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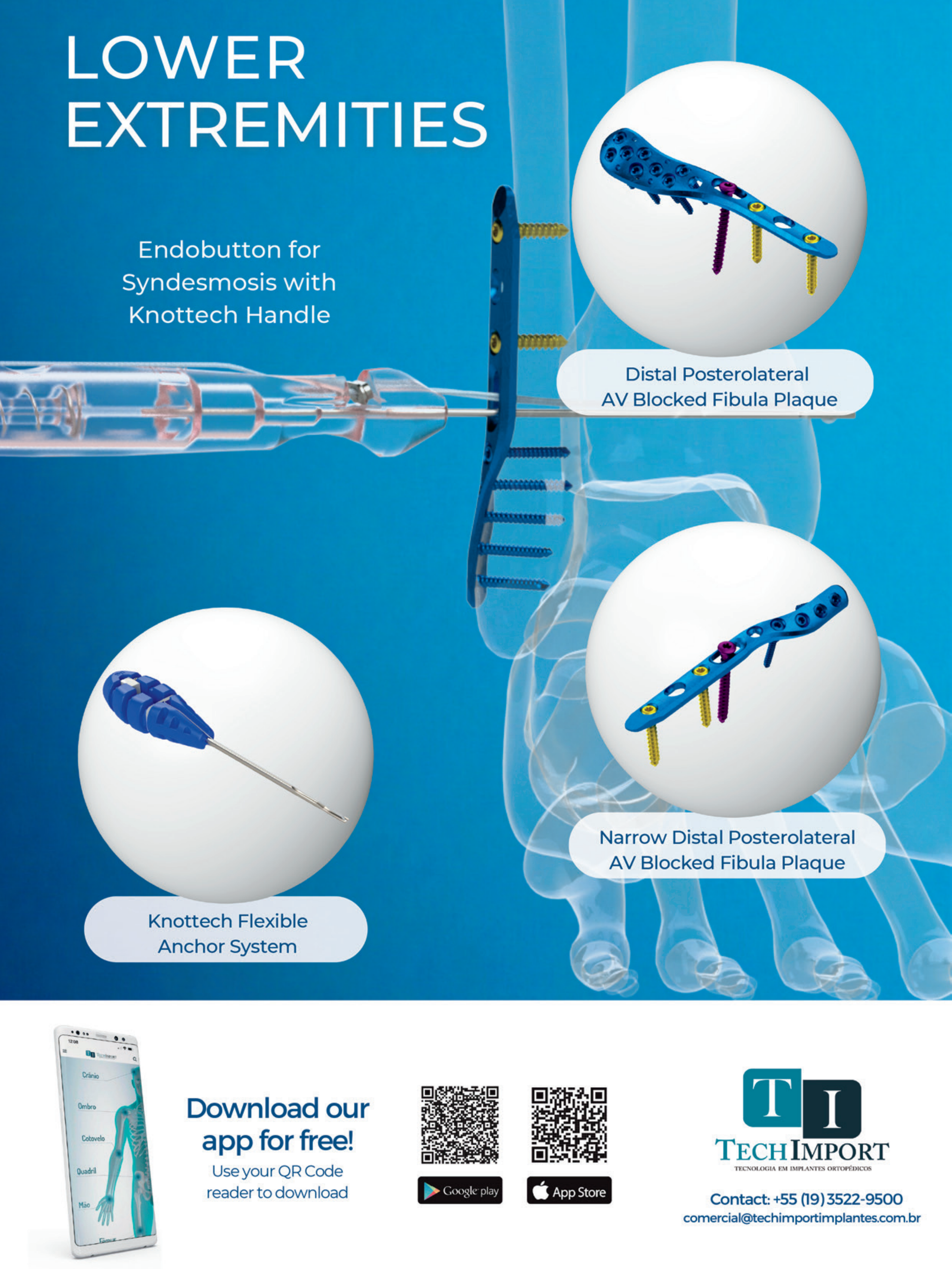
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Editorial

JOURNAL OF THE Foot & Ankle JFA

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The Best of Both Worlds

The minimal invasive surgery in Foot and Ankle is here to stay and its growth and strength is undeniable.

During the 90s in the American continent, forefoot minimal invasive surgery was dominated by North American Podiatrist, during that time the now called "first generation MIS" for Hallux Valgus wasn´t well accepted by orthopedic foot and ankle surgeons.

It was a controversial topic pointed out as a "blind with no fixation technique" that could not be predicted on its outcome. This was supported because of the lack of scientific studies regarding this MIS bunion´s correction and the fact that there were some publications and oral presentations putting it down because of its detrimental outcomes.

In the 2000s and 2010s the orthopedic world started to look more seriously into this ideology and started to do a formal scientific work and resulted in this ultimate generation percutaneous Hallux Valgus correction with hardware fixation backed up with several papers with clinical and radiological outcomes.

Proof of this is the threefold rise in publications on MIS that arouse from 10,127 in med nineties to 30,362 in 2015.

At the same scenario, percutaneous metatarsal osteotomies that were done in despite of Metatarsophalangeal dislocation, found its contraindication on this new paradigm and must be done in an open fashion to reduce it when doing a percutaneous bunion, giving a place to hybrid surgery.

Also Minimal Invasive Queilectomy for Hallux Rigidus yielded more second procedures than open surgery in some publications favoring this latter technique.

Open surgery has been studied for many years reporting good to excellent outcomes in forefoot, midfoot, hindfoot and ankle. Wound Complications and faster recovery time are the main factors that pulled the indications for some open procedures to be done in a minimal invasive fashion like Achilles Rupture repair, arthroscopic ankle fusion, etc.

But there are open techniques such as the Progressive collapsing foot deformity reconstruction, Cavus varus deformity reconstruction, tibial osteotomy for ankle deformities, tendon transfer for neurological pathologies, triple, or double arthrodesis, etc., that are mostly done with "traditional" surgery because of the power of addressing and fixing the problem that isolated minimal invasive procedures could not. Nevertheless, minimal invasive calcaneal osteotomy, arthroscopic arthrodesis, tendoscopy, arthroereisis, arthroscopic or percutaneous lateral ligament reconstruction are excellent complements for those open surgeries.

Patient demands in cosmetic scars and very early return to more than moderate physical activity sometimes pushes the surgeon to choose a different procedure he or she are comfortable with, and this could jeopardize the results and elevates the complications possibility. The surgeon must decide on learning new techniques in the foot area that have more advantages for the patient benefit.

The Foot and Ankle surgeon should be ready to consider both ways of thinking and being capable of performing either one procedure or sometimes both (hybrid surgery) accordingly to each one's experience and expertise to be able to give the best resolution to mild, moderate or severe cases for the patients with the least risk of complications. It is our responsibility to evolve...

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Original Article

Novel surgical management of tibialis anterior tendinosis using an anchor augment

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2. Department of Orthopaedic Surgery, University of the Witwatersrand, Johannesburg, South Africa.

Abstract

Objective: The objective of this paper was to describe a surgical technique for the management of TA tendinosis: Debridement, repair, and augmentation with a suture anchor without tendon transfer.

Methods: This is a retrospective case series including five patients managed surgically for TA tendinosis. If ≥ 30% of healthy tendon remains after debridement, the tendon is augmented with a suture anchor, with the suture incorporating the healthy tendon as a checkrein. Patient outcomes were assessed using the AOFAS midfoot, VAS Pain, and SEFAS score.

Results: The mean AOFAS improved preoperatively from 37.0 (range 18–51) to 97.6 (range 95–100), the VAS pain score from 8.0 (range 7–9) to 0.8 (range 0–1), and the mean SEFAS score at final follow-up was 43.8 (range 41–48).

Conclusions: Tibialis anterior tendinosis is an uncommon degenerative process. Early diagnosis and appropriate management can prevent tendon rupture. This case series of debridement, repair, and augmentation with a suture anchor showed high patient satisfaction and good clinical outcomes without needing a tendon transfer.

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

Keywords: Tendinopathy; Tendons transfer; Suture techniques.

Introduction

Tibialis anterior (TA) tendinosis is a rare condition often missed or diagnosed late as a tendon rupture, causing significant morbidity to the patient. Literature regarding TA tendinosis is scarce, unlike TA rupture, commonly described dating back to 1905[1-4]. Despite the TA having a well-vascularized posterior surface, an avascular zone exists where the tendon runs under the superior and inferior extensor retinacula. This results in an area with decreased blood flow and an increased risk of rupture, extending up to 1–3 cm from the tendon insertion[5-8].

A failed healing response may occur due to overuse or ongoing mechanical forces on the tendon in the area of poor blood supply. This results in the deposition of a disorganized matrix of hypercellular and hypervascular tissue, weakening the tendon and resulting in pain[9]. The TA is active for 54% of the gait cycle during walking and 73% during running while maintaining the longitudinal arch under load[10,11]. This heavy workload interferes with the normal healing response.

Tibialis anterior tendinosis commonly presents in 50- to 70-year-old overweight females. The most common presenting symptom is burning pain over the dorsal medial midfoot[5,12]. This burning pain is worse at night, affecting their sleep pattern. The increased tension from the foot in equinus at night could be a reason for this pain. Burning night pain is not common for tendinopathies and more associated with neurogenic, infectious, or malignant pathologies. As a result, the physician can misdiagnose this pathology. The authors have found that increased pain over the medial midfoot with

Study performed at the Wilgers MRI Department (Magnetic Resonance Imaging), Pretoria, South Africa.

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the patient's heel walking is diagnostic of TA tendinosis. Point tenderness exists over the TA insertion at the medial cuneiform, often associated with local swelling and edema[12]. Beischer et al.[13] described the tibialis anterior passive stretch (TAPS) test, which has a 90% sensitivity and 95% specificity for diagnosing TA tendinosis. The test is performed by plantarflexing the ankle, everting the hindfoot, and abducting and pronating the midfoot, thereby passively stretching the TA. The test is positive if the patient reports reproduction or increased pain over the TA insertion[5,13].

Ultrasound and magnetic resonance imaging (MRI) are the gold standard for diagnosing TA tendinosis by showing characteristic edematous tendon changes, fluid collections, and features of tendon degeneration (including tears)[13,14].

Untreated TA tendinosis can result in tendon rupture, causing a drop foot gait[13,14]. If TA tendinosis is managed appropriately early, it can decrease the patient morbidity from rupture. Management of TA ruptures and tendinosis reported in the literature often describes augmentation with an extensor hallucis longus (EHL) tendon transfer. Beischer et al. managed severe TA tendinosis with debridement, repair, and augmentation with EHL tendon transfer[13]. Cignetti et al.[12] performed only debridement in mild cases and augmentation with extensor digitorum longus tendon, plantaris tendon, or both in moderate to severe cases. Transferring the EHL comes with inherent risks and comorbidities. The authors prefer to avoid tendon transfers by debriding, repairing, and augmenting the tendon with an anchor.

The objective of this paper is to describe a surgical technique for the management of TA tendinosis: Debridement, repair, and augmentation with a suture anchor without tendon transfer. We also report on the functional outcome of a small case series using this technique.

Methods

This retrospective case series includes five patients managed surgically for TA tendinosis. This case series was approved by the university's Human Research Ethics Committee (M220489). Patients with TA tendinosis are initially given a trial of conservative management for up to 12 weeks, which includes immobilization in a moon boot with a forefoot wedge and avoiding all impact sports to prevent tendon rupture. If a patient has more than 50% tendon damage reported on the initial ultrasound, surgical intervention is recommended due to the increased risk of rupture, but conservative management is also explained so that the patient can make an informed decision. All patients older than 18 who had failed conservative management requiring surgical management were included. There were two males and three females in this case series, with a mean age of 68 (range 62–74).

Clinical assessment, surgical intervention, and follow-up were performed by the surgeon and recorded. Demographic data was recorded, including age, gender, body mass index (BMI), recreational activities, and sport participation. Comorbidities, such as inflammatory arthritis, diabetes, hypertension, gout, HIV, and immune suppressive medications, were also recorded. Diagnostic imaging included weight-bearing foot radiographs, ultrasound and/or MRI. The MRI was assessed by a musculoskeletal trained radiologist.

During surgery, the tendon was assessed macroscopically. The length of the longitudinal tear(s), thickness, and general appearance was recorded. Concomitant surgery and postoperative complications were also recorded.

Patient outcomes were assessed using The American Orthopaedic Foot and Ankle Society (AOFAS) midfoot scale and Visual analog pain scale (VAS) preoperatively and at the final follow-up. Patients completed a self-reported foot and ankle score (SEFAS) at the final follow-up. The mean follow-up was 39.8 (range 6.4–74.2) months.

Surgical technique

Patients were operated under general anesthesia, with a regional nerve block for pain control. A curvilinear incision was made 5 mm lateral to the course of the anterior tibial tendon, extending from the extensor retinaculum to its insertion on the medial cuneiform. The tendon sheath was opened, and all synovitis debrided. The tendon was examined and partially detached from the medial cuneiform so that any osteophytes could be removed using a rongeur (Figure 1). All devitalized tendon tissue was excised. If ≥ 30% of healthy tendon remains, the tendon was repaired using Vicryl 2-0 (Figure 2). The medial cuneiform was then drilled using a 2 mm drill bit to allow marrow elements into the tendon attachment area (Figure 3). A suture anchor was placed into the insertion point on the medial cuneiform. The suture anchor was run up

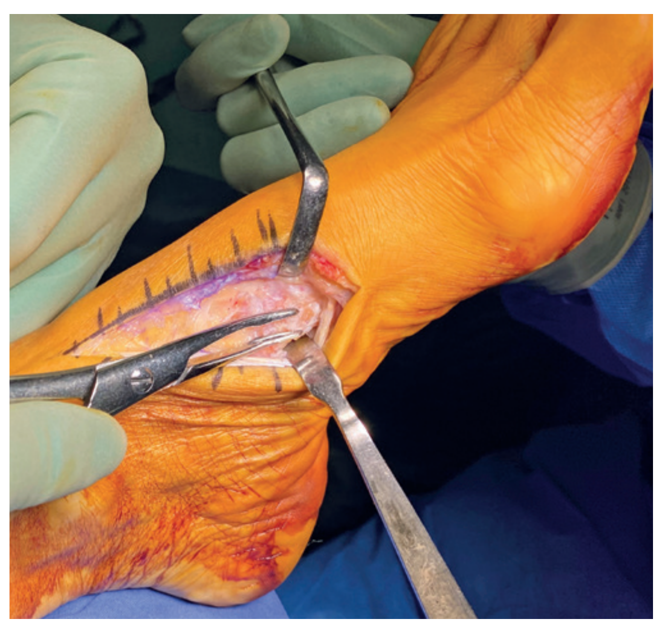

Figure 1. Bone osteophytes were removed from around the insertion site of the tibialis anterior tendon on the medial cuneiform.

the tendon in a whip stitch fashion incorporating at least 2 cm of the normal proximal tendon (Figure 4). The suture anchor was used as a checkrein to protect the damaged portion of the tendon while it heals. The tendon sheath was repaired using Vicryl 3-0 (Figure 5). The wound was closed in layers using Vicryl and Monocryl. The leg was placed in a below-knee plaster cast with the ankle in 10 degrees dorsiflexion.

The patient was instructed to non-weight-bearing in the cast for four weeks. At four weeks, the patient was placed in a moon boot with progressive weight-bearing as tolerated. The patient transitions into supportive shoes at eight weeks. Physiotherapy started at four weeks focusing on edema control, scar management, tendon gliding, and strengthening. The patient was allowed to cycle and swim after six weeks, but no sports were allowed until week 12.

Figure 2. The remaining healthy tibialis anterior tendon was repaired using Vicryl 2-0.

Figure 3. The insertion site on the medial cuneiform was perforated using a 2 mm drill bit to allow marrow elements to aid healing.

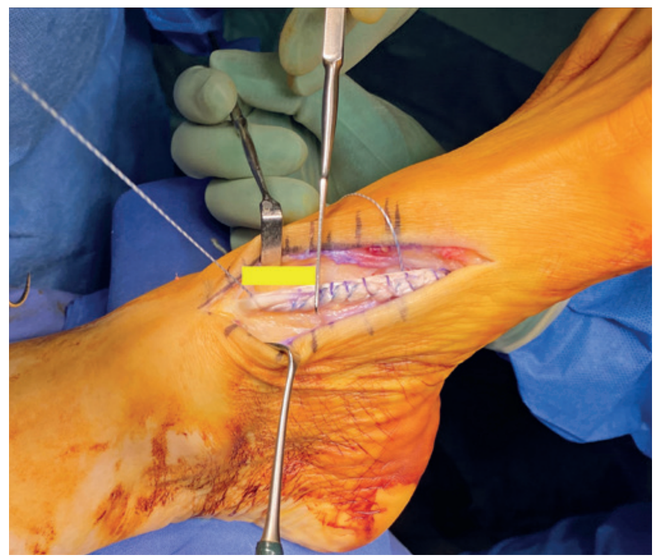

Figure 4. The suture anchor was run up the tendon in a whip stitch fashion incorporating at least 2 cm of the normal proximal tendon (Yellow bar indicates the portion of a normal tendon).

Figure 5. The tendon sheath was repaired using Vicryl 3-0.

Results

The average BMI was 31.8 (range 26–39) kg/m^2, with two being overweight, one obese, and one morbidly obese. None of the patients were smokers. Four of the patients had hypertension, and one suffered from gout. All five patients were physically active, and their recreational activities consisted of walking, cycling, going to the gym, and playing tennis.

All patients presented with a history of pain over the dorsomedial midfoot area, aggravated by impact activities, and present at night. The patient's symptoms were reproduced by asking them to walk on their heels.

All patients had ultrasound examinations reporting inflammation and edema surrounding the TA tendon. There was degeneration and/or a longitudinal tear visible from the insertion of the TA extending up to 40 mm proximally in various degrees of severity in all patients. Two patients had an MRI. Both showed tendinitis over the distal portion of the TA, with degeneration and possible partial tear.

Macroscopically, the pathology ranged from having degenerative changes of the tendon only (in one case) to longitudinal tears from the insertion to between 4 and 6 cm proximally. No complications occurred, and no concomitant surgery was required.

The mean AOFAS preoperatively was 37.0 (range 18–51) and postoperatively 97.6 (range 95–100). The mean VAS pain score improved from 8.0 (range 7–9) to 0.8 (range 0–1). The mean SEFAS score at the final follow-up was 43.8 (range 41–48), with all patients having excellent outcome scores (Table 1). All patients returned to their previous activity level and were satisfied with the result, and would recommend the surgery.

Discussion

Tibialis anterior tendon pathology has infrequently been reported in the literature. The natural history of this pathology is not well known. Coughlin et al.[5] reported that TA ruptures were caused by a traumatic event in patients with comorbidities, such as diabetes mellitus and inflammatory conditions, without a prodromal phase. The authors believe that TA ruptures result from degenerative tendinosis misdiagnosed in its early stages. Bernstein concluded in his paper on the spontaneous rupture of the TA tendon caused due to an abnormal tendon[15]. Kannus and Józsa[16] reported that 97% of tendons had degenerative changes on visual inspection and were structurally abnormal histologically in their review of 891 spontaneously ruptured tendons. Of note, this study included various tendons (including Achilles, biceps, patella, and TA, amongst others).

The cause of tendinosis has been associated with systemic diseases (inflammatory arthropathy, gout, diabetes mellitus), use of immunosuppressive medication, and steroid injections[8,12,17-19]. All five patients in our study group had medical comorbidities, and two were obese, which is also a well-described risk factor[13,14].

Conservative management of TA tendinosis is recommended for three months. Patients are immobilized in a moon boot for the first six weeks, with a forefoot wedge to offload the TA. Physical rehabilitation includes stretching and strengthening. Eccentric exercises also promote new collagen formation and healing[5,14,20,21]. More recent studies suggested treatment modalities include extracorporeal shock wave therapy, platelet-rich plasma, or growth factor injections. However, the effectiveness of these modalities still needs further investigation[5].

The authors feel that if no improvement is found within three months, it is preferable to manage these patients surgically rather than risk the tendon rupturing[12,14]. This study and others showed that prompt diagnosis is important and can lead to more appropriate treatment and negate the need for an EHL transfer[22-24]. The EHL transfer is not innocuous and can have potential complications, including weak hallux extension causing the hallux to catch while walking, and a progressive flexion contracture of the interphalangeal joint requiring a fusion.

Other surgical procedures that have been described for the management of TA tendinosis include decompression, decompressive medial cuneiform exostectomy, and gastrocnemius recession. Decompression of the tendon is limited to the early stages of the disease process before tendon disrepair occurs. De Cock et al.[25] reported excellent results with tendon decompression by releasing the oblique inferomedial band of the inferior extensor retinaculum for cases of distal TA tendinopathy. They consistently reported intraoperative compression and friction on the tendon due to the retinaculum. They highlighted the importance of diagnosing TA tendinosis as this degenerative tendon is at risk of rupturing if left untreated[25]. Gossett et al.[26] presented a case report of bilateral distal TA tendinosis treated successfully with proximal medial gastrocnemius recession only. The antagonizing force of gastrocnemius opposing TA dorsiflexion during the functional arc of ankle motion is decreased with gastrocnemius recession, minimizing tension on the TA tendon. They proposed that gastrocnemius equinus contracture is one of the main driving forces of distal TA tendinosis. As an isolated procedure, this could be limited to early in the disease process but may also be a good adjunct to a reparative procedure if a tight gastrocnemius is

Table 1. Functional and outcome scores

Patient number	VAS preop	VAS postop	SEFAS postop	AOFAS preop	AOFAS postop
1	7	1	43	18	98
2	8	0	48	48	100
3	8	1	43	51	99
4	8	1	41	37	96
5	9	1	44	31	95
Mean	8.0	0.8	43.8	37.0	97.6

present. None of our patients had a positive Silfverskiold test, but it is important to assess for gastrocnemius contractures when managing these patients. Liang et al. equated distal TA tendinosis to insertional Achilles tendinopathy in that a bone prominence may result in frictional damage of the tendon. They had good results with bone resection of the medial aspect of the medial cuneiform and tendon debridement[(21)].

In the management of peroneal tendinosis, if ≥ 50% of normal tendon remains after debridement, a direct repair of the tendon is performed. This 50% cut-off as a guide for when to perform augmentation of the diseased tendon dates back to 1924 from a publication by Meyer[(27)]. Wagner et al.[(28)] recently reported that peroneal tendons with ≥ 33% of healthy tendon are structurally strong enough for a primary repair. We, the authors, believe that EHL transfer for the management of TA tendinosis should be limited to severe cases. We, therefore, perform an EHL transfer when ≤ 30% of healthy tendon is present after debridement. When ≥ 30% of healthy tendon remained, we augmented the direct repair of the tendon by running the anchor suture up along the tendon until 2 cm of normal tendon is included proximally. Including the normal tendon proximally into the anchor augmentation acts as a checkrein, partially offloading the diseased portion of the tendon while it heals and regenerates.

Lemmens et al.[(22)] reported on the management of TA tendinosis in ten feet with debridement, direct repair, and anchor reattachment of the tendon onto the medial cuneiform after failed conservative treatment. Only one of the ten TA tendons had a longitudinal tear, therefore, all tendons were mostly intact. Beischer et al.[(13)] and Grundy et al.[(14)] debrided TA tendinosis, and if ≥ 50% of healthy tendon remained, repaired the tendon and reattached the tendon to the cuneiform with an anchor. None of these authors extended the suture proximally into the normal tendon, as was done in our series. If ≤ 50% of healthy tendon remained, they augmented it with an EHL transfer. In the Grundy et al.[(14)] case series, six patients were treated with EHL transfer and six with direct repair. Fifty percent of patients treated with the EHL transfer complained of a symptomatic hallux interphalangeal joint with extensor lag that caused catching the hallux when walking barefoot. One of the six cases treated with debridement, repair, and suture anchor reattachment presented with delayed spontaneous rupture three months postoperatively after they did an EHL transfer. This led the authors to recommend more aggressive reconstruction and use of the EHL augmentation on a routine basis. We believe that incorporating the suture anchor into the normal tendon reduces the risk of rupture[(14)].

In our small case series, good outcomes have been shown with debridement and augmentation of the TA tendon with a suture anchor incorporating the proximal portion of the healthy tendon. At the final follow-up, patients had a mean AOFAS of 97.6, VAS of 0.8, and SEFAS of 43.8. No complications were related to the surgery, and no additional surgery was performed. This small retrospective case series will hopefully stimulate larger randomized studies.

Conclusion

TA tendinosis is an uncommon degenerative process that the physician needs to pay attention to in older overweight patients complaining of dorsomedial midfoot pain. Early diagnosis and appropriate management can prevent tendon rupture. This small case series of debridement, surgical repair, and augmentation with a suture anchor showed high patient satisfaction and good clinical outcomes without needing a tendon transfer.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JN *(https://orcid.org/0000-0003-1448-4272) and NPS *(https://orcid.org/0000-0002-5566-7588) Wrote the article, interpreted the results of the study, participated in the review process and approved the final version; PNFF *(https://orcid.org/0000-0003-4639-0326) Conceived and planned the activities that led to the paper, interpreted the results achieved and approved the final version. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Is there any weakness in sports performance in volleyball athletes regarding the correlation between foot posture index and lower limb functional hopping performance?

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Abstract

Objective: The aim of the study was to investigate the relationship between 1RM calf raise, countermovement jump (CMJ), and functional hop performance with foot posture index (FPI).

Methods: Twenty-six volleyball athletes were evaluated in this study. Foot posture index was evaluated with six-item criteria; talar head palpation, curves above and below the malleoli, calcaneus inversion/eversion, talonavicular congruence, medial longitudinal arch high, and forefoot abduction/adduction. Single hop, triple hop, crossover hop for distances, medial side triple hop, 90° medial rotation hop, single-leg vertical jump, 6m. timed hop, 1RM calf raise, and CMJ were measured in this study.

Results: All measurements were tested on both right and left side. Significant differences were found in single hop ($p = 0.016$), triple hop ($p = 0.005$), medial side triple hop ($p = 0.001$), medial rotation hop ($p = 0.020$) in single leg vertical jump, and FPI for right and left sides ($p < 0.001$, $p < 0.005$). There were significant differences when comparing the limb symmetry indexes (LSI%) calculated from hop tests. When the correlations between FPI and hop tests were found significant, correlation and no significant correlations were found between left side and FPI.

Conclusion: This study has shown that young female volleyball players may produce low hop performances due to the asymmetric structure relationship FPI scores.

Level of Evidence IV; Therapeutics Studies; Cases Series.

Keywords: Athletes; Foot; Exercise test; Posture; Volleyball.

Introduction

Many neuromuscular dysfunctions are characterized by muscle weakness; in some cases, weakness is symmetrical, others asymmetrical[1]. Specifically, lower limb muscle injury implicated feet with improper foot posture and muscle weakness, such as pes planus and pes cavus. Furthermore, a systematic review showed lower limb muscle pathologies had reported significant relationships between foot posture, medial tibial stress syndrome, patellofemoral joint pain, and patellar tendinopathy[2]. However, the lower limb muscle mechanism linking foot posture injury remains unclear on movement muscle dynamometry, including various hopping tests, jumps tests, and lower leg strength performance[3,4].

Lower limb strength training and heavy stress conditions can cause improper foot posture, plantar fasciitis pain, lowered medial longitudinal arch, and plantar region strain; it is lower limb muscle performance related to foot posture indexes (FPI) in all athletes[5,6]. Variable foot deviation and rotation on functional hopping performances may indicate strength losses and changes in foot posture accompanying both plantar fascia strain and ankle injury in both feet[3,4].

Study performed at the Ondokuz Mayıs University.

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Although the strength function of the lower limb helps absorb more foot force during the propulsion phases[6,7], the torque required for the subtalar joints depends on the medial longitudinal arch and dynamic plantar pressure postural control[8]. A study reported that foot posture is organized by the absorptive rotation of lower limb muscle performance for spring energy return in the foot in intrinsic plantar activation[9]. Indeed, active muscle-tendon resistance to the pressing workout of the lower limb muscle and absorbed muscle activity creates strain to flexion-extension workouts for foot postural gain[8]. Furthermore, functional hopping performance and lower limb strength activities are typically 45°/90°/140° knee-ankle longitudinal postural position, and plantar muscle activation in ankle flexion-extension generates strain from ground reaction force in, for example, single-leg hop test (SLHT)[4,10-12]. During SLHT performances, strength loads affecting a single lower leg may change foot pressure. Investigating the lower limb muscle performance in the athletic population may be essential for evaluating FPI during the ground reaction phases[13]. Therefore, functional ankle stability and intrinsic plantar strength may be related to FPI for performance differences[14,15]. One study Lopezosa-Reca et al.[3] reported basketball players and showed altered FPI. However, more foot supinated is associated with ankle-patella injury according to the player's position.

Foot posture index was produced in response to foot position variety and foot injury model of clinical settings and were created from six-item criteria for a quick, easy, and reliable method. Although evaluation of FPI for rehabilitation is common, it has not been associated with time to injury during athletic performances in athletes[3,16]. Current literature has reported FPI related to foot plantar muscle changes, injuries, and muscle-tendon strain in athletes[17,18]. However, previous studies have not focused on differences in foot posture for lower limb calf raise strength performance, jump tests, and functional hop performance during the stay until active contraction to maintain foot posture[16,17]. Foot posture index evaluation is internal validity and laboratory-based measurement in a standing position for lower limb performance applied in athletes[19]. Moreover, FPI includes multivariate performances in all workout stages within multiple techniques and references rearfoot and forefoot evaluation items[18,20]. This study reported the relationship between the lower limb muscle-tendon complex and functional performance on the FPI.

The main aim of this study was to reveal the correlations between foot pressure, strain, and intrinsic activations with functional hop performance, 1 RM calf raise, and CMJ in young volleyball players.

Our hypothesis is that multiple-direction leg mechanical workouts may show different postural deformity variability, i.e., pronation and supination weakness effects. Thus, FPI was investigated in the volleyball athlete's lower limb muscle mechanical workout variability, and foot deformities may be expected in the strength performing.

Methods

Subject

The study was obtained from Ondokuz Mayıs University Clinical Research Ethics Committee under the number 2022-69.

Twenty-six female volleyball athletes were recruited for this study, age 15.62 ± 1.18 years, height 172.34 ± 6.11 cm, and weight 62.19 ± 5.6 kg. In addition, calf raise 1RM 38.55 ± 9.15 kg and CMJ 23.07 ± 5.28 cm were measured for all athletes. The following inclusion criteria were at least three years of league experience. The exclusion criteria were serious femur, patella, knee, and ankle injuries within one week. The written consent form was signed by all athletes included in the study.

Experimental approach to the problem

This study reported the multivariate foot pressure or types for muscle-tendon strengthening and postural foot deformities[21]. Foot posture indexes such as pressure, strain, and deformity can occur during mechanical workouts of muscle weakness performances. In this direction, our research includes six functional hop performances; single hop (SH) and triple hop (TH), crossover hop (CH) for distance, medial side triple hop test (MSTH), 90° medial rotation hop (MRH), single leg vertical jump (SLVJ), 6m. timed hop (6mTH), countermovement jump (CMJ), and 1 RM calf raise were designed to examine the relationship within FPI criteria. The subjects visited the laboratory one time, including a 10-minute warm-up. The athlete's height, weight, and body mass index (BMI) were measured, and detailed information was given. The SLHT, FPI, CMJ, and 1 RM calf raise measurements were applied in sports training condition. Between the applications, the total training sections were performed in one hour, including all 26 female volleyball players.

Procedures

Foot posture index (FPI) measurement

The FPI is based on rearfoot and barefoot evaluation[22]. Previous studies showed an intraclass correlation coefficient (0.90–0.97) similar to other studies[21]. Foot posture index items were included in six criteria: 1) talar bone arch changes, 2) supra and infra lateral malleolus curvatures, 3) inversion and eversion position of in anterior plane of the heels, 4) talonavicular joint bulging, 5) medial arch longitudinal unity and 6) abduction and adduction of the forefoot on rearfoot. Foot posture index was resolved in the standing digital photography method in 50 cm. Between final scores -2 and +2 are within standard limitation. Supination predominance (+1 to +2) and pronation predominance (-1 to -2). The result scores were obtained in all categories. Results evaluated from supination or pronation difference angle of the longitudinal alignment leg in vertical are (+1) and (-1), standard deviation (+1), potential abnormal (+2), and other results are pathological[23] (Figure 1).

