity, with tortuous vessels seen internally, with blood flow. Fan et al reported 88% accuracy in diagnosing glomus tumors with ultrasound[9].

MRI

MRI assists with location, sizing, and diagnosis of glomus tumors. A glomus tumor appears as a well-delineated dark mass on T1-weighted images and a bright white mass on T2-weighted images. Some glomus tumors may be better visualized on T2-weighted fat-suppressed images with contrast or angiography. Al Qattan et al found MRI to be 90% sensitive but only 50% specific for glomus tumors. Similar findings may be found in cysts and other tumors of the hand[10].

Histology

Histopathological examination is essential for definitive diagnosis. The macroscopic appearance is a well-encapsulated grey-pink mass. Microscopically, glomus tumors are comprised of uniform epithelial cells with abundant vasculature. Glomus cells are small, uniform cells with round, monomorphic nuclei and eosinophilic cytoplasm[8].

Treatment

Because most glomus tumors are benign, the treatment of choice is wide local excision[5]. This is usually curative with Trehan et al reporting complete resolution of symptoms with no recurrences in their series[1]. As most occur in the nailbed, ablation of the nailbed may be required, as in case 2. It is important to explain to the patient that the surgery may result in nail defect or loss. Less than 10% of cases recur. Local recurrence may represent persistent tumor following inadequate excision or missed multiple glomus tumors. Very infrequently, a benign glomus tumor growing in a diffuse or infiltrative pattern may result in recurrence[1].

Conclusion

Glomus tumors are rare, small, and painful benign neoplasms. They are often associated with delayed diagnosis. A high index of suspicion and good clinical acumen are necessary for successful diagnosis. A history of misdiagnosis and/or surgical procedures combined with the triad of severe pain, point tenderness, and hypersensitivity to cold should prompt MRI investigation. Excision of the tumor is curative.

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Case Report

Interdigital neuroma in a patient with macrodactyly of the hallux: case report

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Abstract

A patient with macrodactyly of the hallux, returned 2 years after amputation of the distal phalanx, complaining of pain and swelling in the plantar foot. The Tinel, Moulder, and Gauthier signs were all present. Diagnostic hypotheses were: neuroma of the amputation stump, compressive neuroma, neurofibroma, or schwannoma. Histopathological diagnosis demonstrated that the tumor was a neuroma. This is a rare and unique case associated with macrodactyly, in which nerves tend to be hypertrophic. The location in the first intermetatarsal space is uncommon. The treatment proposed was resection of the entire involved nerve; symptoms improved and there was no relapse.

Level of Evidence V, Therapeutic Studies; Expert Opinion.

Keywords: Neuroma; Foot deformities, congenital; Orthopedic surgery; Neurofibrosarcoma.

Introduction

Macrodactyly is a rare congenital condition in which one or more of the fingers or toes are disproportionately larger than the others. It is caused by hypertrophy of all of the mesenchymal tissues and simultaneously involves soft tissues and bony components of the digits[(1)]. It is present at birth or detected in early childhood and tends to be progressive throughout the normal period of skeletal maturation[(2)].

The etiology of idiopathic forms is still unclear[(2)], although it is consensus that the origins are multifactorial[(2)]. Unilateral manifestation is more common and few bilateral cases are described.

Macroscopically, all of the structures of the affected digits are enlarged. The flexor tendons appear normal, although larger. The digital nerves are thickened and tortuous[(2)].

Treatment of macrodactyly is decided on a case-by-case basis. Several aspects should be taken into consideration: type of macrodactyly, velocity of disease progression, the digits involved, and the age of the patient. The primary objective of treatment of macrodactyly of the toes is to obtain feet that can fit into footwear, enable the patient to walk, and achieve a good clinical appearance of the toes. Surgical treatment is needed to achieve this and can encompass resection of redundant tissues, tenodesis, epiphysiodesis, and shortening of the bone, and in some cases may require amputation of the digit or ray[(1)].

We present a rare case of macrodactyly of the great toe, in which, 2 years after the first surgical procedure, a large, painful, and palpable neuroma developed in the plantar region, located in the first intermetatarsal space of the foot.

Case report

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 29530019.1.0000.5501.

The patient, S.R., was a 46-year-old, white, male laborer who was referred to the foot and ankle surgery clinic at the University Hospital in Taubaté, SP, Brazil, complaining of an excessively large left hallux that made it difficult to wear shoes. He was diagnosed with macrodactyly of the hallux and we recommended amputation of the distal phalanx of the great toe, with resection of excessive soft tissues, thereby reducing both width and length of the toe.

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

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The patient did not have a family or genetic history of macrodactyly and had no associated comorbidities.

Two years after the first operation, the patient returned to the clinic, complaining of progressive pain in the plantar region of the forefoot, exacerbated by walking. Physical examination revealed a palpable and painful nodule. This tumor was mobile, of a fibroelastic consistency, with a largest dimension of approximately 6cm, and was located in the first intermetatarsal space. The Tinel, Moulder, and Gauthier signs were all positive. Palpation of the hallux amputation stump was painless and there were no signs of paresthesia, or shock in response to percussion.

We ordered radiological (X-rays) and magnetic resonance (MRI) examinations of the foot. The X-rays did not show any changes, beyond the amputation of the distal phalanx of the hallux. The MRI images showed a nodular mass located in the first intermetatarsal space, measuring 6cm long by 2cm wide, with no signs of malignancy or invasion of soft tissues (Figure 1).

The patient was scheduled for surgery. Through a plantar incision and careful dissection, the nerve was identified and found to be greatly thickened, enlarged, and yellowed. The perineurium was soft and the interior was hard, without signs of malignancy when examined macroscopically. It did not resemble a stump neuroma, since the nerve was uninterrupted both before and after the neuroma (Figure 2).

Complete resection of the nerve was performed until apparently healthy neural tissue was reached. The surgical wound was sutured closed by planes up to the level of the skin. The foot was bound and the patient instructed to walk immediately. During postoperative recovery the patient remained free from pain and infection and his compressive symptoms improved (Figure 3). Anatomopathological examination revealed fragments of twisted nerve trunks surrounded by fibrosis arranged concentrically, with no signs of malignancy, confirming the preoperative hypothesis that the mass was an interdigital neuroma.

We did not assess the results of surgery by applying the AOFAS scale before and after the operation, since this was a single case, but we did assess pain with an analog scale. The preoperative pain score was 8, which reduced to 3 during the postoperative period, demonstrating good recovery.

Discussion

Macrodactyly is a rare congenital anomaly, which can be associated with other syndromes, although in this study it was an isolated case, with no association with other pathologies. Generally, all structures of the affected digits are enlarged: dermis, subcutaneous tissues, tendons, bones, and nerves.[1-3]

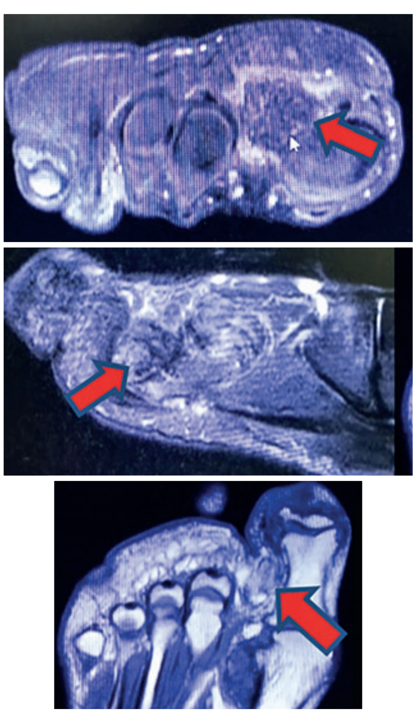

Figure 1. Magnetic resonance images showing details of the nodular lesion.

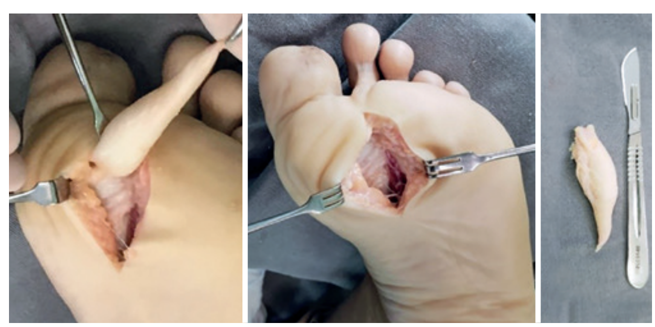

Figure 2. Images showing resection of the neuroma, and illustrating its size

Figure 3. Postoperative appearance of the foot and the surgical scar.

We reported a rare case of an enlarged interdigital nerve, located in the first intermetatarsal space. The patient had previously presented with macrodactyly, which had been treated with surgery. However, 2 years after that first operation, he returned with pain and swelling in the plantar region.

The anatomopathological examination revealed fragments of twisted nerve trunks surrounded by fibrosis, arranged concentrically, and with no signs of malignancy. The patient was diagnosed with an isolated interdigital neuroma.

These symptoms are uncommon in the first space and even rarer in conjunction with macrodactyly. Taken together, the size of the nodule and the clinical status were strongly suggestive of neuroma and were reinforced by the clinical signs present[3].

In the literature, interdigital neuroma, known as Morton's neuroma, is frequently seen in the second and third intermetatarsal spaces, in 29% and 60% of cases respectively. In contrast, it is very rare in the first space, occurring in just 1 to 2.5%[4].

There are very few cases in this region in the literature. Another possibility in the differential diagnosis is schwannoma, a rare lesion that is uncommon in the foot, observed in just six cases in the literature[5-8]. A neurofibroma is easily differentiated with a histopathological study, which will show a myxoid stroma with collagen fibers in the interior, plexiform arrangement, and deformed neuronal axons[5].

We decided to conduct open surgery to treat the nodule because of its size, facilitating safe resection of the lesion.

New treatment methods exist that are reported to improve the painful symptoms, including use of high intensity laser treatment, which has shown promising results. Pain is reduced in up to 80% of cases and the size of the nerve thickening is reduced in up to 51%[9].

Some authors recommend using minimally invasive surgery to treat these neuromas, releasing the intermetatarsal ligament and performing osteotomies on metatarsal bones, creating more space between them and relieving the nerve compression. They report good results at 2-year follow-up.[10]

The results of surgical treatment for neuroma are excellent or good in 89% of cases, irrespective of the technique employed, compared to 85% for ablation with alcohol or radio frequency. The worst results are seen with conservative treatment, which is associated with 47% relapse or treatment failure[8].

Ultimately, surgical treatment is the best choice, improving symptoms in up to 89% of patients. Founded on this theory, a review study also considered that patients who are given good information will exhibit better results with surgical intervention[8].

In the case described here, the procedure performed was the best choice, in view of the size, characteristics, and location of the lesion. The tumor was very large and we needed a precise diagnosis.

We used an extended plantar surgical approach, affording an excellent view and allowing total resection. The patient recovered well after the operation, with relief from symptoms and no complications.

In current databases, it is uncommon to find cases diagnosed as neuromas in the first interdigital space associated with gigantism of the first toe, which is the main reason for this study.

Notwithstanding, other pathologies of the nerves can occur in the presence of macrodactyly, such as, for example: hamartomas, neurilemmoma (schwannoma), neurofibroma, or fibrolipomas, which are very rare in the lower limbs[9].

Interdigital neuromas located in the first space in the forefoot were described in 1% of cases by Bartolome and Wertheimer, in 1983, and in 2.5% of cases by Adante et al., in 1985, who studied 100 patients with Morton's neuroma, as reported by Thomas et al.[4].

All of these factors prompted us to report this uncommon case of a patient with both macrodactyly and a digital neuroma in the first space. We are not certain that the presence of this neuroma was because of the macrodactyly, but it is possible, as a result of compression of the nerve between the first and second metatarsals. The combination is possible, although they are two distinct pathologies.

Conclusions

This study is an alert that it is possible for a compressive neuropathy to develop in the first intermetatarsal patient in a patient with macrodactyly of the hallux.

Authors' contributions: Each author contributed individually and significantly to the development of this article: HSBS *(https://orcid.org/0000-0002-1549-0992) participated in the review process, approved the final version; LCRL *(https://orcid.org/0000-0003-1158-2643) conceived and planned the activities that led to the study, wrote the article, interpreted the results of the study; JAG *(https://orcid.org/0000-0003-4652-4400) wrote the article, participated in the review process; LCATF *(https://orcid.org/0000-0002-0778-2506) conceived and planned the activities that led to the study, approved the final version; LFL *(https://orcid.org/0000-0003-1048-7134) wrote the article, participated in the review process. *ORCID (Open Researcher and Contributor ID) iD.

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Special Article

Current trends in the biokinetic analysis of the foot and ankle

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Abstract

Although the importance of studying the anatomy of structures of the ankle and foot joints is fundamental, evidence points to a low correlation between static and dynamic measurements; this could represent a problem in the study of the functioning of the ankle and foot during daily activities. The aim of the present study is to review the classic knowledge on ankle and foot biomechanics and present new concepts of functional biomechanics (3-dimensional biokinetic analysis) in order to clarify their clinical applications in assisting diagnostic and/or treatment decisions. For this, we performed a literature review and divided the article into 6 sections: (1) functional biomechanics of the ankle and foot; (2) dynamic joint stability; (3) functional stability mechanisms of the foot; (4) functional stability mechanisms of the ankle; (5) gait and running biokinetics; (6) the role of proximal joints in ankle and foot movement. At the end of this article, the reader should be able to understand how the 3-dimensional biokinetic analysis of the ankle and foot can contribute along with imaging examinations to the clinical setting, thus allowing the construction of a more complete profile of the patient. Such information could enable the identification of weaknesses and the implementation of objective interventions for each patient.

Level of Evidence V; Prognostic Studies; Expert Opinion.

Keywords: Activities of daily living; Ankle injury/pathophysiology; Joint instability/pathophysiology; Biomechanical phenomena.

Introduction

The foot supports all the weight exerted by the human body, which can eventually reach 4 to 6 times a person's normal weight[1]. It is the first body segment to absorb the reaction forces caused the contact against the ground in daily activities and sports movements, and it performs the transfer of forces through the proximal joints for power generation[2]. The foot is an anatomically complex structure, consisting of various bones and joints, as well as intrinsic and extrinsic muscles. These aspects provide the necessary mobility to absorb forces, along with a high capacity to change rigidity and be a robust lever arm for transferring forces to the ground[3].

In spite of the importance of studying the anatomy of the ankle and foot joints, evidence indicates a low correlation between static and dynamic foot measurements[4,5]. Böhm et al.[5] (2019) demonstrated that static measurements of foot deformities (performed using radiographs) explained only a small variation in foot movements during gait, especially in children with flexible flat feet. This was possibly related to an overload of the ankle and foot both statically and during different dynamic activities. These findings suggest that the function of the foot cannot be precisely assessed exclusively from manual clinical examinations, provocative tests, and static radiographic observations, although this is commonly performed in clinical practice.

Moreover, individuals with similar anatomopathological diagnoses have been reported to present different biokinetic findings, demonstrating that the functional assessment of specific movements should be seen as a complementary examination that is essential to the conventional practice of ankle and foot specialists[6]. The purpose of this article is to review the biomechanics of the foot and ankle combining

Study performed at the Instituto Brasil de Tecnologias da Saude, Rio de Janeiro, RJ, Brazil.