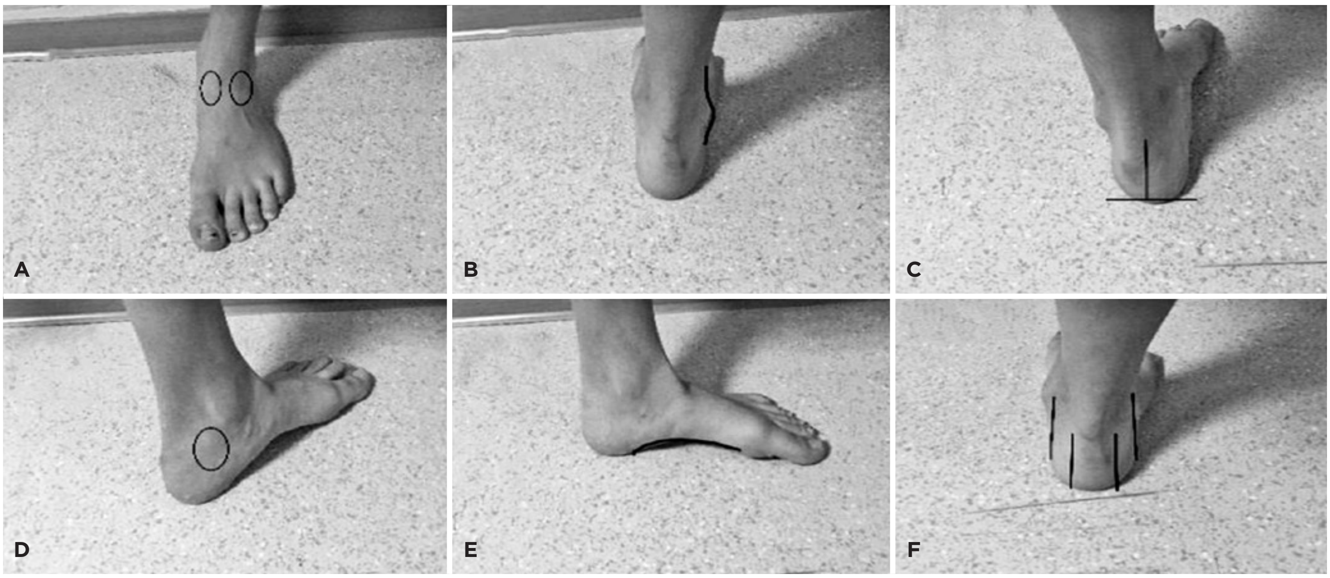

Figure 1. FPI six item criteria evaluations: A) Talar head palpation, B) Curves above and below the malleoli, C) Calcaneus inversion/eversion, D) Talanovicular congruence, E) Medial longitudinal arch high, F) Forefoot abduction/adduction.

1RM calf raise

Among the different lower limb calf muscle-tendon unit techniques, the calf raises muscle weakness strength test allows plantar flexors strength, strain, and pressure to increase muscle energy through absorption(24). Calf raise workouts were conducted on a seated ergometer against maximum strength between upward and downward techniques (ProWellness, LX-50A, TR). Posture techniques were adjusted from 90° knee postural position during strength repetition. All calf raise workouts were conducted 10 min warm-up, then 1RM was performed in three stages 50% of 1RM (1 and 2 rep), 80% of 1RM (1 and 3 rep), and 100% of 1RM (1 and 2 rep) with 10 s and 30 s of rest(25).

Single-leg vertical jump (SLVJ)

Dominant and non-dominant SLVJ performance is countermovement jump performance 180° evaluation of the unilateral lower extremity performance. Single-leg vertical jumps were performed with an infrared jumping device (Inf, SW03, Photocell Stopwatch, TR). The subject was asked to perform a single-leg right or left vertical countermovement jump from a stable upright position. The hip and knee of the nonincluded leg were kept at the mid-shaft height at a 90° flexion postural position. Arm swing was not limited during the jump(26).

Countermovement of jump (CMJ) without arm swing

The CMJ starts upright, performing the first downward movement by bending the knees and hands on the hips with the highest possible jump without the arms swinging. All subjects conducted 2-3 attempts on the jump measuring device and rested for 10 seconds between jumps (Inf, SW03, Photocell Stopwatch, TR). During the CMJ, the high was individual selection(27).

The functional hop performances

The starting line is a 0.3 m strip, and a 6 m long 15 cm wide strip was drawn perpendicularly from the middle of the two strips. The participants were informed how to perform the SH test. In the SH test, subjects started on one foot at the marked starting line and, when ready, jumped as far as participants could to land horizontally on the same leg. The successful attempt was detected between the resulting baseline and the participant's heel level and recorded in cm. In the TH test, they stood on one leg at the starting line and, when ready, jumped forward three times horizontally without stopping. The length between the starting line and the heel where they fell was recorded in cm. Before the tests, they were given three trials for each test. After the trials, they performed three main tests, and the successful performance in the test was determined to land on one leg with complete stability and stay for three seconds. Subjects rested for 30 seconds between trials. The use of arms movement during the test was allowed, and there were no restrictions(4). The subjects then stood on one leg at the starting line and finished in the fastest possible time the 6mTH performance started from the line and ended when the heel touched the first place where it crossed the finished line. All subjects were tested three times, and a 2 min rest interval was given for rest between each test. The test was recorded in seconds with a standard stopwatch. The best time from the three tests was recorded in seconds. The use of arms was allowed, and there were no restrictions[28]. The CH test was three forward jumps and the distance was recorded in cm. The first jump started diagonally opposite the foot used and continued laterally to the side of the fall. For each test, the subjects repeated three times. After the trials, there were three main tests. The successfull performance in the test was determined toland on the leg with complete stability and stay for three seconds. The best jump distance was recorded in cm. Subjects rested for 30 seconds between trials[29]. For the MHST test, the medial aspect of the participant's feet to be jumped was brought to a perpendicular position to the jumping direction. Participants were asked to perform three consecutive jumps on the same foot. The distance of three consecutive jumps was measured as the distance between the medial part of the foot in the starting position and the medial part of the foot in the finishing position[12]. The MRH test ensured that the medial side of the participant's feet to be jumped was perpendicular to the jumping direction. Participants were allowed to perform a perpendicular angle medial rotation with a single jump and complete the jump parallel to the jump direction. The foot's position at the start of the jump was maintained, and at the end of the jump, the foot's position was allowed to deviate by no more than 10° from the jump direction. Jumps other than these cases were considered invalid. Jumping distance was measured between the medial part of the foot in the starting position and the toes in the finishing position[12].

Statistical Analyses

All analyses were performed using SPSS 22.0 for Windows (SPSS Inc., Chicago, Illinois, US). Descriptive data were presented as mean, standard deviation, median, minimum, and maximum. The shapiro-Wilk test was used to evaluate normal distribution. The paired sample t-test was used to compare sets of dependent variables and evaluated differences from the lower limb symmetry index. The Spearman rank test was used for correlations between variables. A two-sided p-value less than $p < 0.05$ was considered statistically significant.

Results

Comparisons of the functional hop performance on the right and left sides are presented in Figure 2. Significances were found in SH ($p = 0.016$), TH ($p = 0.005$), MSTH ($p < 0.001$), and MRH ($p = 0.020$) on the right side, but no significance was found in the CH, SLVJ, and 6mTH tests ($p > 0.05$).

When the FPI scores on the right and left sides were evaluated statistically, significance was found in calcaneus inversion/eversion ($p = 0.040$), medial longitudinal arch high ($p < 0.001$), and forefoot abduction/adduction ($p < 0.001$), but no significance was found in talar head papation, curves above and below malleoli, talanovicular congruence, and total FPI scores ($p > 0.05$) (Figure 3).

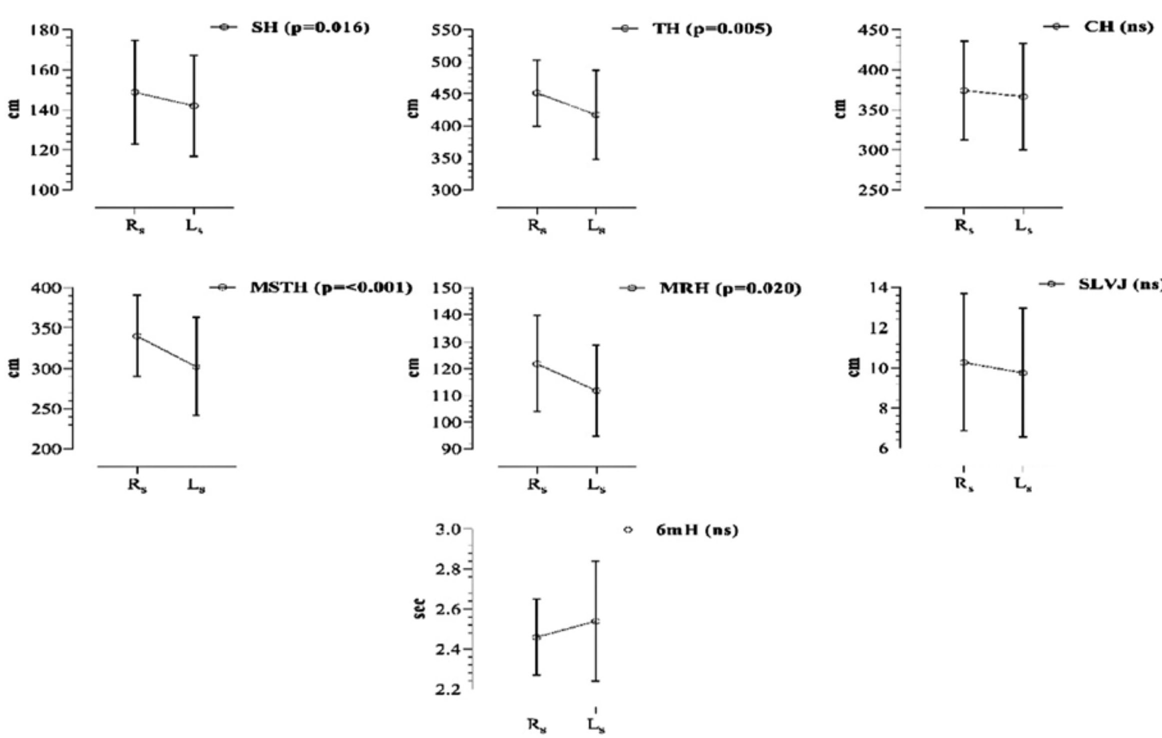

Figure 2. Results of functional hop performances of young female volleyball athletes.

Rs: Right-side; Ls: Left-side; SH: single-leg hop for distance; TH: triple leg hop for distance; CH: crossover leg hop for distance; MSTH: medial side triple hop test; MRH: 90° medial rotation test; SLVJ: single leg vertical jump; 6mH: 6 m. timed hop test.

The significant differences among the groups as LSI% and mean functional hop performances are SH 147 cm, TH 150 cm, CH 360 cm, MSTH 329 cm, MRH 170 cm, 6mTH 2.45 s, and SLVJ 10.5 cm (Figure 4).

When the LSI values from functional hop performance were compared, a statistically significant difference was found only between MSTH and 6mTH ($p < 0.05$). It is seen that other LSI ratios did not reveal a significant difference between each other ($p > 0.05$) (Table 1).

When the correlations between the scores from FPI and functional hop performance on the right side were evaluated, significant positive correlation relationships were found only at curves above and below the malleoli, SH ($r = 0.387$, $p = 0.038$), and MRD ($r = 0.372$, $p = 0.047$). No significance was found between the other parameters ($p > 0.05$) (Table 2).

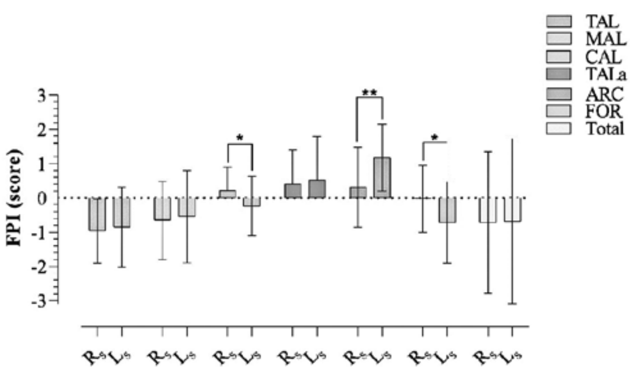

Figure 3. Results of foot posture index (FPI) of young female volleyball athletes.

TAL: Talar head palpation; MAL: Curves above and below the malleoli; CAL: Calcaneus inversion/eversion; TALa: Talanovicular congruence; ARC: Medial longitudinal arch high; FOR: Forefoot abduction/adduction; Total score of foot posture, *p < 0.05; **p < 0.01.

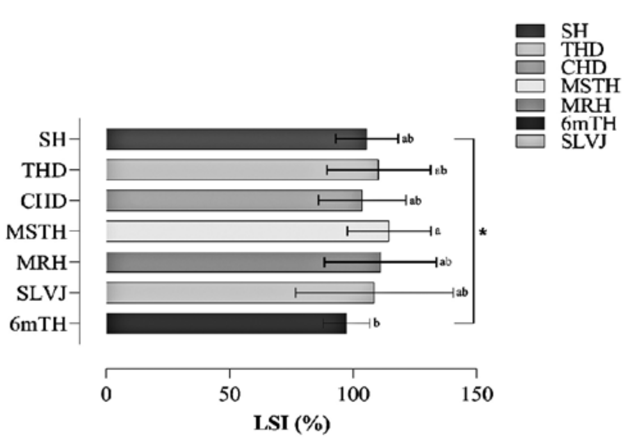

Figure 4. Results of limb symmetry index (LSI%) of young female volleyball athletes.

When the correlations between the scores obtained by the subjects from the results of FPI and functional hop performance on the Ls were evaluated. There were significant positive correlations were found between forefoot abduction/adduction, SLVJ ($r = 0.477$, $p = 0.009$), TH ($r = 0.450$, $p = 0.014$), MSTH ($r = 0.399$, $p = 0.032$), and MRH ($r = 0.407$, $p = 0.029$). No significance was found between the other parameters ($p > 0.05$) (Table 3).

Calf raise 1RM 38.55 ± 9.15 kg and CMJ 23.07 ± 5.28 were measured for volleyball players. The relationship between FPI total scores with 1 RM calf raise left foot ($r = -0.284$; $p = 0.136$), right foot ($r = -0.113$; $p = 0.558$), and CMJ parameters lef foot ($r = -0.147$; $p = 0.445$) and right foot ($r = 0.119$; $p = 0.538$) was evaluated by Pearson correlation. There were no significant correlations between 1 RM calf raise and CMJ parameters with FPI ($p > 0.05$).

Discussion

Performance evaluation of functional hop performance and countermovement jumps in lower limb muscle groups showed multidirectional different muscle-tendon dynamics and FPI criteria typically occurring on talar head position and talonavicular prominence, foot type of volleyball players predominance over others. Our results showed that SLHT performances with FPI scores associated with severe overuse injuries are inclined to occur in more pronated feet. In addition, calcaneus inversion/eversion, medial longitudinal arch high, and forefoot abduction/adduction indexes affected SLHT's results on the right and left side, but our total scores compared to runners, basketball, and handball players showed the most pronated predominance[21]. Thus, CMJ and 1RM calf raise performances caused increased arch highs because of functional hop performance with the medial plantar musculature under stress conditions and strain propulsion phases.

Lower limb strength-force on volleyball players, such as strain, determines muscle performance results during functional hop performance techniques, and absorbed reaction foot angles produce peak muscle force gain, preventing FPI injury risk formation[4,16]. One study found that sprinters have 26% normal foot posture, 34% pronated, and 40% highly pronated foot posture in the dominant foot[8]. Indeed, muscle strain weakness is usually symmetrical and asymmetrical in functional performance. Likewise, pronated feet displaying eversion or inversion are related to medial arch high postural control in all athletes[18]. In the study where the researchers examined the FPI total scores of swimmers and football players with at least ten years of training history, they reported that the swimmers were pathologic results, for example, 6.45 (high pronation) and the footballers were in the normal range.

Additionally, the mean difference between left foot and lower limb injury in the population was (-4.27), and the mean difference in right foot value of (-4.16)[16]. Another risk of injury in FPI resulted in 2.66 more supinated in all basketball athletes. However, center players had a 5.15 standard deviation

Table 1. Correlation between functional hop performance and foot posture indexes of young female volleyball players – right side

	SLVJ		SH		TH		CH		MSTH		MRH		6mTH	
	r	p	r	p	r	p	r	P	r	p	r	p	r	p
TAL	-0.079	0.685	0.049	0.802	-0.089	0.647	0.039	0.840	0.022	0.911	0.105	0.589	-0.247	0.196
MAL	-0.100	0.606	0.387	**0.038***	0.328	0.082	0.266	0.163	0.178	0.357	0.372	**0.047***	0.125	0.519
CAL	-0.198	0.302	-0.312	0.496	0.021	0.912	0.174	0.367	-0.082	0.673	0.008	0.967	-0.118	0.543
TALa	-0.278	0.144	-0.120	0.536	-0.357	0.058	0.104	0.591	0.113	0.560	-0.133	0.492	-0.033	0.864
ARC	0.270	0.156	-0.087	0.655	-0.210	0.275	-0.090	0.642	-0.088	0.650	-0.140	0.470	-0.238	0.214
FOR	0.097	0.618	-0.122	0.528	-0.134	0.489	0.076	0.696	-0.030	0.877	0.288	0.129	-0.273	0.151
$Total_R$	-0.050	0.795	0.057	0.767	-0.166	0.391	0.227	0.235	0.126	0.516	0.273	0.152	-0.247	0.196

*Spearman rank correlation $p < 0.05$.

Table 2. Correlation between functional hop performance and foot posture indexes of young female volleyball players – left side

	SLVJ		SH		TH		CH		MSTH		MRH		6mTH	
	r	p	r	p	r	p	r	P	r	p	r	p	r	p
TAL	-0.288	0.129	0.016	0.933	-0.328	0.083	-0.333	0.079	-0.143	0.460	-0.095	0.624	-0.200	0.298
MAL	0.095	0.625	0.138	**0.476**	0.253	0.185	0.186	0.334	0.003	0.989	0.240	0.210	-0.071	0.716
CAL	-0.289	0.128	0.155	0.423	0.372	0.154	0.154	0.425	0.169	0.380	0.211	0.271	-0.143	0.459
TALa	0.033	0.866	-0.213	0.267	-0.195	0.311	-0.174	0.367	-0.192	0.319	0.078	0.688	-0.220	0.251
ARC	0.180	**0.351**	-0.036	0.852	-0.137	0.476	-0.105	0.588	-0.218	0.256	-0.153	0.427	-0.029	0.251
FOR	0.477	**0.009****	0.243	0.203	0.450	**0.014***	0.169	0.382	0.399	**0.032***	0.407	**0.029***	0.276	0.147
$Total_L$	0.140	0.468	0.045	0.817	0.075	0.699	-0.142	0.464	-0.016	0.936	0.287	0.131	-0.123	0.525

**Spearman rank correlation $p < 0.05$.

Table 3. Correlation between 1 RM calf raise, CMJas, and foot posture indexes of young volleyball players

	$FPI\ Total_R$		$FPI\ Total_L$	
	r	p	r	p
Calf raise (1RM)	-0.284	0.136	-0.113	0.558
CMJ	-0.147	0.445	0.119	0.538

FPI: Total score of foot posture index; R: Right side; L: Left side; CMJ: Countermovement jump without arm swing; 1RM: one-repetition maximum.

that occurred muscle strain activity in different foot posture scores[3].

Normative mean values of FPI scores among adult volleyball athletes have accepted four values. In a study of volleyball players, one player supinated in lower limb posture, and four had highly pronated foot posture in medial arch morphologic[19]. Therefore, FPI values of special (-0.68) left foot, (-0.72) right foot postural pronated deformation of the forefoot, and rearfoot adduction/abduction specifical were obtained in their study. This shows that talus head position is related to biomechanical jump performances and asymmetries, as stated by the researchers[12,17]. In addition, comparing other sports branches, i.e., handball, runners, and basketball, showed that talar head, talonavicular predominance, and medial longitudinal arch congruence had different scores. This shows that FPI can explain the responses to supination postural control in functional hop performances and lower extremity strengths[21]. This may be due to the ground reaction force, solid muscle strength, plantar fascia loading, elastic energy storage predicting dynamic plantar pressure in knee and ankle inversion, supinated foot posture, and lower extremity overuse during multidirectional CH, MSTH, and MRH[28]. In forward or vertical hop performance tests such as SH, TH, and SLVJ, it may be due to the reaction force on the ground, supinated foot posture, and lower extremity overuse. In our study, the different correlations between FPI scores and functional hop performance suggest that they differ according to the conditions mentioned. Other studies and literature reported that the supinated foot is related to CMJ and SLVJ performance; all plantar symmetry and anterior muscle contraction parameters may not risk athletes. No injury has been implicated in excessively pronated feet as a risk factor, such as in our study.

Many FPI scores are characterized by muscle contraction and strengthening; specifically, lower limb muscle foot posture adds medial longitudinal arch highest. Furthermore, significant ecological values of medial-lateral muscle strength and weakness are linked to mechanical force performance. Additionally, hopping performance is still unclear in the training performances of volleyball athletes. In this condition, lower limb strength generally can cause stress conditions in abnormal FPI, plantar fasciitis, lower medial longitudinal arch, and plantar region strain obtained from CMJ and 1RM calf raise related to hop functional performance. Clinical deviations of foot rotation movement on foot functional performances may indicate strength unloading.

Moreover, the lower limb strength function helps absorb more distance hop performance during propulsion phases and more foot force during the propulsion phases; the unloading knee and ankle torque movement required for the subtalar joints depends on the medial longitudinal arch[7,8]. Therefore, our foot posture is crucial to lowering limb muscle performance rotation movements for energy formation in intrinsic muscle activation[9]. Indeed, pressing workouts of muscle activity occurred flexion-extension workouts for foot postural displacement are postural position and plantar muscle activation generated from leg strength as in 6mTH, CH, and MSTH[4,10,12]. The functional performance changes in foot pronation and supination length related to FPI for volleyball athletes and basketball players showed more foot supination and position differences[3]. FPI by strength coaches, therapists, and rehabilitation is commonly applied. However, sports performance examinations have not been applied to individual performance characteristics in the athlete population[16]. Common investigations have investigated FPI and limb strength hop performances in previously focused measurements on differences between active contraction and optimal performances[17].

Moreover, FPI should be examined in a standing position for other sports activities[19]. In addition, when the results of the studies are evaluated, it has been revealed that the FPI rates of the athletes may vary not only depending on the lower extremity strength and foot anatomy but also depending on the muscle volumes, activations, and rehabilitation processes after anterior cruciate ligament reconstruction (ACLR) and calf injuries. The fact that SLHTs reveal different activations in the lower extremity muscles in studies and that SLHTs applied in different directions after ACLR reveal different limb symmetry indexes supports this interpretation.

When our research results were evaluated with the literature findings, it was seen that some significant limitations of the current study emerged. Especially in our current study, FPIs and hops, CMJ, and 1 RM calf raise tests were performed without any kinematic analysis. Making kinematic evaluations in future studies to reveal more detailed findings is crucial. In addition, studies to evaluate the foot and lower extremity anatomy with radiological imaging will provide more apparent evidence for possible relationships. Also, the number of subjects could be higher.

Conclusions

This research has shown that young female volleyball players may produce low hop performances due to the asymmetric structure relationship FPI scores. Continuous follow-up is recommended, especially in volleyball players where jumping and hop performances in different directions are essential, to clarify these results and evaluate the possible negative results in hop performances due to foot posture of lower leg and extremity. This study also concluded that most supination predominance foot patterns to sport performance and lower limb functional hopping performance during sport activities, but further studies are required to encourange these findings.

Authors' contributions: The author contributed individually and significantly to the development of this article: YK *(https://orcid.org/0000-0001-5297-0445) Concept designer, data collection, analysis and interpretation, literature search, writing. The author read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

How to fund clinical research in orthopedics and traumatology? Grants and opportunities

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Abstract

Objective: The aim of the study was to identify: how to fund clinical research in orthopedics and traumatology?

Methods: A survey of funding for clinical research was performed.

Results: According to data from the PIVOT® platform, the funding is concentrated in the USA, UK, and Medical Societies. The main sponsor was the DOD (USA), followed by the SICOT (Belgium). According to data from the DIMENSIONS® platform, there was a reduction of projects financed. The main country was the USA, followed by Japan. Regarding the amounts, the largest funders were the USA and Belgium. FAPESP (Brazil) is in the 7th position among sponsors. According to data from the InCites® platform, the main countries were the USA, China, and Japan.

Conclusion: The reduction of projects in the last two years may be related to the limitations imposed by the SARS-CoV-2 pandemic. Regarding the amounts, the largest funders were the USA and Belgium. This data confirms the importance of funding from the SICOT. The main sponsor was the DOD; this data may be related to injuries that occurred in the war. The fact that the NIDA (USA) is the third largest funder may be related to the increase in the consumption of opioids for pain management. The incidence of falls among the elderly may be associated with Japan being one of the countries most supporting this area. Brazil is in the 8th position, and CAPES, CNPq, and FAPESP are among the top 20 funders.

Level of Evidence IV; Descriptive Observational Study.

Keywords: Capital fundings; Clinical protocols; Musculoskeletal diseases; Orthopedics; Traumatology.

Introduction

Financing is providing resources, usually financial, to support an activity, program, or project by a researcher, group, institution, or company. The most common modality at universities and research institutes is non-commercial research funding from government agencies, research councils, or philanthropic entities[1].

Creating well-designed clinical studies in orthopedics and traumatology can be difficult for various reasons. In today's focus on evidence-based medicine, there is a strong emphasis on selecting treatments based on the results of randomized controlled trials[2]. For this reason, orthopedists should prioritize conducting randomized controlled clinical trials whenever feasible. While the information obtained from other types of studies with less evidence, such as case-control, cohort, case series, descriptions of techniques, and specialist's opinions, is also valuable, it's crucial to be informed of the potential bias and evaluate the results critically. If possible, these results should be interpreted with those from randomized controlled clinical trials[3].

Study performed at the Escritório de Pesquisa Clínica (EPeClin), Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, São Paulo, SP, Brazil.

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Conducting randomized controlled trials take a significant number of resources and may not be appropriate for answering all types of research questions. Other research methods, like case-control studies, prospective cohort studies, and cross-sectional studies, can also be used to gain knowledge in orthopedic trauma[(2)]. Therefore, funding organizations conduct extensive consultations to determine priorities, adapt investments to changes, and contemplate new demands and scientific fields, something especially important when resources are reduced[(4)].

In global terms, a survey on the InCites platform revealed 1,032 active funding entities worldwide mentioned in the texts of documents indexed in the Web of Science database between 2011 and 2018. According to these results, the largest research funding agencies worldwide are the National Natural Science Foundation of China (NSFC), the National Institutes of Health (NIH), and the National Science Foundation (NSF) in the United States of America (USA)[(1)].

Stakeholders involved in the scientific field need to make strategic decisions about allocating resources. These decisions may include determining which research areas should receive the most financial support, selecting the best candidates for open positions, and evaluating which continuing projects should be kept and which new projects should be initiated. Therefore, it is important to understand the various research options available to make these decisions effectively[(4)].

Research funding in Brazil takes place through different development systems and institutions, which are directly or indirectly linked to Brazilian ministries. Among them are Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Financiadora de Estudos e Projetos (FINEP), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Fundo Nacional de Desenvolvimento Científico e Tecnológico (FNDCT), Banco Nacional de Desenvolvimento Econômico e Social (BNDES), in addition to the state agencies that constitute the Foundations Research Support States (FAPs)[(1)].

Improving the ability to conduct health research in nations that are not as economically advanced is considered a top priority in global health. To understand the impact of orthopedic conditions in Latin America, it is necessary to have a strong collaboration between more developed countries and those that do not[(5)]. According to recent literature data, most clinical research related to orthopedic disorders conducted worldwide and in Brazil depended on sponsorship and private institutions, and the importance of the foot and ankle area is evident when it is the 7th most studied worldwide and the 2nd most studied in Brazil[(6)].

Few studies focus on funding agencies as assessment units, but this could change as information systems become more integrated and accessible. In addition, the limitations associated with using funding data retrieved from acknowledgments or footnotes of articles cannot be ignored. Even so, significant insights can be gained from analyzing this data[(1)].

The aim of the study is to identify: how to fund clinical research in orthopedics and traumatology?

Methods

An observational study including clinical trials exclusively in orthopedics and traumatology. A literature review was performed, considering the following terms: "clinical research and orthopedic disorder," "clinical research and musculoskeletal diseases," and "orthopedics, traumatology, funding, and grants." The search was conducted in the PubMed, Scielo, and Google Scholar databases.

A survey of funding opportunities for clinical research in orthopedics and traumatology was performed in three different platforms:

a) **PIVOT® platform:** an active search for research funding related to orthopedic disorders registered on the PIVOT® platform was performed. For this purpose, the PIVOT® platform was accessed on July 22, 2022, at 2:00 pm (Brazilian time), and we used the keywords: "orthopedics" and "orthopedic disorder." This platform presents results on research funding that are available at the time of the search but does not provide retroactive information. Therefore, it was not possible to find data on research funding in the last five years.

b) **DIMENSIONS® platform:** an active search for research funding related to orthopedic disorders registered on the DIMENSIONS® platform was performed. For this purpose, the DIMENSIONS® platform was accessed on August 12, 2022, at 10:35 am (Brazilian time), and we used the filter summary: "orthopedics disorder," "start date from January 01, 2017, to July 29, 2022."

c) **InCites® platform:** an active search for research funding related to orthopedic disorders registered on the InCites® platform was performed. For this purpose, the InCites® platform was accessed on July 29, 2022, at 11:00 am (Brazilian time), and we used the filter summary: "Dataset: InCites Dataset + ESCI. Schema: Web of Science. Domestic/International Collaboration: All. Period Time: [2017, 2022]. Include Early Access documents: true. Document Type: NOT [Review]. Funding Data Source: All Sources. Research Area: [ORTHOPEDICS]. Funding Output Type: Funded. Exported date Jul 25, 2022. InCites dataset updated 2022-06-28. Includes Web of Science content indexed through 2022-05-31."

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

Results

According to data from the PIVOT® platform, in terms of the number of funded projects, the source of financial resources for clinical research in orthopedics and traumatology worldwide is concentrated in the USA, United Kingdom (UK), and funds from Foundations, Societies, or Medical Federations (Figure 1).

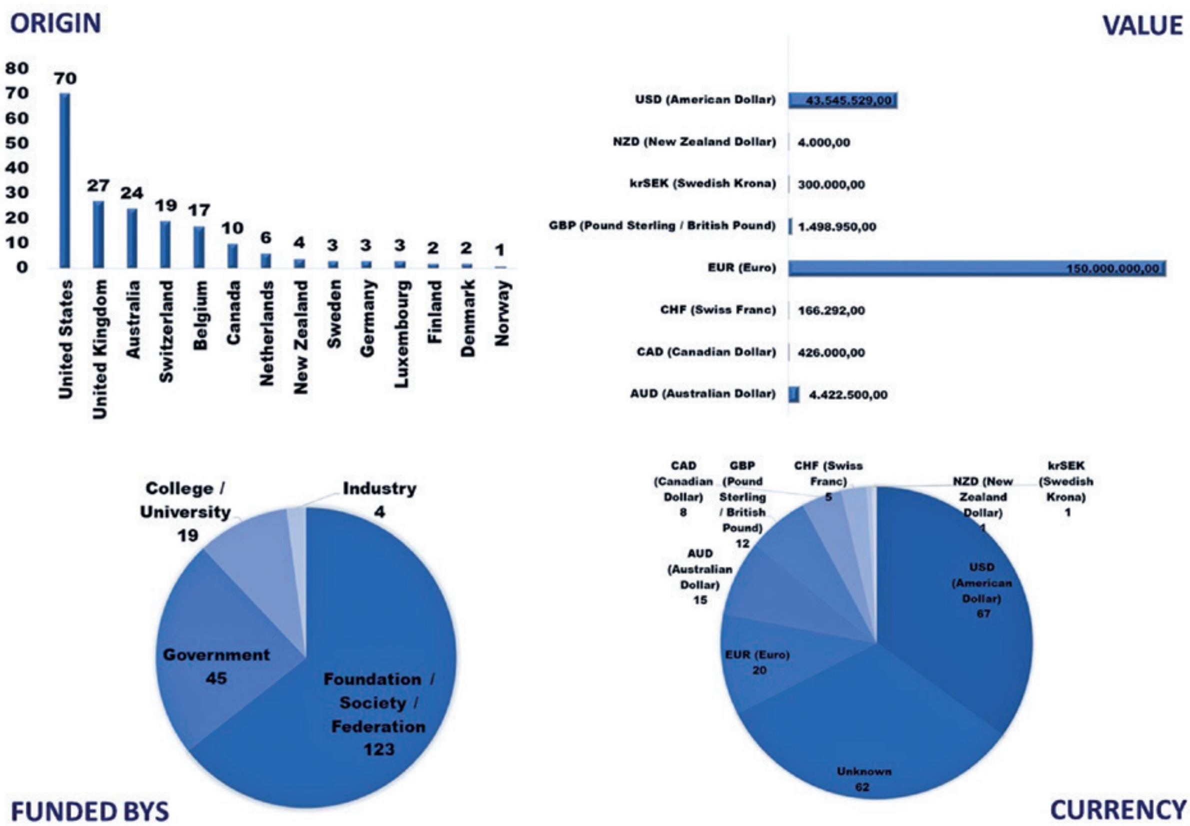

Figure 1. Orthopedic and traumatology research sponsorship registered on the PIVOT® platform (July 2022). Funding opportunities.

The data showed that the largest number of financed projects was concentrated in the USA, and most of the resources (values) were declared in US dollar (USD) (Figure 1). The second largest sponsor of funded projects was the International Society of Orthopedic Surgery and Traumatology (SICOT), an international non-profit association incorporated under Belgian law (Figure 2).

According to data from the PIVOT® platform the main sponsor of projects related to orthopedics and traumatology was the USA Department of Defense (DOD) (Figure 2).

According to data from the DIMENSIONS® platform there was a reduction in projects financed in orthopedics and traumatology in the last two years (Figure 3).

Most registered sponsorships in the DIMENSIONS® platform were declared in USD, and the largest amounts funders were the USA and Belgium (Figure 3).

The data found on the DIMENSIONS® platform showed that the main country in terms of funded projects in clinical research in orthopedics and traumatology is the USA, followed by Japan (Figure 3).

In the USA, the origin of the funding is dispersed among different institutions affiliated with the NIH, such as Congressionally Directed Medical Research Programs, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institute on Drug Abuse (NIDA), and the National Institute of Arthritis and Musculoskeletal and Skin Diseases (Figures 4 and 5).

In Japan, the number of funded projects in clinical research in orthopedics and traumatology, the sponsorship is concentrated in the Japan Society for the Promotion of Science (Figure 5).

According to data from the DIMENSIONS® platform, São Paulo Research Foundation (Fundação de Amparo à Pesquisa do Estado de Sao Paulo - FAPESP) is in the 7th position among sponsors or collaborators who conducted the most research in this area (Figure 5).

According to data from the InCites® platform the main countries of funded projects in clinical research in orthopedics and traumatology are the USA, China, and Japan (Figure 6).

Brazil is in the 8th position among the countries that conducted the most research in this area. CAPES, CNPq, and FAPESP are among the top 20 funders of clinical research in orthopedics and traumatology worldwide (Figure 6).

Figure 2. Orthopedic and traumatology research sponsorship registered on the PIVOT® platform (July 2022). Sponsors or collaborators.

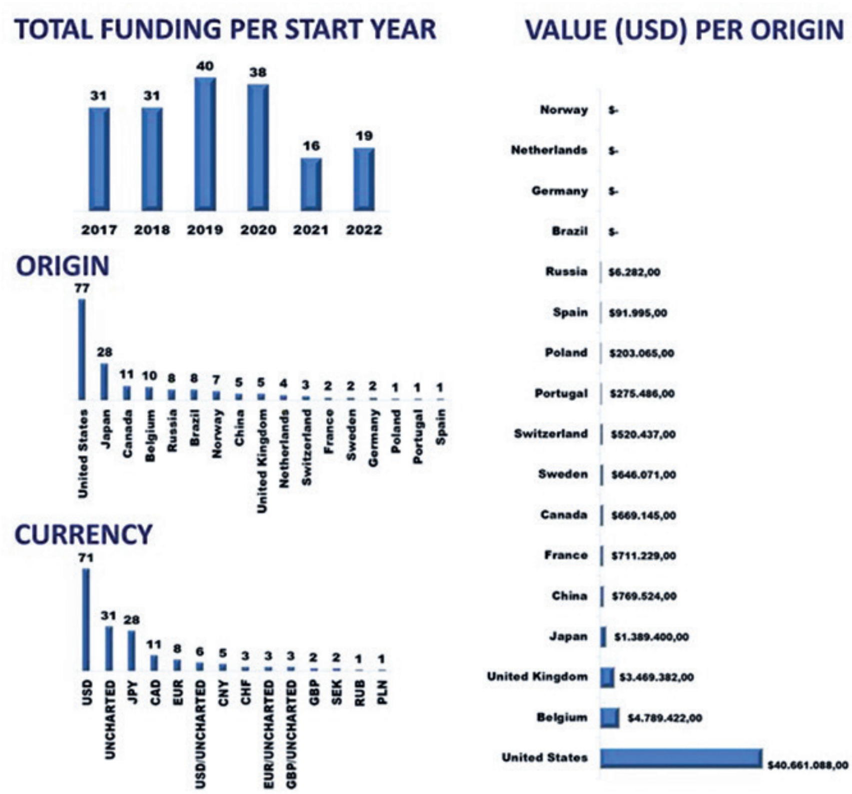

Figure 3. Orthopedic and traumatology research sponsorship registered on the DIMENSIONS® platform from January 2017 to July 2022. Funding opportunities. (Note: $- < $6.000,00).

Figure 4. Orthopedic and traumatology research sponsorship registered on the DIMENSIONS® platform from January 2017 to July 2022. Value (USD) per sponsor or collaborator. (Note: $- < $6.000,00).

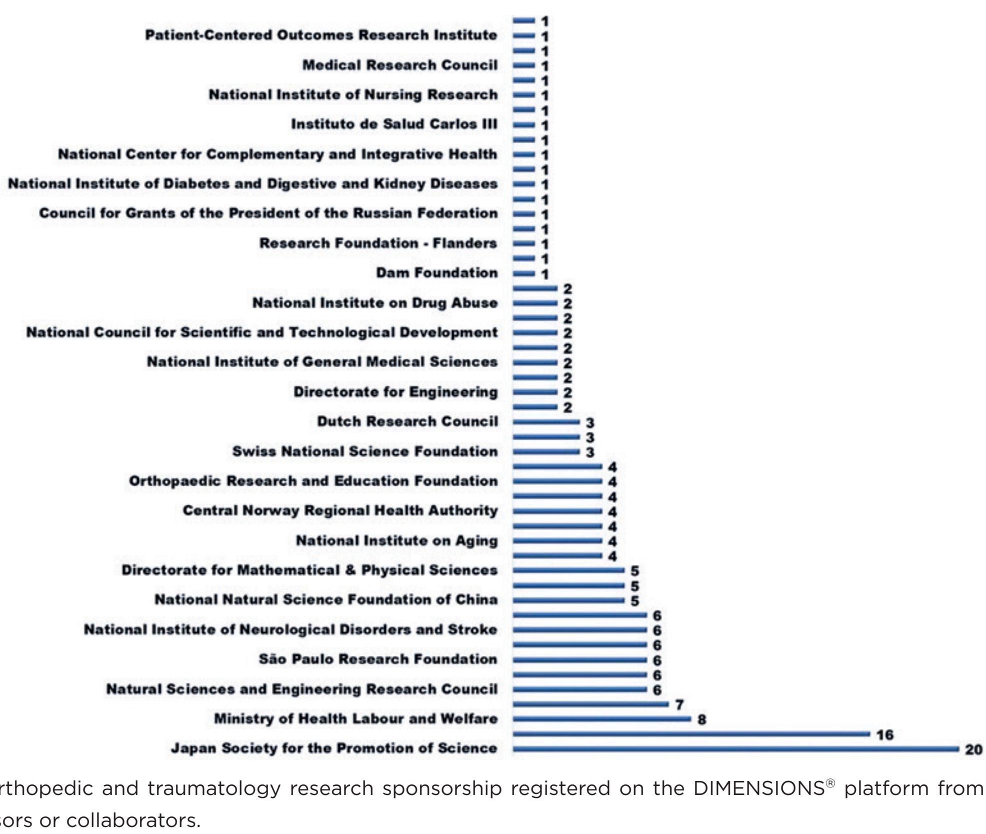

Figure 5. Orthopedic and traumatology research sponsorship registered on the DIMENSIONS® platform from January 2017 to July 2022. Sponsors or collaborators.

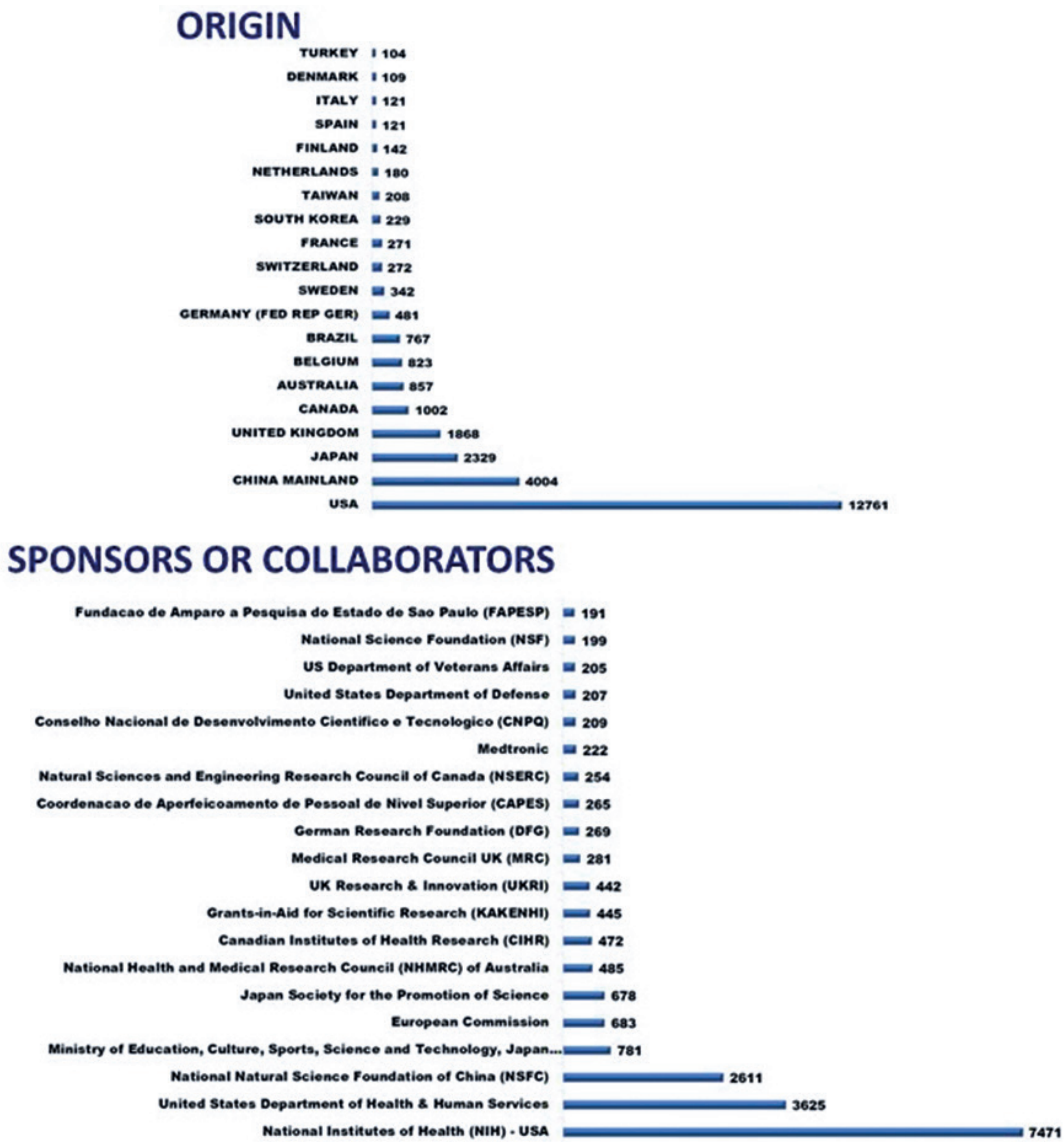

Figure 6. Orthopedic research sponsorship registered on the InCites® platform from January 2017 to July 2022. Sponsorship.

Discussion

The PIVOT® platform allows access only to open grants at the time of consultation. Therefore, data from this tool allow a cross-sectional analysis of funding opportunities for clinical research in orthopedics and traumatology.

According to data from the PIVOT® platform, although the largest number of financed projects was concentrated in the USA and most of the amounts were declared in USD, when we add all resources originating in Europe (values in Euros) this value exceeds the sum of resources originating in the USA (values in USD). Therefore, the fact that the absolute number of funded projects is greater in the USA does not mean that the largest source of funds (values) comes from that country.

According to data from the PIVOT® platform the main sponsor of projects related to orthopedics and traumatology was the DOD (USA). This data may be related to research associated with injuries due to firearms and explosives used in the war.

The DIMENSIONS® platform allows access to the funds registered during the analyzed period. Therefore, data originating from this platform allows a retroactive longitudinal analysis from January 2017 to July 2022.

According to data from the DIMENSIONS® platform, in general terms, we observed a decrease in projects financed in orthopedics and traumatology in the last two years. This reduction of projects supported in orthopedics and traumatology may be related to the limitations imposed by the first years of the new coronavirus SARS-CoV-2 (COVID-19) pandemic.

Regarding the amounts, similar to the results found on the PIVOT® platform, according to data from the DIMENSIONS® platform, the USA and Belgium were the largest funders. This data confirms the importance of funding from SICOT in Belgium.

The fact that the NIDA (USA) is the third largest funder of clinical research in orthopedics and traumatology may be related to the public health issue caused by the increase in the indiscriminate consumption of opioids for pain management.

Fall prevention is challenging in the aging population, and the number of falls increases in magnitude as the number of older adults increases in many nations worldwide[7]. A study in Japan showed that the incidence of falls in the elderly population is 20%[8]. Adhesive capsulitis was more common between 55 and 64 years, and Asian ethnicity is a risk factor for adhesive capsulitis[9]. Therefore, the conditions described above may be related to Japan being one of the countries that most supports clinical research in orthopedics and traumatology worldwide.

According to data from the DIMENSIONS® platform, FAPESP is in the 7th position among sponsors or collaborators who conducted the most research in this area. This can be explained because FAPESP, one of Brazil's main research funding agencies, has an annual budget corresponding to 1% of the total tax revenue of São Paulo state, supports research and finances investigation, exchange, and dissemination of science and technology[10]. This is connected because the Universidade de São Paulo (USP) is in the 6th position among collaborators who conducted the most research in this area[6].

The InCites® platform is a web-based research evaluation tool that allows access to the institutional productivity and collaboration activity registered during the analyzed period. Therefore, data originating from this platform allows a retroactive longitudinal analysis from January 2017 to July 2022.

According to data from the InCites® platform the main countries in terms of funded projects in clinical research in orthopedics and traumatology are the USA, China, and Japan. Over the past decades, there have been great advances in orthopedics in China and Mainland China, which seems to have caught up to Hong Kong and Taiwan regarding research output. Furthermore, Chinese researchers in the orthopedics field have been increasingly active in the global orthopedic community during the past ten years[11]. This data confirms China's growth in the international clinical research scenario.

Our results show that Brazil is in the 8th position among the countries that conducted the most research in this area. CAPES, CNPq, and FAPESP are among the top 20 funders of clinical research in orthopedics and traumatology worldwide. Recently, the Resolution RDC No. 548 of August 30, 2021, Ministry of Health/Brazilian, National Health Surveillance Agency/Collegiate Board (ANVISA), which provides for clinical trials with medical devices in Brazil, increased requirements to register these products in the country[12]. Therefore, Brazil expects more clinical trials related to orthopedic disorders in the coming years[6].

Conclusion

Regarding the amounts, the largest funders were the USA and Belgium. This data confirms the importance of funding from the SICOT in Belgium.

The main sponsor of projects related to orthopedics and traumatology was the DOD (USA). This data may be related to research associated with injuries that occurred due to firearms and explosives used in the war.

The fact that the NIDA (USA) is the third largest funder of clinical research in orthopedics and traumatology may be related to the public health issue caused by the increase in the indiscriminate consumption of opioids for pain management.

The incidence of falls among the elderly in Japan and the fact that Asian ethnicity is a risk factor for adhesive capsulitis may be related to Japan being one of the countries that most supports clinical research in orthopedics and traumatology worldwide. Our data confirm China's growth in the international clinical research scenario.

Our results show that Brazil is in the 8th position among the countries that conducted the most research in this area. CAPES, CNPq, and FAPESP are among the top 20 funders of clinical research in orthopedics and traumatology worldwide.

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Original Article

Prevalence of ankle accessory muscles: a cross-sectional study

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Abstract

Objective: Determine the prevalence of accessory muscles around the ankle of patients with ankle pain using magnetic resonance imaging (MRI) and evaluate its correlation with other foot and ankle disorders. In addition, better understand the association with accessory muscle and types of pain, mechanical due to compression forces around ankle structures or neuropathic due to mass effect around the tarsal tunnel.

Methods: The MRIs obtained from 2007 to 2017 were retrospectively studied and analyzed by a radiologist specializing in foot and ankle pathologies. A total of 9,600 scans were studied after ankle pain; 31 scans had at least one accessory muscle.

Results: The prevalence of symptomatic accessory muscle was 0.32% (31 feet). It was found due to mechanical pain in 45.2% of cases. It was considered an incidental finding in 32.3%. Tarsal syndrome was the main clinical presentation in 19.4%, and 16% had other causes of mechanical disorders: 10% with peroneal tendinitis, 3% with Achilles tendinopathy, and 3% with plantar fasciitis. The prevalence of accessory muscles was 35% of the flexor digitorum, 32% of the peroneus quartus, 19% of the fibulocalcaneus internus, 13% of the accessory soleus, and 6% of the tibiocalcaneus internus.

Conclusion: Although rare, accessory muscles can contribute to ankle pain with various presentations that confound clinical diagnosis or even appear as incidental on MRI and should be considered in the management of ankle pain.

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

Keywords: Ankle joint; Magnetic resonance imaging; Muscle, skeletal; Tendons.

Introduction

Accessory supernumerary muscle can be found on magnetic resonance imaging (MRI) by accident while investigating pain around the foot and ankle[1-3]. Accessory muscles such as peroneus quartus (PQ), peroneus digiti quinti (PQUI), flexor digitorum accessory (FDA), fibulocalcaneus internus (FCI), tibiocalcaneus internus (TCI) and accessory soleus (AS) are frequently underappreciated and often misdiagnosed[1-4]. Few case series studies demonstrated accessory muscles as causative agents in chronic lateral ankle pain; however, its true population prevalence is unknown[5].

Chronic lateral ankle pain is a common complaint in daily practice. It could be related to various soft tissue and osseous abnormalities, like trauma, fracture sequelae, ankle instability, repetitive trauma, and vascular or neurological disorders[1-3]. However, the presence of accessory muscle itself could cause persistent swelling, mechanical pain, or neuropathic disorders even after all conservative treatments[3,6,7]. Pain could result from a mass effect on the tarsal tunnel performing compression forces around the tibial nerve, and symptoms would only be resolved after surgical exploration and resection of accessory muscles[1,4,5,8,9].

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

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Magnetic resonance imaging is frequently necessary to elucidate internal derangement of foot and ankle joints, assessing tendons disarrangements, accessory muscle, soft tissue tears, and nerves and osseous structures[6,7,10]. Previous case series MRI studies demonstrated a 10.6% presence of accessory peroneal tendons[3,6,7]. However, there is a lack of populational studies in the literature associating the presence of accessory muscles and types of ankle pain. In addition, there is no information about which spectrum of symptoms would be more frequently associated with the presence of accessory muscle around the ankle: mechanical or neuropathic disorders[1,6,7,11,12].

The objective of this cross-sectional study was to determine the prevalence of accessory muscles around the ankle of patients with ankle pain using MRI and evaluate its correlation with other foot and ankle disorders. As a secondary objective, establish an association with accessory muscle and types of pain, mechanical due to compression forces around ankle structures or neuropathic due to mass effect around the tarsal tunnel.

Methods

The MRIs obtained from 2007 to 2017 at the Amelia Lins Hospital were retrospectively studied and analyzed by an experienced radiologist specializing in foot and ankle pathologies. This study was approved by the institution's Ethical Committee Board under the number 2698273, and informed consent was obtained. A total of 9,600 sequential patients were included due to pain around the ankle, and 31 exams had at least one accessory muscle: PQ, FDA, FCI, TCI, and AS. Selected exams were confirmed with a second blinded to clinical and radiological findings, also by an experienced radiologist specializing in foot and ankle. All data were then compared with the patient's medical records searching for an association of mechanical or neuropathic symptoms, primary diagnostic hypothesis for ankle pain, gender, age at the time of the exam, and outcome.

Magnetic resonance imaging

T1- and T2-weighted sagittal and axial images were obtained using a 1.5 Tesla Siemens MRI scanner. The repetition and echo times for the T1- and T2-weighted images were 518 msec and 11 msec, and 3,470 msec and 79 msec, respectively. The repetition and echo times for the sagittal T1-weighted fat suppression images were 2,430 msec and 34 msec; coronal T2-weighted fat suppression images were 3,290 msec and 90 msec. The other acquisition parameters were field of view, 100 × 160 mm; matrix size, 182 × 384; and slice thickness, 3 mm.

Statistical methods

All analyses were conducted using Statistical Package for the Social Science (IBM Corp., Armonk, New York, USA) statistics software. Statistical analyses were performed to determine the frequencies of appearance of accessory muscles and the correlation between each accessory muscle and clinical symptoms.

Fischer's exact test was used to compare accessory muscle findings and clinical symptoms. In addition, ANOVA was performed to identify the relationship between variables.

The significance level for all statistical tests was set at $p = 0.05$, power analysis of 80%, and confidence interval of 95% for all relative frequencies.

Results

The prevalence of symptomatic accessory muscle was 0.32% (31 feet) of all symptomatic ankles submitted to ankle MRI from 2007 to 2017 (9,600 exams) with a 95% confidence interval.

In this study, 41% were male (12 cases), and 59% were female (17 cases). There were two cases with bilateral findings. Age distribution was 3% (1 case) of individuals under 18 years old, 45% (13 cases) between 19 and 40 years old, 45% (13 cases) between 41 and 65 years old, and 7% (2 cases) above 65 years old. This demonstrates a 90% prevalence of young adults.

Clinical presentation comparison showed that 45.2% had accessory muscle associated with mechanical ankle pain,16.1% were found as incidents after a traumatic event, 19.4% had tarsal syndrome as the main clinical presentation, and 16% of cases were found with other mechanical symptoms not anatomically related with accessory muscles: 10% had fibular tendinitis, 3% had Achilles tendinopathy, and 3% had plantar fasciitis (Figures 1, 2, and 3).

Prevalence of accessory muscles in this study was 35% for FDA, 32% for PQ, 19% for FCI, 13% for AS, and 6% for TCI (Figure 4).

There was no statistical significance between accessory muscles and tarsal tunnel syndrome as the main clinical

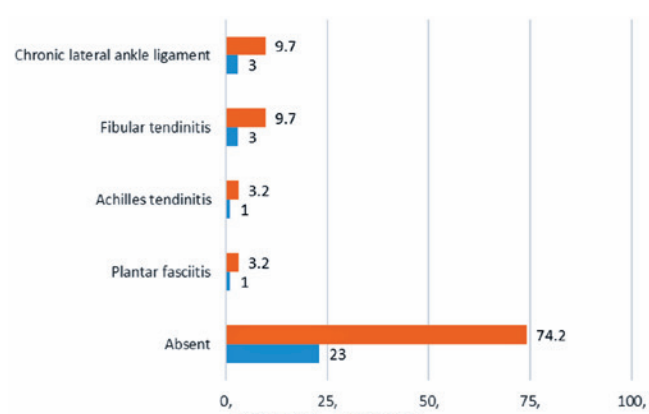

Figure 1. Presence of accessory muscle around the ankle on MRI and each clinical foot and ankle disorder presentation before the exam: chronic lateral ankle ligament, fibular tendinitis, Achilles tendinitis, plantar fasciitis, and absence were considered when ankle pain was not associated with any other foot and ankle disorder on MRI.

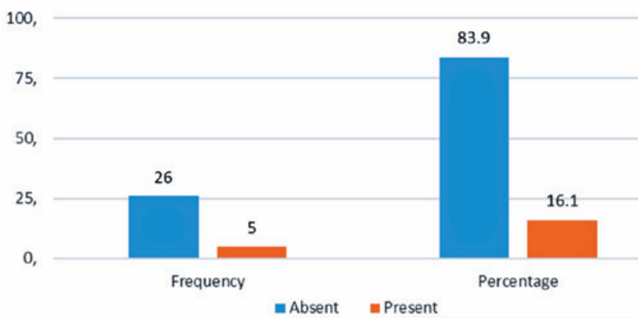

Figure 2. Frequency of incidental accessory muscle around the ankle findings.

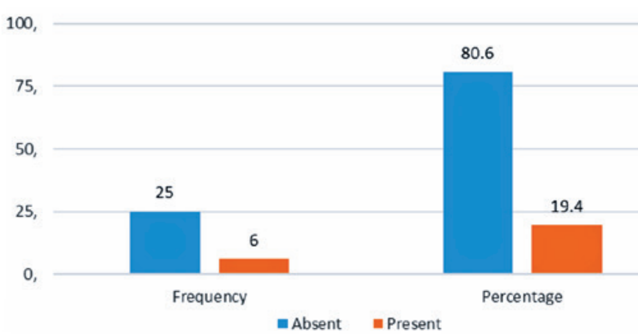

Figure 3. Frequency of tarsal syndrome and presence of accessory muscle around the foot and ankle using MRI.

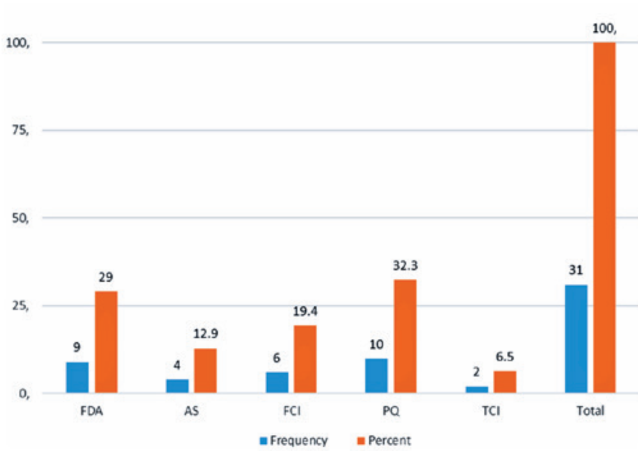

Figure 4. The relative frequency of each accessory muscle around the foot and ankle was found using MRI.

* FDA: Flexor digitorum accessory, AS: Accessory soleus, FCI: Fibulocalcaneus internus, PQ: Peroneus quartus,TCI: Tibiocalcaneus internus.

presentation (p = 0.389). There was no statistical significance between accessory muscle findings and trauma onset (p = 0.499). There was no statistical significance between accessory muscle and clinical mechanical presentation (p = 0.499) (Tables 1 and 2).

Discussion

Ankle pain is a frequent debilitating complaint in general practice caused by several etiologies, like ligament injury, mechanical ankle instability, peroneal tendon lesion, sinus tarsi syndrome, tarsal syndrome, or the presence of accessory muscle around the ankle[4,7,9,13].

Few case reports have described accessory muscle as the main causative agent of ankle pain[4,10,14].

In this study, the prevalence of young adults was 90%, corroborating previous studies, and 45.2% of cases presented accessory muscle and had mechanical chronic ankle pain as the main clinical presentation[11,15-17]. The most frequent symptomatic accessory muscle was FLD (35%), followed by PQ (32%), FCI (19%), AS (13%), and TCI (6%), with no statistically significant difference between them (p > 0.05). According to studies by Yammine[17] and Choudhary and McNally[8], PQ would be the most common accessory muscle around the ankle, located medial or posterior to peroneus brevis or longus tendons with an incidence in literature based on cadaveric studies varying from 6.6 to 21.7%. In contrast, this study encountered FDL as the most prevalent accessory muscle around the ankle, present in 35 % of cases, followed by PQ in 32%.

Neuropathic pain around the ankle with concomitant tarsal syndrome was found in 19.4% of cases. Considering anatomical proximity to the tibial nerve, only TCI played an important role in nerve compression on tarsal tunnel, as the surgical treatment record confirmed, and it conforms with literature[18].

Pain unrelated to the presence of accessory muscle or after a trauma event was considered an incident at MRI. Incidents at MRI with other causes of mechanical pain were found in 16%, 10% due to fibular tendinitis, 3% to Achilles tendinopathy, and 3% had plantar fasciitis. Trauma event was the main reason for MRI and had accessory muscles as incidents in 16.1%. Frequencies of accessory muscles found as incidents were 6% of FLD (2 cases), 9% PQ (3 cases), and 3% of SA (1 case)

Despite their rare appearance, accessory muscles can be associated with ankle pain with various presentations that confound clinical diagnosis and need to be considered to treat better the spectrum of conditions causing ankle pain. This is in agreement with several studies[1,5,8,11,14].

This study intended to analyze epidemiologic data about the prevalence of accessory muscle appearing in all patients submitted to MRI after any ankle complaint from 2007 to 2017 and its correlation with the clinical presentation at the time of the exam. The presence of mechanical ankle pain, tarsal syndrome, or incident asymptomatic found after trauma or even association with other mechanical pathologies around

Table 1. Crosstabulation between each accessory muscle found in MRI and clinical presentation at the time of the exam.

Accessory muscle		Clinical findings				Total
		Tarsal tunnel syndrome	Trauma	Other ankle pathologies	Accessory muscle	
Flexor digitorum accessory	Count	1	3	1	4	9
	% within m_accessory	11.10%	33.30%	11.10%	44.40%	100%
	% within diagnose	25%	60%	20%	23.50%	29%
Accessory soleo	Count	1	0	0	3	4
	% within m_accessory	25%	0%	0%	75%	100%
	% within diagnose	25%	0%	0%	17.60%	12.90%
Fibulocalcaneus internus	Count	2	0	2	2	6
	% within m_accessory	33.30%	0%	33.30%	33.30%	100%
	% within diagnose	50%	0%	40%	11.80%	19.40%
Peroneus quartus	Count	0	1	1	8	10
	% within m_accessory	0%	10%	10%	80%	100%
	% within diagnose	0%	20%	20%	47.10%	32.30%
Tibiocalcaneus internus	Count	0	1	1	0	2
	% within m_accessory	0%	50%	50%	0%	100%
	% within diagnose	0%	20%	20%	0%	6.50%
Total	Count	4	5	5	17	31
	% within m_accessory	12.90%	16.10%	16.10%	54.80%	100%
	% within diagnose	100%	100%	100%	100%	100%

Table 2. Analysis of variance (ANOVA) of tarsal tunnel syndrome, previous trauma event, other mechanical causes of foot and ankle disorders, and presence of accessory muscles around the ankle using MRI.