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classic knowledge with new concepts of functional biomechanics in order to lay the foundation for the clinical application of 3-dimensional (3D) biokinetic analysis in diagnostic and/or treatment decisions.

Functional biomechanics of the foot and ankle

Conventionally, the movements of the ankle and its muscular actions are studied either with the tibia as a fixed point for the free movement of the ankle and foot (usually named an open kinetic chain [OKC] movement) or with a fixed foot, for instance against the ground, where the movement would happen in the proximal segments and be named a closed kinetic chain (CKC) movement[7]. However, these approaches do not fully represent what happens during daily activities. The concept of functional biomechanics advocates that although one segment will always be the base for the other to move, both segments can be simultaneously mobile in any trivial activity. The main difference between conventional and functional biomechanics is that the latter considers that the function of joints and segments cannot be separately observed. The central nervous system (CNS) works as the generator of complex movement patterns based on muscular synergisms, aiming to accomplish a motor task instead of accounting for individual muscular actions[8]. Following this line of reasoning, 3D biokinetic analyses are meant to identify the role of each anatomical, joint, and muscular structure in the functional capacity of an individual throughout his or her daily activities. To facilitate the understanding of this relatively new area of study, it is necessary to establish how the main pillars of functional biomechanics are applied to the study of foot and ankle function.

Dynamic joint stability

Rienmann and Lephart[9] (2002) define dynamic joint stability as the ability of a joint to remain or readily resume to its proper alignment through an equalization of forces. Evidence suggests that the control of active joint stability is orchestrated by the neuromuscular system and not by isolated muscle strength or range of motion[10], highlighting the importance of the CNS as a functional maestro.

The ability to generate safe movement and to improve performance depends on the movement of joints in segments with stable bases. Literature on the importance of functional ankle stability for injury prevention and rehabilitation[2,6,11] is extensive and relates chronic ankle instability to a lower capacity of generating functional strength by the triceps surae muscle[11], lower power production during jump propulsion[12], and a higher risk of ligament and cartilage injuries[13]. Therefore, reducing this instability through specific training or surgery is crucial and should be done before the adoption of an overloading activity such as an increase in sports performance. In order to understand some of the strategies for reversing non-surgical instabilities, it is necessary to address the structures that participate in the joint stability of the foot and ankle.

Functional stability mechanisms of the foot

The main structure that generates stability in the human gait is the foot. Functionally, the foot has 3 main roles:

1) To be a stable base of support for movements of the proximal segments;
2) To assist in the absorption of ground reaction forces;
3) To be a powerful lever arm for the ankle muscles during the propulsion of gait and sport movements.

The intrinsic and complex role of the plantar arch of the foot in maintaining stability and mobility has been the subject of studies in several areas from the Renaissance era, with Leonardo Da Vinci[14], to anatomists of the last century[15] and present day[4]. The medial longitudinal arch (MLA) has been the most studied structure because its load sharing system (arch load-sharing system) is believed to be essential for the proper functioning of the foot[16]. It works as a spring system, changing foot stiffness and allowing deformation for absorbing loads while creating a robust segment for transferring forces to the ground. For a more detailed understanding of the role of the medial longitudinal arch, please refer to Kirby[16] (2017).

Despite widespread research on this reductionist 2-dimensional (2D) view of the MLA, some of the evidence indicates that it functions as a 3D structure. Some authors suggest that the plantar arch should be named "plantar dome," due to the importance of other passive, active, and neuromuscular structures in maintaining the plantar arch[2]. This theory has been confirmed by cadaveric experiments showing that the resection of the plantar fascia reduced foot stiffness by less than 25%[17]. On the other hand, engineering principles demonstrate that even thin structures, when folded in the transverse direction, increase their longitudinal stiffness; this concept that can be easily demonstrated by a slice of pizza curved across in our hands. Recently, Venkadesan et al.[18] (2020) applied these concepts of transverse arch stiffness and observed that the resection of the transverse arch reduced foot stiffness by more than 50%, highlighting its important role in the maintenance of the plantar dome. For an illustration of the effect of transverse stiffness on longitudinal stiffness, the authors suggest the following video: https://youtu.be/adt3sH9O_vE.

Another aspect associated with the functioning of the plantar arch is the windlass mechanism, which is widely observed in orthopedic clinical practice through the Jack's Test[19]. During this test, the hallux extension produces a tension in the plantar aponeurosis, which brings the calcaneus closer to the metatarsophalangeal joints[20] (Figure 1). In association with passive structures, the posterior tibial muscle begins to act concentrically and blocks the midtarsal joints to increase foot stiffness[20]. Functionally, the windlass mechanism occurs with the hallux as a fixed point and with the movement of the metatarsophalangeal joint (Figure 2). This mechanism is initiated by tibiotalar dorsiflexion as the tibia advances over the talus in the midstance (MS) phase of the gait[20]. In the terminal stance (TS) phase, load on the forefoot region increases, activating the fibularis longus muscle and inducing the windlass mechanism and the elevation

Figure 1. The windlass mechanism demonstrated passively: A hallux extension produces a tension in the plantar aponeurosis, which brings the calcaneus closer to the metatarsophalangeal joints.

Figure 2. The windlass mechanism actively provoked on terminal support phase: The activation of fibularis longus and tibialis posterior muscles collaborates in maintaining the plantar arch for adequate triceps surae function and ankle stabilization.

of the calcaneus on a rigid forefoot base, thus creating an effective lever arm to generate propulsion for the second half of the support phase[20].

Increased mobility of the midfoot and reduced mobility of tibiotalar dorsiflexion and hallux may impair the windlass mechanism and contribute to increased foot stiffness in this phase[21]; individuals with flexible flatfeet may not be able to create a rigid base, causing the axis of movement to move towards the midtarsal joints so the lever arm is reduced[21]. As a form of compensation, the triceps surae is more intensely activated and produces more strength; this overload may lead to painful conditions such as Achilles tendinopathies or muscle injuries. Moreover, inadequate triceps activation and/or strength also increases ankle instability[21].

Functional stability mechanisms of the ankle

Several studies have demonstrated changes in the movement patterns of hips, knees, and ankles in individuals with chronic ankle instability[2,6,22], demonstrating that the same condition can lead to different motor adaptations and each case requires individual evaluation. The motor variability among these individuals may reflect either an attempt to explore alternative stabilizing strategies or an inadequate sensory-motor control[23]. In addition, the arthrogenic inhibition of the fibularis longus has been related to continued instability even after the restoration of triceps surae muscle strength[24].

According to Hertel et al.[25] (2002), individuals with ankle instability can be classified into 2 major groups: those with mechanical ankle instability (MAI) and those with functional ankle instability (FAI). MAI is defined as a pathological laxity after ligament injury, while FAI is a subjective symptom or sensation of instability due to proprioceptive deficits and changes in neuromuscular functions.

Several clinical tests are commonly used to measure ankle stability, and subjective measurements of the eversion/inversion of the heel can be performed with activities such as unipodal support and walking on a treadmill. However, in addition to the measurement errors intrinsic to subjective tests, clinically assessing dynamic joint stability does not guarantee the functional competence of the ankle and foot in daily tasks and sports. Despite being more affordable and easier to perform, 2D assessments can present important measurement errors even in individuals with small rotational changes in the ankle and foot[26]. It should also be taken into account that ankle stability is direction- and task-dependent[24], and the ability of an individual to maintain joint stability in one direction does not mean he or she will be able to do so in other directions. It is necessary to evaluate all 3D components of foot and ankle stability to ensure a safe return to daily activities and sports. Therefore, the functioning of the foot and ankle should be tested and analyzed in different activities. In this review, we will summarize relevant information currently published on gait and running.

Gait and running biokinetics

Human gait and running can be divided into stance and balance phases. In gait, the support phase is subdivided into 4 phases: load response (LR), MS, TS, and pre-swing (PS)[1] (Figure 3). In running, the support phase is subdivided into 2 phases: LR and propulsion response (Figure 4). During LR in a non-pathological gait, in the sagittal plane, the foot drops (heel rocker) with a plantar flexion movement eccentrically controlled by the tibialis anterior muscle. In the coronal plane, there is an eversion movement of the ankle, eccentrically controlled by the tibialis posterior muscle. At this moment, motion control is achieved by reducing the stiffness of the foot and turning it into a structure that is able to absorb mechanical loads[1]. In running, the role of eccentric eversion control increases due to increased ground reaction forces. In runners whose initial contact happens with the heel (rearfoot strikers), the sural triceps has a secondary effect in load absorption by preventing excessive advancement of the tibia[1]. On the other hand, in runners whose initial contact occurs with the midfoot or forefoot (midfoot/forefoot strikers), the sural triceps assumes a primary eccentric role, which may increase the risk of Achilles tendinopathies and injuries in the tibialis posterior[27] when no proper training is employed.

The ankle rocker phase during MS is characterized by a rotation of the tibia over the foot, which is fixed on the ground on unipodal support, while the plantar arch is maintained by activating the posterior tibialis and intrinsic muscles of the foot. During TL and PS, the forefoot rocker phase happens when the heel rises from the ground and begins the propulsion phase. At this moment, the sural triceps activation, mostly through the soleus muscle, has the important role of limiting the anteriorization of the tibia and inducing knee extension. The fibularis longus depresses the first metatarsal head and contributes to the formation of the plantar arch and stabilization of the ankle joint. In running, the soleus has an additional propulsion role since it is responsible for more than 50% of the horizontal acceleration of the runner's center of mass[1].

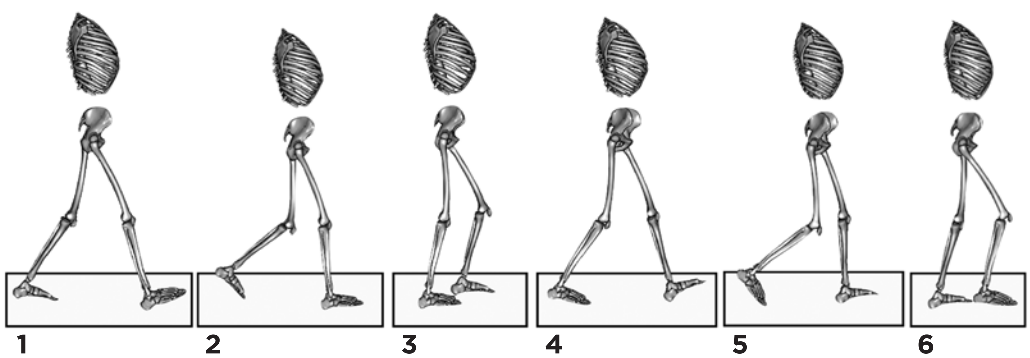

Figure 3. The gait cycle. Using the light limb as reference: (1) initial contact; (2) load response (LR); (3) midstance (MS); (4) terminal stance (TS); (5) pre-swing (PS); (6) swing (Image by Biocinetica Laboratório do Movimento Ltda, Rio de Janeiro, Brazil).

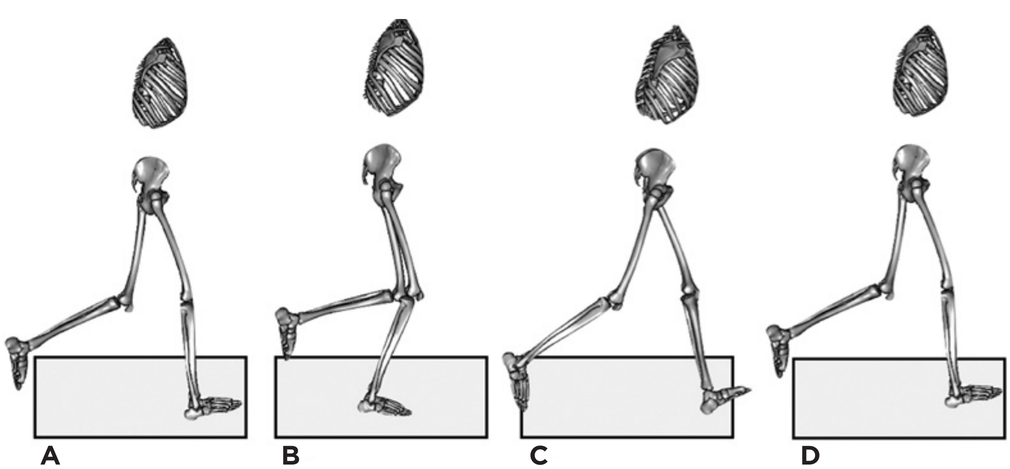

Figure 4. The running cycle. Using the right limb as reference: (A) initial contact; (B) LR; (C) propulsion; (D) swing (Image by Biocinetica Laboratório do Movimento Ltda).

The role of proximal joints in ankle and foot movement

Although it is easy to suppose the influence of neighbor and distant joints in the control of the foot and ankle, the identification and measurement of such influences only recently has been deeply studied. Cavalin et al. [28] (2018) found a strong association between hip adduction and ankle eversion in healthy runners, where 50% showed a descending relationship (hip influencing the ankle), 25% showed an ascending relationship (ankle influencing the hip), and 25% presented a synchronic relationship over time (Figure 5). Other authors have also demonstrated the influence of the ankle dorsiflexion range of motion in femoral medialization, a movement dysfunction often referred as "dynamic valgus". The proximal chain can influence and be influenced by distal changes and interfere on the loading of joints and segments as a whole[29] (Figure 6).

Conclusion

Human motion happens as a system where many variables may individually or collectively influence the loading, mobility, and stability of any one joint or segment. Similar to an

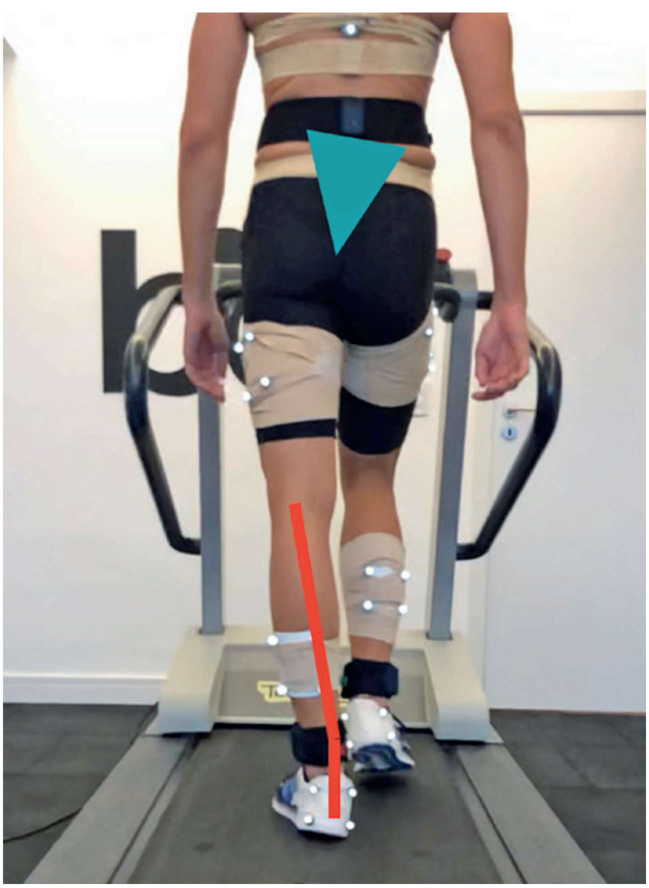

Figure 5. Individual walking on a treadmill at 4.3km/h showing, in the coronal plane, the influence of a pelvic contralateral drop on ankle eversion.