		Sum of squares	Df	Mean square	F	Sig.
Tarsal Tunnel syndrome	Between Groups	0.124	1	0.124	0.765	0.389
	Within Groups	4.714	29	0.163		
	Total	4.839	30			
Trauma	Between Groups	0.055	1	0.055	0.468	0.499
	Within Groups	3.429	29	0.118		
	Total	3.484	30			
Other foot and ankle pathology	Between Groups	0.055	1	0.055	0.468	0.499
	Within Groups	3.429	29	0.118		
	Total	3.484	30			
Accessory muscle	Between Groups	0.677	1	0.677	2.806	0.105
	Within Groups	7	29	0.241		
	Total	7.677	30			

the foot and ankle compared to accessory muscle findings. One limitation of this study is that only symptomatic patients were submitted to MRI, and other causes of mechanical disorders, anatomically distant from accessory muscle encountered, could still interfere with clinical diagnosis. Only 31 feet presented accessory muscle and mostly in young adults. One possibility is that young adults had symptomatic ankles and performed more MRIs than children and older adults in this sample. The overall prevalence in the population could be greater than found in this study because people born with accessory muscles could be asymptomatic and not perform MRIs.

Conclusion

This study of 9,600 subjects with symptomatic ankle disorders presents epidemiological data about the populational prevalence of accessory muscles around the ankle in patients with ankle pain and its correlation with clinical presentation. Although rare, accessory muscles can contribute to ankle pain with various presentations that confound clinical diagnosis or even appear as incidental on MRI and should be considered when in the management of ankle pain.

Authors' contributions: Each author contributed individually and significantly to the development of this article: SIK *(https://orcid.org/0000-0002-9079-6940) and JPFM *(https://orcid.org/0009-0002-8424-9980) Conceived and planned the activities that led to the study, approved the final version; GDH *(https://orcid.org/0000-0002-1830-450X) and RNR *(https://orcid.org/0000-0003-4163-7721) and AAL *(https://orcid.org/0000-0001-8010-8975) Interpreted the results of the study, participated in the review process and approved the final version; AFB *(https://orcid.org/0000-0001-9751-9738) and LRP *(https://orcid.org/0009-0007-8305-7158) and CMM *(https://orcid.org/0000-0003-2469-0424) Data collection and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Original Article

Classification of foot type from podography: correlation of results between six quantitative assessment methods

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Abstract

Objective: Apply the different methods available in the literature to classify a sample of podography and evaluate the level of agreement between the results.

Methods: Six quantitative and one qualitative method to classify foot type from podography were recorded on 30 feet. The podography indexes were calculated, and the level of agreement between methods was explored.

Results: Correlation values were above r = 0.84 except for the test arch footprint angle. The highest correlation values were found between the truncated arch index and footprint index (0.99), arch index and footprint index (-0.94), and arch index and truncated arch index (-0.94), and the lowest was the arch footprint angle with the other parameters. However, there was a difference in the classification between the foot types, indicating a lack of agreement of thresholds between foot types. Qualitative visual inspection was the faster method to classify foot type.

Conclusion: The visual inspection was the fastest test to apply, followed by the quantitative arch footprint angle test. High correlation values were found between tests, especially the arch index and the footprint index, arch-length index, truncated arch index, and Chippaux-Smirak index tests.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Evaluation; Foot; Podography.

Introduction

Feet are the base of support to the human body, allowing functional tasks such as standing, gait, and running(1). Foot alignment can be classified as normal, flat, or high-arch(2). Misalignments of the foot in stance position or during movement can overload interrelated muscles and joints, increasing the risk of injuries(3). Evidence has shown high correlations between flat and high-arch foot with stress fractures(4). Flat foot is associated with a greater number of injuries reported in midfoot and knee in a cadet population(5). Another study found that runners with high-arched foot present a greater incidence of ankle and bone injuries and injuries on the lateral anatomical structures of lower limbs(6); runners with low-arched foot are more likely to develop soft tissue injuries on the medial side of the lower extremity, and knee pain(7).

Foot alignment classification can be performed by qualitative techniques, such as visual inspection (VI), or quantitative

Study performed at the Universidade Federal dos Vales do Jequitinhonha e Mucuri – UFVJM, Diamantina, MG, Brazil.

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methods using baropodometry[8] or podography[9]. Visual inspection is a method to assess the arch and foot alignment and is widely used by physicians; however, their classification is subjective and has high inter-rater variability[10]. Regarding quantitative methods, podographs are low-cost and easier to apply compared to baropodometry[11]; podography has lower variability than VI[12]. The interpretation of podography can be based on different methods, such as VI, arch index (AI), arch footprint angle (AFA), footprint index (FI), arch-length index (ALI), truncated arch index (TAI), and Chippaux-Smirak index (CSI)[12-17]. However, each technique uses different parameters to classify foot posture, and some do not present cut-off thresholds between classifications. Furthermore, the parameters used to classify the foot for each podography method are different[12-17]; it is important to clarify whether the agreement between techniques is satisfactory to allow physicians to use their preferred choice. Thus, the objective of this study is to compare the efficiency of different parameters used in the literature to classify foot types from podographic images and determine the levels of agreement between them.

Methods

A sample of 15 volunteers (11 women and four men) was recruited by convenience through posters fixed at the university physiotherapy clinic. Both feet were assessed, giving a sample of 30 feet. The inclusion criteria of the volunteers were: A) age between 18-25 years, B) capability of staying in a uni-pedal stance, and C) ability to walk without assistance. Exclusion criteria were: A) existing foot deformities or amputations, B) pain in the lower limb during stance, and C) balance deficit or postural instability when in a uni-pedal stance.

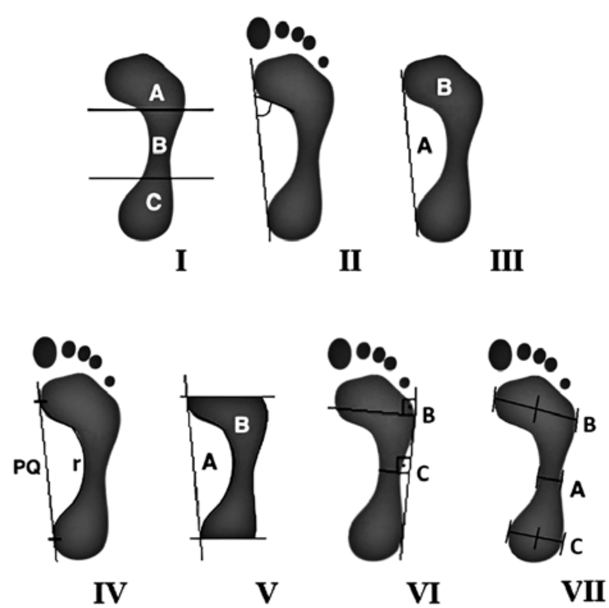
Podography was obtained using an APEX Harris Mat Set (Apex Foot Products Corporation, Englewood, NJ, USA). This instrument consists of two rectangular plastic plates mediated by textured rubber. To obtain a podography with homogeneous color, an equivalent smooth rubber replaced the textured rubber. A Deskjet 2050 scanner (Hewlett-Packard Development Company, LP, Hanover Street, California, CA, USA) was used to digitalize the podography. In addition, a universal goniometer (Carci, São Paulo, SP, Brazil) was used to measure angles for the AFA test.

The study was approved by the Human Research Ethics Committee at UFVJM, and informed consent was obtained from all participants. Demographic data collected were age, gender, body mass index (BMI), height, shoe size, history of foot and ankle injuries, level of physical activity, and limb dominance. After preparing the foot printer with a layer of black ink, a white paper was positioned inside the mat, and the volunteer was asked to keep one foot centralized on the APEX Harris Mat Set. Then, the volunteer was asked to elevate the opposite foot and sustain a uni-pedal position for 30 seconds. Subsequently, the podography was re-inked, and the same procedure was undertaken with the contralateral leg. During the test, the examiner ensured the knee alignment remained in a neutral position. Volunteers were allowed to rest their hands on a table to maintain stability during a uni-pedal stance.

The same researcher, previously trained, obtained and analyzed all podography. Podography order was randomized before applying qualitative and quantitative tests, described below, to classify the foot as flat, neutral, or high-arched. In addition, podographies were scanned with a resolution of 200 dots per inch and transferred to software developed in MatLab (MathWorks, Massachusetts, MA, USA). This software calculates the number of black and white pixels inside the scanned image and the foot area (Figure 1).

The podography was divided into three equal sections, proportional to the length of the foot, by two parallel lines excluding the toes to calculate the AI. Then, the printed area of each section was calculated, and the index was calculated as the ratio between the midfoot area B and the area of the whole foot (A + B + C), as shown in Figure 1(I).

The AFA was calculated from the intersection of two lines; the first was a line connecting the prominent points of the calcaneus and the first metatarsal. The second line was drawn towards the concavity of the foot arch following the medial foot border. The angle between the two lines was obtained by a goniometer, as shown in Figure 1(II). The FI was calculated by the formula A/B, where A was the arch area, delimited by the medial line connecting the most prominent point in the



Arch index = B/(A+B+C); (II) Arch footprint angle; (III) Footprint index = A/B; (IV) Arch-length index = PQ/r; (V) Truncated arch index = A/B; (VI) Chippaux-Smirak index = C/B; (VII) Visual inspection = A≥½ of B or A≤½ of C.

Figure 1. Methods to access podography.

medial aspect of the forefoot and the rearfoot, and B was the area of the toeless podography as shown in Figure 1(III).

To calculate the ALI, the length of a medial line (PQ), which starts at the most prominent point on the medial aspect of the forefoot and ends at the most prominent point on the medial aspect of the rearfoot, was measured. The length of the “r” line was obtained starting from the same point defined on the forefoot, following the contour of the arch, and ending at the same medial point on the rearfoot. The ALI was obtained by calculating the ratio of the length of the medial line and the arc length (PQ/r), as shown in Figure 1(IV).

The TAI was calculated as the FI; however, the foot area (B) was limited to the truncated area. The truncated area is restricted between two horizontal lines through the most medial points of the metatarsal and the heel region, as shown in Figure 1(V) and defined as detailed in the ALI test.

The CSI was drawn as a lateral line connecting the prominent points of the calcaneus and the fifth metatarsal. In addition, two perpendicular lines with a 90º angle to the lateral line were drawn in the podography. One line in the wider zone of the forefoot (B) and another line in the narrower zone of the midfoot (C). The result was obtained by calculating C/B as shown in Figure 1(VI).

Visual inspection of podographs was performed according to the criteria presented by Viladot (1987). According to the Viladot method (Figure 1(VII)), the flat foot is present when the midfoot width is equal to or greater than half the width of the forefoot. High-arched foot is present when the width of the midfoot impression is equal to or less than half of the rearfoot or not visible. Podography not classified as flat or high-arched foot was considered neutral[18].

Data analysis

Data analysis was performed using SPSS version 11.0 (SPSS Inc. Chicago, IL, USA). Initially, the normality of the variables was tested using the Shapiro-Wilk test. The quantitative scores tests were analyzed using Spearman’s correlation coefficient, considering a significance level of 5%.

Results

Eleven women and four men were recruited, and the mean age was 23 years (SD = 2.7). According to their BMI, ten participants were classified as normal, two as pre-obese, one as mild thinness, one as moderate thinness, and one as severe thinness. Regarding regular physical activity, ten were physically inactive, while five stated to practice exercise.

Table 1 describes the frequency of different foot categories when using VI, AI, AFA, and CSI. Categorization among the four tests was not similar. The AFA test categorized the sample into the high-arch classification. Conversely, the CSI categorized most of the sample as neutral and flat arched foot.

Table 2 shows the results of Spearman’s correlation coefficient among the six different categorization methods. Correlation values were above r = 0.84 except for the AFA test. The highest correlation values were found between TAI and FI (0.99), AI and FI (-0.94), and AI and TAI (-0.94), and the lowest was the AFA with the other parameters.

Table 3 shows the mean time taken to classify individuals’ feet using different methods. The VI was the quickest method compared to all other approaches.

Table 1. Feet categorization according to the different indexes

	High-arch (n)	High-arch (%)	Neutral (n)	Neutral (%)	Flat arch (n)	Flat arch (%)
Visual inspection	9	30%	12	40%	9	30%
Arch index	15	50%	11	37%	4	13%
Arch footprint angle	27	90%	2	7%	1	3%
Chippaux-Smirak index	1	3%	16	53%	13	44%

Table 2. Spearman’s correlation coefficient among six different scores

	AI	FI	ALI	TAI	AFA	CSI
AI	1.0000					
FI	- 0.9431	1.0000				
ALI	0.8413	- 0.8853	1.0000			
TAI	- 0.9400	0.9933	- 0.8780	1.0000		
AFA	- 0.4883	0.5469	- 0.6276	0.5218	1.0000	
CSI	0.8836	- 0.7751	0.6703	- 0.7794	- 0.3844	1.0000

AI: Arch index; FI: Footprint index; ALI: Arch-length index; TAI: Truncated arch index; AFA: Arch footprint angle; CSI: Chippaux-Smirak Index.

Table 3. Mean time taken in seconds for feet classification using different methods

VI	AI	AFA	FI	ALI	TAI	CSI
1.03	646	19	814	52	832	33

VI: Visual inspection; AI: Arch index; AFA: Arch footprint angle; FI: Footprint index; ALI: Arch-length index; TAI: Truncated arch index; CSI: Chippaux-Smirak index.

Discussion

The aim of our study was to assess the agreement between different methods to classify a sample of podography. The hypothesis was that the quantitative tests would show high correlation scores; therefore, regardless of the method used by physicians, patients would be categorized under the same group. Moreover, because the time taken to perform each test was recorded, it would be possible to show which test is faster to use, although producing similar results.

Many different methods for podography assessment are available in the literature; however, many have been published before 1987, making access to the full text challenging[12,13,19-24]. In addition, many methods have been adapted and do not follow the original procedure, which can be misleading and result in systematic errors[25-27].

The findings of this study demonstrated that the quantitative and qualitative methods might not classify the podography under the same category. According to Forriol and Pascual[17], the classification is sensitive to the method used. Moreover, the cut-off points differed, which may be the main reason for the low correlation scores[21]. Another important point is that because of soft tissue malleability, feet with similar structural shapes can have different podography[25]. According to Razeghi and Batt[28], quantitative methods are discouraged when assessing high-arch feet because of the medial area discontinuity.

The different quantitative indexes can be categorized as those that use total area, angle values, or length measurements in their formula. These methods require additional time to perform the calculations needed for final results. As shown in Table 3, the VI, which does not need extra time, was the quickest way to assess the foot. However, the results from VI may vary according to the assessor's experience, making their results less reliable than more systematic methods[24]. However, Dahle et al.[21] demonstrated that experienced physiotherapists have high agreement rates while using VI.

One way of improving VI reliability could be by using more systematic methods, which in this study was the criteria proposed by Viladot[18]. Xiong et al.[22] demonstrated a high correlation between AI and VI. Therefore, in the clinical setting, the VI is of great value as it is quick and does not require any equipment, which may not always be available in the clinical setting.

After VI, the methods that used the angle or length of the podography were those that required less time to classify the podography. Among them, the AFA was the quickest. These tests require only drawing lines dividing the podography into areas. They are measured in millimeters with a simple ruler, or in the case of angles, lines are traced and then measured with a goniometer. However, the ALI does not have cut-off points, which are only available for the AFA and the CSI in this category of tests.

Regarding AFA and the CSI, a recent study demonstrated the advantage of a 5-level stratification system (high, normal, intermediary, lowered, and flat medial longitudinal arch). However, Sacco et al.[27] study, comparing the AI, CSI, and AFA, demonstrated that only the AI and the CSI are reliable for anthropometric assessment as the AFA showed strong disagreement with the other indexes.

The tests using the area for podography classification were more time-consuming. The AI is the most commonly described in the literature and was the fastest among the indexes in this group[29,30]. The extra time needed for this index is due to the additional steps, such as digital processing of the image or other equipment, such as planimeters, to obtain the figure area.

Only the AI has cut-off points established among the three methods in the group of indexes using area for classification. Therefore, although the FI and the TAI have similar scores to the AI, it is not possible to determine if the same cut-point from the AI can be used for the other two[31-33].

Regarding the correlation scores, the high correlation scores among tests found were opposite to Hawes et al.[17], where the authors performed a regression analysis in relation to the plantar arch height with five different podography indexes: AFA, FI, AI, ALI, and TAI. In our findings, most of the correlation scores were over 0.84 with the AI, which may suggest that the cut-off points from this index can potentially be adopted for the others, but more studies are needed. The test with the lowest correlation values was the ALI; however, because it was the one with the shortest time needed, it might also be useful in a clinical setting as it has cut-off points that enable the classification of flat, normal, or high-arched foot.

Conclusion

The visual inspection was the fastest test to apply, followed by the quantitative arch footprint angle test. High correlation values were found between tests, especially the arch index and the footprint index, arch-length index, truncated arch index, and Chippaux-Smirak index tests.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RGTF *(https://orcid.org/0000-0001-6118-1181) Data collection and clinical examination; TCP *(https://orcid.org/0000-0002-5245-1298) Survey of the medical records and data collection; ACB *(https://orcid.org/0000-0003-3670-3616) Participated in the review process, formatting of the article and approved the final version; NLMR *(https://orcid.org/0000-0003-1981-8606) Bibliographic review and formatting of the article; BFM *(https://orcid.org/0000-0003-1566-9551) Interpreted the results of the study and statistical analysis; JR *(https://orcid.org/0000-0002-4004-3115) Conceived and planned the activities that led to the study and approved the final version. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Macrodystrophia lipomatosa of the right foot: a case report and treatment

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Abstract

Macrodystrophia lipomatosa (MDL) is a rare congenital disorder characterized by localized gigantism of one or several digits. It may involve the entire limb due to progressive overgrowth of all mesenchymal elements with an excessive increase in the fibro-adipose tissues. It occurs most commonly in the lower limbs. It comes to clinical attention for cosmetic reasons, mechanical problems secondary to degenerative joint disease, or the development of neurovascular compression. We report a case of MDL of the right foot with difficulty walking and wearing footwear. With a complete radio-clinical workup and history review, a provisional diagnosis of MDL was made, confirmed by histopathology and during surgery.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Diagnosis, differential; Foot deformitie; Lipomatosis; Ultrasonography.

Introduction

Macrodystrophia lipomatosa (MDL) is a very uncommon congenital condition that causes localized gigantism in one or more digits, or perhaps the entire limb, due to a gradual overgrowth of all mesenchymal elements and an excessive increase in the fibro-adipose tissues, associated with fibrosis[1]. Few cases of MDL have been reported till now. We describe another anomaly that only affects the right foot, emphasizing the clinical characteristics, alternative diagnosis, and management plan.

Case description

A 16-year-old boy presented progressive enlargement on the second and third toe of the right forefoot since birth. He complained of difficulty in walking and wearing footwear. However, he had no complaints of pain and or ulceration. History of removal of ipsilateral second toe three years back was reported. No record of similar complaints among the family members.

On physical examination (Figure 1)

1. Hypertrophy of the plantar aspect of the right forefoot (Discrepancy of 4 cm circumference compared to the left foot). The plantar swelling was soft to firm in consistency;
2. Hypertrophy of the third toe;
3. Scar mark of the previously amputated second toe;
5. No neurovascular deficit.

Investigations

Radiographs (Figure 2)

1. Increased translucency of plantar aspect suggestive of soft tissue hypertrophy;
2. Enlargement of the third toe phalanges and metatarsal;
3. Lateral deviation of the third digit at the metatarsophalangeal (MTP) joint;
4. Amputated second toe at metatarsal neck level

Study performed at the Vijayawada, Andhra Pradesh, India.

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Figure 1. Preoperative clinical photos showing enlargement of the plantar aspect of the right forefoot (A) and enlargement of the third toe (A and B) of the right foot.

Figure 2. Preoperative radiograph. Lateral view and Anteroposterior view.

Ultrasound

Ultrasound on grayscale and Doppler images showed generalized soft tissue thickening without aberrant blood flow or calcifications.

Histopathology

Histopathology analysis was performed after the first stage debulking procedure. The results showed adipose tissue with dispersed delicate, thread-like fibrous tissue significantly increased.

Diagnosis

Based on the clinical and radiological findings, it was diagnosed as an MDL. After the histological findings, the diagnosis was confirmed.

Management

Line of treatment in this case.

1. First stage debulking procedure of the plantar aspect of the foot (Figure 3);

The surgical procedure was performed under spinal anesthesia after applying a tourniquet. In the first stage, debulking of the enlarged plantar aspect of the right foot was performed after keeping an adequate skin tag for closure. During surgery, excessive fibro-adipose tissue was noted.

2. Second stage excision osteotomy of third toe proximal phalanx (Figure 4).

The surgery was also conducted under spinal anesthesia after applying a tourniquet. As a proximal phalanx of the third toe was enlarged, an excision osteotomy was planned after comparing it with the opposite foot radiograph. The incision

Figure 3. (A) Debulking procedure of the right foot sole; (B) Debulked soft tissue sample; (C) Clinical photo after first stage debulking procedure; (D) Postoperative radiograph showing decreased soft tissue translucency compared to preoperative.

Figure 4. (A) Kirschner wire fixation after second toe proximal phalanx osteotomy; (B) Postoperative clinical photo after second stage surgery; (C) Postoperative radiograph after proximal phalanx osteotomy with Kirschner wire in situ.

was made on the lateral side of the third toe, and a bony fragment was removed from the proximal phalanx shaft. After the osteotomy, the proximal and distal fragments were fixed with a 2 mm Kirschner wire. The wound was closed in layers. A plaster of Paris slab was applied below the knee for six weeks.

Discussion

Although this disease is typically diagnosed in newborns, problems usually arise as the child ages. There is no sex predilection of this anomaly, but the association of the PIK3CA gene may be seen[(2)]. Unilateral foot involvement affecting the second and third toe is more commonly seen in this condition.

Despite functional issues, such as trouble in grasping or walking, surgical consultation is typically taken for aesthetic rather than functional reasons. In our case, the patient had difficulty walking and could not wear the same size shoes on both feet, yet cosmesis was the patient's priority.

According to Southard et al.[(3)], some patients experience affected limb pain due to the rising size, shape, and number of Pacinian corpuscles.

Imaging studies are essential to diagnose this anomaly because they can identify the kind of hypertrophied tissue present. Simple radiographs might show soft tissue enlargement and skeletal abnormalities. The characteristic radiolucencies reveal the lipid composition of the soft tissue. According to Soler et al.[(4)] magnetic resonance imaging is the preferred diagnosis technique for MDL, which demonstrates excessive fibro-adipose tissue with fibrosis and associated abnormal growth of other mesenchymal tissues.

A large amount of adipose tissue is evident in histopathological results, dispersed throughout a delicate, mesh-like fibrous structure[(5)]. Involved tissues include bones, muscles, nerves, and subcutaneous tissues. Even though there are several histological alterations, the exact pathophysiology is unknown.

However, a few potential mechanisms have been proposed, including segmentation defects, abnormal fetal circulation, growth-inhibiting hormone abnormality, and fat cell degeneration[(6)].

Differential diagnosis frequently includes proteus syndrome, fibrolipomatous hamartoma of nerve, Klippel-Trenaunay-Weber syndrome, neurofibromatosis type I, lymphangiomatosis, hemangiomatosis, and lymphangiomatosis.

Neurofibromatosis is the most challenging condition to differentiate from MDL among them. However, hereditary history and specific skin lesions like café-au-lait spots and nodules can help to diagnose neurofibromatosis.

Furthermore, MDL can be differentiated from diseases of similar features by negative family history, bony enlargement, and adipose tissue deposition in nerves, muscles, and tendons with macrodactyly, which are characteristic features of this disease. According to Tatu et al.[(7)], hypertrophy or atrophy of bony and cartilaginous components with interphalangeal joint ankylosis and exostosis may be seen. Basophilic degradation, hyalinosis of collagen tissue, and subcutaneous nerve enlargement with medullary cavity invasion by fat cells are also characteristic findings.

The preferred treatment course for MDL is surgical. The main surgical goal is to make them seem better cosmetically while retaining as much neurologic function as possible. Good outcomes can be achieved with selective and well-planned partial amputations and numerous debulking surgeries. However, if the deformity is not severe and there are no signs of neurological involvement, surgery should be postponed until the patient grows.

Nerve injury is a potential side effect of excessive debulking operations; the published incidence is between 30% to 50%. Treating MDL is difficult due to the local recurrence rate between 33% and 60%[8]. Using debulking and proximal phalanx osteotomy, in our case, we achieved a satisfying result regarding aesthetic and functional outcomes. We operated on the patient with the first stage debulking procedure and second stage osteotomy four weeks apart for proper planning of the bony procedure after the soft tissue procedure, better wound healing, and reduced extensive surgery-related pain and complications. However, we advised the patient for regular follow-ups to determine whether the condition is static or progressive.

Macrodystrophia lipomatosa is the progressive enlargement of soft and bony tissues, causing mechanical and cosmetic problems. A rare disorder should be identified early for prompt intervention and functional improvement. The basic surgical strategy to treat this condition is enhancing the aesthetic look while maintaining neurological function. Good outcomes can be obtained with prudent, well-planned debulking procedures and partial amputation. Surgery should be planned following the patient's maturity, severity, and neurological involvement.

Author' contributions: The author contributed individually and significantly to the development of this article: JD *(https://orcid.org/0009-0008-4691-2087) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, bibliographic review, survey of the medical records. The author read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Chondroblastoma of the talus: a case report

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Abstract

Chondroblastoma is a rare benign cartilaginous tumor comprising approximately 1% of all bone tumors. It usually occurs in patients from 10 to 25 years, being more frequent in men (2:1). It is usually located in the epiphysis of long bones, mainly in the distal femur, tibia, and proximal humerus, in individuals with open physis. This paper presents an atypical presentation of chondroblastoma of the talus, with few similar publications in the literature. A 33-year-old male patient was treated in a hospital with pain in his left ankle for about three years. After imaging and histopathological examinations, the hypothesis of chondroblastoma was confirmed, and resection with intralesional margin was performed.

Level of Evidence V; Case Report; Expert Opinion.

Keywords: Chondroblastoma; Bone neoplasms; Talus.

Introduction

Chondroblastoma is a rare benign cartilaginous tumor comprising approximately 1% of all bone tumors. It usually occurs in patients from 10 to 25 years, being more frequent in men (2:1). It is usually located in the epiphysis of long bones, mainly in the distal femur, proximal tibia, and humerus, in individuals with open physis[1,2]. The differential diagnoses are giant cell tumor (GTC), aneurysmal bone cyst, and chondromyxoid fibroma[3]. Symptoms include progressive pain, which, due to the topography of the lesion, can simulate intraarticular diseases, with joint effusion and limitation of the range of motion[1,2]. It is classified, according to Enneking, into type 2 (active) or 3 (aggressive)[2].

This paper presents an atypical presentation of chondroblastoma of the talus, with few similar publications in the literature. First, it will present imaging and the clinical and histopathological aspects, followed by the surgical approach adopted and the postoperative result.

Case description

This study was approved by the Institution Ethics Committee.

A 33-year-old male patient with no pathological history was referred to a hospital to treat a suspected tumor in the foot. The patient complained of pain and functional limitation in the left ankle, especially in the medial region, lasting three years. The patient attended several emergency rooms without diagnosis or improvement with conventional analgesics and anti-inflammatory drugs.

After consultation in one of the services, imaging tests were requested and brought by the patient during the first consultation at our service. Radiographs of the left ankle were performed on 01/06/2016 (Figure 1) and identified a lytic lesion in the talus. Magnetic resonance imaging was also performed on 01/06/2016 (Figure 2) and detected a cystic formation of thick/hematic content and multiseptate in the anterior region of the talus (2.4x2.2x1.5cm). The patient underwent a trephine biopsy on 09/12/2016; however, it was inconclusive. A new biopsy was performed on 05/23/2017

Study performed at the Hospital Otávio de Freitas, Recife, PE, Brazil.

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Figure 1. Initial profile radiograph of the left foot, demonstrating a solution of continuity in the distal topography of the talus, of predominantly lytic aspect and discrete sclerosis halo.

(Figure 3), and the anatomopathological was compatible with chondroblastoma, due to the microscopic characteristics of chondroblast layers, with a rounded shape, on a chondroid matrix background. Differential diagnosis with GTC is important because multinucleated giant cells are present in about 20% of cases. The typical "chicken wire" appearance, described in the literature on chondroblastomas, was not observed in this histopathological[1].

The initial score of the American Orthopaedic Foot and Ankle Society (AOFAS) was 31 points[4], which demonstrated the morbidity of the condition. Due to its symptomatology and limited bone destruction, the tumor was classified as Enneking type 2 (benign active)[1].

Due to the lesion characteristics, an intralesional approach was performed on 12/28/2017. The anterior access to the ankle was used at a half distance between the malleolus, about 15 cm, and longitudinal. It is an intermuscular plane between the extensor hallux longus and the extensor digitorum

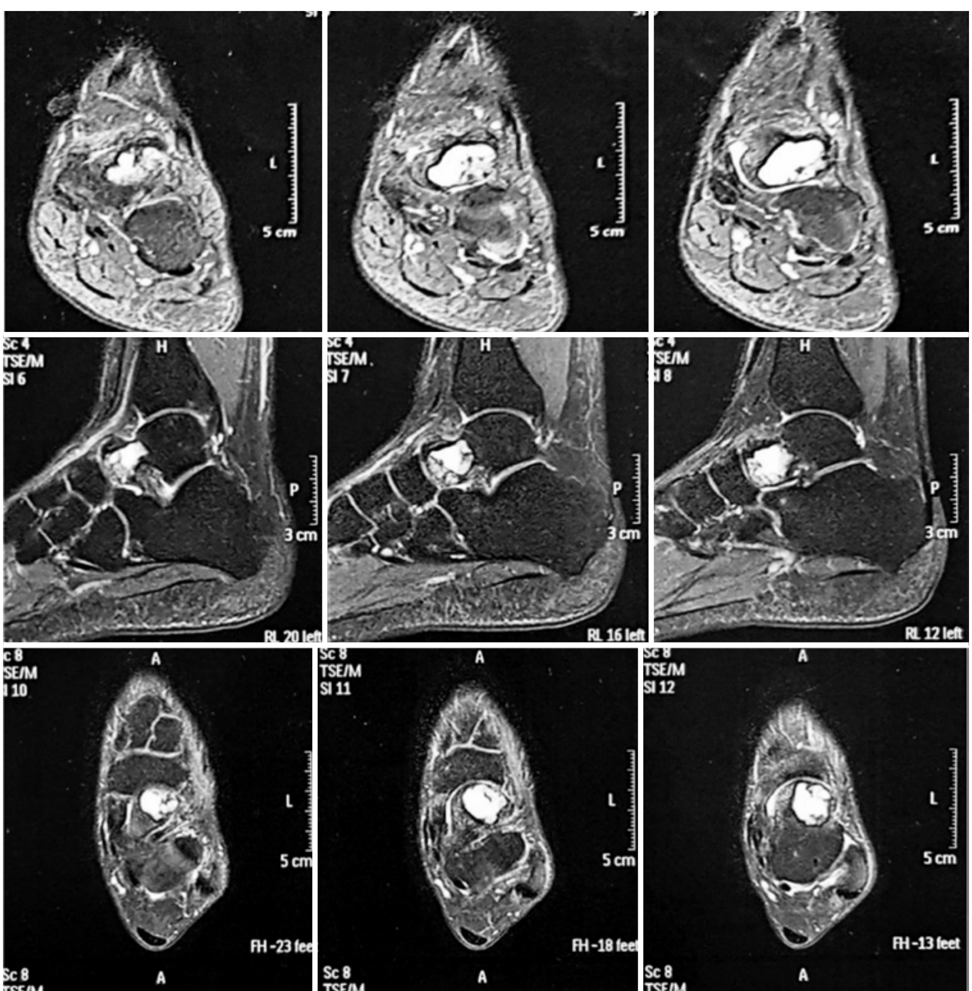

Figure 2. Magnetic resonance imaging in three sections: coronal, sagittal, and axial, and the tumor can be observed in the anterior region of the talus, especially affecting the neck and head.

longus. The structures at risk are the cutaneous branches of the superficial and deep fibular nerve and the anterior tibial artery[5]. After anterior access to the talus, an osteotomy was performed to access the tumor. Then, the tumor resection was performed from curettage, drilling, and subsequent electrocauterization of the lesion walls. Although close to the talonavicular region, the tumor was restricted to the talus. Calcified, whitish, and sclerotic macroscopic material was observed. The cavity (Figure 4) was filled with an iliac crest cancellous graft. The specimen's anatomopathological examination confirmed once again the chondroblastoma.

After more than four years of surgery, there was no tumor recurrence. The radiographs showed the talus remodeling, with adequate bone graft osteointegration. The AOFAS was reapplied, and the patient scored 84 points, demonstrating a significant improvement in functional clinical (Figure 5).

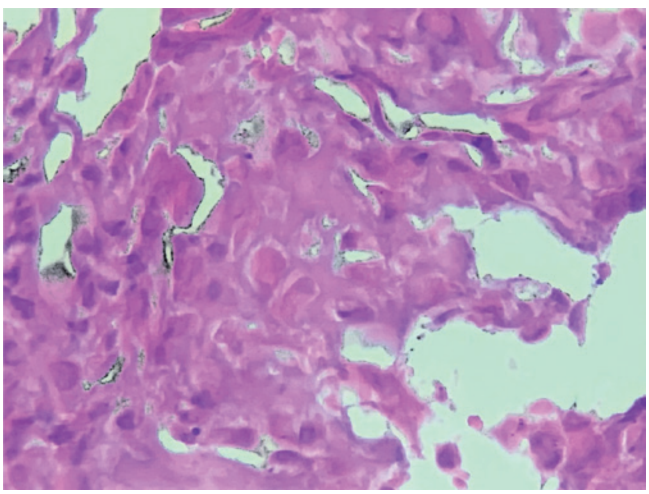

Figure 3. Anatomopathological analysis. Giant cells, amid the proliferation of plasmacytoid cells (pink cytoplasm with rejected nuclei), sketching chicken wire appearance.

Figure 4. Intraoperative image demonstrating excision of the tumor in the talar region.

Discussion

Chondroblastoma is a benign bone tumor usually located in the epiphysis of skeletally immature individuals. It accounts for only about 1% of all bone tumors[3]; of this total, only 4% approximately develop in the talus[6]. When it affects the foot, the most affected sites are the talus and the calcaneus[7,8]. In the literature, chondroblastoma is the most common benign bone tumor found in the talus[9]. In unusual presentation sites, these tumors can be diagnosed delayed by months or even years[10]. Malignancy is rare (less than 2%) and may affect the lungs, bones, or soft tissues[3]. Clinical aspects are nonspecific and may include insidious pain (more common), edema, and joint stiffness[11], which can delay diagnosis. These characteristics were observed in the patient in this study, who resorted to multiple outpatient visits before being correctly conducted.

Radiographically, the lesion is predominantly lytic, rounded, delimited by sclerosis halo, and may present calcifications inside. Computed tomography can be useful in delimitation and more accurate tumor visualization. Magnetic resonance imaging, in addition to this information, allows the evaluation

Figure 5. A more recent profile radiograph of the left foot, five years after tumor resection demonstrating the talus remodeling. It is still possible to observe changes compatible with talonavicular osteoarthritis (slight decrease in joint space and small osteophytes, for example).

of the involvement of adjacent soft tissues, demonstrating, for example, important adjacent edema, and was, therefore, the complementary examination of choice for the present case[1,2].

Anatomopathology is characterized by relatively undifferentiated cell tissue, with cells similar to chondroblasts (round or polygonal) and osteoclasts (multinucleated giants). There is also a small amount of intercellular cartilaginous matrix with calcification areas. This set confers the aspect called “chicken wire”[2]. In addition, secondary areas of aneurysmal bone cysts can be found, especially when the tumor affects the hands and feet[3]. These last two findings, however, were not found in the reported patient.

The treatment choice is surgical, with resection of the lesion from curettage and some adjuvant method (electrocauterization with a scalpel or phenol, for example). Preferably, it is recommended to fill the cavity from excision with an autologous bone graft[2,8,12].

The AOFAS score includes subjective (patient-informed) and objective (physician-assessed) criteria for pain assessment and ankle and hindfoot functionality. It varies from 0-100, so the closer to 100 points, the better the clinical and functional condition. The change in the reported patient’s score (31 initially to 84 points after surgery) evidences the significant improvement obtained by the therapy used in this case. The points lost were probably due to the developing subtalar and talonavicular arthrosis due to the delayed tumor diagnosis. It is worth mentioning that it could be useful to evaluate with hindfoot computed tomography to investigate these factors. Although the prognosis is good after treatment, recurrence rates are relatively high, ranging from 10-20%[1]. However, there are no data specifically related to the talus. Local recurrence is believed to be mainly associated with a poor surgical approach, especially ineffective curettage[13]. The approach should be aggressive, avoiding remaining cells and preserving physis in younger individuals. The use of intraoperative adjuvants, such as electrocauterization, is described in the literature[1]. The patient did not present recurrence in the five years following surgery.

A case of chondroblastoma of the talus, a rare manifestation of the tumor, was presented. After confirmed diagnosis by histopathology, surgical intervention was performed, with resection and lesion filling with a bone graft. After five years of follow-up, a good clinical evolution was observed without local recurrence.

Authors’ contributions: Each author contributed individually and significantly to the development of this article: TMSB *(https://orcid.org/0000-0002-7166-3800) Conceived and planned the activities that led to the study, performed the surgeries and bibliographic review; AMGS *(https://orcid.org/0000-0003-3771-9628) Statistical analysis, interpreted the results of the studies and data collection; JVLBA *(https://orcid.org/0000-0002-1223-2774) Performed the surgeries, participated in the review process and formatting of the article; MSAM *(https://orcid.org/0000-0002-9759-7952) Clinical examination, interpreted the results of the study and approved the final version; KCMV *(https://orcid.org/0000-0003-1579-1020) Performed the surgeries, clinical examination, and formatting of the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Osteoid osteoma - case report and literature review

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Abstract

Osteoid osteoma (OO) is a benign osteoblastic bone tumor, most frequently affecting young male patients. Due to its rarity and nonspecific symptomatology, the OO diagnosis in the foot can be postponed and confused with diseases leading to the absence of the correct diagnosis for years. In this report, we present a 22-year-old male patient diagnosed with OO in the talus. His diagnosis was delayed for approximately three years, confused, and treated as a complication after an ankle sprain. We also conducted a literature review on OO in the foot and ankle.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Osteoid osteoma; Bone neoplasms; Talus.

Introduction

Osteoid osteoma (OO) is a challenge for orthopedists in early diagnosis and choosing the best treatment. When it affects the foot bones due to its rarity, much of the literature is based on case reports[(1)].

Osteoid osteoma is defined as a benign osteoblastic bone tumor, and it is characterized by a nidus surrounded by dense and sclerotic bone, rarely greater than 15 mm[(1-3)]. Responsible for 10% to 14% of benign tumors, this tumor has a higher frequency in young men (between 5 and 25 years old) in a 2:1 ratio[(2,4-6)]. The most common locations are the metadiaphyseal and diaphyseal region of long bones, particularly the tibia and femur[(2,3,5,7-9)]. Foot involvement is rare, ranging from 2% to 10%, and the most affected are the talus, followed by the calcaneus[(2,10,11)]. Although its pathogenesis is unknown, it seems that a high level of prostaglandins is produced in the nidus center resulting in arteriolar vasodilation and edema, which stimulates the nerve terminals, causing pain[(1,6,7)].

Eideken classified OO according to its location as cortical, cancellous, and subperiosteal[(7,10)]. These tumors are usually cancellous or subperiosteal in the foot, where the periosteal reaction is minimal or absent[(7)].

Its clinical presentation frequently is pain, edema, joint stiffness and/or limitation of activities[(7,8,10)]. Locating near the joint can lead to synovitis, muscle spasms, mimicking arthritis, or trauma[(10)]. Classically, the pain worsens at night with improvement after administration of non-steroidal anti-inflammatory drugs (NSAIDs) in about 64% of cases[(7,11)]. Due to its rarity and nonspecific symptomatology, OO can take years to be diagnosed[(4)].

From the complementary exams, the simple foot radiograph hardly presents alterations due to the absence of periosteal reaction, but when positive, it points to a radiolucent lesion surrounded by bone sclerosis[(7)]. Magnetic resonance imaging (MRI) presents nonspecific bone edema, leading to diagnostic errors in 33-35% of cases[(7)]. Bone scintigraphy can be used to locate the tumor due to its high sensitivity[(12)]. Computed tomography (CT) is superior to MRI in showing the nidus attenuation and central calcification associated with perilesional sclerosis[(7,8,12)] and is the main imaging test for diagnosis[(12,13)]. Among the main differential diagnoses are ankle impact syndrome, stress fractures, tenosynovitis, osteomyelitis, osteonecrosis, chronic ankle instability, and inflammatory arthropathy[(8,14)].

Study performed at the Department of Orthopedics and Traumatology, Santa Casa de Misericórdia de São Paulo, São Paulo, SP, Brazil.

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Treatment can be surgical and non-surgical[3]. Using NSAIDs and waiting for spontaneous resolution is an alternative. However, surgery is indicated when there is no improvement with conservative treatment or when the medication presents side effects or risks. The success of surgical treatment is achieved with nidus resection or destruction[6,15]. Other surgical treatment options are percutaneous radiofrequency ablations, reaching 60-100% success[3,6,15]. When the lesion is located in the ankle joint, excision through arthroscopy is also a viable option[4].

The aim of this report is to present a 22-year-old patient diagnosed with OO on the neck of the talus who had his diagnosis postponed for three years.

Case description

This study was approved by the Human Research Ethics Committee under the number (CAAE 37100514.7.0000.5479). A 22-year-old male farmer sought medical assistance at our service due to severe pain in the right ankle that started after twisting approximately three years prior. The patient reported previous treatment in another service with a plaster cast for 40 days, followed by removable immobilization for another 20 days, but without improvement. His pain began during work, worsening at night during rest, and relief after self-medication with NSAIDs. He sought medical help a few times, but according to the patient, the specific diagnosis was not concluded.

On physical exam, the patient presented pain on palpation of the anteromedial region of the right ankle. There was no edema, the ankle was clinically stable, and the pulses were symmetrical and palpable. He did not have a limited range of motion or decreased muscle strength but he presented pain with forced dorsiflexion, both actively and passively, which worsened when standing at his toes or running. At the time, the patient's function and pain were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) scores of the hindfoot and ankle, and visual analog pain scale (VAS) presenting a total of 64 in 100 points and 9 in 10 points respectively.

Bone changes were not detected on a simple ankle radiograph (Figure 1). As the patient had longstanding joint pain, an MRI was requested and showed the lesion and indicated circumjacent medullary edema and joint effusion in the anterior recess of the ankle (Figure 2). A CT was also requested and demonstrated a bone lesion on the neck of the talus of approximately 0.9 cm, well delimited, with perilesional bone sclerosis area and central niche (Figure 3). We hypothesized the OO diagnosis on the neck of the talus and indicated en-block resection surgery.

An open procedure was performed through the anterior route of the ankle. The exposed area presented a wine-colored lesion on the dorsal surface of the talar neck. Ostectomy was performed with the lesion en-block resection (Figures 4 and 5), and the material collected was sent for anatomopathological evaluation. Next, an autologous cancellous bone graft was harvested from the metaphyseal region of the ipsilateral distal tibia to fill the cavity (Figure 6). The anatomopathological report indicated the presence of neoplastic tissue characterized by the proliferation of irregular osteoid beams in their shape and size, surrounded by osteoblasts and interspersed by connective tissue with blood capillaries, proving the OO diagnosis.

After surgery, the patient used suropodalic immobilization without weight-bearing for four weeks, followed by assisted weight-bearing for another four weeks. The follow-up was at two weeks and 1, 2, 4, 8, 12, 24, and 36 months postoperatively.

Figure 1. A) Profile radiograph image of the right ankle with metallic marking at the pain site. B) Oblique radiograph image of the right foot with metallic marking at the pain site.

Figure 2. Magnetic resonance imaging of the right ankle, in the sagittal section, showing bone edema of the talus and periosteal reaction in the anterior region of the tibiotalar joint.

On the first return, the patient reported a complete resolution of night pain. At two months postoperatively, the patient started walking with a full load. The ankle and hindfoot range of motion was similar to the contralateral side, with no pain complaints. The AOFAS scale for ankle and hindfoot at the time was 100 points, and the VAS scale evolved to no pain (0 points). The clinical condition, physical examination, and functional clinical evaluation scales remained unchanged until the last evaluation, three years after surgery (Figure 7).

Discussion

Osteoid osteoma is a benign osteoblastic bone tumor usually smaller than 1 cm. When present in the foot, it is preferably located in the talus and less frequently in the calcaneus, phalanges, and metatarsals[7]. The delay in diagnosis occurs mainly due to the vague symptoms that may be present in varied different diagnoses and the absence of radiographic findings[7,8]. Attention to cases of pain at rest that worsens at night, which improves with NSAIDs, and the chronicity of symptoms is a key point for OO suspicion[2]. In the case

Figure 3. Computed tomography image of the right foot in the sagittal A) and axial B) sections demonstrating the nidus surrounded by sclerotic bone located in the neck of the talus.

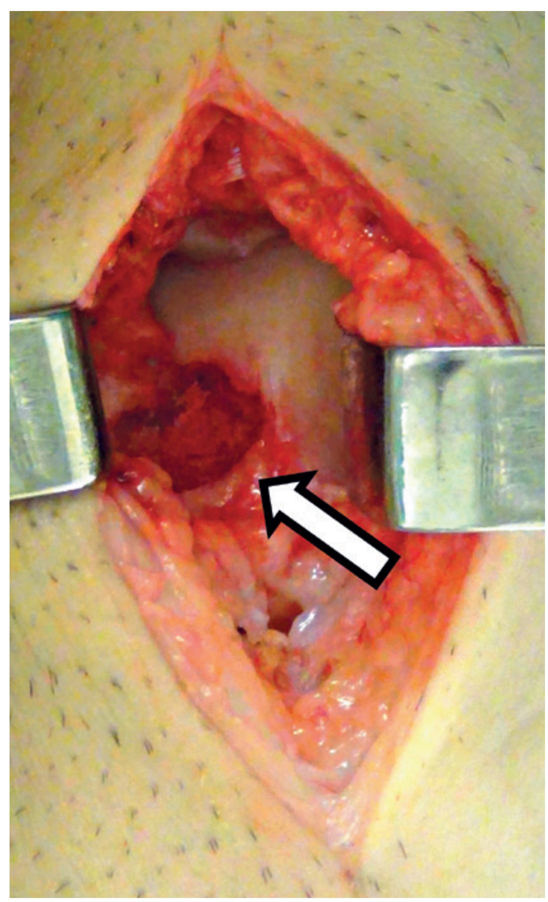

Figure 4. Bone failure on the neck of the talus after resection of the osteoid osteoma.

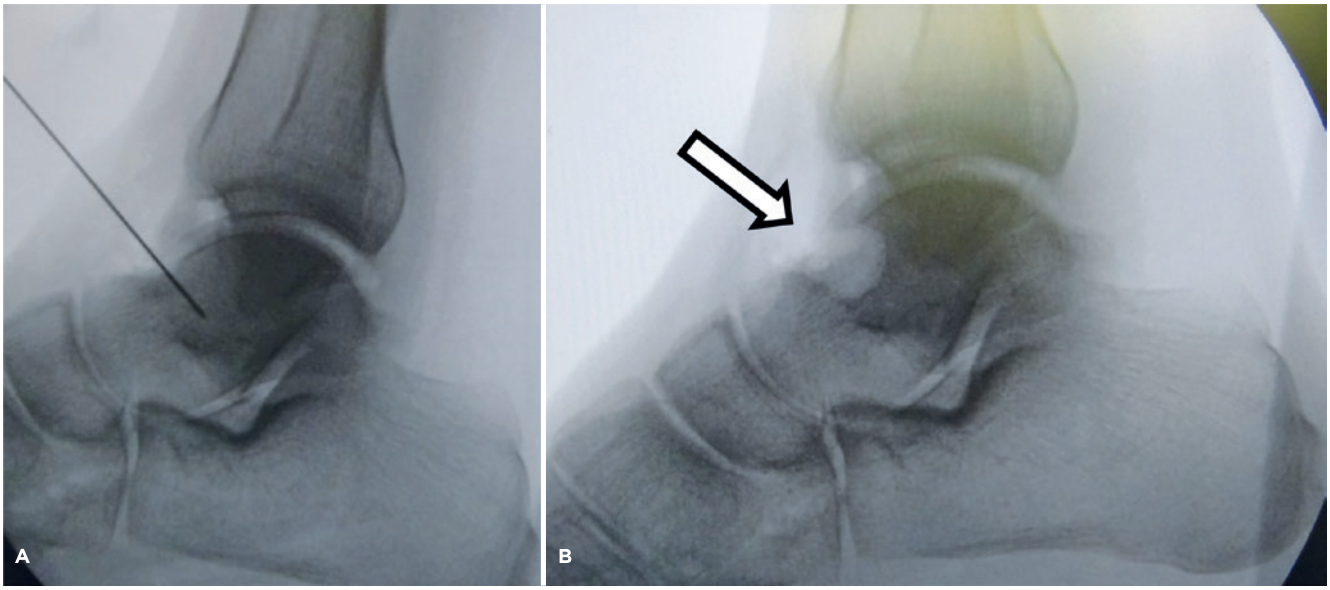

Figure 5. Intraoperative radioscopic images demonstrating. A) the location of the osteoid osteoma marked with Kirschner wire and B) the final result of osteoid osteoma en-block excision.

Figure 6. Immediate postoperative radiograph image of open osteoid osteoma resection and grafting with a cancellous bone graft of the right distal tibia.

reported, the patient had ankle pain for three years that worsened at night and improved with NSAIDs, but during this period, the OO diagnosis was not considered, always correlating it to pain due to old torsional trauma or overload at work. Orthopedists must know the disease and correlate the clinical presentation with appropriate complementary exams to suspect OO diagnosis.

From the exams, the radiograph may show a radiolucent lesion surrounded by bone sclerosis[7]. In cases of OO on the neck of the talus, the radiograph has a sensitivity of up to 61.5%[8]. In the case reported, the radiograph and the MRI showed soft tissue edema in the anterior ankle region of nonspecific character. The test considered the gold standard for diagnosis is CT[2,8]. Sharma et al.[16] compared single-photon emission computed tomography (SPECT-CT) with bone scintigraphy and simple CT. They concluded that SPECT-CT had greater sensitivity and specificity (100% and 100%) when compared with CT (77.8% and 92.3%) and bone scintigraphy (100% and 38.4%)[16]. The SPECT-CT is a tool to be used in cases where there is great doubt about the diagnosis, even after exams of less complexity.

Considering the natural course of OO, spontaneous resolution can occur between two and 15 years, but prolonged use of NSAIDs is discouraged due to their side effects and inefficiency in relieving symptoms in one-third of patients[8]. On the other hand, nidus surgical excisions are curative and provide pain relief[12]. The main treatment methods are open or arthroscopic surgical excision and thermal destruction by laser photocoagulation or radiofrequency[6]. The orthopedist should consider the advantages and disadvantages of these approaches and discuss them with the patient, seeking the best method to solve the problem. We present a case of OO on the neck of the talus in which diagnosis was delayed. This differential diagnosis should be remembered in chronic ankle pain, and additional tests should be requested. The lesion en-block resection resulted in complete relief of symptoms.

Figure 7. Images three years after osteoid osteoma treatment. A) Clinical image showing the leg-foot range of motion; B) Radiograph in profile; C and D) Computed tomography scans showing the eradication of the tumor lesion.

Authors' contributions: Each author contributed individually and significantly to the development of this article: MMC *(https://orcid.org/0000-0001-8133-7892) Conceived and planned the activity that led to the study, wrote the article, participated in the review process; IFL *(https://orcid.org/0000-0002-4973-8271), and LM *(https://orcid.org/0000-0001-5967-0541) Datta colletion, conceived and planned the activity that led to the study; JMPB *(https://orcid.org/0000-0002-5280-1673), and NMN *(https://orcid.org/0000-0001-7696-2220) Conceived and planned the activity that led to the study, participated in the review process; MTC *(https://orcid.org/0000-0001-9411-9376) Wrote the article, participated in the review process. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) .

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Case Report

Acute calcific periarthritis at the metatarsophalangeal joint - a case report

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Abstract

Acute calcific periarthritis (ACP) is an uncommon forefoot condition with a few cases reported in the literature. It is often misdiagnosed and may result in unnecessary diagnostic and therapeutic procedures due to its association with other systemic diseases with similar clinical presentation. A 70-year-old man presented in the emergency room with soft tissue swelling with local erythema and tenderness in the fifth metatarsophalangeal region of the right foot, which started two days prior with no history of injury. Passive and active movements of the joint were painful. Acute calcific periarthritis could be confused with other pathologies. A thorough clinical examination and the knowledge of its clinical presentation could prevent unnecessary diagnostic procedures.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Metatarsophalangeal joint; Soft tissue injuries; Periarthritis.

Introduction

Acute calcific periarthritis (ACP) is an uncommon forefoot condition; only a few cases are reported in the literature. It's an inflammatory, self-limiting, monoarticular, periarticular process of dystrophic mineral deposition[1]. It is more common in the shoulder but can also involve the hip, knee, ankle, foot, elbow, wrist, and fingers[2-4]. Even though the true origin of this condition is unknown, a history of trauma, repeated stress, or strenuous use due to footwear are to blame for one-third of the patients, and it affects both genders equally, with a mean age of 45 years[5,6].

Acute calcific periarthritis is often misdiagnosed and may result in unnecessary diagnostic and therapeutic procedures[7] due to its association with other systemic conditions such as gout and pseudogout, diabetes, rheumatoid arthritis, septic arthritis, and hypothyroidism. The aim of this report is to present an uncommon condition and increase awareness in the medical community, avoid pitfalls in differential diagnosis from all the above forefoot systemic diseases, and reduce further unnecessary investigations.

Case description

This study was approved by the Institution Ethics Committee.

A 70-year-old man presented in the emergency room with swelling and severe pain in the fifth metatarsophalangeal region of the right foot, which started two days prior with no history of injury. Soft tissue was swelling with local erythema and tenderness in the fifth metatarsophalangeal region. Passive and active movements of the joint were painful. According to his medical history, the patient was a regular smoker, had no allergies, and was treated for atrial fibrillation, hypertension, and type-2 diabetes.

Radiographs of the foot demonstrated a small, calcified nodule at the head of the fifth metatarsal (Figure 1). Hematological and biochemical investigations were within the normal range, including full blood count, C-reactive protein, erythrocyte sedimentation rate, calcium, phosphate, and uric acid. At this stage, the diagnosis of ACP was suggested, and 1 ml of betamethasone (3mg/ml) was injected at the point of maximal tenderness under local anesthesia.

Study performed at the General Hospital of Athens "G. Gennimatas", Athens, Greece.

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Figure 1. Radiographs of the patient presented in the emergency room.

After the injection, a calcified toothpaste-like material streamed from the injection point. The patient was recommended to continue using analgesics and visit the department's outpatient clinic five days later.

The patient returned to the outpatient clinic five days later. The pain was relieved, and new radiographs were taken, which ascertained the clinical picture as they revealed a significant decrease in calcification (Figure 2). Laboratory investigations revealed a composition of calcium carbonate and phosphate. The patient was followed up for two months and, six months later, had no symptoms.

Discussion

Acute calcific periarthritis is presented with sudden pain, localized edema, erythema, tenderness, and decreased function of the ailing joint[1]. The pathognomonic finding in radiographs is a varying size homogeneous, monoarticular calcific deposit localized to the symptom's site. There is usually a history of trauma or repetitive stress and unsuitable footwear. Some patients report elevated temperature and inflammation indicators such as c-reactive protein, white blood count, and erythrocyte sedimentation rate may be increased, even though they are usually within the normal range[8].

The cause and ACP pathophysiology are still uncertain and debatable[9]. The prevailing theory for calcium deposition is that mechanical, metabolic, and possibly other factors induce poor blood flow and eventually local tendon hypoxia, ligament, or capsule in the joint area[10]. Four phases of macroscopic calcium deposition and its clinical outcome were described by Chung et al.[11]. In Phase 1, patients are usually asymptomatic, and calcium is contained within the tendon. In Phase 2 (mechanical), the size of the calcium deposit increases, affecting the bursa and causing pain in the affected area. Adhesive periarthritis and/or adhesive bursitis is created in Phases 3 and 4 (intraosseous loculation); calcium deposits may migrate to the tendon insertion or joint capsule of the adjacent bone, which is supported by a combination of mechanical or metabolic factors[11].

Acute calcific periarthritis is usually misdiagnosed as it may clinically imitate other pathology[7]. Its monoarticular character, which does not involve the joint, may assist in

Figure 2. Radiographs of the patient after five days in the outpatient clinic.

differentiating from other inflammatory and erosive arthropathies. Gout is usually previously diagnosed and often has asymmetric polyarticular distribution, and patients report a history of recurrent exacerbations. Calcium pyrophosphate dihydrate (CPPD) crystal deposition disease also has a bilateral distribution, uniform joint space loss, subchondral new bone formation, and intraosseous cysts. In other systemic arthritides, the calcifications tend to be multiple[12]. Tumors, metastatic calcifications, and collagen vascular diseases may mimic the calcifications of ACP; however, they have a completely different clinical presentation.

Naturally, symptoms improve a week after, and full resolution occurs in 3-4 weeks, while relapse is uncommon[3]. Therapeutic choices include local anesthetic and/or corticosteroid injections and oral non-steroidal anti-inflammatory drugs, treating the condition's symptoms and clinical course[1].

This case is presented to help orthopedic surgeons understand the importance of having ACP in their differential diagnostic quiver. Usually, the typical acute clinical presentation with sudden onset pain, swelling, and tenderness, the characteristic radiological findings, and the absence of biochemical findings are sufficient for the diagnosis.

Authors' contributions: Each author contributed individually and significantly to the development of this article: KB *(https://orcid.org/0000-0002-1601-8462) Conceived and planned the activity that led to the study, wrote the article, participated in the review process; KG* (https://orcid.org/0000-0001-7663-0103) Data collection, bibliographic review. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) iD.

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Case Report

Use of autologous tendon of Hamstring in the treatment of irreparable lesions of peroneus tendon. Case report and literature review

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Abstract

The treatment of severe lesions of peroneus longus and brevis tendons is a challenge for orthopedists, and little is described in the literature about the epidemiology. Most of the articles focus on single lesion of one of the tendons, rarely describing what to do when both are severely ill. This case report will show and discuss a surgical technique for when both tendons are injured.

Level of Evidence III; Case Report and Literature Review.

Keywords: Autografts; Fibula; Foot deformities; Hamstring tendons.

Introduction

The peroneus muscles are the evertor and pronator muscles of the foot[1]. They reside in the lateral compartment of the leg and originate in the superior third of the posterior fibula and are divided at least in the longus and brevis. Still, sometimes there is a peroneus quartus tendon at the level of the ankle and hindfoot[1]. Their tendons have a common synovial sheath approximately 4 cm proximal to the tip of the lateral malleolus and a path in the retro malleolar groove where the brevis is anterior to the longus[1]. In this path from the lateral malleolus trough the calcaneus there is a region with low blood supply where most of the lesion of the peroneus tendon tend to happen.

Peroneus tendon tendinopathy is a frequent pathology in the activity of ankle and foot specialists. However, the actual incidence is unknown because the only available data come from two cadaveric studies[2-5]. Its pathology is widely associated with microtraumas and ankle sprains, also the position of the hindfoot as cavo-varus increases the overload of the tendon[2-15].

However, the presentation with severe simultaneous injury of both tendons ends up being an exception; for this reason, the literature focuses mainly on the treatment of the mild injury of one of the tendons[3,16].

While in the acute phase of the disease it can be managed with orthosis and physiotherapy, the chronical presentation tends to need a surgical treatment. When the lesion is small in the peroneal tendon (less then 50%) it can be debrided, however when is more than this the tendon need to be respected[4,17,18].

There are several techniques to treat these irreparable injuries of both peroneals tendons, the most traditional being

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

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local transfers with longus flexors of the hallux[4,5,16]. The use of grafts for reconstruction has been increasing, and in the literature, the most documented is allograft. The idea of using a hamstring tendon (HT) autograft for peroneus tendon (PT) reconstruction came from the observation of specialists who used this tendon for knee ligament reconstruction without major harm to the donor site[19]. This technique has been previously reported in the literature, demonstrating its validity[2,4,19,20].

This study describes one patient who was operated on with the hamstring autograft technique in 2020, a 59-year-old female. And we did a literature review on the treatment of severe simultaneous injury of both peroneal tendons.

Case description

Presentation of patients

The patient was a 59-year-old female. Complaint of bilateral pain in the feet at the lateral edge in the peroneus region with no history of trauma. On foot examination with cavo-varus, no signs of overload. She had movements of eversion preserved but painful on the tendon region, with no pain in the subtalar joint.

On radiography, there were no other significant findings and no sign of arthrosis in any joint (Figure 1A-C). The ankle resonance of the patient showed a significant cystic lesion in the brevis PT in the region between the tip of the fibula between the peroneus retinaculum, and a total lesion of the longus PT was observed with retraction of the same to the region of the superior peroneus retinaculum (Figure 2A-B) On the resonance of the leg, a good quality of the peroneus musculature was verified without liporeplacement.

Figure 1. Weightbearing radiograph image of the first patient. A) an AP view of the foot; B) Saltzman view of the leg; C) Lateral view of the foot.

Surgical technique

Patient positioned in lateral decubitus or ventral decubitus. First, an incision was made in the ipsilateral popliteal region 3 cm below the joint interline. Visualized the tendons of the pes anserine and located the HT. The tendon was released with a stripper to the proximal and distal for graft removal. The graft was prepared by removing muscle fibers from the tendon. Then the graft was tubularized with Vicryl 1 (Figure 3A-C).

Then an incision was made at the posterior edge of the fibula on the region of the PT (3-5 cm superior to the tip of the fibula), where it could see booth tendons and their lesion. A second incision was made at the lateral edge of the foot in the base of the fifth metatarsal region, identified the brevis PT, and resected it from its insertion. There was the necessity for a third incision on the tip of the malleolus to help release adhesions and remove the tendons (Figure 4A-C).

Tenodesis of the proximal stump of the peroneus tendons was performed with Vicryl 2.0. Sutured the graft in the tenodesis with the pulvertaft technique with Vicryl 2.0 and then finalized with a suture with Monocryl 5.0. The peroneus retinaculum tunnel was used to pass the tendon graft. Sutured the distal portion of the tendon graft in the distal fragment left over from the brevis peroneus tendon with an anchor 3. 5mm fixed at the base of the fifth metatarsal and finalized with a suture with Monocryl 5.0 (Figure 5A-C).