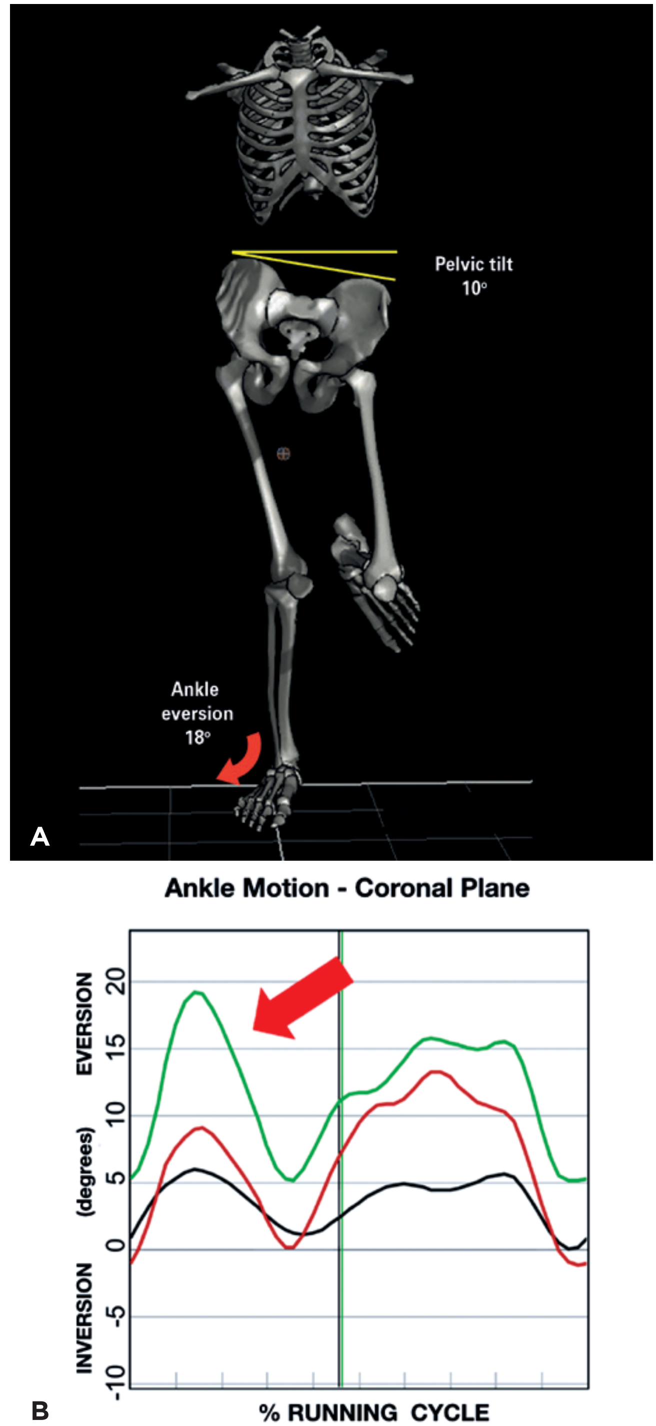

Figure 6. Three-dimensional biokinetic analysis image (A) and graph in degrees (B), in the coronal plane, of a 35-year-old male recreational long-distance runner diagnosed with plantar fasciitis. Peak right ankle eversion (18°) influenced by a peak contralateral pelvic drop (10°) in the stance phase of running. Red arrows: excessive ankle eversion; yellow lines: excessive contralateral pelvic drop; green line: right ankle motion; red line: left ankle motion; black line: expected ankle motion (Image by Biocinetica Laboratório do Movimento Ltda).

airport network, when one terminal is out of order, the others are overloaded, but eventually all planes must get to the ground safely.

The adequate functioning of the foot and ankle depends on the activities of passive tissues and muscles and the neuromuscular control of local and distant joints. Any changes to this system may lead to functional incapacity and subsequent lesions and/or pain. The study of the functional biomechanics of the ankle and foot, in addition to a clinical investigation and imaging exams, contributes to a more complete understanding of the problems of each patient. For these reasons three-dimensional biokinetic assessments have become valuable tools for identifying the weakest links in the movement chain in an objective, measurable, and reproducible manner.

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I dedicate this article to the memory of Prof. Dr. Irocy Guedes Knackfuss, who in 1997 introduced me to the practice of the Foot & Ankle medicine and instigated my vision over the promising horizons of functional biomechanics. *Leonardo Metsavaht.*

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Special Article

Analysis of pressure distribution in the foot using finite elements

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Abstract

The objective of this study is to evaluate the applicability of the finite element method to analyze pressure distribution in the healthy human foot. Images of a foot were captured using computed tomography and converted into a three-dimensional model, which was adjusted with the aid of CAD software. The model was imported into Abaqus software for finite element analysis, considering the different regions of the foot. Observations of displacement, stresses, and pressure distribution demonstrated a biomechanical behavior of the foot consistent with that reported in the existing literature, regarding the regions of peak plantar pressure. These findings demonstrate the feasibility of evaluating the physical and mechanical behavior of the human foot using the finite element method, and can serve as a reference for the study and manufacture of orthotic appliances, prosthetic devices, and insoles.

Level of Evidence V; Prognostic Studies; Expert Opinion.

Keywords: Biomechanics; Foot; Finite element; Diabetic foot; Plantar pressure.

Introduction

Diabetic neuropathy (DN) is a complication that affects about 50% of patients with diabetes mellitus. It manifests chiefly as loss of sensation[(1)]. In the presence of DN, bone microfractures occur, disrupting the plantar arch, changing the points of support and facilitating loss of skin continuity. Secondary infections are compounded by an associated microangiopathic ischemic state[(2)]. It is estimated that, by the year 2025, approximately 333 million people will have been diagnosed with diabetes worldwide[(3,4)]. This socioeconomic impact highlights the need to assess risk factors for the development of lower-limb ulcers and amputations in patients with diabetes and consequently, the study of pressure overload on the diabetic foot[(5)].

Pressure distribution in the diabetic foot is usually measured through pressure sensors applied to the patient. However, such devices are limited to foot pressure distribution and do not reveal the internal influences between bones and soft tissue. An alternative approach is the finite element method (FEM), which would allow one to model and simulate the human foot by predicting the distribution of plantar pressure during use of different shoes, insoles, and orthotic appliances, thus facilitating the manufacture of custom devices for each specific patient. Furthermore, the FEM can also predict the internal forces and deformations of the bones and soft tissues of the foot[(6)]. The present study builds on the work of two groups: Antunes et al. (2007)[(7)] and Cheung and Zhang (2006)[(8)].

Methods

Computed tomography scans (slice thickness 0.5mm) of the right ankle and foot of a healthy female volunteer (age 26 years, weight 56kg) with anatomically normal feet were obtained. The captured images were reconstructed as 3D surfaces (STL format) using InVesalius® v.3.1 software. Separation masks were used to isolate the anatomical structures of the foot into 31 bones and 1 soft-tissue volume (representing the entire foot). Magics® software was used for geometric fine-tuning and smoothing of the STL triangle mesh. The adjusted STL model was then transformed into STEP format[(9)]. Three-dimensional modeling and geometric treatment were performed in the Solidworks® software environment. Briefly, a model was created from the bone structure filled with cartilage (Figure 1A).

Study performed at the Universidade de Caxias do Sul, Caxias do Sul, RS, Brazil.

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This bone-and-cartilage model was then subtracted from the overall foot model to obtain a hollow soft-tissue model, i.e., consisting of skin, fat, and muscle alone. These made up the whole study model (Figure 1B, 1C and 1D).

A finite element model (FEM) was created in Abaqus® 6.14-5 software for further simulation, based on the distribution of contact pressures between the ground and the foot. *Tie* and *surface-to-surface* constraints were created for each bone-cartilage pair in the FEM model. This type of constraint links the nodes of the *master* surface to the *slave* surface, transmitting forces from part to part. In this case, the surfaces of the bone-cartilage set were defined as the *master* and the internal surfaces of the soft tissue as *the slave*. The foot-to-ground interface was defined through a pair of *surface-to-surface* interactions which allowed sliding, with the upper surface of the ground as the *master* and the lower sole of the foot as the *slave*. This allows the generation of a contact pressure field on the plantar surface area. A coefficient of friction of 0.6 was defined for the tangential behavior of the contact, while an *Augmented Lagrange* constraint method was used for the normal behavior of the contact.

The materials used in the model were considered isotropic, homogeneous, and linear-elastic, except for the soft tissue, which was set as hyperelastic due to its characteristic nonlinear elastic behavior. The ground was set as a non-deformable rigid material. The plantar fascia was divided into five axes, represented by truss elements with a cross-sectional area of 58.6mm[2]. To account for the key function of the plantar fascia (stabilizing the longitudinal arch of the foot and sustaining high stress levels during weight bearing), the behavior of the truss element was defined as non-compressible. The nominal properties of the materials were obtained from the literature (Table 1). The nonlinear mechanical behavior of the soft tissue was defined by a hyperelastic model, based on a second-order polynomial strain energy function. The parameters were obtained from Antunes et al. (2007)[7].

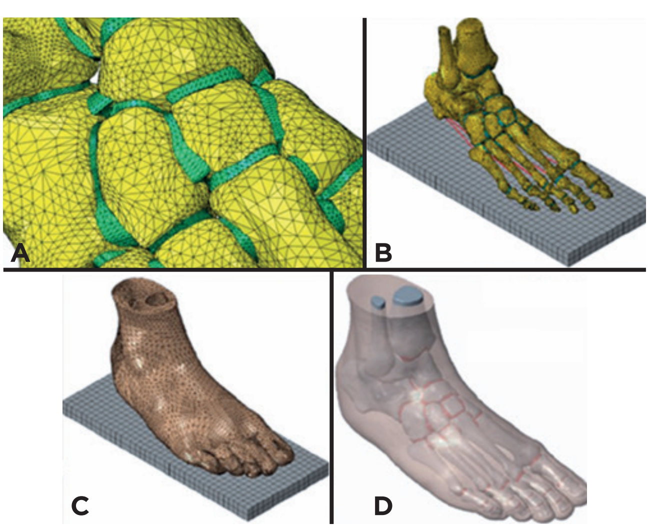

Figure 1. A. Modeling and attachment of cartilage elements for bone support; B. Full 3D model; C. Finite-element mesh model.

To generate the mesh, 3D-tetrahedral elements were defined. Linear formulations were used, except for the soft tissue, which used a hybrid formulation instead to ensures the near-incompressible constraint of the nonlinear elastic behavior of the material. All structures, element types, and formulations were based on the work of Antunes et al. (2007)[7] and Cheung and Zhang (2006)[8] (Table 2). The size of the mesh element was refined on the plantar surface, on the cartilage surfaces in contact with the bone surface, and on the inner soft tissue surface in contact with the bone-cartilage joint. The complete model consists of 680,689 mesh elements.

The load on the posterior face of the calcaneus bone was simulated using five vectors with vertical forces of positive magnitude in the Y-direction[10]. As the volunteer in the present case had a body mass of 54 kg, the weight on each foot was 270 N and the force applied on the tendon was 135 N. Thus, a load of 27 N was uniformly applied to each vector and the weight on each foot (270 N) was applied vertically below the support in the positive Y-direction.

The 270-N force represents the reaction of the person's weight, and could only be applied after rendering the upper surfaces of the soft tissue, tibia, and fibula fixed. In addition, a kinematic constraint was defined so as to allow the ground to move only in the positive vertical direction (Y axis), without any possibility of rotational motion.

Results and Discussion

Displacement was measured by calculating the difference in positions of the nodes before and after application of forces in the model. Figures 2A and 2B show the displacements identified along the Y axis. The peak displacements were

Table 1. Mechanical properties attributed to the study elements

Element	Modulus of elasticity [MPa]	Poisson's ratio (²)	Cross-section [mm²]
Bone	7,300	0.3	-
Cartilage	10	0.4	-
Soft tissue	Hyperelastic	-	-
Plantar fascia	350	0.4	58.6
Ground	210,000	0.3	-

*MPa: megapascal / **v - / ***mm²: square millimeter

Table 2. Element, type of element, and formulation

Element	Type of element	Formulation
Bone	3D-tetrahedron	Linear
Cartilage	3D-tetrahedron	Linear
Soft tissue	3D-tetrahedron	Linear, hybrid
Plantar fascia	1D-truss	Linear
Floor (Ground)	3D-hexahedron	Linear

-0.875mm in the dark blue region and +4 to +5mm in the area of the metatarsals and phalanges. This is a result of the weight reaction force applied to the foot support (positive Y-direction) exceeding the Achilles tendon force (applied to the upper surface of the calcaneus, positive Y-direction) and the forces applied to the model being displaced away from the fixed surfaces (tibia, fibula, and soft tissue). Thus, the weight reaction force deforms the less rigid regions (soft tissue) and displaces the more rigid structures (bones) upwards. As the bony structure of the foot is rigid and the cross-sectional surfaces are fixed, the foot then pivots, causing downward displacement of the bones of the hindfoot (calcaneus, talus). This is also demonstrated by the decrease in displacement from the region of the phalanges to the region of the fibula and tibia, exhibiting a "relief displacement" pattern.

Figures 2C and 2D show that the interactions and constraints between bone and cartilage have been correctly established. In the bone structure as a whole, peak stress levels of 2 to 4MPa (200 to 400N/cm^2) are seen in the metatarsals, talus, calcaneus, tibia, and fibula. High peak stresses, e.g., 15.21 MPa (1521N/cm^2), are also seen at the attachments of the plantar fascia; this is related to tensioning of the truss element.

Regarding plantar pressure distribution, that of the proposed model was consistent with the findings of Hamill et al. (2016)[11]. The greatest pressure is seen the heel, followed by the tuberosity of the fifth metatarsal; pressure is then distributed across the heads of the metatarsals, being highest at the first metatarsal, followed by the second and third metatarsals. Furthermore, the "footprint" (i.e., the pressure distribution of the simulated foot) was similar to a flat map obtained by scanning a rigid PU foam cast of the volunteer's foot (Figures 3A and 3B).

Considering the findings of Cheung and Zhang (2006)[8] and Antunes et al. (2007)[7], our results are similar with respect to the distribution of higher and lower pressures, with the exception of the pressure identified on the head of the fourth metatarsal, which was lower in the proposed model. The models described in the literature also showed more localized pressures on the heads of the metatarsals, while in the present model pressure was distributed more evenly.

The flatness of the foot surface studied herein (as captured by computed tomography) resulted in this more uniform distribution, unlike in models described in the previous literature, which had peak pressure points at the "center" of the heel. Regarding the presence of pressure points in the distal phalanges, the proposed model resembles that of Antunes et al. (2007)[7], rather than Cheung and Zhang (2006)[8]. This may be due to center of pressure (COP) considerations.