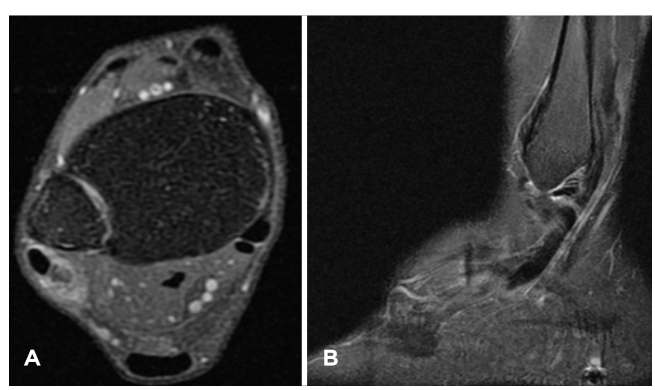

Figure 2. A-B) MRI first patient in an axial and a sagittal cut showing the lesion on the peroneals tendons.

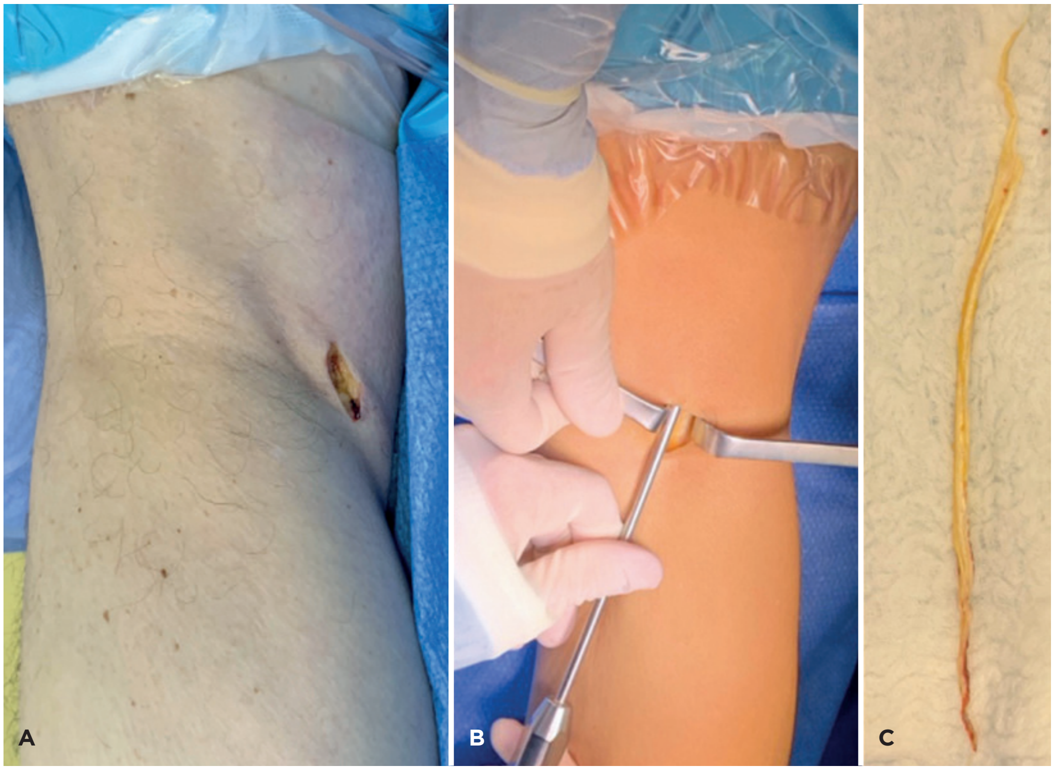

Figure 3. A-C) Show the knee incision, the semitendinosus extraction and the graft acquired.

Figure 4. A-C) Show the incision on the ankle and the foot for the tenolysis of the peroneal tendons and the disease tendons.

Tendon mobility was verified. Suture the tendon sheath with a Vicryl 4.0, then suture the incision by planes and immobilize the lower limb with a short leg splint (Figure 6A-C).

Postoperative follow-up

After two days of surgery, the splint is changed for a controlled ankle movement (CAM) boot, and the patient is released to initiate active combined movements of the ankle at the pain limit for physiotherapy and rehabilitation of the patient, the protocol being two minutes of exercise every two hours. Within two weeks, full weight-bearing is released, and the patient continues to use the CAM boot for another four weeks.

Outcome

The patient has two years of follow-up after the surgery. She had no sign of complications such as an infection or needed a new intervention to treat this disease further. At her latest clinical consult, they presented a strength grade 5- for eversion, a range of motion similar to the contralateral side and none complained about the knee region.

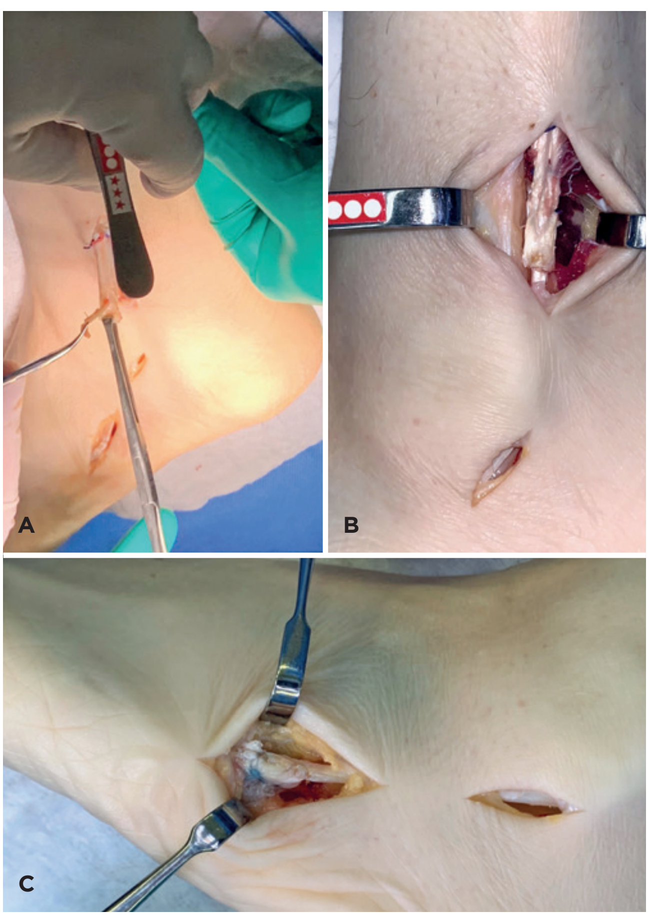

Figure 5. A) The graft through the proximal to the distal incision; B) The proximal suture of the graft to the peroneals tendon; C) Distal suture of the graft to the distal stump of the peroneal brevis.

Discussion

The combined lesion of peroneus tendons is little described in the literature. The first discussions on this topic were from

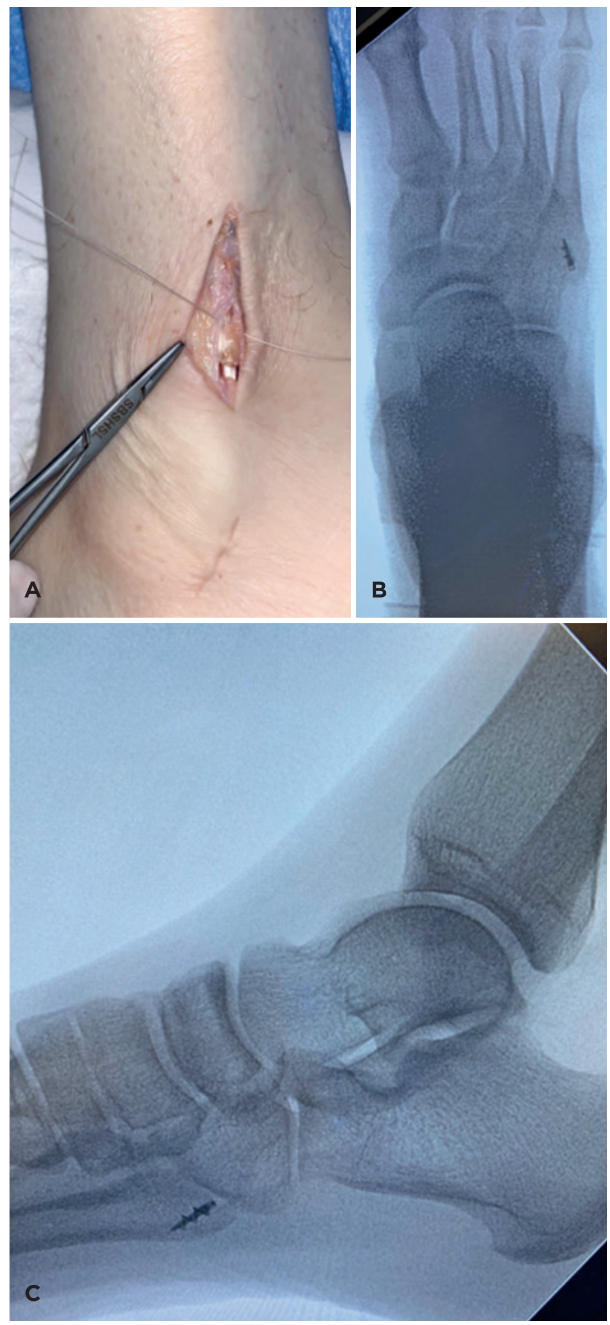

Figure 6. A-C) Closening technique of the peroneal retinaculum and final fluoroscopy.

1998, when Krause and Brodsky created a classification for the treatment of peroneus lesions[11,16].

The first treatments were done through tendon tenodesis and kept the least affected PT and tubolized, however, often the patient maintained the complaint of ankle pain, this can only be done when there is enough tendon left[4,17,18]. Most authors recommend at least 50% of the diameter of the tendon should have good quality.

The next technique to be described in the literature was the use of allografts for the treatment of these sever lesions[5,16]. This allowed for maintaining good mobility and stability of the ankle, significantly improving pain, when there is not enough tendon to tubolize it self. However, there is the problem of availability and the cost of tissue banking for donation and the chance of cross-infection due to the use of donor cadaver tissue[2-4,18,20-24]. Not all doctors have access to a tissue bank for this, and in some places the availability is scarce and the cost for the surgery can skyrocket.

Another technique also described for these patients is the transfer longus flexor of the hallux[16,17]. With the advantage of being activated in the same phase of the gait, and have similar size of one of the tendons. However, his vector is not the same as that of the PT, and patients lose the strength of eversion and stability of the ankle with the change of direction of the tendon and since only one of the function of one of the tendons is reconstruct with this[5,7,20,25-29].

That way, Ellis and Rosenbaum[5] described a hamstring autograft technique for peroneus. For this, it needs the muscular fibers of the PT to be of good quality, without liposubstitution. The remain of the injury tendons needs to have enough excursion in the shaft and good quality tissue so it will allow the graft to work. The use of this graft allows for maintaining the forces of ankle eversion without alteration or losing the function of another foot and ankle tendon, which can be very important for high demand athletes, and if necessary can recreate both tendons since the size of the graft tends to be bigger than the defect, and if necessary it can be extracted the semitendinosus and the gracilis.

Cody et al.[24] demonstrated that removing the HT to treat foot and ankle pathologies brings minor injury to the knee. There was a statistical difference with knee flexion deficit, but without clinical relevance.

The first descriptions of this technique suggested a large incision of 8-12 cm along the entire path of the PT[2-4]. However, it is possible to perform this procedure with only two small pathways, one in the posterior part of the tip of the fibula and the other near the base of the fifth metatarsal, and to use the peroneus retinaculum as the tunnel for the passage of the graft, as demonstrated in case. In the patient, a third incision was necessary between this to release adhesions of the brevis PT.

As the cavo-varus of the hindfoot tends to aggravate the pathologies of the peroneus, osteotomies for correction are often associated with the treatment of severe lesions of the peroneus[16].

Peroneus injury is a common pathology for foot and ankle specialists, but when there is a severe injury of both tendons, there is no consensus on how to proceed. The use of autograft is a technique that may be a good option for these cases with a minimally invasive approach, and in our patients, provided improve the pain and allows to maintain the mobility of the subtalar joint.

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Case Report

Post-traumatic hallux varus: treatment using the mini endobutton technique

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Abstract

Hallux varus is an uncommon involvement in the orthopedic routine and consists of the medial deviation of the hallux from the first metatarsal. In this paper, we report a 45-year-old female patient who arrived at the health service after suffering trauma in the right foot. The patient developed a deformity when presenting a hallux varus post-traumatic, requiring surgical intervention. The mini endobutton technique was applied, presenting advantages over other surgical strategies because it promoted the functional and aesthetic rehabilitation of the patient.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Hallux varus; Hullux valgus; Orthopedic fixation devices; Trauma.

Introduction

Hallux varus is a rare pathology[1], and in most cases, it affects women[2] without hereditary tendency. The most frequent cause is the hypercorrection of hallux valgus (bunion) in surgical procedures[3] and due to trauma in the region. Approximately 1% to 1.6% of surgical procedures for hallux valgus may evolve with varus deformity[3]. The most common orthopedic manifestation of the hallux varus is based on the tripod: medial deviation of the hallux, supination of the phalanx, and interphalangeal flexion (claw toes deformity)[2].

The patient with this involvement in the anamnesis has difficulty wearing shoes and has aesthetic impairments, gait disorders, and pain when there is trauma or arthritis. Treatment may be conservative, but when symptomatic, it is poorly responsive, requiring surgical treatment. Thus, it can be surgically corrected through techniques such as medial capsulotomy, lateral reinforcement with tendon transfer, Kirschner wire placement after a transverse capsulotomy, and proximal phalanx exposure, such as closed wedge osteotomy of the proximal phalanx[4], with the medial axis. The prognosis is usually favorable[1-7].

Case report

A 45-year-old female patient in good health condition arrives at the health service and reports functional limitation, mainly pain in the topography of the first right metatarsophalangeal joint for about two months.

However, this was due to a previous fracture in the region, in which conservative treatment was performed using a plaster cast immobilization. Physical examination showed a hallux varus deformity, and the classic tripod of this disease was identified (Figure 1).

Study performed at the Hospital dos Servidores do Estado de Pernambuco, Recife, PE, Brazil.

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Given the condition, imaging tests were requested to evaluate the prognosis and decide on the best management for the patient. Initially, a fracture of the lateral base of the proximal phalanx of the right hallux was observed on anteroposterior and profile radiographs (Figure 2).

Nuclear magnetic resonance imaging was requested to visualize the affected structures better. Degenerative changes were evidenced, involving the joints with slimming of the chondral surfaces (Figure 3). In addition, area of synovitis and a small bone fragment from the lateral base of the proximal phalanx. Based on these findings and the clinical history, the surgical team decided on surgical treatment through the mini endobutton technique.

The surgery consists of two incisions–one dorsolateral and one medial–to expose the lateral base of the proximal phalanx and the distal region of the first metatarsal. Then, the extensor hallucis longus and medial capsulotomy were released (Figure 4).

Then, the 1.2 mm guidewires were inserted at an angle of about 40–50 degrees oblique after cannulation was performed with drills for anatomical reduction and correction of deformity in the distal region of the first metatarsal and proximal phalanx of the hallux, with fixation through the mini endobutton.

Discussion

The aim of this post-traumatic hallux varus case report was to describe this deformity and the mini endobutton technique, as a surgical strategy, for repairing the lateral

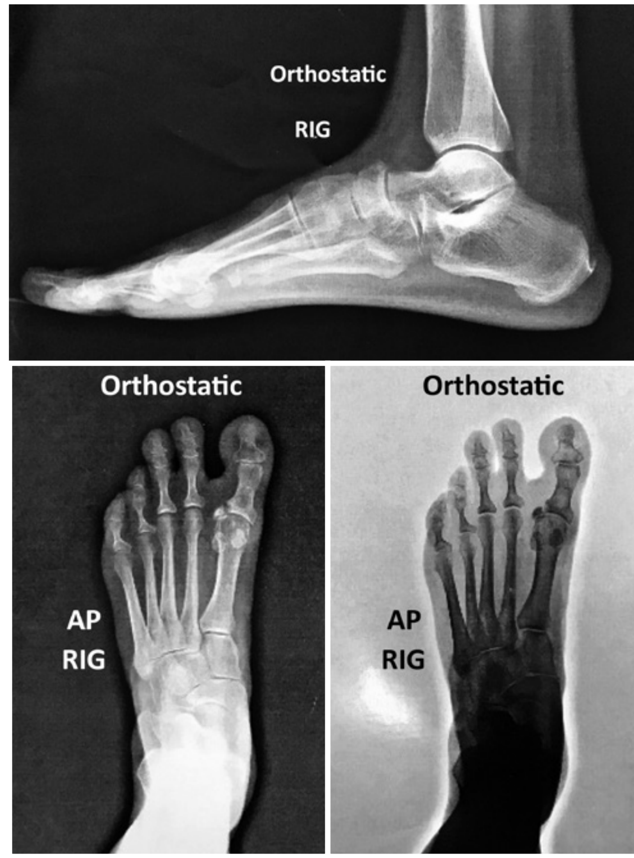

Figure 2. Anteroposterior and profile radiographs.

Figure 1. Immediate preoperative.

Figure 3. T-1 weighted magnetic nuclear resonance.

collateral ligament of the hallux. Such pathology is rare in the orthopedic routine, and because it shows a post-traumatic fact, it further increases its uniqueness and significance[1]. The hallux varus represents a sinuosity of the hallux in the medial direction[4]. The main etiology is the surgery to repair the hallux valgus (bunion)[7], congenital[2], and trauma in the region.

Its main cause is an iatrogenic hypercorrection of the hallux valgus, which is quite common in postmenopausal women[3-7], mainly in patients with long-standing osteoarthritis, with congenital and neurological causes (post-polio). In older adults, hallux varus is a risk factor for falls and subsequent loss of functionality.

Due to its diverse etiologies and clinical presentations, the hallux varus classification is not easily reproducible. Hawkins classified the deformity as static (flexible) or dynamic (rigid). Static deformity is commonly asymptomatic, of uniplanar characteristic, reducible, and not caused by a muscle imbalance. Dynamic deformity is commonly symptomatic, multiplanar, and non-reducible, usually due to a muscle imbalance[8].

Surgical treatment should be indicated according to clinical and radiographic evaluation. Several surgical procedures are capsular repairs, tenotomy and/or abductor hallucis transfer, extensor hallucis longus transfer and hemitransfer, osteotomies, and arthrodeses. There is no consensus on the surgical treatment of choice, and each case should be evaluated individually. Historically, flexible deformities without degenerative joint changes can be treated differently, including bloodless reduction and fixation with Kirschner wires in recent cases, excision tibial sesamoid, or metatarsal and phalangeal osteotomies. However, soft tissue procedures such as medial capsular release, lateral capsuloplasty, abductor hallucis tenotomy, transfers, and tenodeses are described with better results in these deformities[9].

The choice of procedure should be individualized based on the etiology of the deformity, anatomy, objectives, and patient perspectives. In late flexible deformities, there is no evidence that only medial capsular release, lateral capsular overrelease, and abductor hallucis tenotomy are sufficient[10]. In such cases, tendon transfers are indicated. Several procedures are described as extensor hallucis longus transfers and hemitransfer, abductor hallucis transfers, and extensor hallucis brevis tenodesis[11]. There are also new procedures for reconstructing the lateral collateral ligament by the mini endobutton device to correct the hallux varus presenting satisfactory results[10].

Nevertheless, the mini endobutton technique is progressively effective in treating post-traumatic hallux varus, presenting better prognostic results among the patients submitted[6]. Mini endobutton treatment is a reproducible technique that allows the treatment of hallux varus, achieving the same correction of osteotomies but preserving and avoiding complications, which may resemble less invasive percutaneous techniques[12] (Figure 4 and 5).

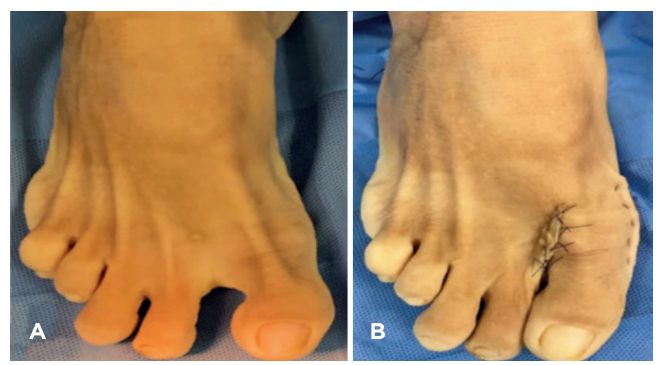

Figure 5. Hallux appearance. A) Preoperative; B) Immediate postoperative.

Figure 4. Medial incision with varus correction using the mini endobutton technique.

Figure 6. Anteroposterior and oblique postoperative radiographs.

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Systematic Review

Periarticular joint arthritis after ankle replacement vs. ankle arthrodesis. A systematic review

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Abstract

Objective: To complete a comprehensive literature review to determine the quantity and quality of literature supporting the incidence of IPJA after AA and TAR.

Methods: A comprehensive review was performed to determine the quantity and quality of literature supporting the incidence of IPJA after AA and TAR. After applying inclusion and exclusion criteria, 23 TAR and 19 AA studies were included.

Results: Only one high-quality level I was found, reporting 1.2% of IPJA after TAR. Majority of the studies were level IV and reported an incidence of subtalar arthritis of 0%-40%, talonavicular 2.8%-34%, and calcaneocuboid 2.8%-3.2% after TAR and an incidence of subtalar arthritis of 7.7%-100%, talonavicular 8.69%-11.6%, and calcaneocuboid of 22% after AA.

Conclusion: There is currently poor quality evidence supporting a higher rate of IPJA after AA compared to TAR. Also there is poor-quality evidence that supports IPJA as a complication of TAR; however, this is the current evidence on this topic. Better-quality long-term studies are required to make definitive and accurate conclusions on the incidence of IPJA.

Level of Evidence III; Therapeutic Studies; Systematic Review.

Keywords: Ankle joint; Arthrodesis; Disease progression; Incidence.

Introduction

End-stage ankle arthritis (ESAA) is a limiting condition that severely compromises the health-related quality of life[1-4]. Ankle arthrodesis (AA) and total ankle replacement (TAR) are currently the most accepted surgical treatments for ESAA. However, there is no clear consensus on whether TAR or AA provides the best clinical outcomes[5].

The introduction of TAR in 1970[6,7] opened a new opportunity for maintaining ankle function; however, AA remains a safe and effective surgical treatment for ESAA[8-21]. Some studies suggest that eliminating motion through AA will result in accelerated degeneration of the periarticular joints at mid or long-term follow-up[22-27]. Despite the benefit that ankle replacement may gain by preserving the tibiotalar motion, certain studies found ipsilateral periarticular joint arthritis (IPJA) after TAR surgery[7,28-54].

The aim of the present study is to systematically review the available literature to determine if there is evidence supporting IPJA as a complication after TAR and AA and a correlation between symptoms and further surgery to treat IPJA.

Study performed at the Queen Elizabeth II Health Sciences Center, Halifax, Nova Scotia, Canada.

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Methods

Search strategy

A comprehensive review of the literature was performed on January 18, 2022, in the PubMed/Medline, Cochrane, and Web of Science databases using the search terms: ((“Arthroplasty, Replacement, Ankle”[Mesh]) AND “Arthritis”[Mesh]) AND “Joints”[Mesh] for total ankle replacement and (((“Ankle Joint”[Mesh]) AND “Arthrodesis”[Mesh]) AND “Arthritis”[Mesh]) AND “Joints”[Mesh] for ankle arthrodesis. The initial search criteria included all dates and types of publications, including retrospective and prospective studies, case reports, and reviews.

Selection criteria

Studies were included if: (1) they evaluated arthritis at least in one of the periarticular joints (subtalar, talonavicular, and calcaneocuboid) after TAR or AA (2) pre- and postoperative radiographs were reviewed. Studies were excluded if: (1) TAR and AA had concomitant periarticular joint fusions at the same stage or before surgery, (2) conversion from AA to TAR occurred, (3) non-English language articles, (4) systematic reviews that contained the studies already included in this review, (5) studies that did not specify the number of patients or joint affected with IPJA.

Two researchers independently reviewed the titles and abstracts and discussed inconsistencies until consensus was obtained; if necessary, a third researcher was consulted to make a final decision to prevent further bias. Next, two researchers independently performed a full-text read for inclusion. In case of disagreement, a consensus was reached on inclusion or exclusion by discussing with a third or fourth researcher until the final decision was determined. Frequencies of IPJA (subtalar, talonavicular, and calcaneocuboid joints) were calculated based on the number of patients treated with TAR from each study.

Level of evidence method

All articles were reviewed and assigned a Level of Evidence Classification from I to V according to the Journal of Bone and Joint Surgery “Levels of Evidence for Primary Research Question”[55].

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used throughout this review for search, data extraction, and results analysis[56].

Results

The literature search yielded 643 relevant publications for TAR and 1295 studies for AA. After removing the duplicates, there were 562 TAR and 952 AA. Next, a title and abstract review for relevance was performed, and 512 TAR and 837 AA were excluded leaving 50 studies for TAR and 115 for AA.

After a full-text review, 27 TAR were excluded (ten German and one Korean studies, six incomplete-data studies, five studies with no or not mentioned preoperative radiographic assessment, and five systematic reviews that included studies already in this study). Ninety-six AA studies were excluded (sixty-eight other-language studies, three systematic reviews that included studies that were already eligible, seventeen incomplete-data studies with no number of patients or joints affected included, and eight studies with no or not mentioned preoperative radiographic assessment). Finally, 23 TAR and 19 AA studies were included for complete analysis (Figure 1).

Most studies were level IV (n = 18, 78.3% TAR, n = 17, 89.47% AA). The best quality study found was level I (n = 1, 4.3% TAR). There were also level II (n = 2, 8.7% TAR) and III (n = 2, 8.7% TAR, n = 2, 10.52% AA) studies.

Overall, the 23 TAR studies revealed a mean age of 62.32 years, and the 19 AA studies had a mean age of 57.1 years. The mean follow-up time was 6.2 years for TAR and 4.75 years for AA. The requirement for further periarticular fusion ranged from 5-13. 8 years after TAR and eight months to 10 years after AA.

Among the studies included, only three[29,30,37] addressed the IPJA as the main topic. The remaining studies performed overall research on outcomes and included IPJA as a complication.

To improve comprehension of the quality of studies, we divided the studies by level of evidence according to the Journal of Bone and Joint Surgery “Levels of Evidence for Primary Research Question”[55].

Level I study

Nunley et al.[49] performed a prospective randomized trial in 2019 comparing outcomes after a mobile-bearing (STAR) versus a fixed-bearing (SALTO TALARIS) TAR. Symptomatic subtalar arthritis was reported in one patient (1.2%) in the mobile-bearing group that required further subtalar fusion. Talonavicular and calcaneocuboid joints were not reported (Table 1).

Level II studies

Only two high-quality level II studies[35,37] were found for the TAR group (Table 1). No level II studies were found for the AA group. These reports did not consider the calcaneocuboid joint in the results. Overall in both studies, 194 ankles receiving TAR were found with a broad range of IPJA. Subtalar arthritis incidence was 8.8%-86%, and talonavicular 10.8%-70%.

Kerkhoff et al.[35] examined 134 ankles after TAR with mobile-bearing (STAR) prosthesis. The authors used the Kellgren and Lawrence classification system to report a total incidence of periarticular osteoarthritis of 19.6%, dividing into subtalar joint (8.8%) and talonavicular joint (10.8%) after pre- and postoperative radiographic assessment. A correlation with symptoms or requirement for further surgery was not considered in this study.

Mayich et al.[37] included 60 ankles and found an incidence of subtalar arthritis of 81%-86%, the majority were grade 1 and

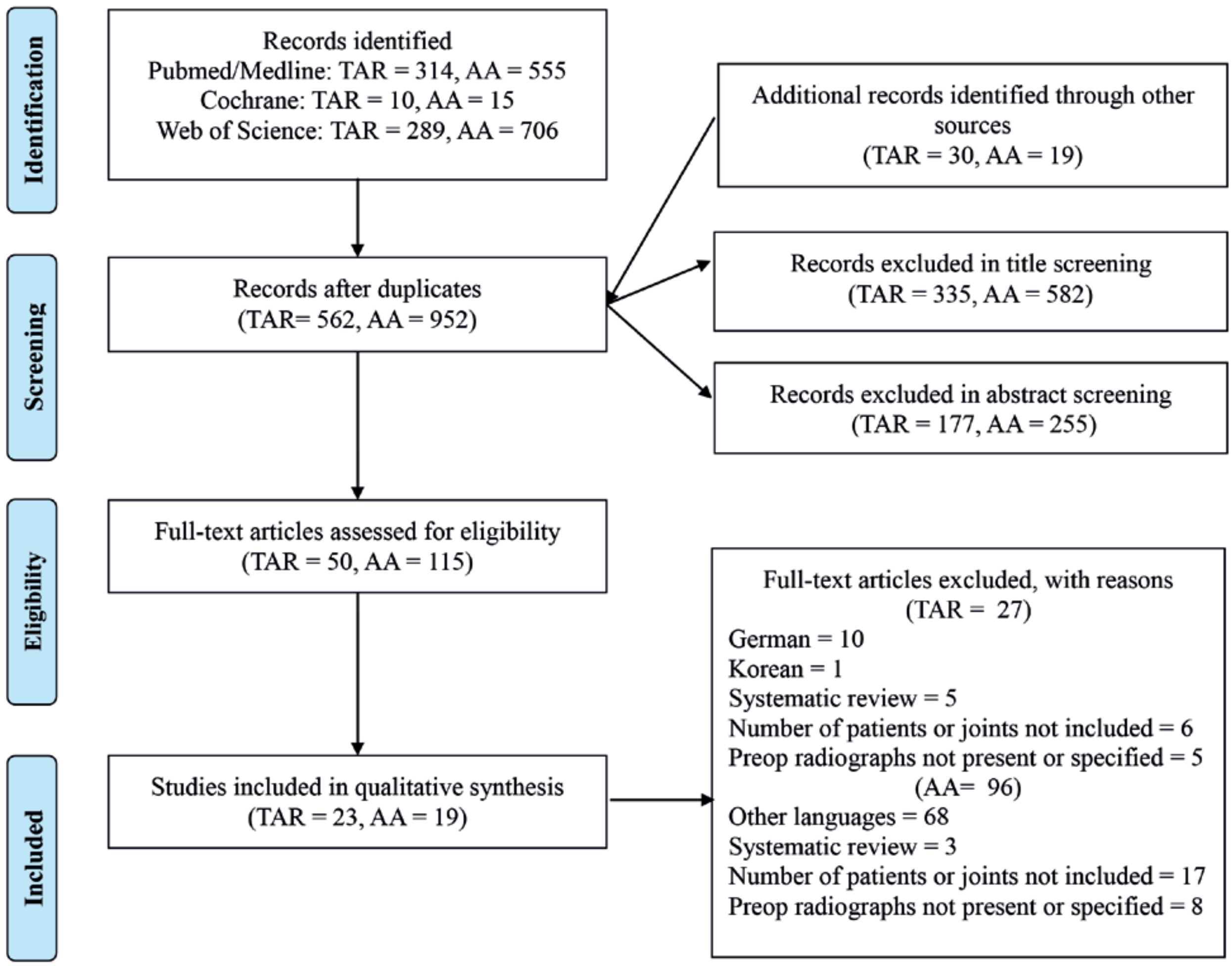

Figure 1. PRISMA flow diagram. The diagram illustrates the search process for published literature meeting the inclusion criteria for this study.

Table 1. Level I, II, III - TAR studies

Authors/ Year	Level	Age	Nº TAR	Follow-up	Implant	Joint	Symptoms	Surgery	Radiographic results
Nunley et al. 2019[49]	I	65 y (35-85)	41 43	4.5 y	STAR SALTO TALARIS	ST: 1.2%	ST pain 1.2%	ST fusion 1.2%	NR
Kerkhoff et al. 2016[35]	II	59y ± 12.5	134	7.5y	STAR	ST: 8.8% TN: 10.8%	NR	NR	KL
Mayich et al. 2013[37]	II	62y (33-90)	60	5y	NR	ST: 81%-86% TN: 62-70%	NR	NR	*KL*: ST: 0 = 8%; 1 = 39%; 2 = 39%; 3 = 11%; 4 = 4% TN: 0 = 29%; 1 = 40%; 2 = 21%; 3 = 6%; 4 = 4%
Marks 2019[50]	III	65.3y (49.4-81.6)	50	4.9y (0.9-8.6)	SALTO TALARIS	ST: 2%	ST pain 2%	ST fusion 2%	NR
Krause et al. 2011[44]	III	64.2y (36-88)	114	38.7m (25-68)	Agility HINTEGRA STAR Mobility	NR	NR	NR	*KL:* Postop: ST: 1.75% (0 to grade 2: 0.88%, 0 to grade 3: 0.88%) TN: 0.88% (0 to grade 2: 0.88%)

* y: years, m: months, ST: subtalar, TN: talonavicular, NR: not reported, KL: Kellgren and Lawrence scale, TAR: Total Ankle Replacement

2, and talonavicular arthritis of 62%-70%, mainly grade 1 of the Kellgren and Lawrence scale.

Level III studies

TAR

Two level III studies[44,50] reported IPJA after TAR and matched the inclusion criteria (Table 1).

Incidence of IPJA

Marks[50] studied 50 patients after TAR with SALTO TALARIS, and 2% of them developed symptomatic subtalar arthritis that required subtalar fusion. Talonavicular and calcaneocuboid joints were not reported.

Progression of IPJA

Krause et al.[44] reported the progression of IPJA using the Kellgren and Lawrence scale in 114 ankles with different types of ankle prostheses. Subtalar arthritis progression was 0.88% each from grades 0 to 2 and 0 to 3. Talonavicular progression was also 0.88% from grade 0 to 2.

AA

Two level III studies[21,44] were identified (Table 2). Both studies reported progression of IPJA after 73 ankle fusions showing a progression of 4.2%-15% for subtalar joint, 2.1% for talonavicular joint, and 3.84% for calcaneocuboid joints.

The studies were analyzed on different scale grading systems. Krause et al.[44] reported the progression of osteoarthritis with the Kellgren and Lawrence scale. Subtalar arthritis progression was 2.1% each from grade 0 to 2 and 0 to 3. Talonavicular progression was 2.1% from grade 1 to 3. Thomas et al.[21] studied the progression with Kellgren and Moore scale, finding IPJA progression rates of 15% and 3.84% from grade 2 to 5 in the subtalar and calcaneocuboid joints, respectively.

Level IV studies

TAR

Eighteen level IV studies[28-32,36,38,40,41,43,45-48,51-54] were included (Table 3).

Incidence of IPJA

Fifteen studies[28,30-32,38,40,41,45-48,51-54] reported the incidence of IPJA. Only three[28,41,46] reported total adjacent joint arthritis of the three joints studied (subtalar, talonavicular, and calcaneocuboid) with a result range of 0%-14.3%. Overall, in 995 ankles following TAR, the incidence of subtalar arthritis was 0-40%, talonavicular arthritis 2.8%-34%, and calcaneocuboid arthritis 2.8%-3.2%.

Three of these studies[28,32,45] found a correlation between symptoms and subtalar joint arthritis in 1.47%-1.7% of patients. The need for additional fusion was reported in eight studies[28,32,38,41,45,46,48,52] with a wide range of timing from 35 months to 13.5 years after TAR. One of the studies[38] showed a higher amount of subsequent joint fusions than arthritis incidence reported due to failed replacement surgery, so we excluded that data in these results. Two studies[43,46] identified no requirement for further surgery, and one reported no IPJA in their results.

Dekker et al.[30] compared three different prostheses in 140 ankles after TAR and reported subtalar arthritis of 40% and talonavicular of 34%, with considerably fewer cases that needed fusion due to painful arthritis (subtalar 11.4% and talonavicular 1%). Regarding the preexisting IPJA, there was an incidence of 40% and 53% grade 1 for subtalar and talonavicular joints.

Saltzman et al.[54] evaluated the incidence of IPJA in a mean follow-up of 4.2 years on 37 patients finding 5% subtalar, 16% talonavicular, and 44% calcaneocuboid joints newly onset arthritis after STAR-TAR.

Progression of IPJA

Seven studies[28-30,36,43,48,54] reported osteoarthritis progression of IPJA after TAR. Four[28,30,48,54] reported the incidence and progression of IPJA. Among 1111 ankles, 14.3%-38% IPJA progression was reported, ranging from 4.8%-59%, 6.4%-38%, and 3.2%-38% in the subtalar, talonavicular, and calcaneocuboid joints, respectively.

Sokolowski et al.[29] reported on secondary subtalar IPJA after TAR, 671 were included, 37 (4%) had subtalar IPJA that required a secondary subtalar fusion. Evaluation of pre- and postoperative radiographs was performed, 99% had previous TAR subtalar arthritis with a correlation of 2% of symptomatic

Table 2. Level III - AA studies

Authors/Year	Age	Nº AA	Follow-up	Joint	Symptoms	Surgery	Radiographic results
Krause et al. 2011[44]	58.5y (28-82)	47 (22 open-22 arthroscopic)	36.5m (28-109) OA: 5y	NR	NR	None	*KL*: Postop ST: 4.2% (0 to grade 2: 2.1%, 0 to grade 3: 2.1%) TN: 2.1% (1 to grade 3)
Thomas et al. 2006[21]	54y	26	44m	NR	NR	NR	*KM:* Progression ST: 15% CC: 2 to 5 = 3.84%

* y: years, m: months, ST: subtalar, TN: talonavicular, CC: calcaneocuboid, NR: not reported, KL: Kellgren and Lawrence scale, KM: Kellgren and Moore scale, AA: Ankle Arthrodesis, OA: Osteoarthritis

Table 3. Level IV - TAR studies

Authors/ Year	Age	Nº TAR	Follow up	Implant	Joint	Symptoms	Surgery	Radiographic results
Sokolowski et al. 2019[29]	58.8y (33.1-74.6)	671	5y (0.1-17)	H3	ST: 99% preop	ST pain 2%	ST fusion 4% (1.9% not for pain) ST fusion: 5y (0.3-10)	*KL:* Preop: Without ST fusion: 0 = 0%, 1 = 8%, 2 = 30%, 3 = 44%, 4= 18%; With ST fusion: 0 = 18%, 1 = 24%, 2 = 29%, 3 = 29%, 4 = 0%. Postop: Without ST fusion: 0 = 0%, 1= 2%, 2 = 19%, 3 = 51%, 4 = 28%; With ST fusion: 0 = 18%, 1 = 21%, 2 = 23%, 3 = 26%, 4 = 12%. Progression: 32%: Without ST fusion: 1 grade = 30%, 2 grades = 2%; With ST fusion: 1 grade = 18%, 2 grades = 3%.
Palanca et al. 2018[28]	73.7y (51.3-92.9)	21	15y	STAR	T: 14.3% ST: 4.8% TN:6.4% CC:3.2%	ST pain 1.6%	ST fusion 1.6% ST fusion: 13.8y	*KL*: Progression 1 grade = ST 3.2%, TN 3.2%, CC 1.6% 2 grades = ST 0%, TN 3.2%, CC 1.6% 3 grades = ST 1.6%, TN 0%, CC 0%
Barg et al. 2018[48]	67y	55	26.6m ± 4.2	Zimmer Trabecular Metal	Preop ST: 67.2%, TN: 36.3%. Postop: ST: 71%, TN: 36.4%	NR	TN fusion post TAR 1.8%	*KL:* Preop: ST: 0 = 32.7%, 1 = 52.7%, 2 = 3.6%, 3 = 1.8%, 4 = 0% TN: 0 = 63.6%, 1 = 23.6%, 2 = 1.8%, 3 = 1.8%, 4 = 1.8% Postop: ST: 0 = 29.1%, 1 = 56.4%, 2 = 5.5%, 3 = 0% , 4 = 0% TN: 0 = 63.6%, 1 = 25.5%, 2 = 1.8%, 3 = 0%, 4 = 0%
Eckers et al. 2018[51]	43 y (27.4-57.6)	17	9.6 (3.3-17.8)	Agility HINTEGRA STAR Mobility	ST: 17.64%	NR	NR	NR
Dekker et al. 2017[30]	70.5y (31-91)	140	6.5y (5.0-8.9)	SALTO TALARIS STAR INBONE	ST: 40% TN: 34%	ST pain 11.4% TN pain 1%	ST fusion 11.4% TN fusion 1%	*KL*: Preop: ST:0 = 20%, 1= 40%, 2 = 21%, 3 =19%; TN: 0 = 31%, 1 = 53%, 2 = 8%, 3 = 8% Postop: ST: 1 grade = 27%, 2 grades = 1%, TN: 1 grade = 31%, 2 grades = 1% Progression of 1 grade: SALTO TALARIS: ST 29%, TN 38.5% STAR: ST 22%, TN 23.1% INBONE: ST 27%, TN 29.5%
Frigg et al. 2017[38]	58y (38.0-81.8)	50	14.6y(12.9-16.4)	STAR	ST: 6%	NR	ST fusion 12% TN fusion 4%	NR
Stewart et al. 2017[52]	61.9 y	72	81.1m (60-115)	SALTO TALARIS	ST: 2.8%	NR	ST fusion 2.8%	NR
Chao et al. 2015[40]	68.6 y (53.2-85.4)	23	36m(24-49)	SALTO TALARIS	ST: preop 65.2%, postop 100%	ST pain 0%	ST fusion 21.7%	Preop: ST: None = 34.8%, Mild = 39.1%, Mod = 4.3%, Sev = 17.3%. Postop: ST: None = 0%, Mild = 69.5%, Mod = 0%, Sev = 8.7%.
Rodrigues-Pinto et al. 2013[32]	55.6y (24-81)	119	38.7m (18-72) OA: 11.5m	SALTO TALARIS	ST: 1.7%	ST pain 1.7%	ST fusion 1.7%	NR
Choi et al. 2013[41]	63y (40-78) 62y (36-77)	77	53m (24-76) 32m (24-45)	HINTEGRA Mobility	HINTEGRA ST: 3.1% Mobility T: 8.6%, ST: 2.8% TN: 2.8% CC: 2.8%	NR	None	NR
Mann et al. 2011[43]	61.4y	55	9.1y (2.6-11) OA: 9.1y	STAR	T: 38% ST: 20% TN: 13% CC: 4%	None	None	Progression: ST: 1 grade = 18.2%, 2 grades = 1.8% TN: 1 grade = 10.9%, 2 grades = 1.8% CC: 1 grade = 3.6%
Saltzman et al. 2010[54]	64y	37	4.2 y (2.2-5.9)	STAR	preop: ST 95% TN 82% CC 21% postop: ST:100%TN 98% CC 65%	NR	NR	*KL*: Preop: ST: 0 = 5%, 1 = 32%, 2 = 41%, 3 = 22%, 4 = 0%; TN: 0 = 19%, 1 = 46%, 2 = 30%, 3 = 3%, 4 = 3%; CC: 0 = 78%, 1 = 16%, 2 = 5%, 3 = 0%, 4 = 0%. Postop: ST: 0 = 0%, 1 = 0%, 2 = 49%, 3 = 38%, 4 = 14%; TN: 0 = 3%, 1 = 16%, 2 = 57%, 3 = 22%, 4 = 3%; CC: 0 = 35%, 1 = 43%, 2 = 22%, 3 = 0%, 4 = 0%. Progression: ST: 1 grade = 59%, 2 grade = 14%, TN: 1 grade = 38%, 2 grades = 19%, CC: 1 grade = 38%, 2 grades = 11%.

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Table 3. Level IV - TAR studies

Authors/ Year	Age	Nº TAR	Follow up	Implant	Joint	Symptoms	Surgery	Radiographic results
Wood et al. 2008[31]	NR	200	88m (60-156)	STAR	ST: 15%	NR	NR	*KL*: Preop: ST: 4 = 45.5% Postop: New cases: ST 15%
Ali et al. 2007[47]	69y (58-84)	35	5y (3-150m)	Buechel-Pappas	ST: 5.7%	NR	NR	NR
Kopp et al. 2006[58]	63y (32-85)	40	44.5m (26-64)	Agility	0%	NR	None	NR
Knecht et al. 2004[36]	61y (27-83)	132	9y OA: 7.2y (2-14)	Agility	Preop: ST: 100% TN: 100%	NR	ST fusion 2.3% Triple arthrodesis 2.3%	*KM:* Preop: ST: 1-2-3 = 85%, 4-5 = 15%; TN: 1-2-3 = 87%, 4-5 = 13%. Postop: ST: 1 = 15%, 2 = 33%, 3 = 31%, 4 = 11%, 5= 27%; TN: 1 = 22%, 2 = 41%, 3 = 21%, 4 = 11%, 5 = 22%. Progression: ST: 19%; TN: 15%
Valderrabano et al. 2004[45]	56.1y (22-85)	68	3.7y (2.4-6.2)	STAR	ST: 1.47%	ST pain 1.47% Symptoms: 6m	ST fusion 1.47% ST fusion: 35m	NR
Kofoed et al. 1998[53]	61 y (34-76)	41	9y (6-14)	NR	ST: 0%	NR	NR	NR

* y: years, m: months, ST: subtalar, TN: talonavicular, CC: calcaneocuboid, T: subtalar, talonavicular and calcaneocuboid, NR: not reported, KL: Kellgren and Lawrence scale, KM: Kellgren and Moore scale, TAR: Total Ankle Replacement

arthritis. Time from primary TAR to subtalar joint fusion due to IPJA was 5.0 (0.3-10) years.

Dekker et al.[30] postoperative follow-up also reported osteoarthritis progression, showing 1 grade progression in 27% of subtalar joint and 31% of talonavicular. There was no difference in the progression among the three kinds of prostheses.

Saltzman et al.[54] compared pre- and postoperative IPJA using the Kellgren and Lawrence scale, finding progression of 59%, 38%, and 38% of 1 grade in subtalar, talonavicular, and calcaneocuboid joints, respectively.

AA

Seventeen level IV studies[8-13,15-18,20,54,57-61] were analyzed after researching IPJA after AA (Table 4).

Ten studies[10,12,13,15,16,20,58-61] reported pain in the adjacent joints. One[16] reported no association of osteoarthritis with pain, and the remaining showed a range of 6.25%-39.13%. Furthermore, ten studies[10,12,13,15,17,18,57,59-61] reviewed the need for further surgery; subtalar fusion was reported in 1.61%-25%, talonavicular 0.95%-3.84%, triple arthrodesis 0.95%. One study[18] was the only one that reported no surgery due to IPJA.

Incidence of IPJA

Ten level IV studies[10,11,13,17,20,54,57,58,60,61] reported the incidence of IPJA after AA. Three studies[12,18,54] reported the incidence and progression of IPJA. A broad range of subtalar arthritis of 7.7%-100% was reported, the talonavicular joint of 8.69%-11.6%, and calcaneocuboid joint had 22%.

Progression of IPJA

Eight reports[8,9,12,15,16,18,54,59] analyzed the osteoarthritis progression of IPJA. Subtalar joint progression was 30%-47.82%, talonavicular joint 8.69%-48.5%, and calcaneocuboid joint 18.18%-26%.

Jones et al.[8] performed a study on 101 ankles classifying subtalar and talonavicular arthritis in both Kellgren and Lawrence and Van Dijk scales, with 15% of osteoarthritis progression on the Kellgren and Lawrence scale and 4% on the Van Dijk scale.

Saltzman et al.[54] compared pre- and postoperative IPJA using the Kellgren and Lawrence scale, finding progression of 47%, 47%, and 26% of 1 grade in subtalar, talonavicular, and calcaneocuboid joints, respectively.

Discussion

Nowadays, AA and TAR are surgical options for the management of ESAA. While AA has been considered the gold standard for several years and is still one of the main options, TAR has improved with better prosthesis development[5]. For many years, mid or long-term complications had been reviewed for these procedures, exposing potential higher incidence of IPJA after AA with no conclusive results in the literature due to many confounding factors that may suggest but not confirm this statement.

Furthermore, there is no conclusive evidence in the literature to confirm or deny the presence of IPJA after TAR which has not been implied as a possible complication after this procedure. For that reason, the aim of this review was to perform a systematic review to have a documented basis for incidence and/or progression after TAR and AA.

Table 4. Level IV - AA studies

Authors/Year	Age	Nº AA	Follow-up	Joint	Symptoms	Surgery	Radiographic results
Jones et al. 2017[8]	61.1 y (35.8-79.6)	101	86 m (24-247)	NR	NR	NR	*KL:* Progression: 15% ST: 0 = 47.5%, 1 = 16.8%, 2 = 3.96%, 3= 0.99% TN: 0 = 59.1%, 1 = 5.94%, 2 = 2.97%, 3 = 0.99% *VD:* Progression: 4% ST: 0 = 47.5%, 1 = 18.8%, 2 = 2.97%, 3 = 0% TN: 0 = 60.4%, 1 = 5.94%, 2 = 2.97%, 3 = 0%
Morasiewicz et al. 2017[9]	Ilizarov: 43y (17-66) Internal fixation: 47y (17-67)	62 (29 Ilizarov - 33 internal fixation)	Ilizarov 43m (24-108). Internal fixation 45m (24-104)	Ilizarov T: 65.5% Internal fixation T: 100%	NR	NR	Ilizarov: Preop: T = 48.3%, ST = 48.3%, TN = 34.5%, CC = 34.5%. Postop: T = 65.5%, ST= 65.5%, TN= 48.3%, CC = 34.5%. Internal fixation: Preop: T = 81.8%, ST = 75.8% , TN = 33.3%, CC = 30.3%. Postop: T = 100%, ST = 96.9%, TN = 81.8%, CC = 66.6%.
Flint et al. 2016[10]	60y (29-84)	60	1.1y (0.3-4)	ST: 20%	Hindfoot pain 12% Midfoot pain 5%	ST fusion 1.66%	NR
Lee et al. 2016[12]	62.4y (39-79)	23	41m (15-80)	Preop: ST: 96.65% TN: 81.8%	ST pain: 39.13%	ST fusion 4.34%	Progression: Isolated ST = 47.82%, TN = 8.69%, ST + TN = 18.39%. Postop: New TN = 8.69%
Jain et al. 2015[11]	59.4y (27-80)	52	32.1m (8-78)	ST: 11.54% TN: 3.85%	NR	NR	NR
Vaughan et al. 2015[13]	68.5y (59-80)	8	58.5m (24-100)	ST: 25%	ST pain 25%	ST fusion 25% ST fusion: 34-89 m	NR
Strasser et al. 2012[15]	74.5y ± 3.7	30	8.5 y ± 1.7	NR	ST pain 36.6%	ST fusion 6.66% ST fusion: 9-10y	*KL*: Preop: ST: 1 = 40%, 2 = 46.66%, 3 = 6.66% Progression: ST: 36.6%
Hendrickx et al. 2011[16]	47y	66	9y	Preop: ST: 91% TN: 77.2% CC: 10.6% Progression: ST: 30.3% TN: 28.78%, CC: 18.18%	OA not correlated with pain	NR	*VD*: Progression: ST: 0 to 1 = 2.7%, 0 to 2 = 1.3%, 0 to 3 = 0%, 1 to 2 = 20%, 1 to 3 = 9.3%, 2 to 3 = 5.3% TN: 0 to 1 = 12.1 %, 0 to 2 = 0%, 0 to 3 = 0%, 1 to 2 = 16.7%, 1 to 3 = 0%, 2 to 3 = 0% CC: 0 to 1 = 15.2%, 0 to 2 = 0%, 0 to 3 = 0%, 1 to 2 = 3%, 1 to 3 = 0%
Dannawi et al. 2011[17]	63y (32-84)	62	63m (21-92)	ST: 24.19%	NR	ST fusion 1.61%	*KL:* ST: 2 = 17.74% , 3 = 3.22%, 4 = 3.22%
Zwipp et al. 2010[18]	53y (34-69)	72	5.9y (4.8-7.8)	Preop ST: 35% TN: 18%	NR	None	*BH:* New postop: ST: 17%, TN: 11% Progression: ST: 30%, TN: 19%
Saltzman et al. 2010[54]	56y	23	4.2 y (2.2-5.9)	Preop: ST: 94%, TN: 92%, CC: 45%. Postop: ST: 100%, TN: 100%, CC: 67%	NR	NR	*KL*: Preop: ST: 0 = 5%, 1 = 25%, 2 = 32%, 3 = 32%, 4 = 5%; TN: 0 = 11%, 1 = 50%, 2 = 32%, 3 = 5%, 4 = 5%; CC: 0 = 53%, 1 = 40%, 2 = 5%, 3 = 0%, 4 = 0% Postop: ST: 0 = 0%, 1 = 0%, 2 = 42%, 3 = 38%, 4 = 21%; TN: 0 = 0%, 1 = 17%, 2 = 63%, 3 = 16%, 4 = 5%; CC: 0 = 33%, 1 = 46%, 2 = 16%, 3 = 5%, 4 = 0% Progression: ST: 1 grade = 47%, 2 grade = 11%; TN: 1 grade = 47%, 2 grades = 11%; CC: 1 grade = 26%, 2 grades = 11%
Gougoulias et al. 2007[20]	Group A: 51.8 ± 13.5y (18-81) Group B: 57.6 ± 14.23y (23-80)	78	21.1m (6-68)	ST: 7.7%	ST pain 7.7%	NR	NR
Winson et al. 2005[57]	57.2y (20-86)	105	65m (18-144) Surgery: 48 m	ST: 42.85% Grade 3 or 4	NR	ST fusion: 5.71%, TN fusion: 0.95%, Triple arthrodesis: 0.95%, TTC 0.95%	*KL* Preop: ST: 1 and 2 = 20.95%, 3 = 26.66%, 4 = 5.71%
Kopp et al. 2004[58]	42y (17-82)	46	7.3 y (2-20)	ST: 21.73%	ST pain 10.86%	NR	NR
Takakura et al. 1999[59]	57.9 y (25-79)	43	7.2y (2.4-14.11)	ST: 32.5% TN: 11.6%	ST pain 2.32%	ST fusion 2.32% ST fusion:4y	Progression ST: 0 to 1 = 6.97%, 1 to 2 = 18.6%, 2 to 3 = 4.65%
Felix et al. 1998[60]	60 y (28-73)	26 (14AA-12 TTC)	5y (2-8) Surgery: 8m	ST: 84.61%	ST + TN pain 3.84%	ST+ TN fusion 3.84%	ST postop: Mild: 7.69%, Moderate: 38.46%, Severe: 38.46%
Dennis et al. 1988[61]	50.8 y (23-72)	16	15.1m (3-25)	NR	ST pain 6.25%	ST fusion 6.25% ST fusion: 2y	NR

y: years, m: months, ST: subtalar, TN: talonavicular, CC: calcaneocuboid, T: subtalar, talonavicular and calcaneocuboid, OA: osteoarthritis, AA: Ankle Arthrodesis, NR: not reported, KL: Kellgren and Lawrence scale, VD: Van Dijk scale, BH: Bargon and Henkemeyer scale, TTC: Tibiotalocalcaneal

Onggo et al.[62] developed the latest systematic review and meta-analysis of outcomes after TAR; however, the incidence or progression of IPJA after TAR was not specified. Ling et al.[63] performed a systematic review on IPJA after AA, reporting 24 studies with a wide range of incidence between 24% to 100% for the subtalar joint and 18% to 77% for the talonavicular joint (mainly level IV of evidence). In our review, they were no high-quality level studies for ankle fusion. The highest quality was level III, with just two studies. The level IV studies showed similar wide ranges of 7.7%-100% for subtalar, 8.69%-11.6% for talonavicular, and 22% for calcaneocuboid reported in just one study[54]. Only one high-quality level I study reported briefly on subtalar joint arthritis after TAR, with 1.2% of incidence after 4.5 years of the procedure.

Also, two level II studies reported TAR with a broad range of IPJA. Nevertheless, in this group, it is important to highlight that the study performed by Mayich et al.[37] showed a higher incidence of IPJA; however, it reported a poor intra- and interobserver reliability of the Kellgren and Lawrence scale in these joints.

Another finding of our study is that even if there is a high incidence of IPJA after AA, the symptomatic patients are less than one-third of the cases, and fewer require further surgery due to IPJA pain. Similar was found in the TAR group, with a minor incidence of IPJA but still present. Thus, it is important to correlate the radiographic and clinical assessment when evaluating these patients since a significant amount of patients have non-symptomatic IPJA.

The follow-up was variable in both groups, and the few long-term studies had a higher incidence of IPJA, another reason for the wide range of incidence found.

The main limitation of our review is the quality of the studies found in the literature, only one level I study was found[49], and unfortunately, this study did not assess specifically our topic, which could decrease the reliability of the study in this regard; also there were two level II studies for TAR, these reported on incidence but not on progression.

Our study also shows that there are cases of IPJA after TAR that were not previously reported. This information will lead us to question whether the IPJA is caused by the implant change in the biomechanics or is part of an ongoing degenerative disease. Regarding this aspect, there is still no consensus on a cause for IPJA. This is likely multifactorial rather than just the arthrodesis or the replacement.

This study demonstrates that the literature provides limited evidence on IPJA and could be a potential topic of study in the future with the population increase for both procedures to complete the outcome expectations.

Conclusions

There is poor quality evidence that supports a higher rate of IPJA complication after TAR and AA. The literature does provide some support that IPJA occurs after TAR with a lower incidence and progression than AA. There are insufficient high-quality studies to determine the IPJA accurate rate, thereby would be classified as "I" according to the Journal of Bone and Joint Surgery "Grades of recommendation" [64].

It is important to mention that despite the quality of the studies identified, this is the best available evidence on this topic and will be supportive evidence for future high-quality clinical trials.

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Technical Tips

Tibiotalocalcaneal arthrodesis with femoral head allograft, external fixator provisional compression, and locking plate fixation after failed total ankle arthroplasty

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Abstract

The number of total ankle arthroplasties has increased in recent years with the improvement of implants and advanced attempts to maintain ankle movement. However, this technique presents complications, such as aseptic loosening and infection, requiring revision surgery. In this scenario, conversion by tibiotalar or tibiotalocalcaneal arthrodesis is highly accepted and can be performed with external fixators, intramedullary rods, screws, or locking plates. This article shows the resolution of a case of aseptic loosening tibiotalocalcaneal arthrodesis fixed with a locking plate associated with bone allograft.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Ankle joint; Arthrodesis; Arthroplasty, replacement, ankle; Femur head.

Introduction

Advanced osteoarthrosis is a common cause of pain in the ankle, often due to sequelae of trauma. Arthrodesis is the most established and performed treatment for this pathology, but improving techniques and implants, in addition to the greater concern for maintaining ankle movement, have made total ankle arthroplasty (TAA) a useful choice in treating ankle arthrosis(1-8). The success of this procedure depends on selecting adequate patients with good soft tissue conditions and mild or moderate deformities(2,4,5).

However, the failure rate of this technique remains high compared to tibiotalar arthrodesis (TA) and arthroplasties of other joints(8,9). The main causes of failure are aseptic loosening, infection, and misalignment(2-4,6,7,9-11). In such cases, the physician has three options: revision to implant another prosthesis, conversion to arthrodesis, and, in extreme cases, amputation(2,3,6,10,12). This decision considers the possibility of infection and bone loss in removing components, so many physicians prefer to convert the procedure to arthrodesis(1,3,4,6,9).

When opting for an arthrodesis, ideally should go for TA, keeping intact the subtalar complex. However, in some cases, a great bone defect in the talus leads to unstable fixation. In these cases, a tibiotalocalcaneal arthrodesis (TTC) might present some advantages, helping to promote a more stable arthrodesis with a better chance of consolidation(1,2,6,8). Literature shows several techniques for this conversion using

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external fixators, screws, intramedullary nails, or plates[1,3,6,9]. In addition, to compensate for the bone loss, many authors recommend using iliac autograft or bone allograft, usually the femur head[1,3,4,9].

This article presents a technical tip for converting from TAA with aseptic loosening and severe bone loss at the talus to a TTC using an external fixation compression fixed with a locking plate associated with bone allograft.

Technical tip description

The studied patient is a 68-year-old male professional soccer player between the 1970s and 1980s in Brazil. During this time, he has presented a history of repetitive right ankle sprains. He was diagnosed with chronic instability and ankle osteoarthritis, complaining of pain for ten years (Figure 1A-C).

The patient had been attended by several foot and ankle specialists who tried conservative treatment options (physiotherapy, change of footwear, and visco-supplementation) without success. Then, the patient opted for surgical treatment with TAA of the right ankle with the Zennith implant (Corin Group, United Kingdom) performed by another surgical team (Figure 2A-B).

However, after a postoperative period of four months, the patient's ankle region pain persisted and worsened over time. The pain location was the lateral part of the ankle, and 26 months after TAA, a toilet procedure on the lateral part was performed to improve pain (Figure 2C-D).

In the following months, the patient presented with pain in the medial side of the ankle, being submitted to a medial toilet procedure 38 months after the first surgery. Nevertheless, he was still in pain (Figure 2E-F).

After all these procedures, the patient presented good alignment of the ankle but a high level of pain with mobilization, which is why he sought our care. Radiographs were performed and showed aseptic loosening of the tibial component (Figure 2G-H). He also underwent a computed tomography scan (CT) of the affected limb (right ankle) of both tibial and talar components associated with bone stock loss in the talus near the posterior subtalar joint. A PET/CT and SPECT/CT confirmed the loosening and local overload (Figure 3A-H).

A TAA revision to TTC using a femoral head allograft was performed in common agreement. The previous anterior ankle 12 cm incision was used to access the tibiotalar joint and verify the loosening of the tibial component with metallosis in the region (Figure 4A-B). Debridement of metal debris was performed, and devitalized bone parts were removed (Figure 4C-F). Then, the femur head allograft was cut, modeled, and perforated to fill the tibiotalar joint failure gap (Figure 5A-E). Subsequently, we performed a lateral 3 cm incision to access the subtalar joint and prepare the joint for fusion.

Provisional positioning and compression of the joints were performed with a modular external fixator type AO, then the alignment was checked clinically and radioscopically. Once the allograft position and the ankle and hindfoot alignment were correct, we performed a definitive fixation with an

Figure 1. Initial ankle radiograph before total ankle arthroplasty. A) Anteroposterior (AP) view. B) Lateral view. C) Salzmann view.

anterior locking dynamic compression plate and screws (Wright Medical Group N.V. or its affiliates, Memphis, TE, USA).

The plate was positioned in the anterior ankle face, with neutralizing function, as the external fixator assured the compression. The posterior subtalar arthrodesis was additionally compressed with two traction screws, and the external fixator was removed (Figure 6A-E).

After subcutaneous and skin closure, the patient's ankle was immobilized in a below-knee splint. Solid clinical and radiographic signs of consolidation could be seen within 12 weeks of the procedure.

Discussion

Increased use of TAA will lead to an increase in cases requiring revisions. For this reason, several techniques and flowcharts have been described to deal with these issues[1-4,7-9].

The diagnosis of loosening ankle arthroplasty is associated with persistent pain complaints after surgery. The investigation begins with laboratory infection tests and ankle radiographs in anteroposterior incidences, mortise, and lateral view, being supplemented by CT[4,9,11]. With these tests, it can be defined whether the patient presents an aseptic loosening or an infection, besides allowing prediction of the patient's bone loss.