The results obtained were compared with those of baropodometry. In the proposed model, the Achilles tendon force was not calculated; instead, we used the parameter reported by Hamill et al. (2016)[11]. The position of the center of pressure was obtained as shown in Figures 3C and 3D. Confrontation of the calculated COP against baropodometry shows that the Achilles tendon force does not correspond to 50% of the weight-bearing force in each foot. This is due to the fact that the COP was located elsewhere. Indeed, the physical therapist who performed baropodometry noted that the volunteer had genu recurvatum. The examination showed that peak pressure was exerted on the heel (~ 14.73N/cm^2). There were no localized pressures on the heads of the metatarsals, only a large area of distributed pressure corresponding to the forefoot, with a peak pressure of 2.72N/cm^2.

Finally, the difference in Achilles tendon forces may be due to the fact that Cheung and Zhang (2006)[8] modeled more than 100 ligaments to connect the bones (thus allowing the possibility of slight slippage between the bones) instead of geometrically generating cartilages to connect the bones (tie constraint), as was done in the present model.

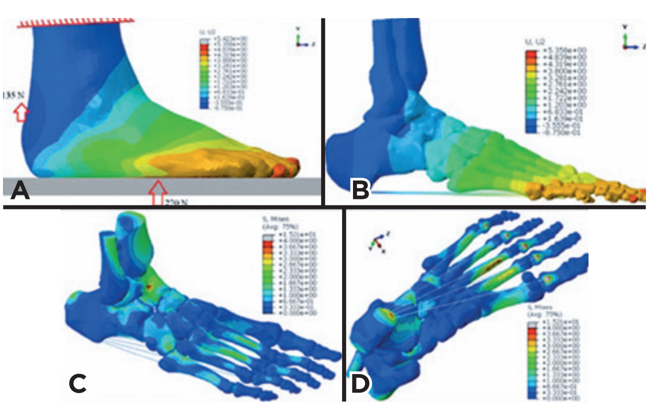

Figure 2. Distribution of displacements identified in the simulation: A, soft tissue; B, bone tissue; C and D, internal Von Mises stress distribution (MPa).

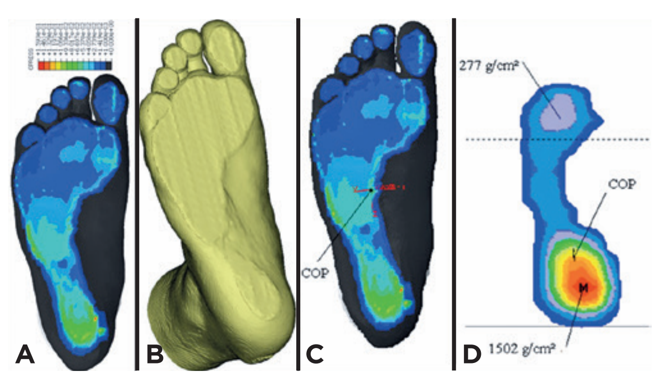

Figure 3. A and B, simulated model versus flat map of plantar surface; C and D, comparison between simulated model and baropodometry findings.

The clinical use of pressure distribution analysis through a finite element computational model, especially in patients with diabetic foot, should allow development of customized insoles by homogeneous weighting of foot pressure distribution, thus eliminating points of excessive stress at the foot-footwear-ground interface and helping prevent ulcers, infections, and amputations. The same technology can be offered to patients who have undergone partial amputations of the foot, redistributing stump pressures and avoiding further amputations.

Conclusion

Finite element analysis provides a feasible, reproducible manner of reproducing the biomechanical behavior of healthy feet.

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Special Article

Minimally invasive internal fixation of distal tibia fractures with a nonconventional implant: description of surgical technique

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Abstract

Fractures of the distal end of the tibia without joint involvement are usually the result of high-energy trauma. Local anatomic conditions lead to high rates of infection, delayed consolidation, and exposure of fixation hardware. In this setting, minimally invasive techniques are indicated to mitigate the complications of surgical treatment. The aim of this study is to present an alternative for the surgical treatment of distal tibia fractures using a minimally invasive technique and a nonconventional implant.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Tibial fractures/surgery; Fracture Fixation, Internal/methods; Prostheses and implant; Minimally invasive surgical procedures.

Introduction

Fractures of the distal end of the tibia without joint involvement are usually the result of road traffic collisions and other high-energy impacts[1]. Due to the scant soft-tissue coverage and limited vascularization of the skin and subcutaneous tissue in the region, complications such as infection, delayed consolidation, and exposure of fixation hardware can make treatment of these fractures a major challenge to the surgeon[2,3].

Intramedullary nails and plates are the two main options for the treatment of extra-articular fractures of the distal tibia. Both options have some theoretical disadvantages. While intramedullary nail fixation can result in nonunion and a higher incidence of knee pain, plate fixation is associated with a higher risk of surgical wound dehiscence and infection due to less soft tissue coverage over the anteromedial aspect of the tibia. The advent of minimally invasive percutaneous plate osteosynthesis (MIPO) brought reductions in damage to soft tissues and in the rate of complications such as infection and impaired fracture healing[4-6]. Although intramedullary osteosynthesis remains the technique of choice for the treatment of most tibial shaft fractures, some cases—some due to their distal location, others due to changes in the morphology of the intramedullary canal—make this form of fixation impossible[6]. Expansion of this indication to the treatment of distal tibia fractures has been associated with increased rates of instability and malunion[7].

Treatment of distal tibia fractures aims to achieve good functional alignment and a stable fixation while respecting the soft tissue envelope, allowing early rehabilitation[8]. To follow these tenets and thus ensure superior preservation not only of bone circulation but also of soft-tissue coverage, minimally invasive and more biological techniques were developed to preserve the fracture hematoma by means of minimal dissection and indirect reduction[9]. Use of the bridge plating technique via MIPO, based on the principle of relative stability, has proven to be an effective, low-cost technique associated with few complications[10]. Likewise, Oh et al.[11] concluded that percutaneous plate osteosynthesis minimizes soft-tissue damage at the fracture site, thus increasing the consolidation rate.

Study performed at the Hospital Estadual Jayme Santos Neves, Serra, Espírito Santo, ES, Brazil.

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In this paper, we describe an operative technique for extra-articular fractures of the distal tibial metaphysis with nonconventional use of an extra-medullary internal fixator in a bridging role, inserted in a retrograde, minimally invasive fashion following the tenets of MIPO.

Description of operative technique

The treatment protocol consisted of staged management as proposed by Sirkin et al.[12].

1. During the damage control orthopedics stage, external fixation in delta formation was accomplished with two Schanz screws placed on the tibial shaft and two others on the foot, one in the posteromedial portion of the calcaneus and the other at the base of the first metatarsal, with the ankle in neutral position (Figure 1).
2. A 16-hole T-shaped plate of the type usually employed for proximal tibial fractures and six full-thread screws, three 4.5-mm for cortical bone and three 6.5-mm for cancellous bone, were used for definitive fixation.

The treatment principle chosen was relative stability through the use of an extra-medullary internal fixator and the aforementioned bridge plate.

This choice of hardware was due to the fact that there is no consensus in the literature regarding the optimal principle and method to be applied in this region, the low profile and low cost of this implant model, and the operator-friendly, easy-to-perform technique. Some points bear stressing: as it is a biological technique, the use of Hohmann retractors should be avoided so there is no additional injury to the soft tissues; correction of the axes should be done manually and gently; and the screw size must be selected so as to allow placement of three screws in the distal fragment, two of which must be slightly offset and the third, placed in the hole immediately superior to and parallel to the articular surface.

The plate was inserted via a minimally invasive technique, distal to proximal, in a retrograde and upward fashion through an approximately 4-5cm incision; the greater saphenous vein was used as a landmark (Figure 2). Unlike when using a dynamic compression plate (DCP), which must be angulated approximately 20 degrees to reproduce the distal tibial torsion, there is no such concern when using this technique because the plate adapts easily to the contour of the distal tibial segment as the screws are driven and tightened alternately.

The plate performs both bridging and reduction roles. As the first 4.5-mm cortical screw is driven proximal to the fracture site, the fracture is reduced by an implant interference mechanism. At this stage, image intensification is used to analyze the reduction and the two distalmost cancellous screws are then driven (also under fluoroscopic guidance). The fourth screw is placed into cortical bone in the most proximal hole; the fifth and sixth screws to be placed are cortical and cancellous respectively. Judicious intraoperative control is essential so that the screws placed in the distal fragment do not pierce the distal tibiofibular joint (Figure 3).

Figure 2. Intraoperative appearance, showing the distal incision and three proximal incisions.

Figure 1. Aspecto da montagem em delta utilizada como forma de controle de danos pré-operatório.

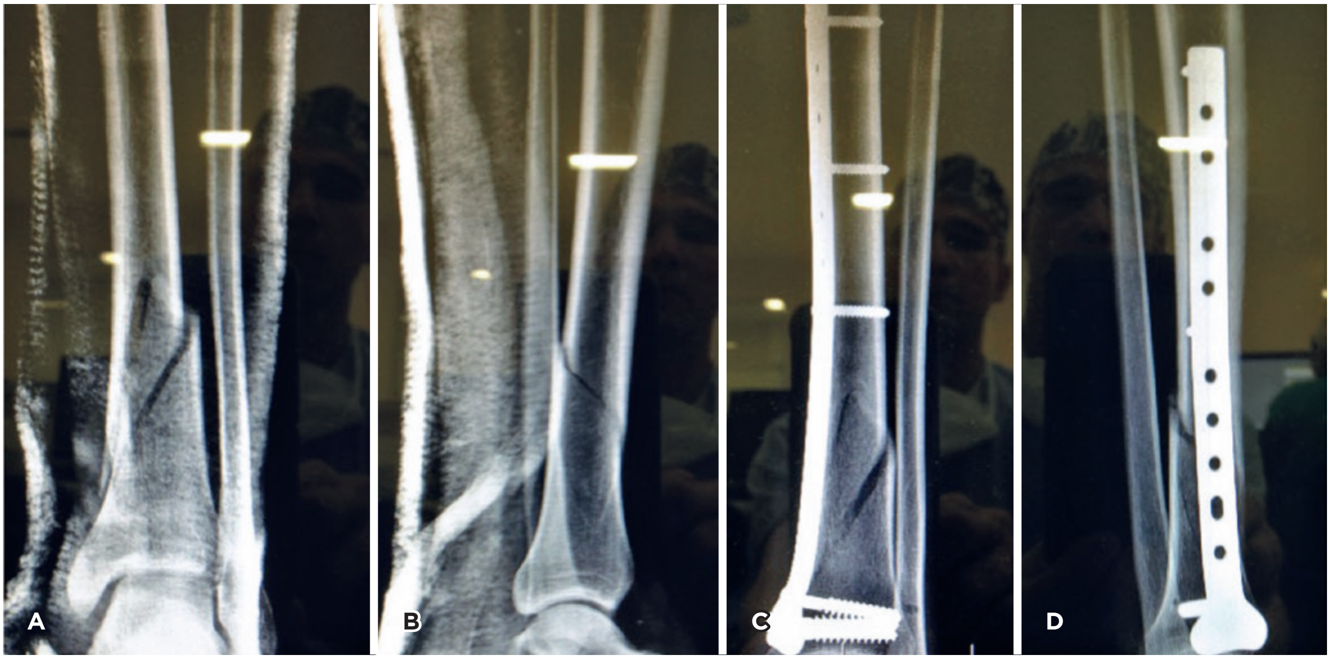

Figure 3. A and B: extra-articular fracture of the distal tibia; C and D: appearance of the fracture after placement of a T-plate inserted in retrograde, ascending fashion. Note location and arrangement of screws in the distal segment.

The surgery is performed with the patient under locoregional anesthesia, in the supine position, with both lower limbs prepared, thus allowing intraoperative comparison of length, rotation, and angulation. In the immediate postoperative period, active and early mobilization (including ambulation with the aid of crutches) were encouraged. Discharge was scheduled for 24h after surgery, except in cases of compound fractures, which had a longer hospital stay.

The radiographic parameter used to define consolidation was the formation of an appreciable callus on at least three tibial cortical views (Figure 4).

According to the AO classification, 23 fractures (63.9%) were classified as type 43A, 11 (30.5%) as type 43B, and only 2 cases (5.6%) as type 43C.

Radiological evaluation showed satisfactory functional alignment in 27 patients. Nine patients had rotational or axis deviations, which included varus/valgus greater than 5°, more than 5° recurvation or antecurvation, shortening greater than 1 cm, and twist greater than 10°.

Seven cases (6 compound fractures and 1 closed fracture) were complicated by infection.

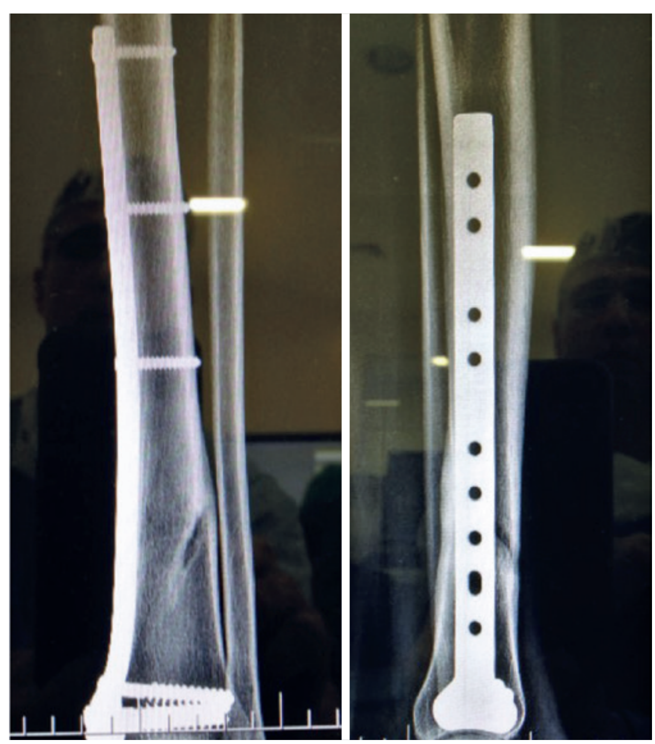

Figure 4. Extra-articular fracture of the distal end of the tibia. Note consolidation of the fracture site.

Discussion

Borelli et al.[13] demonstrated that open reduction and internal fixation of distal tibial fractures carries a high risk of damaging the local blood supply. This led to the development of minimally invasive techniques (MIPO) where a plate is inserted percutaneously and attached to the bone above and below the fracture, as described by Krettek et al.[14]. However, MIPO has been criticized for the greater difficulty in achieving adequate correction of the anatomical and mechanical axes as compared to conventional techniques. The literature is unclear as to the acceptable degree of reduction in tibial shaft fractures. Milnar et al.[15] studied 164 tibial fractures with long-term (30-year) follow-up and concluded that there was no significant association between malunion of the tibia and development of knee or ankle arthrosis. None of the patients in this series developed valgus or varus deformity greater than 5°. Fracture of the tibia is unquestionably the leading cause of pathological leg rotation in adults. According to the literature, the incidence of rotational malreduction is less than 1%; however, the method used was clinical or not reported[16].

Associated fibular fractures were present in 32 patients in our sample, 17 of whom underwent osteosynthesis with a one-third-tubular plate, as they had fractures of the distal third of the fibula whose fixation contributed to the reduction and fixation of the tibia. Labronici et al.[17] demonstrated that fibular fixation performed simultaneously with repair of fractures of the distal third of the tibia does not interfere with bone healing.

Conclusion

Internal fixation of distal tibia fractures based on the principle of relative stability, with nonconventional use of a bridge plate inserted through a minimally invasive approach, proved to be a good treatment alternative in our sample, with a high consolidation rate, low potential for soft-tissue complications, and low hardware cost.

Authors' contributions: Each author contributed individually and significantly to the development of this article: LABC *(https://orcid.org/0000-0003-678-6254) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; NE *(https://orcid.org/0000-0002-4277-6128) wrote the article, participated in the review process; JEGRF *(https://orcid.org/0000-0003-1424-5095) participated in the review process; ELBC *(https://orcid.org/0000-0002-5986-8395) participated in the review process. *ORCID (Open Researcher and Contributor ID) iD.

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Systematic Review

Arthroscopic subtalar arthrodesis – results and complications: a systematic review

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Abstract

Objective: The objective of this study is to evaluate the results and complications of the subtalar arthrodesis technique conducted via arthroscopy.

Methods: Searches were run on PubMed/Medline and Google Scholar for publications dated from 2007 to 2020. Original articles were included that reported the results of at least one comparative postoperative scale. Methodological quality was assessed using the PRISMA tool. Union rate, complications, and the American Orthopedic Foot and Ankle Society (AOFAS) score were prioritized.

Results: A total of 124 references were identified and, after application of the inclusion and exclusion criteria and the PRISMA tool, 9 articles were eligible. A total of 180 patients were analyzed, with mean postoperative follow-up of 18 months (± 6) and with before and after AOFAS scores varying from 44 to 79 with p<0.001, demonstrating statistical relevance with significant improvement of AOFAS scores during the postoperative period. Deformity correction, improvement of pain, and rates of union were good and there was clinical improvement according to postoperative AOFAS scores, with few complications. However, the heterogeneous nature of studies, with variations in techniques and samples, prevents generalization of the findings.

Conclusion: The results of arthroscopic surgery for subtalar arthrodesis are good and rates of complications are low, but there are still few studies with high evidence levels that demonstrate the efficacy of the technique, although preliminary results are encouraging.

Level of Evidence I; Therapeutic Studies; Systematic Review.

Keywords: Arthrodesis; Subtalar joint; Arthroscopy.

Introduction

Degenerative injuries of the subtalar joint have multiple etiologies, such as primary osteoarthrosis, posttraumatic arthritis, inflammatory arthropathy, congenital pathologies, or acquired deformities. When conservative treatment is unsuccessful, arthrodesis can relieve pain and improve functional status. Arthroscopic techniques are becoming increasingly popular, because they involve reduced surgical trauma, fewer complications, and faster recovery[1-3].

Painful symptoms, primarily when walking on rough ground, and instability are both common, leading to loss of function and restriction of activities[4].

Fractures of the calcaneus cause chronic pain, are incapacitating, and have uncertain prognosis. Pain may be caused by subtalar and/or calcaneocuboid arthritis, widening of the lateral wall, causing impact on the fibular tendons, malalignment of the hindfoot, loss of heel height and inclination of the talus (causing ankle pain and reducing impulse strength), in addition to damage to the fat pad of the heel and/or injury to sensory nerves of the hindfoot[5].

The most common clinical findings of subtalar arthritis are: lateral swelling of the hindfoot, painful amplitude of subtalar movement, and altered tactile sensitivity. Diagnosis is confirmed by weightbearing X-rays of the foot in anteroposterior,

Study performed at the Unievangélica, Centro Universitário, Anápolis, GO, Brazil and Hospital Santa Marcelina, São Paulo, SP, Brazil.

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oblique, and lateral views. Additional projections include Broden's view (showing the posterior facet of the calcaneus for assessment of the extent of arthritis), the Harris axial view (to determine whether widening of the heel is causing subfibular impact, as occurs after calcaneus fractures), and the Saltzman view (to objectively assess alignment of the calcaneus in relation to the tibia). Radiological examination is important to identify hindfoot malalignment that must be treated during surgery and to determine the loss of calcaneus height and changes to the inclination of the talus(6).

Subtalar arthrodesis is a procedure commonly performed on the foot to reduce pain and correct deformity. It has several indications, such as: surgical treatment of primary arthritis, posttraumatic arthritis, and correction of hindfoot deformity. Causes of deformity include failure of the posterior tibial tendon which can aggravate deformity in valgus and lateral impact, causing pain in the tarsal region. Any trauma to the subtalar joint and posterior facet can lead to posttraumatic subtalar arthritis, and certain fractures of the calcaneus with severe comminution can benefit from this procedure(7-9).

Other studies confirm that subtalar arthrodesis is a treatment option for pain caused by arthritis subsequent to fractures of the calcaneus. It was described by W. Van Stockum in 1912 and popularized by W. E. Gallie in 1943 for treatment of fractures in which there is comminution of the calcaneus. The procedure is performed to relieve subtalar joint pain, especially in patients with posttraumatic osteoarthrosis after fractures of the calcaneus or talus, or in patients with subtalar primary osteoarthrosis for acquired flatfoot, congenital deformities (tarsal coalition), neuromuscular dysfunction, or inflammatory disease(4,5,10-12).

There are several techniques, approaches, and fixation options for subtalar arthrodesis in isolation, which can be performed as an open procedure or assisted with arthroscopy. The arthroscopic technique is limited to cases without major malalignment of the subtalar joint or major bone loss(6,13).

The open technique for subtalar arthrodesis is used more often and results are generally favorable. It is a minimally invasive technique that theoretically preserves the blood supply to the calcaneus and the talus, reduces perioperative morbidity and can preserve the foot's proprioceptive sensitivity. However, several complications may occur because the open procedure involves removal of interosseous and periarticular ligaments and requires a lateral incision that can cause neurovascular dysfunction. The open technique involves greater risk of wound infection, of non- union, and of neurovascular injury(11,14).

According to Vilá-Rico et al.(10), around 30% of patients will have a degree of pseudarthrosis and bone grafts are commonly used to improve the likelihood of union. Therefore, minimally invasive techniques such as arthroscopic subtalar arthrodesis improve on the results of traditional open methods, with the advantages of preserving the blood supply to the tarsus, reducing postoperative morbidity, and preserving proprioception.

Arthroscopic arthrodesis provides surgeons with an alternative to the open technique for treatment of severe arthritis of the ankle(15).

Arthroscopic procedures are less invasive than conventional open techniques and posterior arthroscopy, performed in ventral decubitus, may be more advantageous than the conventional anterior and/or lateral approaches(4,16).

Arthroscopic subtalar arthrodesis was first described in 1992 by J. P. Tasto and was conceived of as a minimally invasive approach. The technique was used in patients with rheumatoid arthritis, degenerative osteoarthritis, and subtalar instability with paralytic disorders. Absolute contraindications include: presence of major deformities, infection, and failure of anterior union. The best-known relative contraindication is subtalar arthritis after calcaneus fracture, because of narrowing of the joint space and presence of arthrofibrosis, which make the procedure more difficult(17).

Contraindications for this procedure are failed prior arthrodesis, deformities that require correction and/or additional procedures that cannot be performed with the patient in ventral decubitus. After the advent of this procedure, the majority of surgeons began to use lateral portals (anterolateral, posterolateral, and accessory)(14).

Arthroscopic procedures reduce morbidity and arthroscopic subtalar arthrodesis is a surgical procedure for subtalar arthritis that achieves high union rates(12).

This procedure demands a high level of experience with ankle and subtalar arthroscopy, which can be considered a disadvantage compared with the open procedure. Patients should be carefully selected, since malalignment of the hindfoot exceeding 15 degrees in valgus or 5 degrees in varus are contraindications for this procedure, because correction of the deformity cannot be achieved with this technique(18).

Regardless of the approach – open or arthroscopic – nonunion of the site of subtalar arthrodesis is an unwelcome possibility. Risk factors for this outcome are: smoking, osteonecrosis, ipsilateral union of the ankle, and surgery to re-treat. Progressive arthritis of the ankle and foot has been documented after subtalar arthrodesis, but was not clinically relevant(6).

The objective of this study is to evaluate the results and complications of arthroscopic subtalar arthrodesis treatment.

Methods

A systematic review of the literature was conducted to evaluate the arthroscopic subtalar arthrodesis technique, in accordance with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses. This study is registered on PROSPERO (the International Prospective Register of Systematic Reviews).

Searches were run on PubMed/Medline and Google Scholar using the keywords: "arthroscopic subtalar arthrodesis" (n=75) and "arthroscopic subtalar fusion" (n=49). Studies published from January 2007 to March 2020 were included.

Studies were selected by analyzing the title and/or abstract of all of the articles identified by the database searches. The full texts of potentially relevant studies were then retrieved and assessed for eligibility. Additionally, the references of relevant studies were also searched for studies missed in the initial searches.

Studies were included that reported complication and union rates by technique used, with follow-up ≥ twelve months, and which administered at least one standardized scale to assess postoperative surgical results (the American Orthopedic Foot and Ankle Society – AOFAS – Ankle Hindfoot Scale).

Studies were excluded if they were published in languages other than English, if they employed unknown or little-used techniques, were case reports, reports of experience with techniques, technical experiments on cadavers, descriptions of surgical anatomy, or articles with very poor evidence levels.

Four reviewers extracted data from the articles according to the following predefined: surname of first author, number of feet, duration of follow-up, before and after AOFAS scores, rate of union and time taken, grafting and complications (Table 1). These data were used in the analysis and discussion in this article.

Results

A total of 124 references were identified, but after application of inclusion and exclusion criteria and the PRISMA tool, 9 articles were eligible for inclusion.

The searches run with the keywords mentioned returned a total of 124 articles. After exclusion of duplicates and irrelevant articles, 23 studies were carefully analyzed by the authors. Finally, 9 articles were found to be eligible and were selected for the meta-analysis. These steps are illustrated in a flowchart (Figure 1) according to the PRISMA guidelines, to aid understanding.

The majority of the articles have level 4 evidence – with a predominance of prospective studies and studies of treatment cases. There was also 1 article with level 3 evidence, in which Rungprai compares outcomes and complications between open and arthroscopic subtalar arthrodesis techniques.

An analysis was conducted of the 9 articles selected, in which a total of 180 feet were assessed, with a mean postoperative follow-up of 18 months (± 6) and with before and after AOFAS scores varying from 44±6 to 79±4 with $p<0.001$, demonstrating statistically relevant, significant improvement of AOFAS scores during the postoperative period (Table 2 and Figure 2).

The ages of the patients in the studies analyzed ranged from 37.8 to 50.9 years (mean: 45.2), but no correlations between age and other variables could be detected.

With regard to the relationship between postoperative AOFAS score and number of complications, no strong rela-

Table 1. Characteristics of studies and surgical methods

Author and year	N	Grafting?	Surgical method	Follow-up	Scales used	AOFAS before	AOFAS after	Union rate	Complications
Coulomb, R. (2019)	22	No	Posterior approach, 2 screws	≥12 months	AOFAS, EVA, SF-12	46±13	76±10	91%	1 case of paresthesia of the tibial nerve and 1 of the sural nerve 2 cases symptomatic hardware, 2 did not achieve union
Albert,A. (2011)	10	Yes	Posterior approach, 2 screws	≥12 months	AOFAS	47 (22-65)	78 (60-91)	100%	2, Lateral submaleolar entrapment
Amendola A. (2007)	11	Yes	Posterior approach, 2 screws	≥24 months	AOFAS	36 (19-57)	86 (78-94)	91%	1 did not achieve union, 1 symptomatic hardware
El Shazly O. (2009)	10	No	Posterior approach, 1 screw	≥24 months	AOFAS	38	74	100%	1, neuroma
Glanzmann M. (2007)	41	Yes	Posterior approach, 1 screw	≥24 months	AOFAS	53 (22-69)	84 (41-94)	100%	10, Symptomatic hardware; 3, ankle pain; 1 fibular tendinitis
Lee K. (2010)	16	No	Posterior approach, 2 screws	≥12 months	AOFAS, Angus & Cowell	35±7	85±7	94%	1, did not achieve union
Vilá-Rico (2018)	37	No	Posterior approach, 1 or 2 screws	≥24 months	AOFAS	49±11	76±8	92%	1, superficial infection; 2, symptomatic hardware; 3, did not achieve union
Martín Oliva (2017)	19	No	Posterior approach, 2 screws	≥24 months	AOFAS & EVA	43±9	80±5	94%	1, reversible neuropraxia; 2, implants removed; 1 did not achieve union
Thaunat M. (2011)	14	No	Posterior approach, 1 or 2 screws	≥12 months	AOFAS	51±10	77±9	78%	3 did not achieve union; 1 sural paresthesia

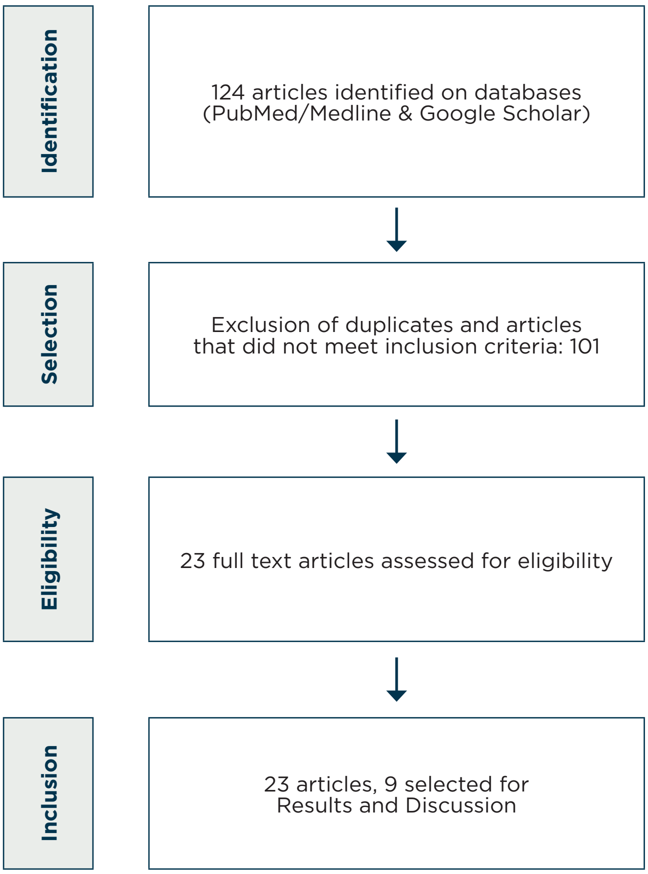

Figure 1. PRISM flowchart (adapted) illustrating process of selection of articles.