Most of the literature indicates the TAA revision to arthrodesis when significant bone loosening is associated with a bad outcome predictor. When the bone loosening is related to severely compromised talus, the literature suggests TTC arthrodesis since it will not have enough bone to stabilize only with the TA[1]. Egglestone et al.[2] showed a better rate of a union in TTC and TC than in TA, and some TA needed to be converted to TTC revision, with all the patient that underwent conversion to TTC leading to a symptom-free

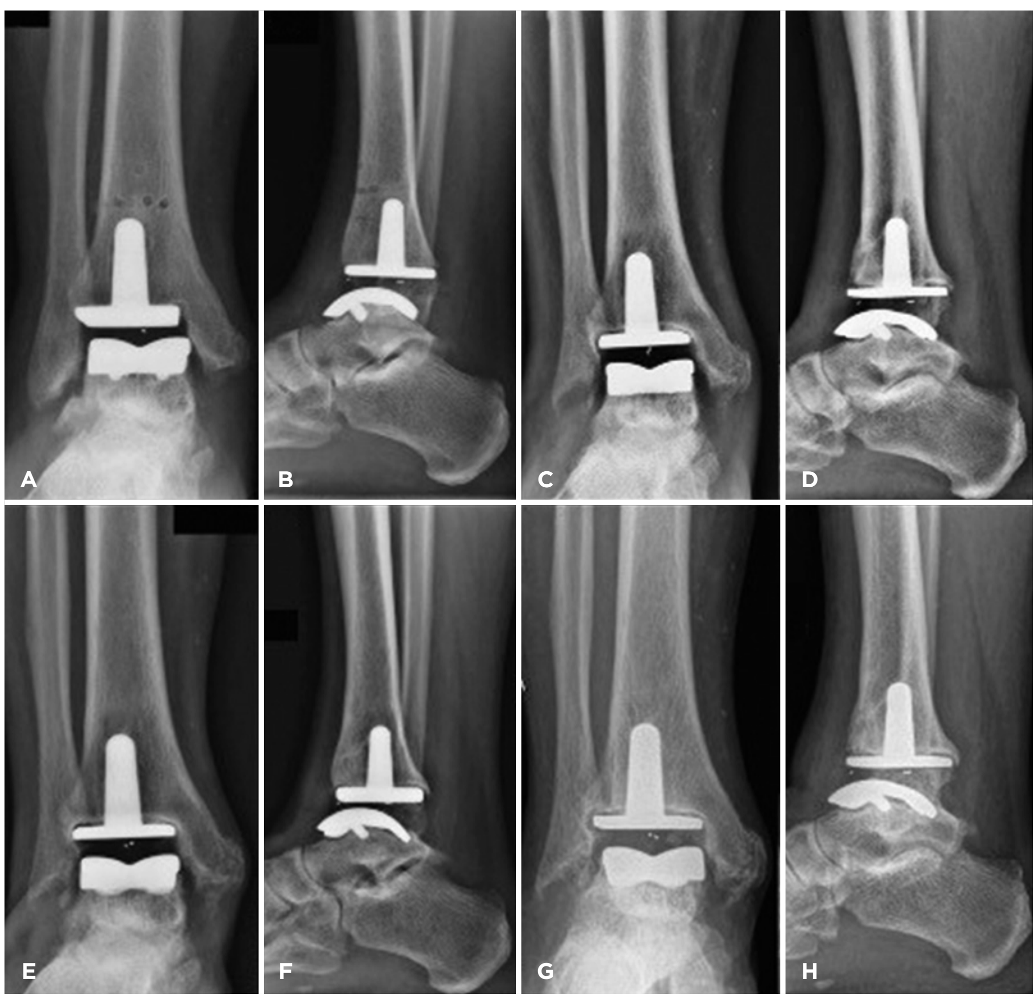

Figure 2. A) Immediate (i) postoperative (PO) AP radiograph of the ankle. B) iPO lateral radiograph of the ankle. C) PO ankle radiograph at 26 months, after medial procedure, AP view. D) PO ankle radiograph at 26 months, after medial procedure, lateral view. E) PO ankle radiograph at 38 months, after lateral procedure, AP view. F) PO ankle radiograph at 38 months, after lateral procedure, lateral view. G) Ankle AP radiograph with loosening. H) Ankle lateral radiograph with loosening.

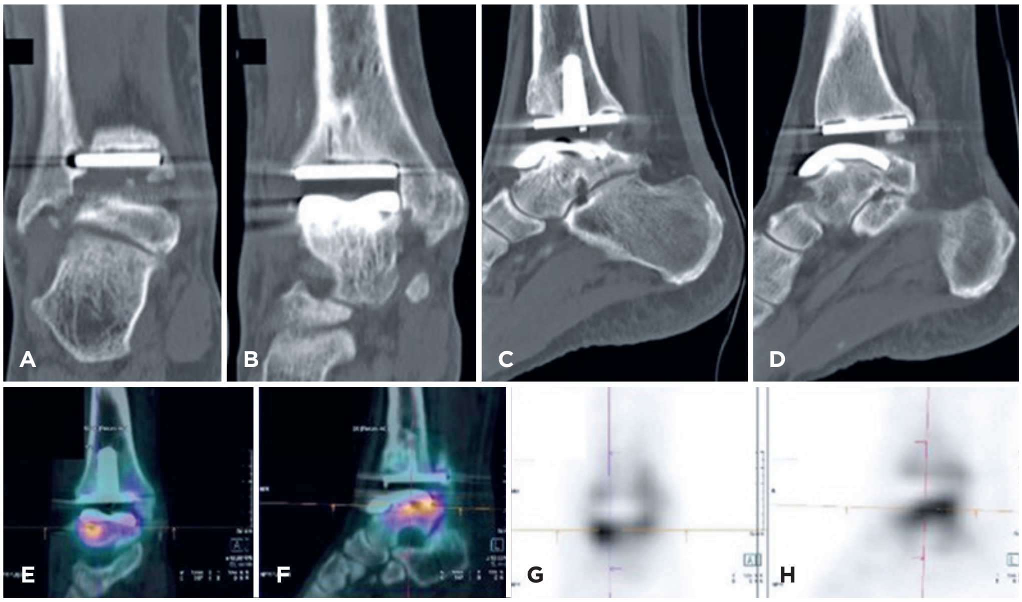

Figure 3. Preoperative revision surgery supplementary examinations. A-B) Coronal section CT. C-D) Sagittal section CT. E-F) PET/CT. G-H) SPECT/CT.

Figure 4. A) Anterior incision. B) Local tissue with metallosis. C-D) Component loosening. E) Broken prosthesis components. F) Debridement.

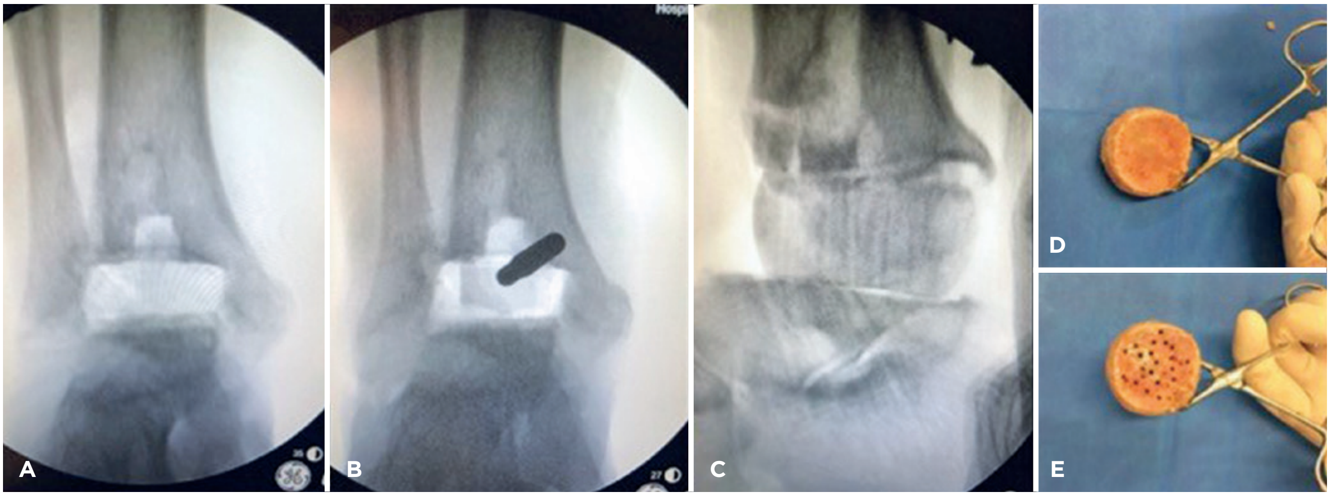

Figure 5. A) Fluoroscopy after the debridement. B) Proof test fluoroscopy. C) Femur head allograft fluoroscopy. D) Femur head allograft. E) Femur head allograft after perforation.

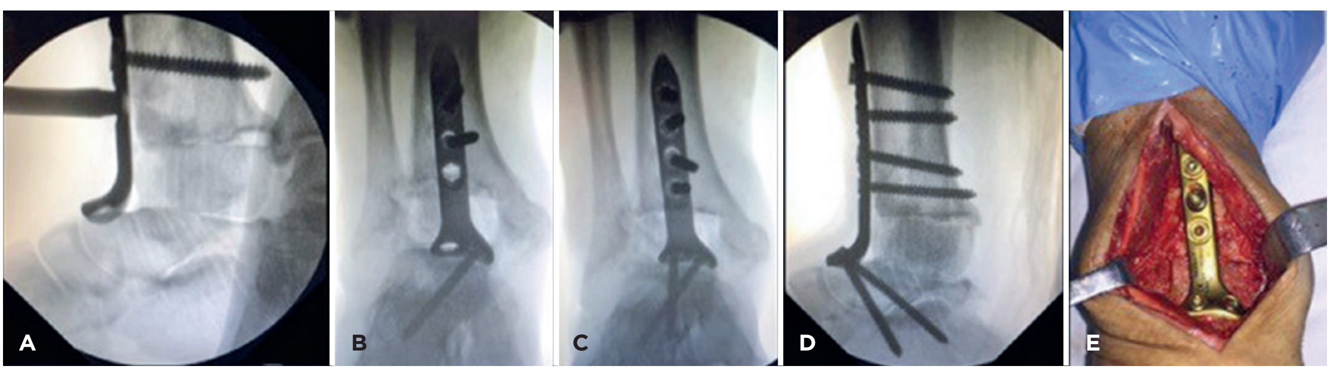

Figure 6. A-B) Initial fixation of the arthrodesis fluoroscopy. C-D) Final fixation of the arthrodesis fluoroscopy. E) Final fixation.

clinic union, while 50% of the patients that opted for a TA had a failed arthrodesis.

Wagener et al.[13] described using a custom-made total ankle as a revision instead of a standard one. They showed a case series of 11 patients with 6.9 years of follow-up with a good outcome, improving the AOFAS and VAS scores. However, only this paper discusses this possibility and the high cost of a costume-made device.

It is common to use a femoral head bone allograft to solve the problem of bone failure and the shortening that most of these patients end up presenting[7,8]. This kind of graft offers some advantages because it is spherical, with a great bone volume, allowing good bone contact area and easy foot positioning after modeling with a saw or an osteotomy[3,8]. Allograft use is associated with lower consolidation rates, so it is recommended when more than 2 cm shortening is expected[6,7,9].

In case of revision to arthrodesis, several options for implants, such as external fixators, intramedullary nails, screws, and locking plates, could be used alone or combined. In a systematic review, Gross et al.[6] verified that the best consolidation rate was obtained using plates, while a rod with a metal cage presented the lowest consolidation rate.

This case had a large gap due to the talar body bone loss. We opted to do the compression with an external fixator because it allowed a good compression of the tibia, allograft, talus, and calcaneus extrinsically with a provisional external fixation. Thus, we did not need to pass several screws through the talus and the graft to do the compression, an advantage considering the bone stock loss the patient already had. Also, not all plates can do axial compression through it.

Conclusion

Ankle arthroplasty failure creates several challenges for the ankle surgeon. One of the main challenges is bone failure due to prosthesis placement. A bone graft can help fill this defect without major shortening and maintaining good bone contact. In addition, using an external fixator allows for robust compression between the fragments without relying on plates with specific systems. It enables fewer screws for final fixation without compromising the talus, which already has a low bone stock.

Authors' contributions: Each author contributed individually and significantly to the development of this article: DLR *(https://orcid.org/0000-0003-0183-8641) Conceived and planned the activities that led to the study, performed the surgeries and bibliographic review.; RM *(https://orcid.org/0000-0002-5025-4338) Statistical analysis, interpreted the results of the studies and data collection; RBS *(https://orcid.org/0000-0003-1085-09117) Performed the surgeries, participated in the review process and formatting of the article; ALGS *(https://orcid.org/0000-0002-6672-1879) Clinical examination, interpreted the results of the study and approved the final version; TDF *(https://orcid.org/0000-0002-9687-7143) Performed the surgeries, clinical examination, and formatting of the article.All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID) .

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Technical Tips

Description of minimally invasive technique for the surgical treatment of acute Achilles tendon ruptures with locking suture – a low-cost option

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Abstract

Acute Achilles tendon rupture is a frequent injury of the lower limbs, and there is controversy regarding the ideal treatment. Several methods are described in the literature, including conservative treatment, open repair, and minimally invasive surgery. Open repair is associated with a higher complication rate, while minimally invasive techniques present an increased risk of iatrogenic sural nerve injury. Some devices have been developed to reduce the complications of the first minimally invasive techniques described. We present a technique to repair acute Achilles tendon injuries in a minimally invasive surgery using simple materials available in most operating rooms without special instruments. Associated with this technique, we adopted a protocol of early functional rehabilitation, which has already proven beneficial in recovering the patient's functions.

Level of Evidence V; Therapeutic Studies; Expert Opinion.

Keywords: Achilles tendon; Minimally invasive surgical procedures; Rupture.

Introduction

The Achilles tendon is the largest and strongest tendon in the body but is also the most commonly ruptured tendon in the lower limbs[(1)]. The incidence of its rupture has recently increased due to the population's aging and the increase in sports practice[(2)].

The ideal treatment of acute Achilles tendon ruptures, whether conservative or surgical (open or minimally invasive), and the conduct in conservative or functional protocols (weight-bearing and early mobility) has been the subject of constant discussion in the literature in recent years. Recent studies have shown that functional rehabilitation implies better quality healing in addition to the surgical technique approach[(3)].

Based on previous studies, open surgical intervention was recommended, preferably than conservative treatment or minimally invasive techniques, because they were associated with high rates of re-rupture and loss of strength. Increasingly, conservative treatment, or minimally invasive techniques when opting for surgical treatment have been considered since it reduces complications associated with conventional surgical treatment or a no load protocol with long immobilization[(4)].

This study describes an adaptation technique for the minimally invasive technique of acute Achilles tendon ruptures, different from the others described for being low-cost and allowing the locking suture within the paratendon, currently possible only using specific and higher cost devices.

Study performed at the Hospital Márcio Cunha, Ipatinga, MG, Brazil.

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Technical tip

The study was approved by the Institution Ethics Committee of the Hospital Márcio Cunha/Fundação São Francisco Xavier.

The surgical procedure was performed under spinal anesthesia with the patient in a prone position, and it may be unnecessary to use a tourniquet if preferred by the surgeon. A transverse incision was performed at the rupture level, evidenced by the noticeable gap at the injury level (Figure 1).

Dissection under the paratendon was performed after hematoma drainage, exposing the proximal and distal stumps at the rupture level. If the proximal stump retracts, it can be brought distally using an Allis forceps (Figure 2).

Figure 1. Noticiable gap at the injury level (the procedure can be performed with or without a tourniquet). As the surgeon gains experience with the procedure, the tourniquet becomes dispensable.

By pulling the proximal stump using the Allis forceps, a long curved Foerster forceps was inserted inside the paratendon to capture the Achilles proximal stump. This justifies our option for the long forceps, making it possible to reach a better-quality portion of the stump outside the ruptured portion (Figure 3).

After passing the Foerster forceps, under controlled tension to capture the tendon without causing additional injury to the proximal stump, two guidewires or needles were passed through the hole of the forceps about 8 cm from the incision. The two guides or needles were passed at nearby points, separated by about 1 cm, so they serve as routes to the wires used for suturing, increasing the wires anchoring in the following steps (Figure 4).

Now the wires for suturing inside the forceps have been passed (in this case, we used three Vicryl® 1, two of which are passed in the most proximal guide and one in the distal one), the Foerster forceps are distally pulled, bringing the wires to the surgical incision (Figure 5).

The long curved Foerster forceps were then inserted again under the paratendon, with the proximal stump tensioned by the wires already passed, the tendon was captured at approximately 1.5 to 2 cm distally to the point where the Vicryl® wires were passed to be used for tenorraphy. Two other sutures (our preference in this step is for Ethibond® 5 since wires of lower resistance tend to break when pulled) were passed to cross the proximal stump of the three wires initially passed. These Ethibond® wires will only be used as guides to allow the looping of Vicryl® wires inside the tendon body to anchor to the proximal stump, consequently lowering the risk of fraying (Figure 6).

Figure 2. Transverse incision at the injury level (the transverse incision facilitates the closure of the paratendon after tenorrhaphy).

Figure 3. On the left, long curved and straight Foester forceps and the guidewires; in this case, we use conventional guides, which needles or jelcos can replace. As for the forceps, we prefer the curve, which facilitates insertion inside the paratendon.

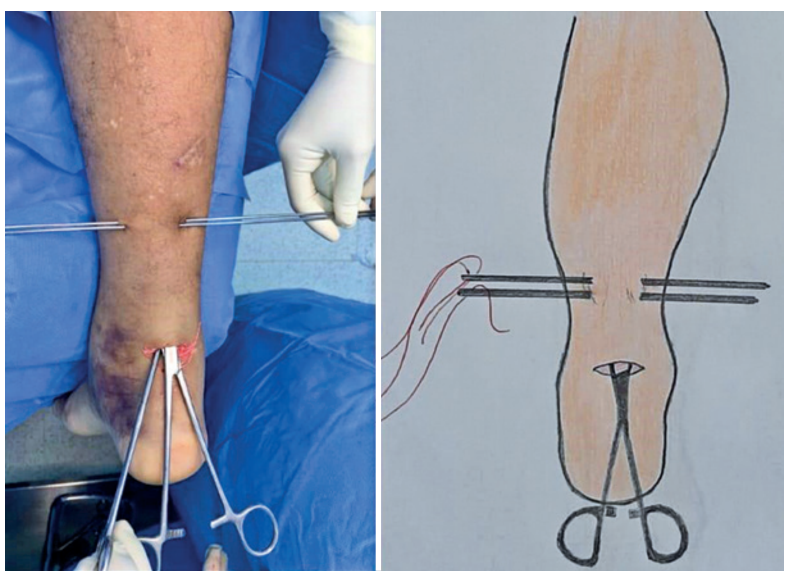

Figure 4. The guidewires are passed through the forceps hole inserted under the tendon approximately 8 cm from the incision.

Once the wires had been crossed, we performed traction to test their real anchorage at the proximal stump (Figure 7) and thus allowing satisfactory and reliable tenorraphy.

A similar procedure can be performed to pass the suture wires to the distal stump, but due to the smaller amount of subcutaneous in the insertional region of the calcaneal tendon, it is more easily palpable, and the same two guidewires or needles can be passed without the Foerster forceps by four incisions of approximately 3 mm (Figure 8). At this time, it is important to use the two guides or needles for the crossing suture wires since, if passed separately can occur the rupture of some of the wires by the pointed end of the guide or needle used to pass the distal suture wires, we also use three distal Vicryl® wires.

The ends of the wires are then sutured, observing the correct tensioning and positioning of the tendon stumps (Figure 9). It follows with the proper suture of the paratendon (Figure 10), an important structure in tendon nutrition[5], followed by the subcutaneous with absorbable wires and the skin with non-absorbable wires.

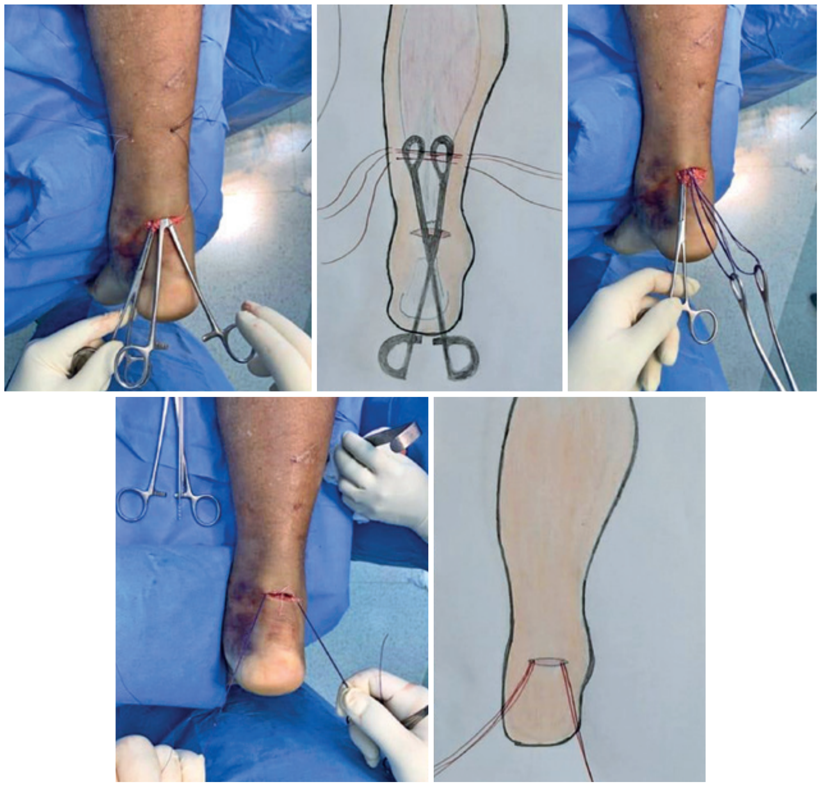

Figure 5. The wires of the proximal stump to be used for tenorrhaphy, at this moment, were passed only once by the tendon and brought to the surgical incision.

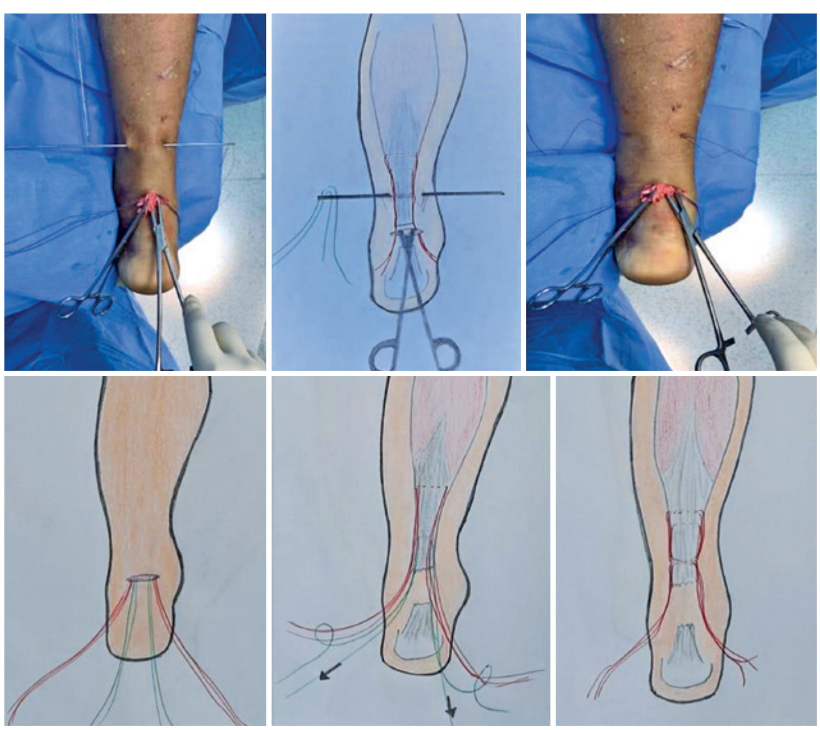

Figure 6. We pass two Ethibond® wires at a point 1.5-2 cm distally to the previously passed Vicryl® wires that will be used in tenorraphy; we cross the Vicryl® wires by tying them to one end of the Ethibond® that will be pulled by the other end.

Figure 7. Once the sutures were already anchored to the proximal stump, the sutures were passed twice, then traction was performed to test the fixation of the proximal wires.

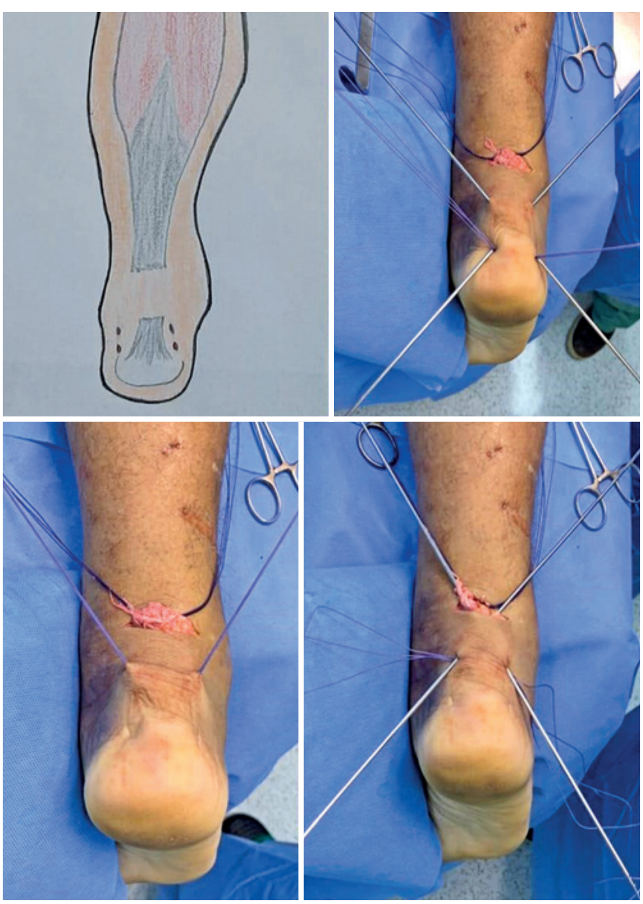

Figure 8. The suture wires were passed through the distal stump for two punctiform incisions performed in the insertional region of the Achilles, and two others performed 1.5-2 cm proximally.

Figure 9. Once the suture wires have been passed to the distal stump, proceed with the tenorraphy of the wires proximal to the distal.

Figure 10. Paratendon closure.

Based on Brumann et al.[6] recommendations, rehabilitation begins in the second week after surgery, allowing loading with the operated limb initially with partial weight-bearing with crutches, using a 30° plantar flexion brace or shim with the same purpose, with the progressive reduction of plantar flexion performed between four and eight weeks. Weight unloading occurs progressively in the postoperative period, and the crutch is dispensed according to the patient's tolerance and adaptation from the fifth week. At eight weeks, the total range of motion is released, and physiotherapy can progress with dorsiflexion, limited to neutral until this stage.

Discussion

Despite the controversy regarding the modality of the treatment of acute Achilles tendon injuries, many authors prefer the surgical approach due to the lower rate of re-rupture compared to conservative treatment[7]. However, this approach entails other risks, such as infection, necrosis, and wound dehiscence, which can be considerably reduced using minimally invasive techniques[8], as first described by Ma and Griffith[9].

For a few years now, studies have shown favorable results for treating acute injuries of the calcaneal tendon using the minimally invasive technique[10], which also allows accelerated functional rehabilitation. This accelerated functional rehabilitation and the protected weight-bearing have been more effective since it stimulates the deposition of type I collagen, not type III fibrous scar tissue. In addition, it has the best alignment of the fibrous scar tissue and, thus, forms a better quality tissue, reducing re-rupture rates, especially when compared to prolonged immobilization[11,12].

Compared with conventional open treatment, the first percutaneous techniques described presented a lower rate of surgical wound complications but a higher risk of sural nerve injury[13], in addition to scar tissue adhered to the subcutaneous[14] or iatrogenic compressions of the sural. New devices, such as the PARS Artrhex®[15] and Achillon®[16,17], have emerged to minimize these risks and with better suture strength. Despite this, many surgeons do not have access to these devices with higher operating costs and supply availability by large companies.

The technique used in this study does not require special instruments, so it does not add cost to the treatment. The use of forceps as a guide inside the paratendon prevents the adhesion of nodes to the subcutaneous since the wires are carried inside the paratendon.

Avoiding complications of surgical treatment of Achilles tendon injuries remains a challenge, but by minimizing dissection and exposure of the tendon, associated with an accelerated rehabilitation protocol, we believe it is possible to achieve an excellent result with the technique described, results that will be demonstrated in later studies.

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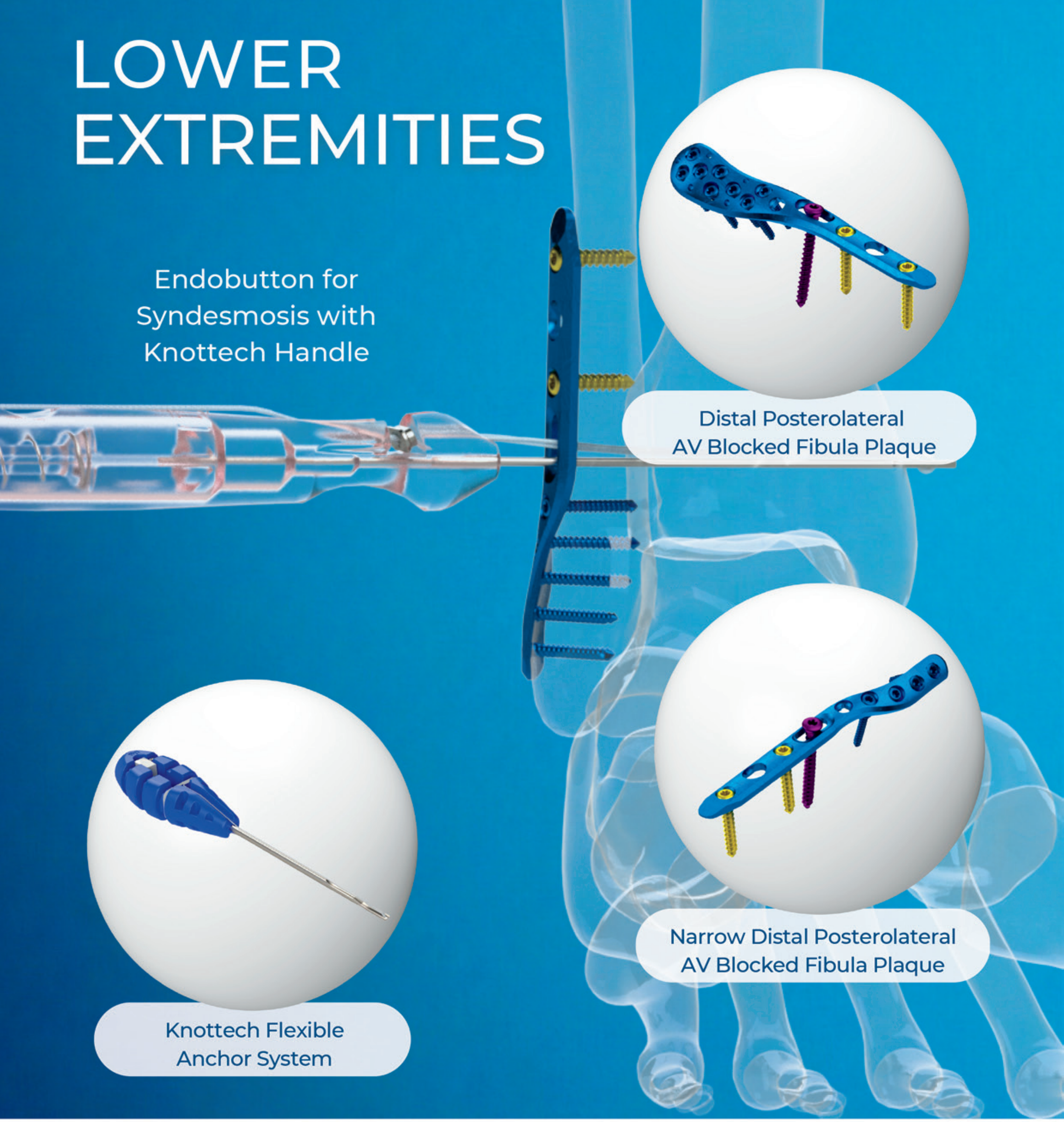
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