Table 2. Analysis of means and standard deviations for variables

Variable	Mean	Standard deviation
AOFAS after	79.5	4.4
AOFAS before	44.2	6.6
Union rate	93%	6.9
Time to union (weeks)	10.3	1.7
Complications per study	4.4	4

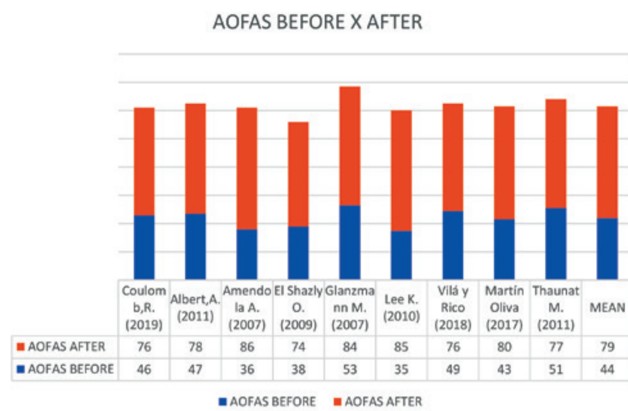

Figure 2. Comparison of AOFAS before vs. AOFAS after.

tionship was observed according to the Pearson correlation coefficient (used to measure correlations between numerical variables). Complications cited in the studies included: superficial infection, neuropraxia, neuropathic pain, neuroma, and fibular tendinitis.

Discussion

The rate of union after arthroscopic subtalar arthrodesis found in the studies analyzed was 93%±7 (range: 78% to 100%), which is compatible with Lee et al.[12], who report that arthroscopic subtalar arthrodesis is an acceptable surgical procedure for isolated subtalar arthritis, with union rates of 94% (range: 91% to 100%).

Also in the abovementioned study by Lee et al.[12], the mean time taken for union was 11 weeks (range: 8 to 16 weeks). The time to union found in the studies reviewed here was 10.3 weeks (range: 7 to 12.5 weeks). In a different study, union rates were reported that ranged from 65% to almost 100%, depending on whether bone grafts were added, on patient selection, and on operating technique[19].

In turn, a consecutive series of 65 patients treated with arthrodesis reported by Vilá-Rico et al.[5] had mean follow-up of 57.5 months and union was achieved in 62 patients (95.4%) after a mean of 12.1 weeks, while nine patients (13.8%) exhibited complications (superficial infection of the wound, need for removal of prominent screws because of pain, and failure to achieve union).

According to Vilá y Rico et al.[19], failure to achieve union is one of the most feared complications and surgeons recommend debridement of joint surfaces and addition of bone grafting to avoid it. The majority of authors reported mean AOFAS scores in the postoperative period in the range of 70 to 76 points, although some achieved mean postoperative AOFAS scores exceeding 80 points.

Amendola et al.[11] described a series of 11 patients who were treated with arthroscopic posterior subtalar arthrodesis using bone grafting, with just one union failure in a mean period of 10 weeks. Moreover, Albert et al.[4] reported a series of 10 patients treated with bone grafting who were followed-up prospectively for a minimum of 1 year (range: 12 to 31 months), among whom there was a 100% union rate in a mean time of just 7 weeks. Union had occurred in all cases within 9 weeks, without complications and mean AOFAS score improved from 47 to 78.

Martín Oliva et al.[14] confirm that many researchers have used the arthroscopic technique and reported high rates of union and few complications.

Initially, arthroscopic subtalar arthrodesis was only used in cases of subtalar osteoarthrosis in isolation, with no malalignment. However, over time, indications have been expanded to include increasingly severe deformities and a range of different pathologies. The lateral and posterior techniques are reproducible and are associated with very low rates of iatrogenic complications. The procedure has also gained popularity because of evidence of bone union in more than 90% of cases, shorter healing times, a simpler postoperative course, and fewer complications than with open surgery[20].

Posterior arthroscopic subtalar arthrodesis achieves significant improvement in pain scores and a good level of patient satisfaction, confirming the good union results[1].

Rungprai et al.[21] conducted a study with level 3 evidence, involving retrospective review of the medical records of 121 patients (129 feet) who underwent subtalar arthrodesis with the open technique (60 feet in 57 patients) or the arthroscopic technique (69 feet in 64 patients) from 2001 to 2014. They did not observe significant differences between groups in terms of the rate of union or time taken for union when analyzed by different screw sizes and types of bone graft. Return to work, to activities of daily life, and to sporting activities were earlier in the arthroscopic arthrodesis group.

With regard to relationships between grafting and other variables (grafting against union rate, against time to union in weeks, and against postoperative AOFAS scores), there was no statistical basis for determination of any relationship, because each study reported a different observation.

Albert et al.[4] commented that, since arthroscopy cannot be used for structural bone grafting, it would be better to treat significant deformities of the hindfoot with the open procedure.

There is not yet any consensus on the most effective technique for subtalar arthrodesis[22], although excellent results have been demonstrated with arthroscopy.

In the past, double arthrodesis (subtalar and talonavicular) or triple arthrodesis (subtalar, talonavicular, and calcaneocuboid) were the preferred treatments for subtalar arthritis with major deformity. However, since the function of the talonavicular joint has a great influence on the overall function of the hindfoot, subtalar arthrodesis only has become the option of choice, to preserve hindfoot mobility and reduce the risk of secondary degenerative disease of the neighboring joints[14,23].

One of the most unwelcome complications of arthrodesis is failure to achieve union and for this reason many surgeons prefer to use the open approach, to guarantee adequate debridement of all affected joint surfaces. However, problems involving the soft tissues can occur and infections are common after open surgery[10].

In the study by Vilá-Rica et al.[10], arthroscopic subtalar arthrodesis was shown to achieve higher union rates without the need for supplementation by bone grafting and lower rates of complications than open techniques, in addition to being a safe and reliable procedure, providing that the surgical technique is followed rigorously. The AOFAS scores improved significantly in all patients and patient satisfaction was high, even among patients followed for more than 5 years.

Several published series have proved the safety and efficacy of arthroscopic subtalar arthrodesis, but the majority of them included patients with varied indications, both posttraumatic and non-traumatic. The ideal would be to conduct a study comparing open and arthroscopic arthrodesis, but it would be difficult to run such a study prospectively, in view of the low numbers of cases in the majority of published case series[5].

In general, the studies observed good correction of deformities, with improvement of pain, good union rates, clinical improvement according to postoperative AOFAS scores, and low rates of complications. However, because of the heterogeneous nature of the studies, with variations in the techniques used and the samples studied, findings cannot be generalized.

Vilá y Rico et al.[19] explain that arthroscopic techniques cause less damage to soft tissues, preserving local vascularization and proprioception, which promotes union and faster recovery, in addition to reducing pain and shortening hospital stays. They also confirm that although the safety and efficacy of the technique have been confirmed in several different studies, the majority of series are limited to small numbers of patients with variables indications for subtalar arthrodesis, preventing comparisons between them.

The results of this review confirm the hypothesis that the arthroscopic technique is a reliable option for achieving consistent union, with low rates of complications and high level of patient satisfaction.

Conclusion

As observed, subtalar arthrodesis can be performed using open or arthroscopic techniques. It was possible to conclude that arthroscopic surgery for subtalar arthrodesis achieves good results with low rates of complications, but that there are few studies with high evidence levels that confirm the efficacy of the technique, although preliminary results are encouraging.

The arthroscopic technique is safe and effective and achieves significant clinical improvement in patients with indications for subtalar arthrodesis.

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Technical Tips

Talocalcaneal coalition resection and bone block subtalar joint arthrodesis: a techinical tip

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Abstract

In this technical tip, we present the case of an obese 17-year-old female diagnosed with a severe, rigid, and symptomatic flatfoot on a background of exuberant talocalcaneal and residual calcaneonavicular coalition. Through a technical modification of the fusion resection, both coalitions were quickly and safely removed with two single cuts of an oscillating saw, resecting a medial wedge through a medial approach, without the need for "peel-off" tarsal coalition resection. To protect and guide the resection osteotomy, one Freer elevator ws inserted under direct visualization on the patent posterolateral aspect of the subtalar joint posterior facet and a second elevator was positioned underneath the talar neck. Under fluoroscopic guidance, an osteotomy was performed connecting these two points. The patient also received a bone-block subtalar joint arthrodesis and a Cotton osteotomy. Good short-term alignment correction and functional outcome were achieved.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Tarsal coalition; Talocalcaneal coalition; Calcaneonavicular coalition; Cotton osteotomy; Subtalar fusion.

Introduction

Tarsal coalitions are a well-known cause of pain and disability in the foot and ankle, especially in the pediatric population[1,2]. These problems often lead to inability to participate in activities of daily living and sports, decrease quality of life, and are often associated with foot deformities, most commonly flatfoot[3]. The most common types of tarsal coalitions are calcaneonavicular (CNC) and talocalcaneal (TCC) coalitions[3-6].

Many of these coalitions are asymptomatic, diagnosed only after trauma or incidentally during investigation of the limb[7]. Nevertheless, some cases present with quite exuberant signs and symptoms, as well as pronounced hindfoot deformity, abnormal bone growth, and dysplasia[8]. In severe cases with dysplastic talar formation, a ball-and-socket mortise joint may be found[9].

There are osseous, fibrous, and cartilaginous subtypes of coalitions[3-6]. Differentiation between subtypes is primarily radiographic, but magnetic resonance imaging (MRI) and computed tomography (CT) scans can also be used in diagnosis and treatment planning[10]. Most mild and early cases are successfully treated with nonoperative measures, such as physical therapy and insoles, but failure of these modalities usually leads patients to surgical intervention[3-6,11].

A joint-sparing procedure with adequate coalition resection is the cornerstone of surgical treatment and, in several cases, the only required technique for treatment, especially when less than 50% of the mediolateral extension of the subtalar joint is involved[3]. Even when deformity is present, removal of the bone bridge is essential to correct foot alignment and relieve pain[12]. Different surgical techniques have been described for this purpose; all share the intention of safely removing the coalition as easily and quickly as possible[13-16].

This article describes the treatment of a 17-year-old female with a symptomatic severe flatfoot deformity and obesity on a background of massive TCC and residual CNC, with history of a prior failed attempt at CNC resection. The patient

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

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underwent resection of the coalitions through a novel medial approach (the subject of this technical tip) consisting of an osteotomy line connecting two fluoroscopic landmarks, followed by a medial wedge resection for hindfoot valgus correction and corrective lateral-wedge bone-block allograft arthrodesis and Cotton osteotomy for residual forefoot supination.

Case description

A 17-year-old (BMI 36) presented to an outside orthopedic service with a complaint of chronic right medial foot and ankle pain since childhood. The patient reported a history of rigid symptomatic flatfoot in childhood, which had been treated with physical therapy and insoles. She also had a history of an attempt at surgical CNC resection 18 months earlier, with only partial resolution of her symptoms (Figure 1). Following a recent minor injury, she had experienced a flare-up of symptoms. On physical examination at the time, a severe flatfoot deformity was observed, with significant hindfoot valgus of approximately 20-25° and a supinated forefoot. There was evidence of a healed sinus tarsi approach, with painful, rigid passive hindfoot inversion and eversion. She was also tender to palpation along the medial side of the foot and ankle, where a bony prominence could be palpated at the level of the sustentaculum talus, and had moderate tenderness on the sinus tarsi area. Conventional radiographs showed possible residual CNC, with indirect signs of a TCC (talar beaking and C-sign) in the right foot, and a mild valgus talar tilt of the talar dome (Figure 2). Initial treatment plans included a walking cast for 6 weeks and brace immobilization; however, there was no significant improvement in the symptoms. MRI and weightbearing CT (WBCT) images were obtained to elucidate the extent of the coalition, assess the subtalar joint, and, possibly, assist in surgical planning.

Images demonstrated a recurred/residual CNC, mostly plantar, and a massive TCC affecting both the middle and the posterior facets of the subtalar joint, compounded by with severe hindfoot valgus (tibiocalcaneal angle of approximately 45°) and a mild valgus tilting of the talar dome (Figures 3 and 4).

The patient and her family decided to proceed with surgical treatment. Coalition resection followed by a bone block arthrodesis and a Cotton osteotomy were proposed to the patient and her family. Once the participants had agreed, surgery was formally indicated and performed.

Surgical technique and technical tip

The operation began with aspiration of bone marrow from the right iliac crest for concentration and later injection into the subtalar joint fusion mass.

An extensive medial foot approach was selected and performed along the trajectory of the posterior tibial tendon (PTT), from the medial malleolus down to the navicular tuberosity. The tendon was exposed and found to be intact pro-

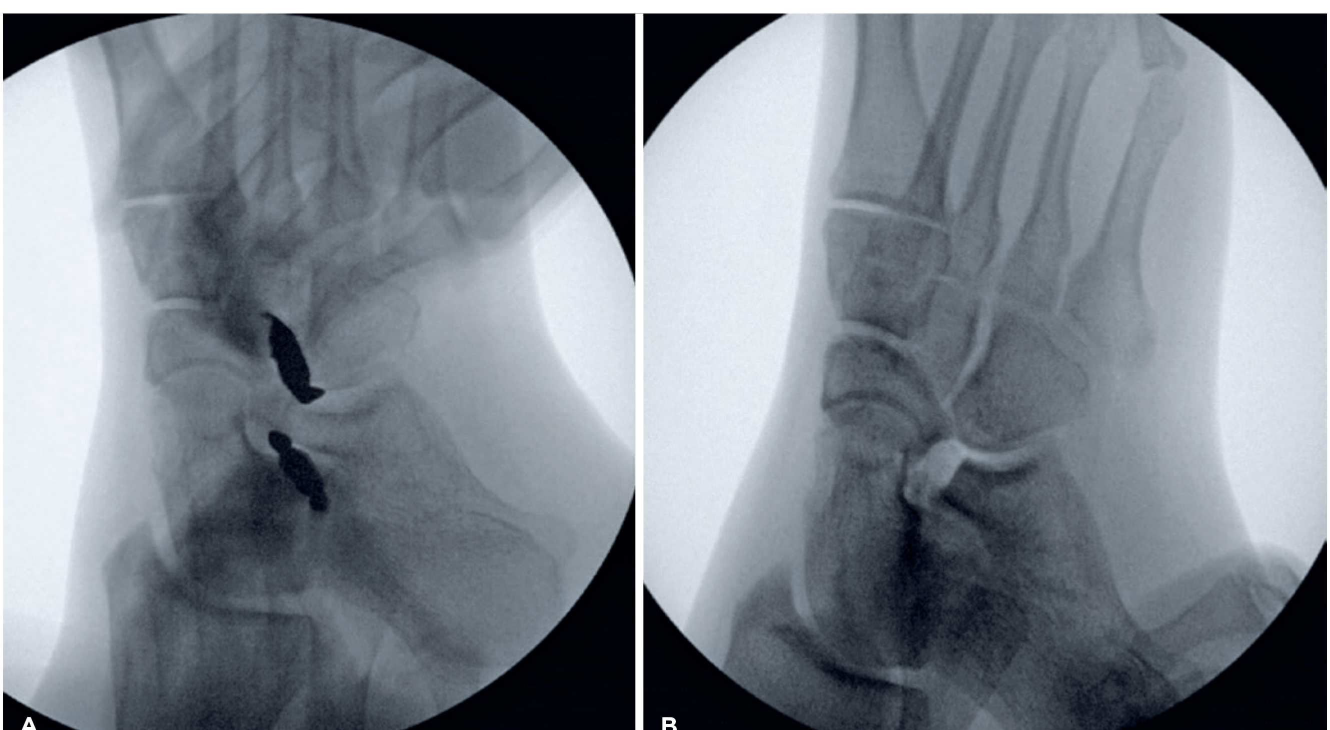

Figure 1. Intraoperative fluoroscopic views of prior surgical treatment of calcaneonavicular coalition, (A) before and (B) after resection.

ximally, but with some insertional tendinopathy. The PTT was partially detached from the navicular tuberosity and retracted plantarly. The flexor digitorum longus (FDL) and flexor hallucis longus (FHL) tendons were identified by periosteal dissection, isolated, and retracted plantarly with the PTT, thus protecting the neurovascular bundle and exposing the medial aspect of the subtalar joint (SJ). A large bony prominence at the level of the sustentaculum tali, middle, and anteromedial aspect of the SJ posterior facet was identified, consistent with a talocalcaneal bony coalition.

Instead of using a "peel-off" coalition resection technique with resection of multiple slices of bone or a small wedge resection technique, both usually used to identify a line of fibrotic tissue where the articular line was supposed to be positioned, we performed a modified technique that can be applied in cases where a collation resection or a SJ fusion is plane. The technique modification consists of using two Freer elevators as fluoroscopic markers to guide a single-cut osteotomy to separate the talus and the calcaneus. To achieve that, the deep dissection is carried posterolaterally along the posterior aspect of the SJ and ankle to identify the posterolateral and patent aspect of the SJ posterior facet. The first Freer elevator is inserted into the joint under direct visualization. The second Freer elevator is positioned under the talar neck, to ensure that no talar neck bone is resected or osteotomized (Figure 5).

Under fluoroscopic guidance, an oscillating saw was used to perform the osteotomy connecting the two markers. In this specific case, as a severe hindfoot valgus existed and a SJ fusion was planned, once the talus and calcaneus were separated

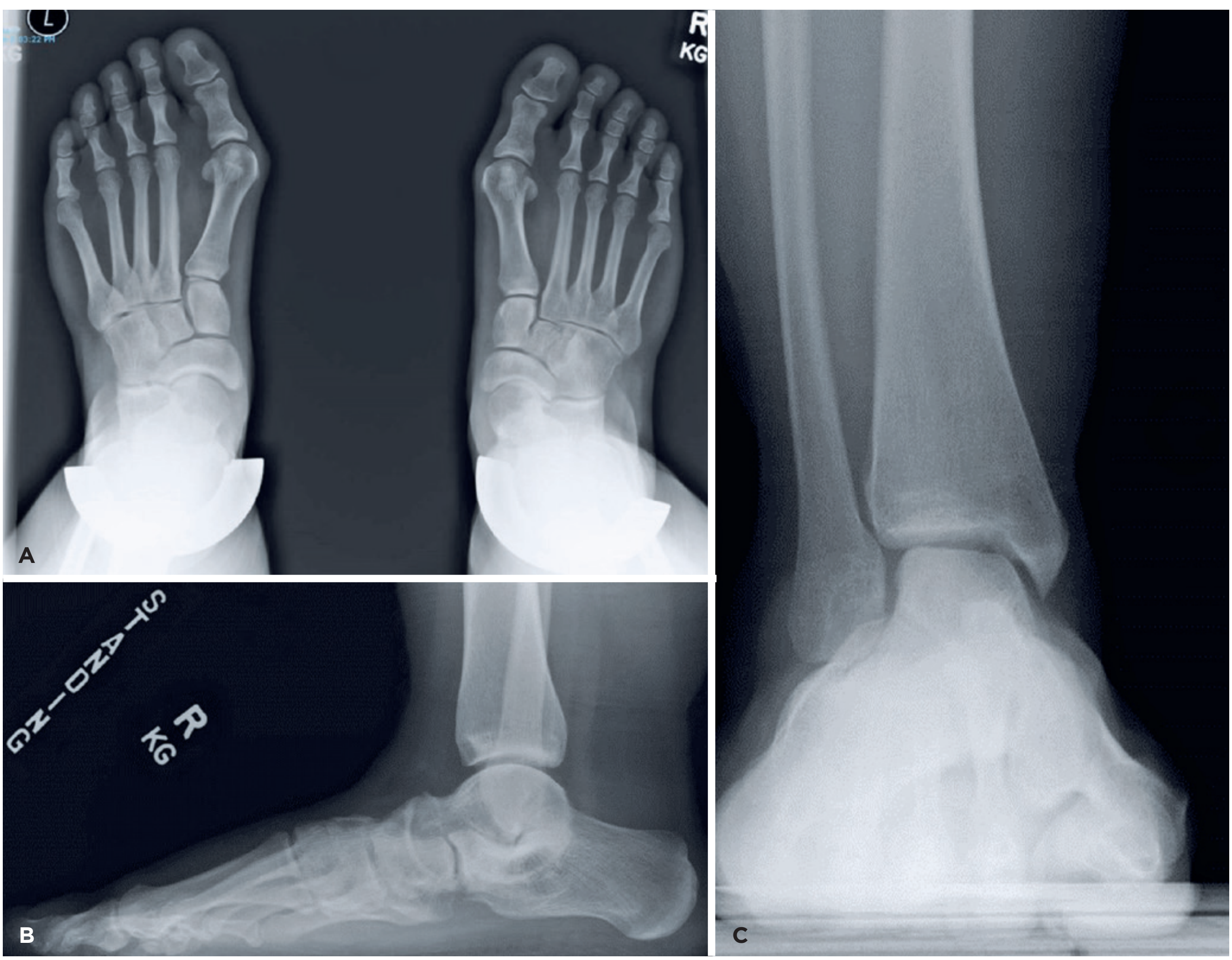

Figure 2. (A) AP bilateral foot radiographs and (B) lateral view of the right foot demonstrating severe flatfoot, forefoot abduction, dysplastic talar head/neck, and indirect signs of tarsal coalition (C-sign and dorsal talar beak). (C) AP view of the right ankle demonstrating mild valgus talar tilt.

Figure 3. (A) Weightbearing CT (sagittal view). Talocalcaneal and calcaneonavicular (residual) coalitions. (B) Weightbearing CT (coronal view). Subtalar joint middle facet coalition. (C) Weightbearing CT (coronal view). Severe hindfoot valgus (approximately 45°). (D) Weightbearing CT (axial view). Residual calcaneonavicular.

Figure 4. (A) Posterior, (B) medial, and (C) anterior weightbearing CT 3D reconstructions of patient's foot and ankle surface anatomy, demonstrating severe hindfoot valgus and flatfoot. (D, E, and F) Weightbearing CT 3D bony reconstruction showing extensive SJ middle (MF) and posterior facet (PF) coalitions, as well as the residual plantar calcaneonavicular coalition (CN).

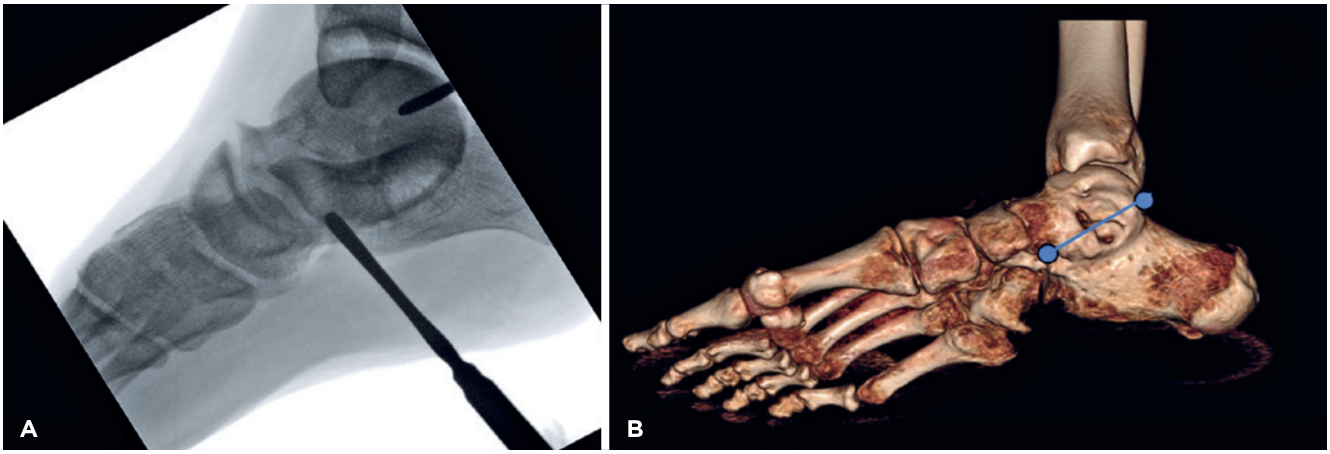

Figure 5. Technical tip. (A) Two Freer elevators are inserted under direct visualization to guide the orientation of the osteotomy: one in the posterolateral patent aspect of the posterior facet of the subtalar joint and one underneath the talar neck. (B) 3D Weightbearing CT bony reconstruction showing the dots representing the tip of the Freer elevators and a straight line connecting the dots, following a very similar path when considering a patent posterior facet.

by the first osteotomy, an additional osteotomy line was then performed in the calcaneus to resect a medial wedge of bone aiming to correct the valgus deformity. In cases where the posterior facet would be preserved and an isolated coalition would be performed, this second osteotomy line and wedge resection would not be performed. After removing the wedge and being able to correct the valgus deformity to some extent, the residual cartilage on the talar SJ facets was resected with curettes and osteotomes, and the extra bone on the medial surfaces of the talus and calcaneus, composing the bulky aspect of the talocalcaneal coalition, was resected with the oscillating saw and sharp osteotomes.

During a trial for a bone-block arthrodesis with a lateral wedged allograft (inserted from the same medial approach), no adequate correction was achieved secondary to residual stiffness for mobilization of the calcaneus. At that point, the osteotomy line created previously was extended distally in the calcaneus side aiming to separate the residual connection between the calcaneus and the navicular bone, aiming for the plantar aspect of the anterior process of the calcaneus, and avoiding injury to the calcaneocuboid joint. Following this step, adequate mobilization of the calcaneus was possible, and correction of the valgus deformity was achieved with medial displacement of the calcaneus and a lateral-based allograft bone-block trial wedge (12mm lateral base height) (Figure 6).

Clinical evaluation (with the heel centered underneath the leg from a posterior view and the leg elevated) and fluoroscopic assessment demonstrated adequate correction of the deformity and apposition of the trial bone block with the calcaneal and talar surfaces. The trial was removed and both osseous surfaces were prepared with multiple drill holes to stimulate healing, using a 1.9-mm drill bit. The wedge-shaped allograft was soaked in the bone marrow aspirate for 5 minutes and then inserted into the fusion site. Additional morselized cancellous bone allograft with demineralized bone matrix and viable cells (with osteoconductive, osteoinductive, and osteogenic potential) was also inserted in between the bone block and calcaneal and talar surfaces (Bonus Triad®, Zimmer-Biomet®). After adequate deformity correction under clinical and fluoroscopic guidance, two slightly divergent guidewires for 5.5-mm cannulated screws were inserted. Adequate deformity correction and positioning of the wires was confirmed, followed by insertion of the headed screws, one of them partially threaded (compression) and the second one fully threaded (position). Adequate compression between bone block and bone surfaces was noted under direct visualization, as was the stability of the construct. An additional amount of the same morselized cancellous bone graft was inserted in the sinus tarsi and around the bone block.

With the hindfoot corrected into neutral alignment, attention was turned to the forefoot. Palpation of the heads of the first and fifth metatarsals demonstrated residual fixed supination of the forefoot. We then proceeded with a Cotton osteotomy to reestablish the foot tripod and protect the fusion site and the ankle from a valgus thrust. A 6-mm trial wedge was inserted and was noted to correct the deformity. The trial was removed, and a 6-mm Cotton wedge allograft, soaked in bone marrow aspirate, was inserted into the osteotomy site. Insertion of the allograft provided adequate osteotomy stability and resulted in the correction of forefoot supination, bringing the heads of the first and lesser metatarsals to a more harmonic plantigrade position.

The patient was released with a non-weight–bearing splint. This was replaced with a boot at the 14-day visit, while the non-weight bearing regime gains momentum. During this period, physical therapy was introduced, and ankle range of motion exercises were slowly initiated. By the 7th week, progressive bearing was initiated, and the boot was removed by the 12th week. A good short-term alignment correction and functional result were achieved (Figure 7).

During evaluation, this study received approval from the Institutional Review Board and both patient and family provided written informed consent for participation.

Discussion

Tarsal coalitions are found in less than 1% of the population[17]. Though it is not an extremely common condition, its management remains challenging. The TCC in this case was drastic, involving a large fusion between the two bones. Presence of an adjunctive CNC and a severe hindfoot valgus and

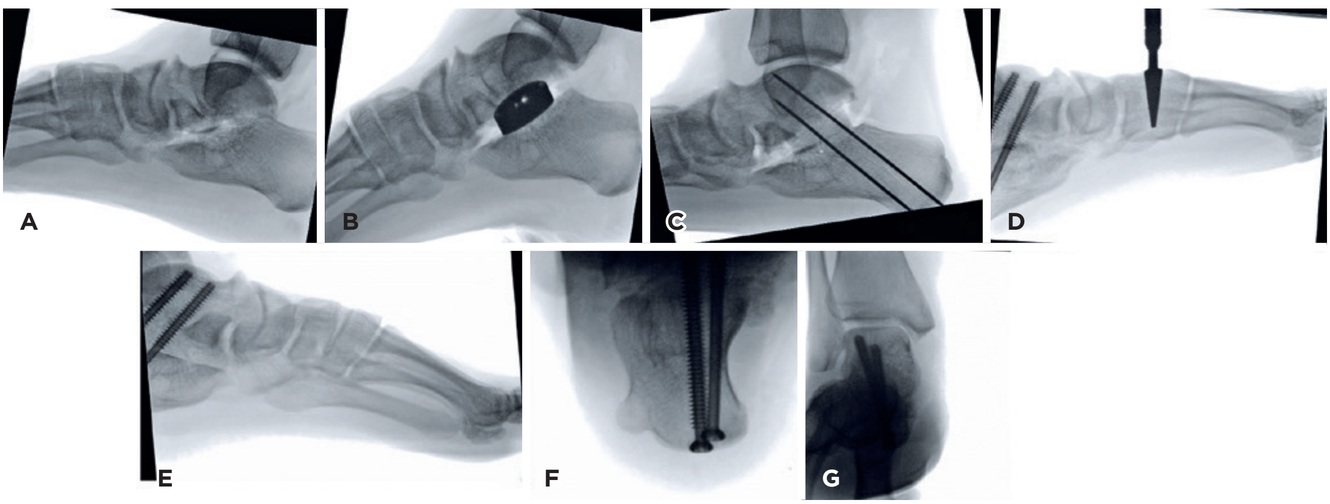

Figure 6. (A) The sagittal saw was used to connect the dots marked by the Freer elevators and, later, the osteotomy line in the calcaneus was extended distally to the plantar aspect of the calcaneocuboid joint to free up the residual calcaneonavicular coalition. (B) Fluoroscopic view. The bone block (12-mm lateral-based trial wedge) is inserted, and its alignment checked. (C) Fluoroscopic view of the bone block allograft in place and secured with two guidewires for 5.5-mm cannulated screws. (D) Fluoroscopic view of the 6-mm trial wedge for Cotton osteotomy correcting the residual forefoot supination. (E) Final lateral fluoroscopic view after insertion of the Cotton osteotomy wedge allograft. (F and G) Final fluoroscopic calcaneal axial and anterior ankle views demonstrating adequate hardware positioning.

Figure 7. (A and B) Postoperative non-weightbearing radiographs demonstrating the correction achieved on lateral and hindfoot alignment views, with adequate apposition of the bone-block arthrodesis and positioning of the hardware, as well as significant correction of the hindfoot and forefoot deformities.

residual forefoot supination, although not unprecedented, portended a complex scenario[4,18,19].

Tarsal coalitions are commonly identified in pediatric patients. Although the coalition is already present at birth, negative effects are not normally observed until later growth stages. Pain during physical activity is the main symptom, with recurrent ankle sprain sometimes arising as another. Approximately 90% of tarsal coalitions are either TCC or CNC[1].

Surgery is an expected denouement to these patients, as non-operative treatment usually presents a certain fragility in maintaining a pain-free environment[20]. Coalition resection is a well-established technique, often employed alone, especially in patients with small coalitions, focal pain/tenderness, and absence of associated deformities[21,22]. Removal of the correct amount of bone without harming good cartilage or neighboring structures is vital to the procedure success. This study presents a technical tip for middle TCC resection using landmarks easily identifiable under direct visualization that can also be used as fluoroscopic landmarks for a safe, rapid, and reliable separation of talus and calcaneus, allowing quicker access to the residual SJ posterior facet.

A subtalar arthrodesis is usually anticipated in severe cases, when more than half of the joint is affected and arthritic changes may be found, as well as in recurrences. It may be also the first line of treatment, as advocated by some authors who believe this is a more durable strategy[23,24]. In situ fusions are normally implemented, but vast deformities associated with dysplastic anatomical changes through the bones require hindfoot alignment correction and a bone-block arthrodesis[25]. This is accomplished in order to regain alignment and talar/hindfoot height, measures that may be lost due to the disease or its withdrawal. Indeed, this was the proposed tactic in this case, which required a medial wedge resection and insertion of an additional lateral-based bone wedge graft for adequate correction of the severe hindfoot valgus. In addition, the forefoot supination and medial column insufficiency was addressed by a medial cuneiform plantarflexion osteotomy (Cotton), reestablishing the foot tripod, correcting the forefoot supination and protecting the ankle joint, that already demonstrated mild valgus talar tilting preoperatively. Although largely performed in the flatfoot environment, the use of bone-block arthrodesis in the tarsal coalition patients remains anecdotal.

In summary, as nonsurgical measures had been exhausted, a prior attempt at surgical calcaneonavicular coalition had been unsuccessful, and pain was persistent, a comprehensive approach to addressing and treating the patient's severe hindfoot valgus, rigid flatfoot, and exceptional tarsal coalitions was employed. This approach involved a modification of surgical technique to expedite intraoperative resection time of the talocalcaneal coalition using two Freer elevators as fluoroscopic landmarks, positioned in the posterolateral aspect of the patent posterior facet of the subtalar joint and underneath the talar neck, allowing a single saw cut to separate the talus and calcaneus and providing access to the subtalar joint. This specific patient needed additional medial wedge resection and lateral wedge bone-block arthrodesis for adequate correction of severe hindfoot valgus, as well as a Cotton osteotomy to correct forefoot supination and reestablish the foot tripod. We would recommend this technical tip/technique modification for resection of TCC in an accelerated fashion intraoperatively.

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Professor Roberto Attilio Lima Santin (1938-2020)

Professor Roberto Attilio Lima Santin passed away peacefully on the morning of July 13, 2020. Born in the countryside of the state of Sao Paulo, he graduated from University of Sao Paulo at Ribeirao Preto. He entered residency in orthopedic surgery in the early 1960s at Santa Casa de Misericordia de Sao Paulo, where he later became a staff member. Prof. Santin was appointed chief of the Foot and Ankle Group on two different occasions. He was also president of several professional societies, such as the Brazilian Society of Orthopedics and Traumatology (SBOT), Paulista Association of Orthopedics and Traumatology, Brazilian Society of Orthopedic Trauma, and Brazilian Society of Limb Lengthening and Reconstruction (ASAMI), and was known for his ethical and peaceful attitude.

Prof. Santin's pioneering and consistent support for a single Latin American scientific journal for foot and ankle surgery led to its creation. He constantly sought opportunities for learning and teaching and found special joy in sharing his wide knowledge. Although he had a preference for foot and ankle surgery, his practice involved all areas of orthopedic surgery. His work combined simplicity in handling unique situations, devotion to helping those in need, elegance while performing operations, and cordiality in coexisting with different personalities. The remarkable characteristics of this beloved master have earned him wide recognition and admiration in the medical community. His ideas, advice, and his standing as physician and professor will always be remembered, and he will be dearly missed by those who had the honor and pleasure of his company.

May God bless and comfort his family and friends in this time of grief. Rest in peace beloved teacher.

MARCO TÚLIO COSTA

CHIEF OF THE FOOT AND ANKLE GROUP OF SANTA CASA DE MISERICORDIA SAO PAULO, SÃO PAULO, SP, BRAZIL

MARIA FERNANDA SILBER CAFFARO

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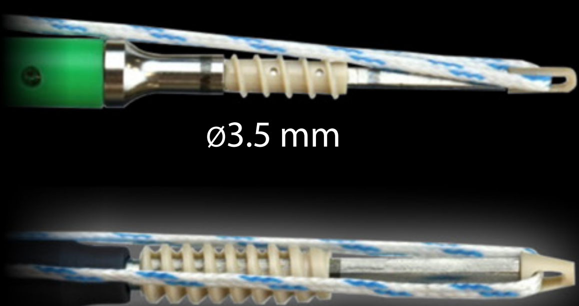

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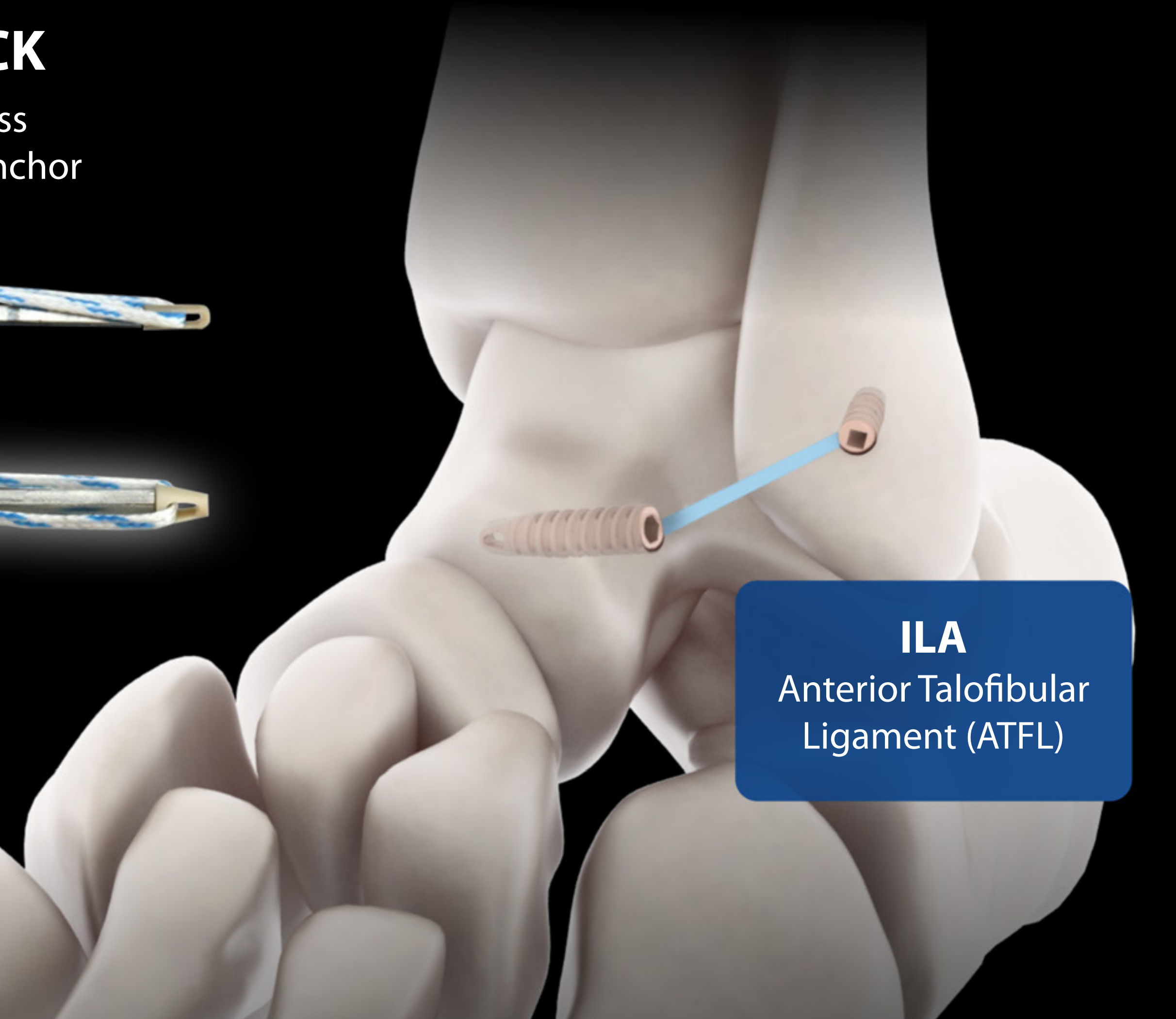

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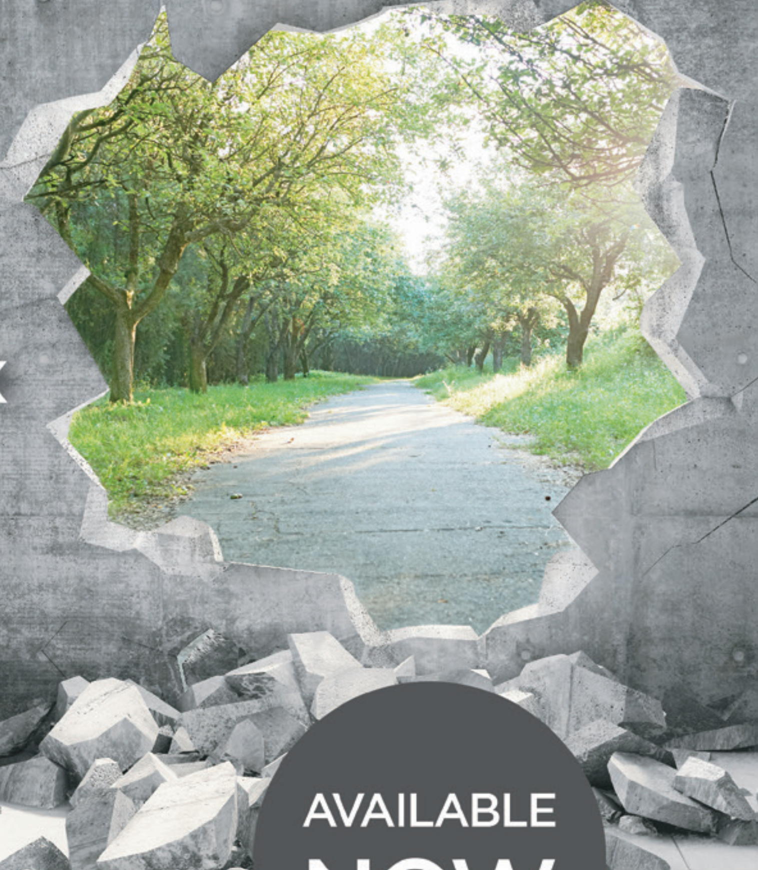

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CASE STUDY 18 | Dorsal Diabetic Foot Ulcer

Patient: 57 year-old male with diabetic foot ulcer

Past medical history:

- Acute abscess with seropurulent exudate on the dorsal foot

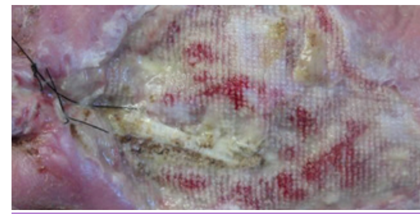
Previous Treatment:

- Incision and drainage of the abscess
- Systemic antibiotics for 2 weeks
- Negative pressure wound therapy (NPWT) with cellular tissue based produ for 2 weeks
- CPT continued for another week post discontinuance of NPWT

Wound Treatment:

- Endoform dermal template, Restore contact layer FLEX,
- Hydrofera Blue classic foam, secured with stretch gauze.
- Unna boot applied. Dressings changed every 72 hours

One week post cellular tissue based product. CPT appears to be incorporating well.



Three weeks later, tendon is exposed. No signs of infection. CPT appears to not be incorporating well.

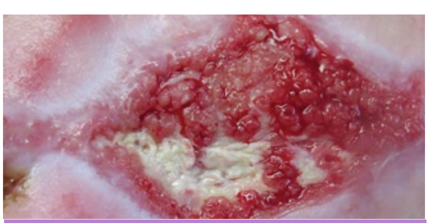
Week 0:

Endoform® dermal template added to treatment.

Endoform® dermal template applied over the remaining CPT, covered with Hydrofera Blue classic foam. Hydrofera Blue classic foam changed and **Endoform**® dermal template applied every 72 hours.

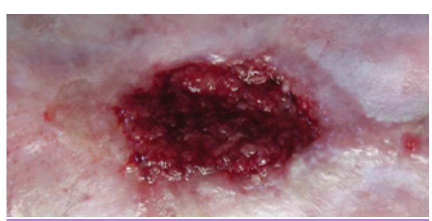
Week 4:

Wound decreased in size, wound bed has granulation tissue with tendon exposed. Wound edges are smooth and flattened with epithelial cells. Remnants of **Endoform**® dermal template (clear to light yellowish film) is observed in the wound bed on dressing change. **Endoform**® dermal template added to the wound and continued with same wound treatment.



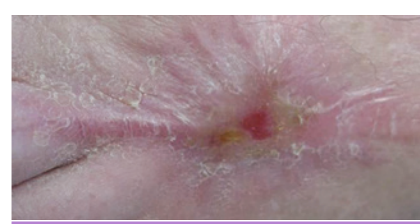
Week 6:

Wound size continues to decrease. Red beefy granulation growing over the tendon.



Week 10:

Tendon completely covered and wound size significantly reduced.



Week 17:

Re-epithelialized.

Case provided by:

Eric Lullove, DPM CWS FACCWS, Medical Director, West Boca Center for Wound Healing, Boca Raton, Florida.

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